An ergonomic evaluation of a data preparation task

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AN ERGONOMIC EVALUATION OF A DATA PREPARATION TASK

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Summary

This thesis is concerned with information processing in the data preparation section of a commercial company and falls into two parts.

The first part is concerned with determining what causes discomfort and difficulties for the keypunch operators. A questionnaire was given out to the operators to get their opinions about the environment in which they worked, their keypunch machines and the documents from which they worked.

The key and error rates for the operators were determined. It was found that the error rate was 2 - 5 times higher than the error rate quoted in the literature.

Because of this the second and main part of the thesis is primarily concerned with error rate. The errors made by the operators were related to the source documents from which they worked. The layout of the documents was closely examined and one document was redesigned. An experiment was carried out to compare keying and error rates obtained on the new document with those found on the 'old' document.

The error rate on the new document was about half that found on the old document. The implications of these results are discussed in terms of the increased productivity which can be obtained by the use of the new document in the data preparation section of the Company.

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1.0. Introduction

A major concern in an increasing number of modern computer based systems is the man-machine data entry sub-system. Manual input is the slowest and most inaccurate process in many data processing systems. The creation of enormous data bases required by new data processing systems places increased demands upon this method of data entry. The keypunch machine has traditionally been used to prepare source input for data processing systems. As electronics computer systems have developed in sophistication, the keypunch operation has begun to impair system efficiency. The computer system itself has become cheaper per unit of throughput, whereas the cost per unit of throughput for data preparation by keypunch machines has actually increased as operators' salaries have risen.

Because of this, and because of the increasing workload, companies find themselves looking into the data preparation situation, seeking means to increase simultaneously the operators performance, and system output, whilst reducing overall costs.

This thesis is concerned with a data preparation section in a large pharmaceutical company, which was planning its data preparation arrangements for the next five years.

The thesis first examines the present situation in the company from an ergonomics point of view and seeks to establish what, if anything, causes discomfort for the operators, for example the thermal, visual, and auditory environment, the workplace environment, (seats, desks, and the layout of the office), and, what, if anything, causes difficulties for the operators, for example, the source documentation from which the operators work.

Secondly, the thesis reports on how the situation for the punchcard operators may be improved.

1.1. Background

This section describes the situation in the company and the data preparation section at the end of 1970.

The company is engaged in the manufacturing, wholesaling and retailing of pharmaceutical and other products, but principally the former. It has about 1,700 branches nationally served by warehouses located in Nottingham, Manchester, London and Aldershot. The factories are in Nottingham and Airdrie.

The central administration and computer centre are located in Nottingham.

The computer service department which incorporates computer operators, data control and data preparation, is a part of the management service organisation.

The company commenced work on electronic data processing in 1956, initially using EMIDEC computers with papertape and mark sensed card input.

Later the work was transferred onto an IBM System 360 computer using full operating system and multi-programming techniques.

IBM computers are designed to accept primary input from cards. Data is prepared by the company for input into the computer in two forms:-

1. 80 column punched cards.

2. Mark sensed cards.

The data preparation section of the company is located in the Head Office in Nottingham. The office was built in 1967. It is of an open plan design and fully carpeted and air conditioned. A detailed plan and photograph of the data preparation section is given in Figures 1 and 2 respectively.

The company uses the following data preparation equipment:

(a) 31 IBM 029 punch machines (21 print, 10 non-print)

(b) 22 IBM 059 verify machines

(c) 3 IBM 519 mark sense reproducers

About 25,000 cards per day are punched and verified, and 35,000 cards per day are mark sensed (front and back).

The mark sense equipment is not examined in this thesis.

The present operator staff is:

Day shift	26 punch operators
	20 verify operators
Evening shift	3 punch operators
	3 verify operators
Night shift	4 punch operators
	3 verify operators

The operators on the day shift are divided up into three sections. Each section has a section leader. The sections have certain specialised work that only they do. Some work, however, is common and may be given to any operator in any section.

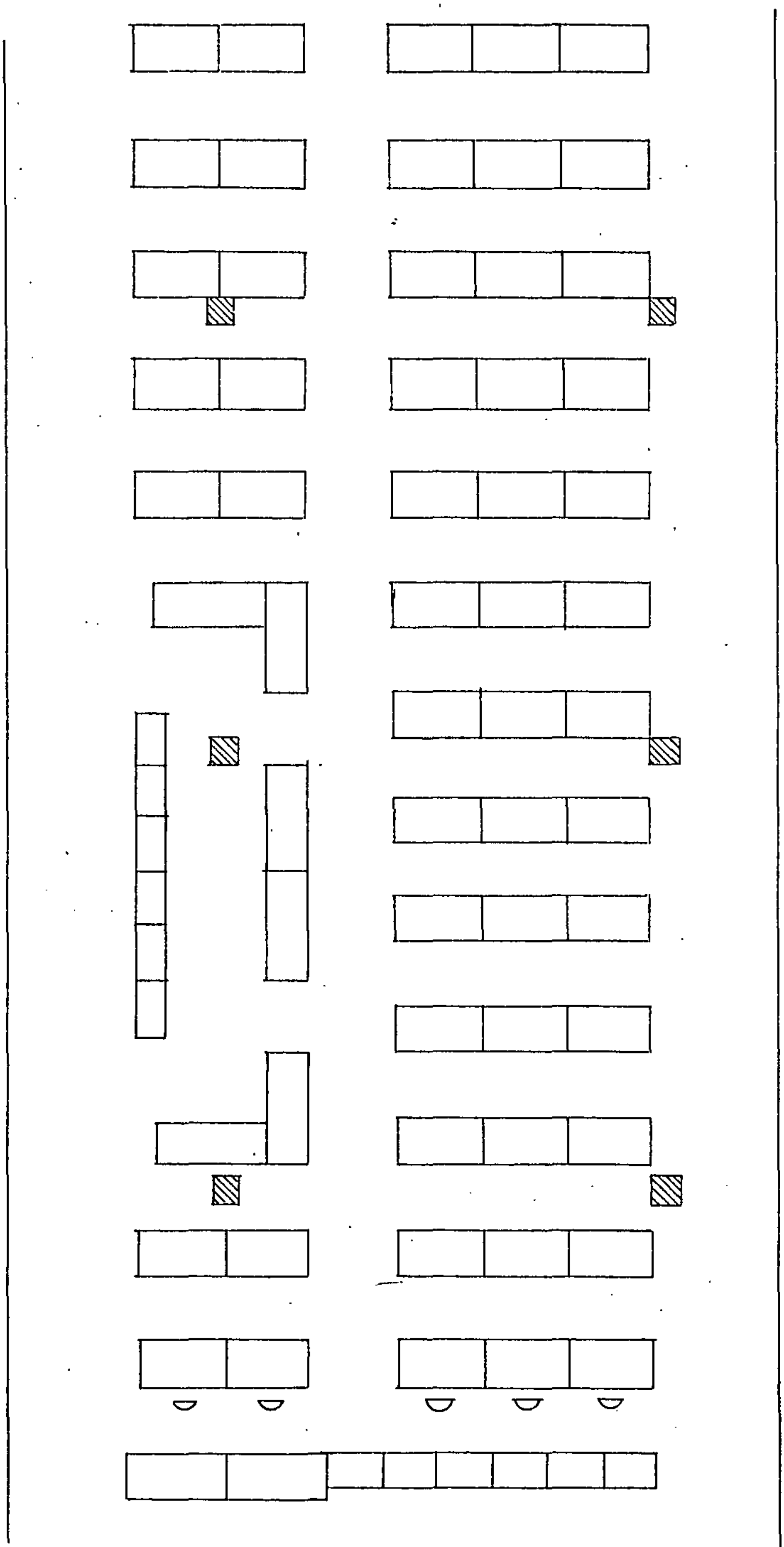


Figure 1. Layout of the data preparation

Figure 2. Layout of the data preparation section.

The company operates a scheme, based upon a work study report that was made in 1969, in which the output of all punch and verify operators is monitored. Standard minutes are allowed for given punch work. Efficiencies are calculated making due allowance for number of batches, errors, holiday, sickness, overtime, and waiting time.

The company itself trains the operators. The training is of six weeks duration and consists of two parts, each of which is three weeks long.

The first part is divided up into four components.

1. IBM keyboard exercises for IBM card punching machines. This component of the training is as the name suggests, a keyboard exercise, i.e. the trainee operators learn where the different keys on the keyboard are.

The trainee operators are not allowed to proceed to the next component of training, (see 2 below), unless they satisfactorily perform on the IBM keyboard exercises.

2. IBM 024/026 Key punch exercises.

This exercise is a contunuation of the first component of the training, the IBM keyboard exercises, but it is more advanced and more concentrated on actual keypunching.

3. Programs.

At this stage when they know the keyboard fairly well, the trainee operators are taught how to make up a program card and instructed on IBM 029 card punch how the machine works.

4. Real work.

Throughout phases 1 to 4 inclusive of this part of the training, the trainee supervisor keeps a record of each trainee's error rate. An operator is not allowed to continue to the second part of the training unless her error rate is less than 2%. Speed is judged by the Company to be only of secondary importance. Typically, an operator's speed is about 3,000 keystrokes/hour after the first three weeks training.

The second part of the training is carried out at the data preparation section itself. The supervisors give the new operators jobs that are fairly easy to do, and make sure that they understand and can do them. Each job assigned to a trainee by a supervisor must be satisfactorily completed before the trainee is allowed to proceed to a new job. This part of the training normally takes about three weeks.

The present keypunching workload can be divided up according to the clerical activity generating source documents for punching by the operators. See Table 1.

Table 1. Different keypunch applications.

APPLICATION	CARD TYPES TOTAL	CARD TYPES DAILY USE	CARDS PUNCHED DAILY	BATCH SIZE	ORIGIN OF DOCUMENT
Merchandise Accounting	300	36	15500	25	Branch W/House B. Office
Credit Sales	35	8	5000	40	Branches
Local Purchases	10	5	2500	80	Branches
Retail Takings	14	5	500	80	Branches
Other Projects	153	14	1000	-	H. Office Depts.
Programs	-	-	500	-	Internals
TOTAL	512	68	25000	35	

Three major clerical activities, viz. those associated with merchandise accounting, credit sales and local purchases account for about 90% of the present punching and verifying workload.

1.2. Informal Discussions with the Management, Supervisors and Section Leaders.

In order to obtain an initial impression of the Company's view of the difficulties associated with the punch cards operators' task, informal interviews were held with representatives of the management and with supervisors and section leaders in the data preparation organisation.

The only thing that the management thought could cause difficulties for the operators was the input to the operators, namely the source documents. The reason given was the large number of different types of source documents and the lack of compatibility between them, particularly in respect of design layout.

Both the supervisors and the section leaders were fairly satisfied with the present situation and did not think that anything needed to be improved or could be improved in the data preparation section.

No interviews were held at this stage with the operators for the following reasons.

1. The Company wanted me to disturb the operators as little as possible.

2. All the operators subsequently had an opportunity to write down their own comments in a questionnaire described in Section 2.

1.3. The approach adopted for the thesis.

After having had informal discussions with the management, supervisors and the section leaders, and having studied some of the most common source documents, it was decided to divide the research into two parts.

To establish, by questionnaire, what the operators thought of the present situation, in particular their opinions about the thermal, visual and auditory environment, the work place environment, (seats, desks and the layout of the office), and the source documents.

1. To establish keying and error rates for the source documents, and to try and relate the errors to particular types of documents.

2. (Consequential upon 1) to try and remedy the difficulties, if any, which were revealed in Part 1.

2.0. The Questionnaire.

The questionnaire was administered individually on the same day to the 59 keypunch operators in the data preparation section. Returns were obtained from 58.

The questionnaire (see Appendix 1) consisted of 48 questions, covering the thermal, visual and auditory environments, the workplace environment, (seats, machines and layout of the office), and source documents. In respect of the latter, operators were asked to list the five documents they regarded to be the best, the five most difficult to work from. They were also asked to state why they regarded the documents as good or bad.

2.1. Results of the Questionnaire.

The results of the questionnaire are reported below. The responses to most of the questions are reported in tables. Some of the questions are not reported in tables as the responses were all in the same response category, or the responses to the questions could not be conveniently displayed in tabular form. This was the case where subjects were invited to make free responses.

The age distribution of the punch card operators, partitioned by sex and shift is given in Table 2. It will be seen that all operators on day and evening shifts are female. On the day shift the operators are very young and are all aged 25 years or less. The evening shift on the other hand comprises more mature women. The night shift is entirely male who are comparable in age to the female evening shift.

Table 2. Age and sex distribution of operators.

Scale	Day Shift	Evening Shift	Night Shift	Total
Sex:				
Male	-	-	7	7
Female	44	7	-	51
Age:				
- 18	18	-	-	18
18 - 21	20	-	-	20
22 - 25	6	1	2	9
26 - 30	-	-	1	1
31 - 35	-	2	-	2
36 - 40	-	2	2	4
41 - 45	-	1	-	1
46 -	-	1	2	3
Total	44	7	7	58

The length of experience of the punch card operators by shift was as follows. The average experience for the day shift was 2 years 6 months, ranging from 6 months up to 6 years 3 months. The average experience for the evening shift was 7 months, with a range from 2 months up to 1 year 6 months.

The average experience for the night shift was 1 year, ranging from 3 months up to 2 years 4 months. All operators obtained their training with the Company with one exception, a girl on the day shift.

All operators found their job very easy or easy to do. Nevertheless, 50% found the job very or fairly tiring. In Table 3 is given the subjective feeling of tiredness experienced by each shift.

Table 3. Degree of tiredness experienced by different shifts.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very tiring	-	-	-	-
Fairly tiring	27	1	1	29
Not particularly tiring	17	6	4	27
Not tiring at all	-	-	2	2
Total	44	7	7	58

Chi-squared tests were carried out on the data relating to each question reported below, with the exception of questions 14 - 19, which unfortunately were not appropriate for a chi-square, to establish the following:

(i) Whether or not the frequency of response was equally spread over response categories, when no distinction was made between shifts.

(ii) Whether or not there was an association between subjective response and shift worked.

(iii) Whether or not the frequency of response was equally spread over the response categories within the day shift.

To facilitate the analyses certain response categories for a given question were combined, for example, 'very and fairly tiring' were combined into one cell. Similarly, the response categories 'not particularly tiring' and 'not tiring at all' were combined.

A complete example is shown in the chi-square carried out on the data shown in Table 3, the chi-square carried out on the other tables follow exactly the same pattern.

Chi-squared tests were carried out on the data in Table 3, to establish the following:

(i) Analysis of differences in subjective responses with no distinction made between shifts, (henceforward termed "total responses"). To facilitate the analysis 'tiring' responses, i.e. very and fairly tiring were combined into one cell. Similarly the responses 'not particularly tiring' and 'not tiring at all' were combined. It will be seen that an equal number of operators found the job tiring and not tiring.

(a)	'Very tiring' and 'fairly tiring'	29
(b)	'Not particularly tiring' and 'not tiring at all'	29
		58

$\chi^2 = 0$ Non significant, i.e. there is no difference in frequency between (a) and (b) responses.

Even though the result is statistically non significant, it cannot be overlooked that 29 out of 58 operators i.e., half of them find the work "tiring".

(ii) Analysis of the relation between subjective responses and shift worked, (henceforward termed "interaction"). The original four response categories were divided up as in (i) above. Frequency of a response against shift is given below.

	Day shift (D)	Evening shift (E)	Night shift (N)
(a)	27	1	1
(b)	17	6	6
	44	7	7

Analysis is not possible in the present form due to small expectations in certain cells, (Siegel, S., 1956, Nonparametric statistics). E and N can be combined as the response patterns are identical.

	D	E + N	
(a)	27	2	29
(b)	17	12	29
	44	14	58

$\chi^2 = 9.42$ with 1 df $(.001<p<.01)$.

Significant, i.e. there is a significant association between response and shift worked. By looking at the data in the table above it will be seen that a majority of the day shift workers find the work tiring) but that a large majority of the operators on the evening and night shift (i.e. 12 out of 14 operators) find the work non-tiring.

(iii) Analysis of difference in subjective response within the day shift, (henceforward termed "within the day shift"). The original four response categories for the day shift were combined as in analysis (i) and (ii) above. Frequency of response within the day shift is given below.

(a)	27
(b)	17
	44

$\chi^2 = 2.27$ ($.10 < p < .20$). Non significant, i.e. the difference in frequency between (a) and (b) responses is non significant. The result, even though non significant statistically should not be overlooked, as a large number i.e. 27 of the day shift operators found the work very or fairly tiring.

The operators were asked to specify why they found the work tiring, if they had answered 'very tiring' or 'fairly tiring' to question 10. Their comments varied a good deal, but some of the more frequently occurring are listed below.

Boring

Same work all the time

Sometimes the batches of work are too big

Not enough work

Strain on the eyes

A lot of concentration needed

Lighting causes headache

Table 4 shows the responses to the question, "How frequently do you get headache?".

Table 4. Frequency of report of headache.

Scale	Day Shift	Evening Shift	Night Shift	Total
Often	6	2	–	8
Sometimes	24	2	2	28
Rarely	11	3	4	18
Never	3	–	1	4
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 4.

(i) Total responses.

(a) Often and sometimes 36

(b) Rarely and never 22

58

$\chi^2 = 3.38$ with 1 df ($.05<p<.10$) almost significant, i.e. the difference in frequence between (a) and (b) is almost significant. Even though the number 36 is not significantly different from 22, nevertheless it can be seen that the frequency of complaint in relation to headaches (represented by the former number) is large.

(ii) Interaction.

Analysis is not possible in the present form, (see (ii) for Table 3). But if the responses for the evening shift are to be combined, it must first be determined if the response patterns for these two shifts are the same.

	D	E	N
(a)	30	4	2
(b)	14	3	5
	44	7	7

To determine whether the response patterns are significantly different, Table I in Siegel, S., 1956, Nonparametric statistics, was used. It was found that the difference in response patterns was non significant. Because of this it is possible to combine them.

	D	E + N	
(a)	30	6	36
(b)	14	8	22
	44	14	58

$\chi^2 = 2.89$ with 1 df ($.05 < p < .10$) almost significant, i.e. there is an almost significant association between responses and shift worked. That is to say, there is a tendency for more complaints to be made in relation to headaches by the day shift than the evening and night shifts.

(iii) Within the day shift.

(a)	30
(b)	14
	44

χ^2 = 5.82 with 1 df $(.01<p<.02)$ significant, i.e. there is a significant difference in frequency between (a) and (b) responses. That is to say, a majority of operators (i.e. 30) on the day shift complained about headache.

Table 5 shows the responses to the questions about eyestrain.

Table 5. Frequency of report of eyestrain.

Scale	Day Shift	Evening Shift	Night Shift	Total
Often	7	2	2	11
Sometimes	23	2	4	29
Rarely	8	1	-	9
Never	6	2	1	9
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 5.

(i) Total responses.

(a)	Often and sometimes	40
(b)	Rarely and never	18
		58

$\chi^2 = 8.34$ 1 df ($.001 < p < .01$) significant, i.e. the difference in frequency between (a) and (b) is significant. That is to say when no distinction is made between the shifts, a majority of the operators (i.e. 40) stated that they suffered from eyestrain.

(ii) Interaction.

Analysis is not possible in the present form, see (ii) for Tables 3 and 4.

	D	E	N
(a)	30	4	6
(b)	14	3	1
	44	7	7

The difference between the response patterns for the evening and night shift is non-significant. Therefore the data for these two shifts may be combined.

	D	E + N	
(a)	30	10	40
(b)	14	4	18
	44	14	58

χ^2 = .05 with 1 df non significant, i.e. the association between responses and shift worked is non significant. That is to say, proportionately the same number of operators complain of eyestrain in the day shift as in the evening and night shift.

(iii) Within the day shift.

(a)	30
(b)	14
	44

χ^2 = 5.82 with 1 df ($.01 < p < .02$) significant, i.e. there is a significant difference in frequency between (a) and (b) responses. That is to say, a majority of the day shift operators, (i.e. 30) suffer from eyestrain.

The results from the questions about the environment are shows below. Table 6 shows the responses to the question about the temperature in the office during winter.

Table 6. Responses to the temperature experienced in winter.

Scale		Day Shift	Evening Shift	Night Shift	Total
Too cold	1	-	-	-	-
	2	5	-	1	6
	3	13	1	2	16
	4	17	3	3	23
	5	7	1	-	8
	6	1	1	-	2
Too hot	7	1	1	-	1
No reply		-	1	1	2
Total		44	7	7	58

Table 6 shows that the operators are fairly satisfied with the temperature in the office during winter.

Table 7 shows the responses to the question about the temperature in the office during summer.

Table 7. Responses to the temperature experienced in summer.

Scale		Day Shift	Evening Shift	Night Shift	Total
Too cold	1	-	-	-	-
	2	1	-	-	1
	3	2	1	-	3
	4	11	2	2	15
	5	15	-	2	17
	6	11	-	-	11
Too hot	7	4	-	-	4
No reply		-	4	3	7
Total		44	7	7	58

Table 7 shows that the operators are fairly satisfied with the temperature in the office during summer, but there are slightly more responses towards "too hot" than towards "too cold" Tables 8 and 9 show the responses to the questions about the ventilation during winter and summer.

Table 8. Responses to the ventilation experienced in winter.

Scale		Day Shift	Evening Shift	Night Shift	Total
Stuffy	1	13	1	2	16
	2	11	1	2	14
	3	12	1	-	13
	4	5	2	1	8
	5	2	-	1	3
	6	-	1	-	1
Fresh	7	1	-	-	1
No reply		-	1	1	2
Total		44	7	7	58

Table 9. Responses to the ventilation experienced in summer.

Scale		Day Shift	Evening Shift	Night Shift	Total
Stuffy	1	11	-	-	11
	2	10	-	2	12
	3	10	1	-	11
	4	11	2	2	15
	5	1	-	-	1
	6	1	-	-	1
Fresh	7	-	-	-	-
No reply		-	4	3	7
Total		44	7	7	58

Tables 8 and 9 show that the majority of the responses about the ventilation in the office, both during the winter and during the summer, are towards "stuffy". Table 10 shows responses to the question about the lighting in the office.

Table 10. Responses to lighting.

Scale		Day Shift	Evening Shift	Night Shift	Total
Dim	1	-	-	1	1
	2	4	-	-	4
	3	7	2	-	9
	4	20	3	5	28
	5	2	1	1	4
	6	5	1	-	6
Too bright	7	6	-	-	6
Total		44	7	7	58

Table 10 shows that the majority of the operators are satisfied with the lighting in the office. Table 11 shows responses to the question about the noise in the office.

Table 11. Responses to noise.

Scale		Day Shift	Evening Shift	Night Shift	Total
Quiet	1	-	1	-	1
	2	-	2	1	3
	3	10	2	2	14
	4	15	2	4	21
	5	11	-	-	11
	6	3	-	-	3
Intolerably Noisy	7	4	-	-	4
No reply		1	-	-	1
Total		44	7	7	58

Table 11 shows that most operators are fairly satisfied with the noise in the office, but there is a difference between the day, evening and night shift. The day shift complains more about the noise that the evening and night shift, this is not surprising as there are more operators on the day shift and the noise level in the office is probably higher.

The reason for there being no replies by some of the operators in Tables 6, 7, 8 and 9, is that they had not been working long enough in this office to have experienced the questions.

The reason that one operator did not answer the question about noise (Table 11) is that the operator is deaf.

No objective measurements were carried out on the thermal, visual and acoustic environments. It was originally hoped that it might be possible to do so but there was some resistance from the management, and the matter was not pressed further.

It is the author's subjective opinion (after having worked in the office for several months) that it would be worth an investigation into the environment, and mainly the auditory environment.

The noise is sometimes very disturbing, mainly when the section has a lot of work to do, e.g. 30 - 40 punch machines are working at the same time. Furthermore, the auditory enviroment is made even more unpleasant by the prescence of a teletype machine. This machine punches a tape and also types a printout. Both of these operations are very noisy. The teletype machine is used three times a day. Altogether it is used for about one hour and fifteen minutes per day. This machine could easily be acoustically shielded to reduce the noise level.

Table 12 shows the responses to the question about glare from the artificial lighting.

Table 12. Response to glare for artificial lighting.

Scale	Day Shift	Evening Shift	Night Shift	Total
Not noticeably	8	5	2	15
Hardly noticeably	11	-	1	12
Just noticeably	14	2	4	20
Very noticeably	11	-	-	11
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 12.

(i) Total responses.

(a) Not noticeable and hardly noticeable 27

(b) Just noticeable and very noticeable 31

58

χ^2 = 0.28 with 1 df non significant, i.e. the difference in frequency between (a) and (b) is non significant. Even though the result is statistically non significant, it cannot be overlooked that 31 out of 58 operators find the artificial light glaring.

(ii) Interaction.

Analysis is not possible in the present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	19	5	3
(b)	25	2	4
	44	7	7

The difference in response patterns between the evening and night shift is non significant. Therefore the data for these shifts may be combined.

	D	E + N	
(a)	19	8	27
(b)	25	6	31
	44	14	58

χ^2 = 0.83 with 1 df non significant, i.e. the association between responses and shift worked is non significant. That is to say, proportionally the same number of operators complain about glare on the day shift as on the evening and night shifts.

(iii) Within the day shift

(a)	19
(b)	25
	44

χ^2 = 1 non significant, i.e. the difference in frequency between (a) and (b) responses is non significant. Even though the result is statistically non significant, it cannot be overlooked that 25 out of the 44 operators on the day shift find the artificial light glaring.

Table 13 shows the responses to the question about the working surface.

Table 13. Responses about the working surface.

Scale	Day Shift	Evening Shift	Night Shift	Total
Plenty	1	-	1	2
Enough	21	5	4	30
Barely enough	11	2	2	15
Not enough	11	-	-	11
Total	44	7	7	58

Figure 3 shows the machine and the working surface. Chi-squared tests were carried out on the data in Table 13.

(i) Total response.

(a) Plenty and enough 32

(b) Barely enough and not enough 26

58

χ^2 = 1 non significant, i.e. the difference in frequency between (a) and (b) is non significant. Even though the result is statistically non significant it will be noted that 26 out of the 58 operators find the working surface barely adequate to inadequate from a spatial point of view.

Figure 3. Punch operator machine and the worksurface.

(ii) Interaction.

Analysis is not possible in the present form, see (ii) for Table 3 and 4.

	D	E	N
(a)	22	5	5
(b)	22	2	2
	44	7	7

The difference in pattern of responses between the evening shift and night shift is non significant. Therefore, the data for these shifts may be combined.

	D	E + N	
(a)	22	10	32
(b)	22	4	26
	44	14	58

χ^2 = 1.97 with 1 df non significant, i.e. the association between responses and shift worked is non significant. That is, proportionately speaking, the same number of operators find adequate space available on the work surface both in the day shift on the one hand, and the evening and night shift on the other.

(iii) Within the day shift

(a)	22
(b)	22
	44

χ^2 = <1 non significant, i.e. the difference in frequency between (a) and (b) responses is non significant. Even though the result is statistically non significant, it can be seen that a large number (i.e. 22) of the 44 operators on the day shift find the working surface area barely adequate or inadequate.

Table 14 shows the responses to the question, "How easy is the machine to operate?".

Table 14. Responses about difficulties of machine operation.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very easy	15	3	1	19
Easy	19	3	3	25
Satisfactory	10	1	3	14
Difficult	-	-	-	-
Very difficult	-	-	-	-
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 14.

(i) Total responses.

(a) Very easy, Easy and Satisfactory 58

(b) Difficult and Very difficult 0

58.

χ^2 = 58.00 with 1 df ($p < .001$) (highly significant) i.e. the difference in frequency between (a) and (b) is highly significant. That is to say, none of the operators find the machine difficult to use.

(ii) Interaction

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	44	7	7
(b)	0	0	0
	44	7	7

The difference in pattern of response between the evening and night shift is non significant. Therefore the data for these shifts may be combined.

	D	E + N	
(a)	44	14	58
(b)	0	0	0
	44	14	58

χ^2 = <1 with 1 df (non significant), i.e. the association between responses and shift worked is non significant. That is to say, proportionately speaking, the same numbers of operators on the day shift and on the evening and night shift combined have no difficulties in operating the machines.

(iii) Within the day shift.

(a) 44

(b) 0

44

$\chi^2 = 44.00$ with 1 df ($p < .001$) (highly significant), i.e. the difference in frequency between (a) and (b) responses is highly significant. That is to say, all the operators on the day shift have no difficulties in operating the machines.

Table 15 shows the responses to the question about keeping documents and cards readily to hand.

Table 15. Responses about keeping documents and cards readily to hand.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very easy	5	1	-	6
Easy	17	5	2	24
Satisfactory	21	1	5	27
Difficult	1	-	-	1
Very difficult	-	-	-	-
	44	7	7	58

Chi-squared tests were carried out on the data in Table 15.

(i) Total responses.

(a) Very easy, Easy and Satisfactory 57

(b) Difficult and Very difficult 1

58

χ^2 = 54.07 with 1 df ($p<.001$) (highly significant), i.e. the difference in frequency between (a) and (b) is highly significant. That is to say, the vast majority of the 58 operators find it easy to keep documents and cards readily to hand.

(ii) Interaction.

Analysis is not possible in the present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	43	7	7
(b)	1	0	0
	44	7	7

The difference in response pattern between the evening and night shift is non significant. Data for the evening and night shifts may therefore be combined.

	D	E + N	
(a)	43	14	57
(b)	1	0	1
	44	14	58

χ^2 = <1 with 1 df non significant, i.e. the association between responses and shift worked is non significant. That is to say, proportionately the same number of operators on the day shift as on the evening and night shifts combined have no difficulties in keeping documents and cards readily to hand.

(iii) Within the day shift.

(a) 43

(b) 1

44

χ^2 = 40.09 with 1 df ($p<.001$) highly significant, i.e. the difference in frequency between (a) and (b) responses is highly significant. All but one of the 44 operators on the day shift have no difficulties in keeping documents and cards readily to hand.

Table 16 shows the responses to the question about how well they see the cards in the machine.

Table 16. Responses to how well the operators see the cards in the machine.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very well	8	-	1	9
Well	10	2	-	12
Satisfactorily	25	4	3	32
Badly	1	1	3	5
Very badly	-	-	-	-
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 16.

(i) Total responses.

(a)	Very well, Well and Satisfactorily	53
(b)	Badly and very badly	5
		58

$\chi^2 = 39.72$ with 1 df ($p < .001$) (highly significant) i.e. the difference in frequency between (a) and (b) is highly significant. Only 5 out of the 58 operators have difficulties in seeing the cards in the machine.

(ii) Interaction.

Analysis is not possible in the present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	43	6	4
(b)	1	1	3
	44	7	7

The difference in response patterns between the evening and night shift is non significant, the data for these shifts may therefore be combined.

	D	E + N	
(a)	43	10	53
(b)	1	4	5
	44	14	58

$\chi^2 = < 1$ with 1 df (non significant) i.e. the association between responses and shift worked is non significant. That is to say, proportionately the same number of operators on the day shift as on the evening and night shift combined have no difficulties in seeing the cards in the machine.

(iii) Within the day shift.

(a) 43

(b) 1

44

$\chi^2 = 40.09$ with 1 df ($p < .001$) (highly significant) with difference in frequency between (a) and (b) is highly significant. That is to say, a significant number (i.e. 43 out of 44 operators) on the day shift have no difficulties in seeing the cards in the machine.

Table 17 shows the responses to the question about space around the machine for normal movements.

Table 17. Satisfaction with space around the machine for normal movement.

Scale	Day Shift	Evening Shift	Night Shift	Total
Plenty	4	3	2	9
Enough	29	4	5	38
Barely enough	8	-	-	8
Not enough	3	-	-	3
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 17.

(i) Total responses.

(a)	Plenty and Enough	47
(b)	Barely enough and Not enough	11
		58

χ^2 = 22.34 with 1 df ($p < .001$)(highly significant), i.e. the difference in frequency between (a) and (b) is highly significant. That is to say, a significantly large number, (i.e. 47 out of 58 operators) have sufficient space around the machine for normal movement.

(ii) Interaction

Analysis is not possible in present form, see (ii) for Table 3 and 4.

	D	E	N
(a)	33	7	7
(b)	11	0	0
	44	7	7

The difference in response pattern between the evening and night shift is non significant, the data for these two shifts may therefore be combined.

	D	E + N	
(a)	33	14	47
(b)	11	0	11
	44	14	58

$\chi^2 = <1$ non significant, i.e. the association between responses and shift worked is non significant. That is to say, proportionately the same number of operators express satisfaction with the space round the machine on the day shift as on the evening and night shifts.

<u>(iii)</u> Within the day shift.

(a)	33
(b)	11
	44

$\chi^2 = 11.00$ with 1 df ($p < .001$ (highly significant) i.e. the difference in frequency between (a) and (b) responses is highly significant. That is to say, a significant number (i.e. 33 out of 44 operators on the day shift) are satisfied with the space for normal movement around the machine.

Table 18 shows the responses to the question about space while adjacent machine is under repair.

Table 18. Satisfaction with space while an adjacent machine is under repair.

Scale	Day Shift	Evening Shift	Night Shift	Total
Plenty	3	1	-	4
Enough	8	5	4	17
Barely enough	25	1	1	27
Not enough	8	-	-	8
No reply	-	-	2	2
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 18.

(i) Total responses.

(a) Plenty and enough 21

(b) Barely enough and nor enough 35

56

$\chi^2 = 3.50$ with 1 df ($.05<p<.10$) (almost significant) i.e. the difference in frequency between (a) and (b) is almost significant. Even if the statistical result is not highly significant, it cannot be overlooked that 35 out of 56 operators are dissatisfied with the space provision while an adjacent machine is under repair.

(ii) Interaction.

Anslysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	11	6	4
(b)	33	1	1
	44	7	5

The difference in response pattern between evening and night shift is non significant; therefore the data for these shifts may be combined.

	D	E + N	
(a)	11	10	21
(b)	33	2	35
	44	12	56

$\chi^2 = 13.68$ with 1 df ($p < .001$) (highly significant), i.e. the association between responses and shift worked is highly significant. The majority of the day shift complained about space around the machine (while an adjacent machine was under repair). The majority of the evening and night shift operators found the space adequate.

(iii) Within the day shift.

(a)	11
(b)	33
	44

$\chi^2 = 11.00$ with 1 df ($p < .001$) (highly significant) i.e. the difference in frequency between (a) and (b) responses is highly significant. That is to say, a substantial majority (i.e. 33 out of 44 operators on the day shift) are dissatisfied with the space available while an adjacent machine is under repair.

The operators were also asked to write down their comments, if they thought anything else caused problems or difficulties with the space around the machines. A couple of the comments supplied by several of the operators are listed below.

1. Not enough space for the trolleys.
2. Not enough space behild the chairs where there is a storage unit behind them that is frequently used.

Table 19 shows the responses to the question about the likes and dislikes of the chair.

Table 19. Responses to seating.

Scale	Day Shift	Evening Shift	Night Shift	Total
Like the chair	31	6	3	40
Dislike the chair	13	1	4	18
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 19.

(i) Total reponses.

(a)	Like	40
(b)	Dislike	18
		58

χ^2 = 8.34 with 1 df ($.001<p<.01$) significant, i.e. the difference in frequency between (a) and (b) is significant. The great majority of the operators like the seating provided. Nevertheless one cannot overlook the fact that 18 operators out of 58 dislike the chairs provided.

(ii) Interaction.

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	31	6	3
(b)	13	1	4
	44	7	7

The difference in response pattern between the evening and night shift is non significant: the data for these shifts may therefore be combined.

	D	E + N	
(a)	31	9	40
(b)	13	5	18
	44	14	58

χ^2 = <1 with 1 df non significant, i.e. the association between responses and shift worked is non significant. That is to say proportionately the same number of operators like the seating provided on the day shift as on the evening and night shift.

(iii) Within the day shift

(a) 31

(b) 13

44

χ^2 = 7.36 with 1 df ($.001 < p < .01$) (significant) i.e. the difference in frequency between (a) and (b) responses is significant. The majority of the day shift operators like the seating provided. However, 13 out of 44 operators dislike the chair.

Table 20 shows the responses to the question about adjustability of seat height.

Table 20. Responses to adjustability of seat height.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very easy	6	-	1	7
Easy	17	2	2	21
Satisfactory	7	2	4	13
Difficult	12	1	-	13
Very difficult	2	1	-	3
No reply	-	1	-	1
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 20.

<u>(i)</u> Total responses.

(a) Very easy, Easy and Satisfactory	41
(b) Difficult and Very difficult	16
	57

$\chi^2 = 10.96$ with 1 df ($p < .001$) (highly significant) i.e. the difference in frequency between (a) and (b) is highly significant. The majority of operators find the adjustability of seat height satisfactory or better. Nevertheless, one cannot overlook the fact that 16 out of 57 operators find it difficult to adjust the seat height.

<u>(ii)</u> Interaction.

Analysis is not possible in present form, (see <u>(ii)</u> for Table 3 and Table 4.)

	D	E	N
(a)	30	4	7
(b)	14	2	0
	44	6	7

The difference in response pattern between the evening and night shift is non significant, therefore, the data from these shifts may be combined.

	D	E + N	
(a)	30	11	41
(b)	14	2	16
	44	13	57

χ^2 = 1 with 1 df (non significant) i.e. the association between responses and shift worked is non significant. The response patterns for the day shift is the same as that for the evening and night shift combined.

(iii) Within the day shift.

(a) 30

(b) 14

44

$\chi^2 = 5.82$ with 1 df ($.01 < p < .02$) (significant) i.e. the difference in frequency between (a) and (b) responses is significant. The majority of the day shift operators find seat adjustability satisfactory and better. Nevertheless, it cannot be overlooked that 14 out of 44 operators on the day shift find it difficult to adjust the seat height.

Table 21 shows the responses to the question about adjustability of the back rest.

Table 21. Responses to adjustability of back rest.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very easy	1	-	1	2
Easy	10	3	3	16
Satisfactory	17	1	3	21
Difficult	12	1	-	5
Very difficult	4	1	-	5
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 21.

(i) Total responses.

(a) Very easy, Easy and Satisfactory	39
(b) Difficult and Very difficult	19
	58

$\chi^2 = 6.90$ with 1 df ($.001 < p < .01$) significant, i.e. the difference in frequency between (a) and (b) is significant. The majority of the operators find the adjustability of the seat back rest satisfactory or better. Nevertheless a substantial number, (i.e. 19) find the adjustment mechanism difficult or worse.

(ii) Interaction

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	28	4	7
(b)	16	3	0
	44	7	7

The difference in response patterns between the evening and night shift is non significant: the data for these shifts may therefore be combined.

	D	E + N	
(a)	28	11	39
(b)	16	3	19
	44	14	58

$\chi^2 = < 1$ with 1 df non significant, i.e. the association between responses and shift worked is non significant. The pattern of response on the day shift is effectively the same as the pattern of response for the combined data for the evening and night shifts.

(iii) Within the day shift.

(a)	28
(b)	16
	44

$\chi^2 = 3.27$ with 1 df ($.05 < p < .10$) almost significant, i.e. the difference in frequency between (a) and (b) responses is almost significant. Even though the result is statistically almost significant in form of desirable responses, one cannot overlook that 16 out of 44 operators on the day shift find it difficult to adjust the backrest.

Table 22 shows the responses to the question about chair comfort.

Table 22. Responses to chair comfort.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very comfortable	2	-	1	3
Comfortable	23	5	-	28
Satisfactory	13	2	3	18
Uncomfortable	6	-	3	9
Very uncomfortable	-	-	-	-
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 22.

(i) Total responses.

(a) Very comfortable, Comfortable and Satisfactory 49

(b) Uncomfortable and Very uncomfortable 9

58

χ^2 = 27.59 with 1 df ($p<.001$) (highly significant) i.e. the difference in frequency between (a) and (b) is highly significant. The majority (i.e. 49 out of 58 operators) are satisfied with chair comfort.

(ii) Interaction

Analysis is not possible in the present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	38	7	4
(b)	6	0	3
	44	7	7

The difference in response pattern between the evening and night shift is non significant: the data for these shifts may be combined.

	D	E + N	
(a)	38	11	49
(b)	6	3	9
	44	14	58

χ^2 = <1 with 1 df non significant, i.e. the association between responses and shift worked is non significant. That is to say the pattern of response for the day shift is the same as that for the evening anf night shifts combined.

(iii) Within the day shift.

(a)	38
(b)	6
	44

χ^2 = 23.27 with 1 df ($p<.001$) highly signficant, i.e. the difference in frequency between (a) and (b) responses is highly significant. That is to say, a substantial majority (i.e. 38 out of 44 operators on the day shift) are satisfied with the chair comfort.

Table 23 shows the responses to the question about being able to keep the feet comfortable on the floor when working.

Table 23. Responses to feet comfort.

Scale	Day Shift	Evening Shift	Night Shift	Total
Feet comfortable on the floor	29	4	7	40
Feet uncomfortable in the floor	15	3	0	18
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 23.

(i) Total responses

(a)Feet comfortable on the floor 40

(b)Feet uncomfortable on the floor 18

58

$\chi^2 = 9.93$ with 1 df ($.001 < p < .01$) (significant) i.e. the difference in frequency between (a) and (b) is significant. That is to say, a substantial majority (i.e. 40 out of 58 operators) can place the feet comfortably on the floor when working. It should be noted that quite a number (18) cannot do so.

(ii) Interaction

Analysis is not possible in the present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	29	4	7
(b)	15	3	0
	44	7	7

The difference in response pattern between the evening and night shift is non significant: therefore the data from these shifts may be combined.

	D	E + N	
(a)	29	11	40
(b)	15	3	18
	44	14	58

χ^2 = 2.01 with df non significant, i.e. the association between response and shift worked is non significant. That is to say the pattern of response for the day shift is the same as for the evening and night shifts combined.

(iii) Within the day shift

(a)	29
(b)	15
	44

χ^2 = 4.45 with 1 df ($.02 < p < .05$) significant, i.e. the difference in frequency between (a) and (b) responses is significant. That is to say a substantial majority (i.e. 29 out of 44 operators on the day shift) can have the feet comfortably on the floor when working. Nevertheless, 15 operators cannot place their feet comfortably on the floor when working.

Table 24 shows the responses to the question about the support provided by the back rest on the seat.

Table 24. Responses to support provided by the chair back rest.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very good	2	-	-	2
Good	11	5	1	17
Satisfactory	18	2	3	23
Poor	12	-	2	14
Very poor	1	-	1	2
	44	7	7	58

Chi-square tests were carried out on the data in Table 24.

(i) Total responses.

(a) Very good, Good and Satisfactory	42
(b) Poor and Very poor	16
	58

χ^2 = 11.66 with 1 df ($p < .001$) highly significant, i.e. the difference in frequency between (a) and (b) is significant. That is to say, a majority of the operators, (i.e. 42 out of 58) are satisfied with the support provided by the backrest. Nevertheless 16 operators find the support provided poor or worse.

(ii) Interaction.

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	31	7	4
(b)	13	0	3
	44	7	7

The difference in response pattern between evening and night shift is non significant, the data in these shifts were combined.

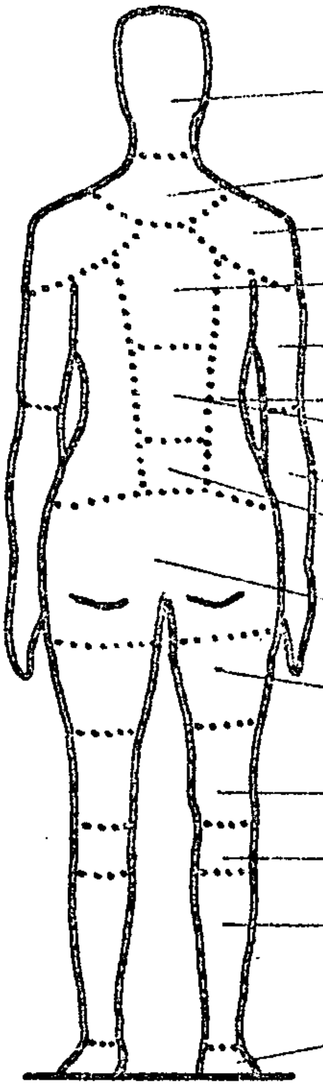
	D	E + N	
(a)	31	11	42
(b)	13	3	16
	44	14	58

$\chi^2 = < 1$ with 1 df (non significant) i.e. the association between responses and shift worked is non significant. That is to say the pattern of response for the day shift is the same as that for the evening and night shift combined.

(iii) Within the day shift.

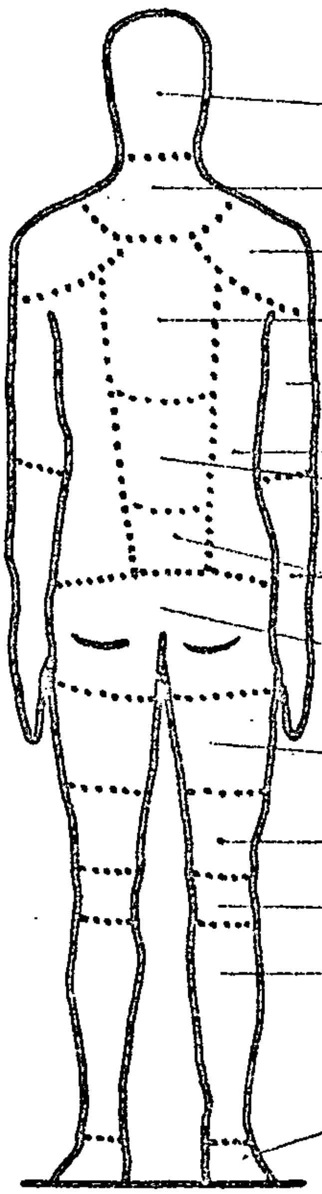
(a)	31
(b)	13
	44

$\chi^2 = 7.36$ with 1 df $(.001 < p < .01)$ (signficant) i.e. the difference in frequency between (a) and (b) response is significant. That is to say, a majority (31 out of 44 operators on the day shift) are satisfied with the support provided by the backrest. It will be noted that 13 of the 44 operators find the backrest support poor or worse.



	Day Shift N=26	Eve-ning Shift N=3	Total N=29
Head	4		4
Neck	16	1	17
Shoulders	12	1	13
Upper back	5	3	8
Upper arms			
Sides	1		1
Mid-back	12		12
Lower Arms	4		4
Lower back	19		19
Buttocks	2		2
Upper thighs	2	1	3
Lower thighs			
Back of knee	6		6
Legs	3	1	4
Feet	2		2

Figure 4. (Woman) The figure shows where on the body the operators complained of pain.



	Night N=6	Total N=6
Head	1	1
Neck	4	4
Shoulders	1	1
Upper back		
Upper arms		
Sides		
Mid-back	5	5
Lower Arms	1	1
Lower back		
Buttocks	1	1
Upper Thighs		
Lower Thighs		
Back of knee	2	2
Legs		
Feet		

Figure 5. (Man) The figure shows where on the body the operators complained of pain.

Table 25 shows the responses to the question about muscular pain.

Table 25. Responses about muscular pain.

Scale	Day Shift	Evening Shift	Night Shift	Total
Often	6	-	1	7
Somestimes	20	3	5	28
Rarely	12	2	1	15
Never	6	2	-	8
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 25.

(i) Total responses.

(a) Often and Sometimes 35

(b) Rarely and Never 23

58

χ^2 = 2.48 with 1 df (non significant) i.e. the difference in frequency between (a) and (b) is non significant. Even though the result is non significant, it cannot be overlooked that 35 out of 58 operators suffer from muscular pain.

(ii) Interaction.

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	26	3	6
(b)	18	4	1
	44	7	7

The difference in response pattern between evening and night shift is non significant: the data from the two shifts may therefore be combined.

	D	E + N	
(a)	26	9	35
(b)	18	5	23
	44	14	58

$\chi^2 = < 1$ with 1 df (non significant) i.e. the association between responses and shift worked is non significant. That is to say the response pattern for the day shift is the same as that for the evening and night shifts combined.

<u>(iii)</u> Within the day shift

(a)	26
(b)	18
	44

χ^2 = 1.45 with 1 df non significant, i.e. the difference in frequency between (a) and (b) is non significant. Even though the result is non significant, it will be noted that 26 out of the 44 operators on the say shift suffer from muscular pain.

If the operator answered 'often' or 'sometimes' on the question reported in Table 25, they were asked to try to specify on a diagram of the body, where they got muscular pain. The results are shown in Figure 4 and Figure 5. The operators were also asked if they had anything they would like to say about the chair, that had not been included in the questionnaire. Some of the comments are listed below.

1. Not enough adjustment height.

2. Footrest needed.

3. Back rest not stiff enough.

4. The adjustability of the back rest in height never stays in the correct position.

5. Could do with more cleaning.

6. Oil comes off the chair and spoils clothes.

Table 26 shows the responses to the question about space in the data preparation section as a whole.

Table 26. Responses about space in the office as a whole.

Scale	Day Shift	Evening Shift	Night Shift	Total
Plenty	2	4	3	9
Enough	35	3	4	42
Barely enough	4	-	-	4
Not enough	3	-	-	3
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 26.

(i) Total responses.

(a) Plenty and Enough	51
(b) Barely Enough and Not Enough	7
	58

χ^2 = 33.38 with 1 df ($p < .001$) (highly significant) i.e. the difference in frequency between (a) and (b) is highly significant. That is to say, a substantial majority (i.e. 51 out of 58 operators) think there is enough space in the office as a whole.

(ii) Interaction

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	37	7	7
(b)	7	0	0
	44	7	7

The difference in response pattern between the evening and night shift is non significant: the data from these shifts may therefore be combined.

	D	E + N	
(a)	37	14	51
(b)	7	0	7
	44	14	58

$\chi^2 = < 1$ with 1 df (non significant) i.e. the association between responses and shift worked is non significant. That is to say, proportionately the same number of operators in the day shift as in the evening and night shift combined think there is enough space in the office.

(iii) Within the day shift

(a)	37
(b)	7
	44

$\chi^2 = 20.45$ with 1 df ($p < .001$) highly significant, i.e. the difference in frequency between (a) and (b) is highly significant. That is to say a substantial majority (i.e., 37 out of 44 operators on the day shift) think there is enough space in the office as a whole.

Table 27 shows the responses to the question about the layout of the data preparation section.

Table 27. Responses about the layout of the data preparation section.

Scale	Day Shift	Evening Shift	Night Shift	Total
Very good	1	2	2	5
Good	10	4	2	16
Satisfactory	28	1	2	31
Poor	5	-	-	5
Very poor	-	-	-	-
No reply	-	-	1	1
Total	44	7	7	58

Chi-squared tests were carried out on the data in Table 27.

(i) Total responses.

(a)	Very good, Good and Satisfactory	52
(b)	Poor and Very poor	5
		57

$\chi^2 = 38.75$ with 1 df ($p<.001$) highly significant, i.e. the difference in frequency between (a) and (b) is highly significant. The vast majority (i.e. 52 out of 57 operators) are satisfied with the layout of the data preparation section.

(ii) Interaction

Analysis is not possible in present form, see (ii) for Table 3 and Table 4.

	D	E	N
(a)	39	7	6
(b)	5	0	0
	44	7	6

The difference in response pattern between evening and night shift is non significant: the data for these shifts may be combined.

	D	E + N	
(a)	39	13	52
(b)	5	0	5
	44	13	57

$\chi^2 = < 1$ with 1 df (non significant), i.e. the association between responses and shift worked is non significant. That is to say, proportionately the same number of operators in the day shift as in the evening and night shift combined are satisfied with the layout in the data preparation section.

(iii) Within the day shift.

(a)	39
(b)	5
	44

$\chi^2 = 26.27$ with 1 df ($p < .001$) (highly significant), i.e. the difference in frequency between (a) and (b) responses is highly significant. That is to say a very substantial number (i.e. 39 out of 44 operators on the day shift) is satisfied with the layout of the data preparation section.

Tables 26 and 27 show that the operators are satisfied with the amount of space in the office as a whole and that they are satisfied with the layout of the office. See Figures 1 and 2 for the office layout.

Once again the operators were asked to write their comments.

The only comment they had, (and it was said by several of the operators), was that "the position of the supervisor leads to unfair distribution of work".

As can be seen in the questionnaire, the operators were asked to list the five documents which they thought were easiest to read. They were also asked to try to specify why they were difficult to read, and if they thought they could be improved, they were asked what changes they would suggest.

The five documents that were regarded as most difficult are listed below.

Table 28. Most difficult documents.

	Day shift	Evening shift	Night shift	Total
Document number	403	403	234	403
" "	243	243	403	243
" "	Credit sales	245	241	Credit sales
" "	204	241	81	204
" "	245	244	398	245

Table 28 shows the five documents that were regarded as difficult for each shift, plus a total, e.g. the documents that had most complaints including all shifts. Some of the reasons, given by the operators why they thought the documents are bad are listed below.

1. Bad writing.
2. Bad carbon.
3. Not first copy.
4. Not enough space for writing on the documents.
5. Print not clear enough.
6. Alterations are unreadable.
7. Transparent paper.
8. Illegible.

9. Because of bad writing, letters are very easily mistaken for another.

Some of the suggestions for improvement supplied by the operators are listed below.

1. Whenever possible documents should be typed.
2. Course in handwriting.
3. Alterations should always be made on a new line.
4. Bigger writing space.
5. Documents should not be on transparent paper.

The five documents that are regarded as easy to read are listed below, in the same way as the difficult ones.

Table 29. Easy documents.

	Day shift	Evening shift	Night shift	Total
Document number	247	247	247	247
" "	Local Purchases (PA20)	145	150	Local Purchases (PA20)
" "	141	141	246	141
" "	398	149	244	398
" "	399	150	161	399

Some of the comments given by the operators why they thought they are easy to read are stated below.

1. Some are only numeric.
2. More space on these documents.
3. They are arranged in a better way.

On the last two questions in the questionnaire, the operators were asked if they had anything to say about their office or their job that had not been mentioned in the questionnaire. Some of the comments made by the operators on the first question which dealt with the office, are listed below.

1. Better lighting.

2. Not enough room under the machine.

3. Too many restrictions.

The comments on the last question which dealt with the job, are listed below.

1. Unfair distribution of work, no relation to working abilities.

2. Pain in the hand sometimes.

From the results of the questionnaire it can be seen that the majority of the operators are satisfied with the work stations and the office. The only question in connection with space, where complaints were made by a majority of the operators was that relating to space availability when an adjacent machine was under repair, (see question 27, see also Table 18). The results reported in Table 18 are almost significant.

An interesting result was obtained in seating, a majority of the operators find their chair acceptable in terms of ease of adjustment of seat height and back rest, and in terms of the general comfort provided, the facility of being able to put the feet on the floor, and the support provided by the back rest. Though these results are significant, a substantial minority of operators, in general numbering around 15 per question, commented adversly on the chair. An exception to the latter statement is provided by the question relating to chair comfort where only half a dozen or so commented adversly. Thus it would be mistaken to conclude that the chairs are necessary fully comfortable, or, if acceptable used to the best advantage in terms of adjustment available. This view is reinforced by the responses of the operators to the question about muscular pain. A very substantial number of operators, a majority, complained about muscular pain in the lower back and mid-back. See Figure 4.

All operators think their job is easy, but about 50% of them find it tiring, and a majority of the operators complained about headache and eyestrain. Table 4 shows the responses to the question about headache and the total responses are almost significant. The responses within the day shift are significant. Table 5 shows the responses to the question about eyestrain, the total responses are highly significant and the responses within the day shift are significant. But Table 10 shows that the majority of the operators are satisfied with the lighting, even if about 50% of the operators complained about glare, (see Table 12), but the results in Table 12 are not significant.

It seems unlikely from the responses to the questionnaire that the environment could cause any discomfort and difficulties for the operators. It also seems unlikely that the complaints about headache and eystrain are caused by the lighting, the cause for this is probably to be found somewhere else, for example, the source documents. The responses to the question about the most difficult shows that two high volume documents 403 and Credit Sales are regarded as difficult documents. The reasons given for them being difficult are bad handwriting, illegibility, etc. It seems more likely that this would be the reason for the headache and eyestrain as the operators spend a large proportion of their time working on these documents. An additional factor observed by the author, but not specifically mentioned in the questionnaire, was the wide variety of source documents and the lack of compatibility between them, particularly in respect of layout. This undoubtedly, on a priori ergonomics grounds, adds to the difficulties and discomfort experienced by the operator and already mentioned above.

To be able to find out whether the source documents cause difficulties for the operators, it is first necessary to establish the key and error rate one can expect in a data preparation task like this. This has been done in the next section.

3.0. Literature Review of Production and Error Rates on Keyboard Entries

3.1. Production Rates

An upper limit to manual input rates, generally cited, was established by Dessler in 1892 (quoted in Devoe, 1967) in his studies of rates obtained in tapping a telegraph key. He reported a range of 5 - 14 taps/sec., with a mean of 8.5 taps/sec. which is equal to 510 strokes/min.

Synchronized multi-finger tapping, as an element of perceptual motor skill, such as typing, yields much higher rates under favourable conditions. Coover (1923), Lahy (1924) and Harding (1931) (quoted in Fox and Stansfield, 1964) have shown that the highest rates are achieved and maintained over a short burst, when successive taps are produced by fingers on alternate hands. They reported 21.8 taps/sec., which is equal to 1308 strokes/min.

Entry rates of normal work for a typist are, of course, lower. For example, Hershman and Hillix (1965) found that a trained typist had an entry rate of about 60 words/min. Seibel (1964) says that a "good" typist will enter something under 100 words/min, and a "top" typist about 150 words/min. Since normal English text usually averages five characters (including space) per word the entry rates in strokes/min are about 300 for a trained typist, 500 for a good typist and about 750 strokes/min for a top typist.

575 typists, with at least six months experience with an electric typewriter did a ten minute speed test in experiments reported by Droege and Hill (1961). The average entry rate was 65.28 words/min which is about 326 strokes/min. Entry rates for unskilled typists ranged down to 20 strokes/min, and lower.

The fast rates for typists are related to free text, which the typist reads well ahead of the characters being typed. Closely related to typing is the use of a keyboard for punching cards.

Klemmer and Lockhead (1962) provide excellent data from several keypunch installations. They collected data on productivity and error rates for more than a thousand operators of IBM card punches. They found that for short-run tests, speed on the keypunch averaged more than 5 strokes/sec, which is equal to 300 strokes/min, on tasks with no complications. On regular working days, averaging over jobs and operators, an average production rate of 2.8 strokes/sec., which is equal to 168 strokes/min was obtained during time actually spent on the machine. The range was from 127-206 strokes/min. They also found that better operators would produce a daily average of more than 250 strokes/min. for some "easier" data entry jobs.

Production rates for skilled oeprators for entry of straight numeric data on a 10-key keyboard, are unknown. Some data for untrained operators, however, are available. Devoe (1967) says in a short review that occasional entries by untrained operators vary from 55-75 strokes/min.

Conrad and Hull (1968) report on housewives entering random numbers at a rate of 78 strokes/min. Kramer and Mahood (1967) quoted in Klemmer (1971) measured speed and error rate of factory workers entering data via a 10-key numeric keyset. They found that the average speed during short input periods was 1.5 strokes/sec. which is equal to 90 strokes/min.

Klemmer and Lockhead (1960) found that the best operators had an entry rate twice as fast as the worst operators. Siebel (1970) says in his excellent review, that for keypunch operators in large installations one may expect the frequency distribution of production rates for different operators to approximate a normal distribution with a standard deviation of 12% of the group mean.

3.2. Error Rates

Klemmer and Lockhead (1960, 1962a and 1962b), provide an excellent estimate of error rates in high volume data entry situations. Their data are taken from four keypunch installations. The average error, estimates in terms of number of keystrokes/error, ranged between 1600 and 4300 keystrokes per undetected error, which is equal to 0.02% and 0.06% keystrokes per error. These errors were those detected in a second punching for verification, and not errors detected and corrected by the original operator.

In order to estimate the number of self-detected and self-corrected errors, a sample of several hundred cards was analysed from each of 46 operators. These errors are sometimes called re-starts or spoiled. The average percentage of detected errors was 0.2% of the keystrokes compared to an undetected error rate of 0.05% for the same operators. Thus, the detected error rate was about four times the undetected error rate. The authors suspected that still higher ratios would be obtained for jobs of a less routine nature.

Klemmer and Lockhead (1962b) also analysed 650 errors to try to find out what kind of errors the operators make (see Table 30). This table is adapted from Klemmer and Lockhead (1962b).

Table 30. Percentage of Different Types of Error found by Lockhead and Klemmer (1962b).

Single character errors		70%
Single numeric errors	40%	
Single alphabetic errors	30%	
Transposition of two or more characters		15%
Omitted character		4%
Extra character		1%
Procedural errors		10%
		100%

Referring to Table 30, in the case of the single-character numeric errors about 80% of them involved striking a key immediately adjacent, either horizontally or vertically, to the correct key. This "aiming error" tendency was not present for the alphabetic characters.

There are no data available on error rates for numeric pushbutton entries for skilled operators on a 10-key keyboard. Devoe (1967) reports an error rate ranging from 0.6-6.0%, but this is for unskilled operators.

Kramer and Mahood (1967) quoted in Klemmer (1971) found an undetected error rate of about 0.5% for occasional users. Smith (1967) quoted in Klemmer (1971) found similar error rates in several production reporting systems.

Individual differences in error rates among keypunch operators are very large. The difference in performance between the best and worst operators is much more striking for errors than for production rates. The 99th percentile operator makes 6 to 10 times as many errors as the 10th percentile operator (Klemmer and Lockhead, 1962). It is essential to note that the figures quoted above are for undetected errors. Whether the ratio is the same for self-detected errors is not known. Since the error range is in about a ten to one ratio and the speed in about a two to one ratio, one wonders if the fastest operators also are the operators who make most errors. In fact Klemmer and Lockhead (1960) showed the opposite, i.e. the operators who are better in respect of speed also make fewer errors. Klemmer and Lockhead (1960, 1962a and 1962b) report that they found that the operators performance for both speed and error rate imporved with time on the job over periods of at least a year or two.

3.3. The Impact of Source Documents on Key and Error Rate.

In the typical high volume data entry situation the human operator receives information from a source, and transcribes it, usually by means of some form of keyboard. A first and obvious principle is that speed and accuracy of the data entry will be dependent upon orderliness and clarity of the source document. Klemmer and Lockhead (1960) report that the production rate for the 'best' document in a keypunch installation is ten times as fast as for the 'poorest' one.

If an operator has to skip visually around a document in order to read the appropriate data, or if the operator has to decipher partially illegible letters or numbers, then the operator is likely to make more errors and to enter the data more slowly.

Klare et al (1957), quoted in Sieble (1970) showed that information written in rectangles across a page or spaced by the insertion of blanks, (as illustrated below), were both better than standard printing.

| L | E | T | T | E | R | L E T T E R

The authors conclude: "It should be emphasised that the advantages of the newer arrangement are best described as potential, since they interfere with strongly developed reading habits. This study indicates, however, that these arrangements may be of value for subjects who have some practice in reading them and/or high ability.

Klemmer and Lockhead (1960) report rather surprising results:

(a) They found no consistent difference in punching speed for documents which contained alphanumeric or straight numeric data.

(b) They found no consistent difference between printing and good handwritten documents in terms of punching speed. Hershman and Hillix (1965) report in an experiment with skilled typists, that keyrate for normal text was slightly faster than for random words, and, furthermore, than random words were typed much faster than random characters. One, 2, 3, 6 or an unlimited number of characters were exposed. The more characters exposed, the better was the typing for the normal text and random words material. For random characters, only a small increase in typing rate was observed when more than three characters were exposed.

Shaffer and Hardwick (1968) found that speed and errors for skilled typists were the same for prose and random word text, and that performance became worse from random letters. Siebel (1970) states that if a particular data entry job involves random or near random strings of alpha or alphanumeric characters then the job will proceed more slowly, and with more errors, than a job with a corresponding number of only random numeric characters.

Siebel (1970) also says that lack of compatibility between documents leads to a more difficult translation from source data to entry responses.

4.0. Company Procedure

4.1. Introduction

Since the production and error rates that may be expected in a keypunch installation have now been established, at least partially, it is important to compare these rates with those obtained in the data preparation section of the Company.

It was stated in section 1.1 that the Company is operating a scheme in which the output of each operator is monitored, i.e. it records the numbers of cards punched and the numbers of error cards produced each month for each operator. Errors produced by the ordinary operators are detected by verifiers. In a somewhat similar manner the numbers of cards verified by the verifiers is monitored. The error rate of verifiers is monitored by a data control system. Standard minutes are allowed for given punch work. Efficiencies are calculated making due allowance for number of batches, errors, holidays, sickness, overtime and waiting time for work to be punched. From this a monthly report is produced, stating efficiency and error rates for each operator and for the whole data preparation section. Calculations made for monthly reports are based upon data taken from a work study made in 1969.

When punchwork comes into the data preparation section it is divided up into batches, the size of the batch depends upon how many operators are free for the moment. A cardtype is a punch card which is used solely with one document or a limited range of documents. Generally speaking each source document has a special corresponding cardtype on to which its data is punched. In one or two instances, for example the credit sales invoice, (C006) which consists of three documents, data is punched on to one corresponding **cardtype**.

In most cases the information from a source document can be punched onto one card, (in other words, most documents contain less information than can be punched in 80 columns). In some cases, so little information is present on the document that the card can be punched to contain the information from two documents. For example, for the C006 (Credit Sales invoice) it is possible for a card to hold information from two documents. The first document starts in column 5 and the second in column 42. In yet other cases a document may contain so much information that it overruns onto two or more cards. For example, with cardtype 403 (Stock Order), it is possible to punch five cards from one document.

Together with a batch of work, the operators are given a sheet with punch instructions, this sheet informs them whether there is one document per card or not. Examples of punch instructions are shown is sections 5.3.1., 5.3.2., and 5.3.3. where they are discussed further.

In the following sections of this chapter, the work study report, the documents, the production rates calculated from the work study report and the error rate reported in one monthly report (for March 1971) will be discussed.

4.2. The Workstudy Report

Because of certain limitations posed on the project by the Company, it was not always possible for the author to collect data he wanted. Instead it was necessary to rely on the workstudy report made in 1969 by the Company Work Study Group. Because of this, the work study report will be briefly reported here.

The Work Study Group used a manual called 'Manual of Standard Time Data for Office' and produced by W.D. Scott and Co. Ltd., Management Consultants, London.

The principle with this manual is that a job is divided into its basic tasks. It is then possible to look the tasks up in the manual. For each basic task are given times allowed under different conditions. There is a special chapter in the manual for operations connected with a punchcard department. At the beginning of that chapter the following is stated.

"The following standards cover the manual operations connected with a punch card department. They include the normal 16 2/3% personal need and fatigue allowance. The time values cover only the actual key punching and verifying operations. Additional allowances must be made for other duties performed, such as non-productive "get ready" and "put away" operations. Since the conditions of the source data, with respect to legibility and arrangement of data, will affect production speeds, the element time values have been developed on the basis of good, fair and poor source data. The following are considered in determining source data classification:

Good source records are those on which data to be punched is arranged in approximately the same sequence as the card columns; data is typewritten or in legible longhand, and no positioning of document or searching time is required between cards.

Fair source falls short of the above requirements, but not to the extent that the continuity or tempo of punching performance is greatly affected.

Poor source records are those on which the arrangement or legibility of the data to be punched is such that balanced motions cannot be developed or maintained.

Good source	5½ hole/sec.
Fair source	4 hole/sec.
Poor source	3 hole/sec."

The Work Study Group of the Company regarded all the documents as "good source". The efficiency figure that is calculated each month for each operator is based on the work study report.

The Work Study Group also calculated the average number of key strokes per card. The extent of the data used in this calculation is not known. The average number of key strokes per card and the number of standard minutes per 100 cards as given in the work study report are given below in Table 31.

Table 31. (From the Work Study Report).
Average number of Keystrokes per Card and Number of Standard Mins. per 100 cards.

	Keystrokes/Card	Standard Mins. per 100 Cards.
Stock Orders	48	23
Ammendments	35	17
Chemical Costing	29	27
Credit Sales	67	42
Names and Addresses	72	32
Br. Stock Investment	25	18
Retail Impact	49	24
Wholesale Impact	49	27
Local Purchases (PA20)	35	17

The work study report said nothing about the error rate likely to be associated with different documents or groups of documents, (such as, for example, those subsumed under the credit sales application).

4.3. The Documents

Table 1 shows that there are 512 different cardtypes used in the data preparation section, and 68 of them are in daily use. In general, as has already been stated, one cardtype corresponds to one document. Many documents in use have not changed since data processing started, i.e. they are designed for clerks, not for punch operators.

The Work Study Group it will be recalled, regarded all documents as "good source records" (see section 4.2.) There are very few documents which would qualify for this description. For example, the credit sales documents, which account for about 1/5th of all punching, (see Table 1), should be regarded as "poor source records". The reasons for this are given below.

(a) Data is not arranged in the correct sequence for punching.

(b) Because the document from which punching is carried out is a carbon copy and the handwriting entries on it are often poor the legibility leaves much to be desired.

Other documents such as some associated with Merchandise Accounting are made of transparent paper. The reason for this is said to be that the document has to be photocopied, sometimes up to 12 times. In a batch of documents made of transparent paper it is very difficult for a punch operator to see whether she is reading data from the first, second or a mixture of the first and second document.

There is no standard size or sizes on the documents. They come in many different sizes, sometimes even in the same batch,

Figure 6. The figure shows an operator working with a batch made up of documents of different sizes.

(see the documents under the punch operators left hand in Figure 6).

The observations made above are of a general nature, but since there are over 500 different documents it was not possible to analyse each one of them in detail. Three documents have, however, been analysed in considerable detail and are reported on in sections 5.3.1., 5.3.2., and 5.3.3. Now when the keyrates that one can expect are known and the work study report that the production rates are based upon and the documents have been discussed, the next thing to do is to find out the production rate for the different documents.

4.4. Present Production Rate

Because of certain limitations posed on the project by the Company, it was not possible to measure the production rate for the different documents. Because of this, data from the work study report had to be used to estimate the production rate. It can be calculated from the work study report, that 100% efficiency in terms of keyrate for all jobs, is equal to 181.8 keystrokes/min. Keystrokes/min. for different applications are given in Table 32.

Table 32. Keyrate for different applications.

Stock Orders	208.8 keystrokes/min.
Amendments	205.8 - " -
Chemical Costing	107.4 - " -
Credit Sales	159.6 - " -
Names and Addresses	225.0 - " -
Br. Stock Investment	138.6 - " -
Retail Impact	204.0 - " -
Wholesale Impact	181.2 - " -
Local Purchases	205.8 - " -

The data in Table 32 have been calculated from the data reported in Table 31 in the following way using the amendments application as an illustration.

	Keystrokes	Standard minutes per 100 cards
Amendments	35	17

$$\frac{35 \times 100}{17} = 205.8 \text{ keystrokes/min.}$$

As Table 32 shows the range over application is from 107.4 keystrokes/min up to 225.0 keystrokes/min.

The personal allowances which it is recalled from section 4.2 is equal to 1/6th is included in the above production rate. Without the personal allowance the 100% efficiency for all jobs is 218.1 keystrokes/min. with a range from 128.1 keystrokes/min. up to

270.0 keystrokes/min. It must be reiterated that the keyrates given above are average figures for several documents, since even within a given application, e.g. credit sales, there are several different documents.

The exact keyrate for each document is not known. The overall efficiency for all three shifts at the beginning of 1971 was about 75%. See Table 33.

Table 33. The average efficiency for all operators on different shifts.

Dayshift	84 - 89%
Eveningshift	47 - 48%
Nightshift	50 - 54%

Since the efficiency figure takes into account the error rate, it is difficult to state precisely the operators present key entry rate. Both the self detected and self corrected error rate and the errors detected by the verifier have to be known to be able to calculate the key entry rate for each operator.

The self detected error rate is not known from Company records, but the number of error cards detected by the verifier and by data control is known and will be discussed in the next section.

Nevertheless, even allowing for these difficulties the entry rate calculated over all documents for all operators seems to correspond, to a first order of magnitude to that quoted in the literature and described in section 3.1.. The calculated key rate refers to 100% efficincy. The actual overall efficiency for all three shifts at the beginning of 1971 was about 75%. That is to say, the actual overall keyrate in the data preparation section is well below the key rate quoted in the literature and described in section 3.1. The reasons for this are not known, but one reason may be that advanced by the management in the informal interviews (see section 1.2) i.e. the large number of different types of source documents and the lack of compatibility between them, particularly in respect of design layout.

4.5. Present Error Rate

The error rate to be discussed here is mainly that associated with the punch operators. The error rate of verifiers will be discussed very briefly.

The only errors made by the punch operators and which are recorded by the Company, are the errors found by the verifiers. There are no records of the number of self detected and self corrected (sometimes called spoils) errors made by the punch operators.

The only errors recorded for the verifier are the errors that go through to the computer.

There are no records of the number and distribution of errors made for the different documents. Neither are there records of the type of errors made or where they occur. The overall error rate both punch operators and verifiers for the month of March as reported in the monthly report was 0%. After having studied the monthly report, it was decided to divide the personnel in the data preparation section into punch and verify operators, and to recalculate the error rates. These are given in Table 34.

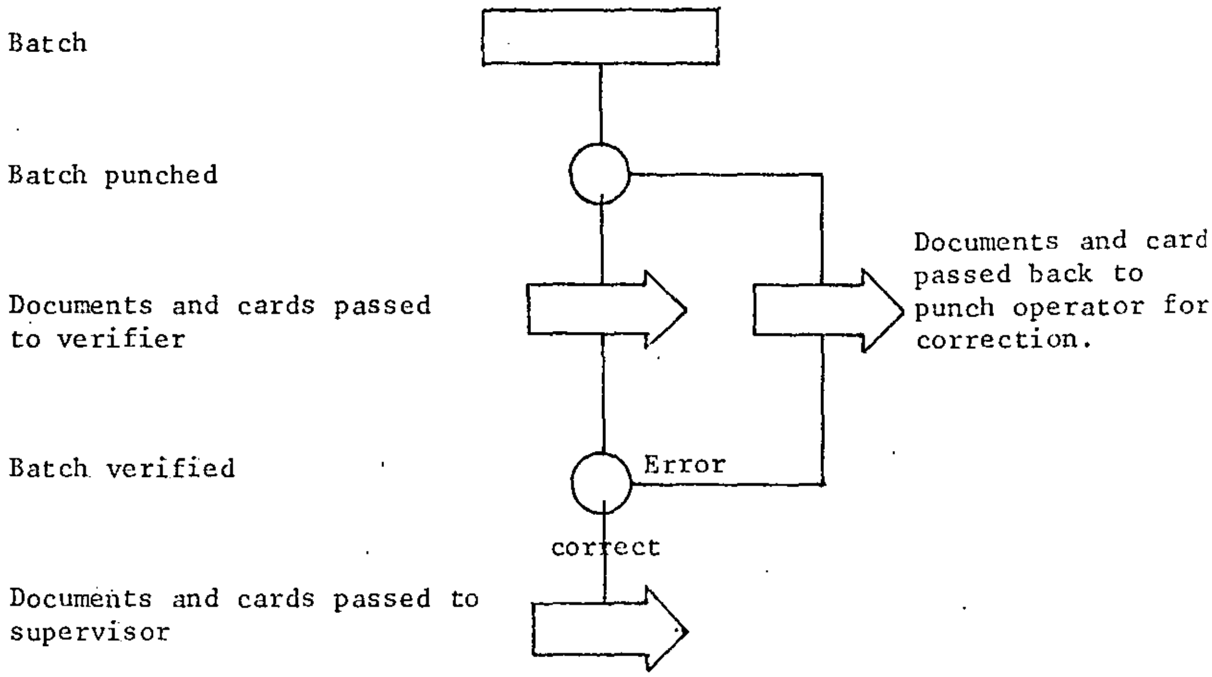
Table 34. Card output, error cards and error rate for punch operators and verify operators on each shift.

	Card Output	Error Cards	Error Rate in % of Cards
Punch operators (day)	396208	12981	3.27
Punch operators (evening)	39774	1022	2.56
Punch operators (night)	68469	832	1.21
Total	504451	14835	2.94
Verify operators (day)	396208	156	0.039
Verify operators (evening)	39774	29	0.072
Verify operators (night)	68469	42	0.061
Total	504451	227	0.045
Grand Total	1008902	15062	1.49

It can be seen from Table 34 that the error rate for punch and verify operators combined is equal to 1.49%. The total card output and the total number of error cards are exactly the same as in the monthly report. The reason for the total error rate being 0% in the monthly report is not known.

The cost of an error (detected or otherwise) depends upon the system for detecting errors, for correcting errors, and considerations of what happens if the error "gets through". The error correction procedure within the data preparation section is reported below in flowchart form.

Flowchart



As can be seen, this is a rather complicated and long winding way of correcting errors. Since, however, the verify machines do not have a punch facility this is the only reasonable way to organise the work.

An important set of questions that can be raised with an error recording system like this is:

Do the verifiers record every error they detect?

If not, what is the actual error rate found by the verifiers?

What is the self detected and self corrected error rate for the punch operators?

To be able to compare the error rate reported in the literature review (section 3.2), with the error rate reported in the monthly report produced by the Company, it is necessary to convert the error rate reported in the monthly report from error rates in % of cards to keystrokes per error, since the data in the literature are reported in the latter terms.

Table 31 shows the average numbers of keystrokes per card for each application, and from this the average number of key strokes per card for all applications can be calculated. It is 45. The card output for the punch operators is 504451 (see Table 34) and the number of error cards is 14835. That is to say, the error rate found by the verifier in the data preparation section in keystrokes per error is equal to:

$$\frac{(504451 + 14835) \times 45}{14835} = 1575 \text{ keystrokes/error}$$

The error rate reported in Klemmer and Lockhead (1960, 1962) is 1600 - 4300 keystrokes/error, (see section 3.2) i.e. the error rate for the punch operators reported in the monthly report is slightly higher than the error described in the literature review (see section 3.2).

It has now been established that both the keyrate (that was calculated from the Work Study Report) and the error rate (reported in the monthly report) are worse than the data given in the literature.

The average error rate for punch operators reported in Table 34, i.e. 2.94% refers to the errors found by the verifier and not the total error rate, i.e. the figure of 2.94% does not include the self detected and self corrected errors. Klemmer and Lockhead (1962) found that the ratio between the self detected error rate and the error rate found by the verifier was 4:1, (see section 3.2). Because of this, and also because of what have been determined and discussed earlier, i.e.

(a) the impact of a document upon key and error rate, (see section 3.3),

(b) the documents used in this installation, (see section 4.3),

(c) the way the punch operators errors are recorded, and the fact that error rate reported in the monthly report was below the error rate given in the literature review, (see section 3.2), it was decided to establish the total error rate for the punch operator, i.e. both the self detected and self corrected error rate and the error rate found by the verifiers. This is described in the following section.

5.0. The Collection of Error Cards

This part of the project is concerned with why an operator makes an error, i.e. the problem under consideration is what causes an error. Kinkead (1967) reports that most errors are detected as they are made, except for errors such as skipping words or lines which are usually not noted without subsequent visual inspection.

An article in Computer International 1971, "Finding out why keyboard operators go wrong", reports a research project where it was found that operators keying into keypunch machines can tell by ear when they make a mistake.

Because of this, it should be possible to find out what causes an error, since an operator immediately stops when she thinks she has made an error, and if it is an error she throws the card away, i.e. the error was made on the last column punched on the card.

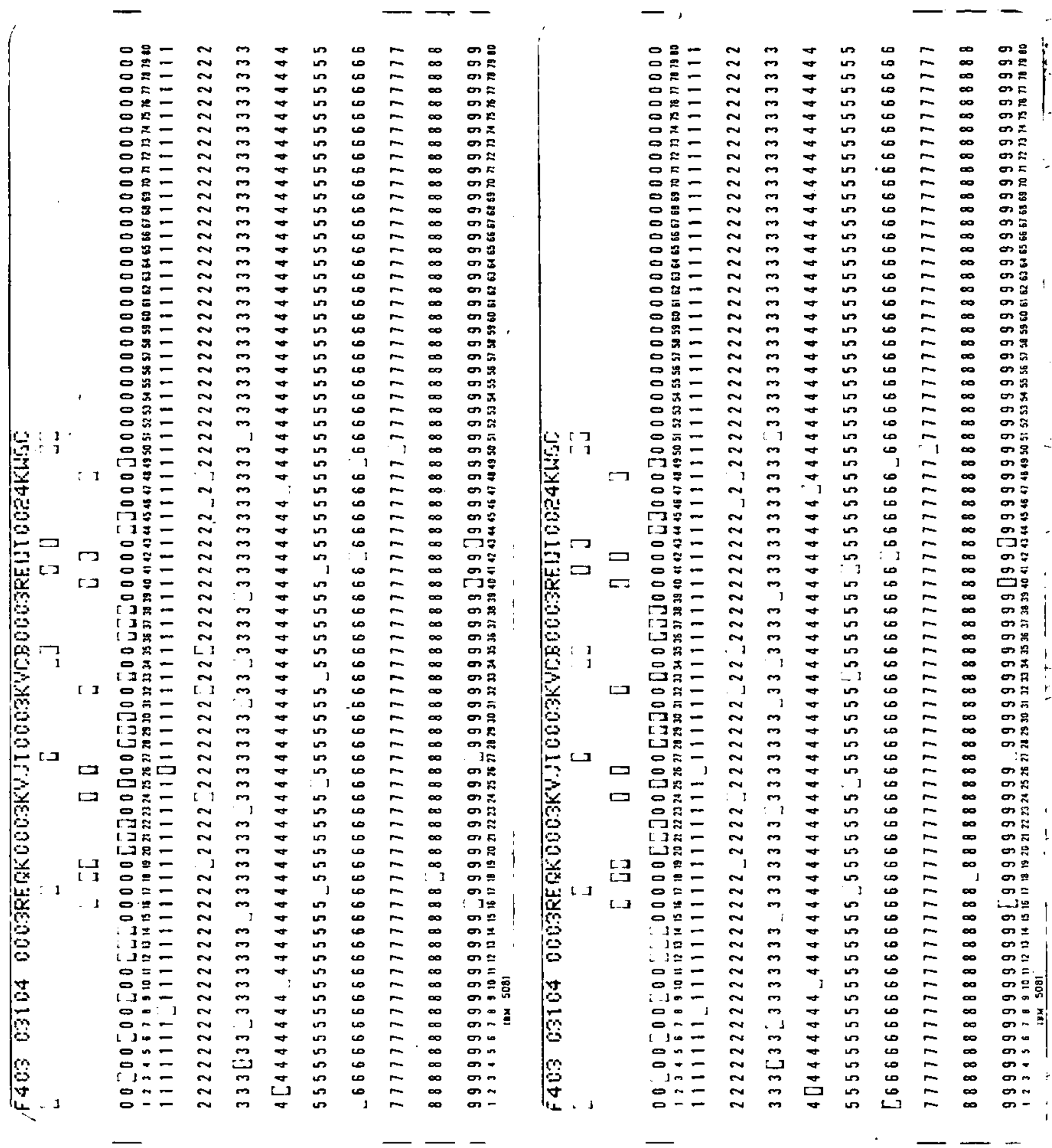
It was thought by the author that the self detected and self corrected error rate for the punch operators could be high in the data preparation section. The reasons for this were:-
(a)the large number of different documents used in the data preparation section, (b) the layout of the documents, and (c) lack of compatibility in terms of size and layout between the documents. Klemmer and Lockhead (1962b) found that the self detected error rate was about four times the undetected error rate, and they suspected that still higher ratio would be

found for jobs of a less routine nature, (see section 3.2). Because of this it was decided to determine, if possible, the total error rate for the punch operators, which, if any, document caused more errors than the others, and also to see if there were any similarities between the errors made on the different documents.

It was not possible to collect the error cards per operator per document since the Company thought that the procedures involved might disturb and interrupt the operators in their work. It was possible, however, to collect error cards for the section as a whole with no distraction between operators and documents. It was possible to distinguish between cards associated with different card types (but not operators) in subsequent analysis.

All error cards were collected each day for a whole working week in March from bins into which error cards were put by the operators and verifiers. The collection was made after the working day for each shift.

A first sorting of the error cards was carried out immediately to separate verified and unverified cards. This was easily achieved because verified cards are notched on the card whereas unverified cards are not, (see Figure 7).



Unverified

Verified

Figure 7. The figure shows a verified and an unverified card.

5.1. Analysis of the Error Card

The cards were sorted, counted and analysed twice using computer facilities in the data preparation section. Sorting, counting and analysis were carried out separately for unverified and verified cards.

Table 1 in section 1.1 shows the different applications, such as Merchandise accounting, Credit sales, etc. Two of the applications, program and other projects, are normally not punched from documents. Since this part of the project is concerned with what document feature causes an error, it was decided to treat all cards that had not been punched from a document as one group, regardless of the application to which they belonged. It is possible to separate a card that has been punched from a document from a card that has not been so punched. This is because all cards that have been punched from a document have a letter in the first column. This is not the case for other material.

The sorting, counting and analysis procedure was done in the following way:-

1. A sort was carried out on the first column to separate the cards with a letter in the first column from the cards with a digit or another character in the first column. This was done to separate cards punched from a document from cards which were not punched from a document. All cards that did not have a letter in the first column were treated as one group and called 000.

2. A second sort was carried out on columns 2, 3 and 4. These columns provide information on the card type. For a discussion of card types the reader is referred back to section 4.0.

For a few card types, for example PA20 (Local Purchases) there is a letter in the second column, but for the majority of documents there are three numbers in columns 2, 3 and 4. This sort also put the card types in ascending order alphabetically and numerically. For each card type the following were recorded:-

(a) The numbers of cards. This was done so that the percentage of error cards for each card type could be calculated.

(b) The number of columns punched, and which columns were punched.

(c) The last column punched for each card. This was done to try to find out where the errors occurred. See section 5.0.

(d) Whether the last column punched was alpha or numeric.

The results of the analysis are shown and discussed in the next section.

5.2. Results of the Error Card Analysis

The error rate shown below is calculated in the same way as on the monthly report, i.e. total number of correct cards over error cards. This is done so it is possible to compare the error rate obtained in the survey with the error rate reported in the monthly report.

The total number of correct cards punched in the week under investigation was 104,877. This is regarded as a low figure by the Company. The reason for this low figure is that it is always a slack period in March. The proportions of different documents are about the same, however, whether it is a slack period or not.

The total number of error cards, produced by the punch operators for this week was 31,925. This figure includes unverified cards, (both cards containing self detected and self corrected errors (spoils) and verified cards, i.e. cards containing errors detected by the verifier). The number of self detected and self corrected error cards was 25,162. The number of cards containing errors detected by the verifier was 6,763.

Total number of error cards expressed as a percentage of the total number of correct cards was:-

$$\frac{31{,}925 \times 100}{104{,}877} = 30.44\%$$

Total number of self detected error cards expressed as a percentage of the total number of correct cards was:-

$$\frac{25{,}162 \times 100}{104{,}877} = 23.99\%$$

Total number of verified error cards expressed as a percentage of the total number of correct cards was:-

$$\frac{6,763 \times 100}{104,877} = 6.45\%$$

It is interesting to note that the ratio between self detected error cards and verified error cards is about 4.1, i.e. exactly the same as Klemmer and Lockhead found. Their ratio, however, was calculated from percentage of errors per key strokes while the present ratio is calculated from percentage of error cards.

The difference between the error rate found in this survey and the Company's monthly report can be seen in Table 35.

Table 35. Error rate found in the survey compared with the error rate reported in the Company's monthly report.

NO. OF CARDS PUNCHED	NO. OF ERROR CARDS	TOTAL ERROR RATE %	NO. OF SELF DETECTED ERROR CARDS	SELF DETECTED ERROR RATE %	NO. OF VERIFIED ERROR CARDS	VERIFIED ERROR RATE %	COMPANY'S MONTHLY REPORT: PUNCH OPERATORS ERROR RATE %	COMPANY'S MONTHLY REPORT: VERIFIERS ERROR RATE %	COMPANY'S MONTHLY REPORT: TOTAL ERROR RATE %
104,877	31,925	30.44	25,162	23.99	6,763	6.45	2.94	0.045	1.49

The author thinks that the most appropriate way to measure error rate in a card punch installation is in the terms of the metric employed here, i.e. cards containing an error. The reason is that if an error is made the card is spoiled, and a new card has to be punched. On some other data preparation equipment it is possible to backspace and correct the error. When this is the case the correct way to measure error rates is in key strokes per error.

To be able to compare the error rate found in this installation with data reported in the literature it is necessary to convert the error rate in terms of percentage of cards containing an error to error per key stroke.

The number of cards correctly punched for the different applications were:

Application	Cards Punched		Keystrokes/card (from work study report)		Total keystrokes
Merchandise Acc.	63330	x	48	=	3039480
Credit Sales	14144	x	67	=	947648
Retail takings	2402	x	49	=	117698
Local purchases	11102	x	35	=	388570
Programs	8678	x	50	=	433900
Others	5221	x	50	=	261050
	104877				5188346

Thus, it will be seen that for cards correctly punched 5188346 keystrokes were made. To obtain error rates in terms of keystrokes per error it is necessary to know for the error cards:-

(a) the total number of keystrokes made,

and (b) the total number of incorrect keystrokes.

Unfortunately, it is not possible to break down this information by application. From computer analysis however it appeared that on the error cards a total of 833791 keystrokes were made. Of these 31,925 were errors. In other words there was effectively one keystroke error per error card. Thus, the total keystroke per error rate including both self detected and verified errors is equal to

$$\frac{5,188,346 + 833,791}{31,925} = 188.63 \text{ keystrokes/error} = 0.53\%$$

Klemmer and Lockhead (1960) reported that the error rate was 1600 - 4300 strokes/error, but this was for errors found by the verifier. The error rate found by the verifier in this installation was calculated as follows.

Cards containing 5188346 keystrokes were passed to the verifiers and found to be correct. In addition a further 6763 cards were passed to the verifiers. These contained 569,963 keystrokes, of which approximately 6763 keystrokes were in error. Therefore, the error rate as found by the verifiers, in terms of keystrokes per error is equal to

$$\frac{5,188,346 + 569,963}{6763} = 851.44 \text{ keystrokes/error} = 0.12\%$$

The error rate for self detected and self corrected error was calculated as follows.

Cards containing 5,188,346 keystrokes were punched and passed on to the verifiers by the punch operators. In addition a further 25162 cards punched by the punch operators, but on these cards the operators themselves detected an error. These cards contained 263,828 keystrokes of which approximately 25162 keystrokes were in error. Therefore, the self detected error rate in terms of keystrokes per error is equal to:

$$\frac{5,188,346 + 263,828}{25,162} = 216.68 \text{ keystrokes/error} = 0.46\%$$

The above error rates in key strokes/error, is only a rough figure, because it was necessary to rely on the work study report. But it gives an indication of how error rate in this data preparation section compares with what has been reported in the literature. There is no evidence in the literature on the total error rate, but there is one report on the self detected and self corrected error rate. Klemmer and Lockhead (1962) reported that the average percentage of detected errors was 0.2% of key strokes compared with an undetected error rate of 0.05% for the same operators.

The error rate found by the verifier in the present case is about 2 – 5 times as high as the data reported by Klemmer and Lockhead (1960).

In the analysis of errors occurring in the week under review, altogether 470 different card types were recorded. In order to obtain a better understanding of why the production rate was low and the error rate, however conceived high, it was decided to look in more detail at a limited number of card types and their associated documents to try and determine the reasons for poor performance. The card types and documents chosen for study and the results obtained are described in the next section.

5.3. Choosing the Documents

The criteria for choosing the documents associated with particular card types were high error rate and high volume on the cards. Three card types were chosen for an in depth study:-

C006 (Credit Sales Invoice)

PA20 (Local Purchases)

403 (Stock Orders)

All of them are high volume documents and all of them have a high error rate. Since the above three card types are high volume, it was thought that the operators and the Company would benefit more if these three were analysed in detail and then redesigned.

It is interesting to note that the documents associated both with C006 and 403 are regarded as difficult by the operators, (see section 2.1). PA20's document is regarded as easy, (see section 2.1). These three card types account for about 30% of all punched cards.

The total error rates associated with these card types are reported in Table 36.

Table 36. Error rate obtained in the survey in % of cards for C006, PA20 and 403, and punch rate obtained in the work study report.

CARD TYPE	NO. OF PUNCH CARDS	NO. OF ERROR CARDS	TOTAL ERROR RATE % OF ERROR CARDS	SELF DETECT AND SELF CORRECT ERROR CARDS	SELF DETECT AND SELF CORRECT ERROR RATE % OF ERROR CARD	VERIFIED ERROR CARDS	VERIFIED ERROR RATE % OF ERROR CARDS	PUNCH RATE (FROM WORK STUDY REPORT) KEY-STROKES/ MIN%
C006	8,204	2,212	27.0%	1,604	19.6%	608	7.4%	159.6
PA20	11,102	1,775	16.0%	1,477	13.3%	298	2.7%	205.8
403	11,956	3,649	30.5%	2,793	23.3%	856	7.2%	208.8

The error rates, in keystrokes/error and percentage terms, are shown below for each cardtype. These data have been calculated in the same way as the error rates in keystrokes/error reported in section 5.2.

Table 37. Total error rate in keystrokes/error.

C006 $\frac{549668 + 85432}{2212}$ = 287 keystrokes/error = 0.34%

PA20 $\frac{388570 + 42357}{1775}$ = 242 keystrokes/error = 0.41%

403 $\frac{573888 + 126448}{3649}$ = 191 keystrokes/error = 0.52%

The error rates, in keystrokes/error, for the self detected errors and for the errors found by the verifier are given below. See Tables 38 and 39.

Table 38. Self detected error rate in keystrokes/error.

C006 $\frac{549668 + 49993}{1604}$ = 373 keystrokes/error = 0.26%

PA20 $\frac{388570 + 33326}{1477}$ = 285 keystrokes/error = 0.35%

403 $\frac{573880 + 81385}{2793}$ = 234 keystrokes/error = 0.42%

Table 39. Verified error rate in keystrokes/error.

C006 $\frac{549668 + 35439}{608}$ = 962 keystrokes/error = 0.10%

PA20 $\frac{388570 + 9031}{298}$ = 1334 keystrokes/error = 0.07%

403 $\frac{573888 + 45063}{856}$ = 723 keystrokes/error = 0.13%

The three card types will be analysed separately in more detail in the following sections.

5.3.1. Error analysis of C006 - Credit Sales Invoices

The card type C006 is used in association with three different documents, (see section 4.1). Two of them, a small invoice (OM826) and a big invoice (OM830) are used in branches of the Company. The third invoice (OM850) is used by the agricultural section of the Company. All these invoices are illustrated in Appendix 2.

It is always the second copy of the invoice, completed in carbon form, that comes to the data preparation section. The reason for this is said to be that the first copy, i.e. the best copy, must go to the customer.

It can be seen in Appendix 2, that two OM826 (the small invoice forms) are kept together by a perforation. Since OM826 and OM830 are always mixed in a batch, both big and small invoices containing the same type of information are presented together in one pile to the operator. It is thus very easy for a punch operator to miss a small invoice in a batch, especially when a small invoice comes alone, i.e. two of them are not kept together by the perforation, (see Figure 6).

The third invoice OM850 is not mixed with other invoices in a batch.

The colour of the copies of OM826 and OM830 that come to the data preparation section are sometimes white, sometimes green.

The information from two documents can be punched on each card, (see section 4.0) the first document starts in column 5 and the second document in column 42.

When the operators are given a batch, they are also given a punch instruction, (see Figure 8 and section 4.0).

The documents and associated punch procedures have now been described. The analysis of the error cards for card type C006 follows.

The number of cards ending in the different columns are shown in Table 40.

CREDIT SALES ACCOUNTING

TITLE: INVOICE

DEPTL. LETTER: C

CARD TYPE: 006

SEQUENCE: FOLLOWING BATCH CONTROL CARD

PROGRAM NO: FC0100

PUNCHING DOCUMENT

FIELD NAME	FROM	TO	TYPE		NOTES
CARD CODE	1	4	A		
BRANCH NUMBER	5	9	N	L	
CHECK LETTER	10		A		
CUSTOMER NUMBER	11	14	N	L	
DAY (INVOICED)	15	16	N	L	1
MONTH (INVOICED)	17	18	N	L	2
INVOICE SERIAL LETTER	19		A		
INVOICE SERIAL NUMBER	20	24	N	L	
SETTLEMENT DISCOUNT CODE	25		N	B	3
DISSECTION	26	27	N	LB	4
AMOUNT £	28	32	N	L	
p	33	34	N	L	
TRADE DISCOUNT £	35	39	N	LB	
p	40	41	N	LB	

NOTES:

1. Punch 1-31
2. Punch 1-12
3. Punch 1 = 2½% 5 = 12½%
   2 = 5% 6 = 15%
   3 = 7½% 7 = Group
   4 = 10%
4. Fieldsman = 1 - 13

Two transactions may be punched into each card at Cols 5 and 42.

Figure 8. An example of a punch instruction for Credit Sales Invoices (C006)

Table 40. Cards ending in different columns.

Field No.	Column No.	Verified Cards	Non-Verified Cards
Card code	1 - 4		
Branch number	5	1	16
	6	0	9
	7	0	17
	8	0	18
	9	1	28
Check letter	10	0	32
Customer number	11	0	8
	12	0	15
	13	0	13
	14	0	41
Day (invoiced)	15	2	34
	16	0	25
Month (invoiced)	17	0	15
	18	0	26
Invoice serial letter	19	0	57

/continued...

Field No.		Column No.	Verified Cards	Non-Verified Cards
Invoice serial number		20	0	16
		21	0	7
		22	3	13
		23	0	13
		24	0	41
Settlement discount code		25	0	9
Dissection		26	1	7
		27	0	8
Amount	£	28	0	2
		29	0	10
		30	0	10
		31	0	10
		32	0	11
	p	33	3	21
		34	9	77
Trade discount	£	35	0	6
		36	0	1
		37	0	3
		38	0	1
		39	0	12
	p	40	0	17
		41	9	59

/continued...

Field No.	Column No.	Verified Cards	Non-Verified Cards
Branch number	42	0	9
	43	0	4
	44	0	3
	45	0	9
	46	1	86
Check letter	47	2	39
Customer number	48	0	9
	49	0	9
	50	0	8
	51	0	27
Day (invoiced)	52	0	33
	53	0	25
Month (invoiced)	54	1	16
	55	0	22
Invoice serial letter	56	1	89
Invoice serial-number	57	0	16
	58	0	18
	59	0	18
	60	0	15
	61	0	41
Settlement discount code	62	0	10

/continued...

Field No.		Column No.	Verified Cards	Non-Verified Cards
Dissection		63	0	12
		64	0	10
Amount	£	65	0	3
		66	0	4
		67	0	6
		68	0	2
		69	5	13
	p	70	47	20
		71	244	101
Trade discount	£	72	1	10
		73	0	1
		74	0	2
		75	0	3
		76	3	9
	p	77	25	18
		78	249	99
		79	0	2
		80	0	2

It can be seen from Table 40 that the majority of error cards that were found by the verifier, end, as one might expect in column 71 and 78. The reason for this is that the information from the second document on the card end in column 71, if there is no trade discount, and in column 78 if there is trade discount.

It is also interesting to see in which columns the cards that have not been verified, i.e. the self detected error cards, end. Table 40 shows that the last columns punched, for the self detected error cards determine what feature of the document caused the errors, another table was made up in which more details of the documents are shown, in particular, which information is alpha and which numeric. See Table 41.

Table 41. Error analysis of C006.

FIELD NAME	COLUMN NO. FROM	COLUMN NO. TO	NO. OF ERRORS	TYPE	AV. NO. OF ERROR/ COLUMN
Card code	1	4	73	AN	
Branch No.	5	9	88	N	17.6
Check letter	10		32	A	32
Customer No.	11	14	77	N	19.3
Day (invoiced)	15	16	59	N	29.5
Month (invoiced)	17	18	41	N	20.5
Invoice serial letter	19		57	A	57
Invoice serial No.	20	24	90	N	18
Settlement discount code	25		9	N	9
Dissection	26	27	15	N	7.5
Amount £	28	32	43	N	8.6
Amount p	33	34	98	N	49
Trade discount £	35	39	23	N	4.6
Trade discount p	40	41	76	N	38
Branch No.	42	46	111	N	22.2
Check letter	47		39	A	39
Customer No.	48	51	53	N	13.3
Day (invoiced)	52	53	58	N	29
Month (invoiced)	54	55	38	N	19
Invoice serial letter	56		89	A	89
Invoice serial No.	57	61	108	N	21.6

/continued...

FIELD NAME	COLUMN NO. FROM	TO	NO. OF ERRORS	TYPE	AV. NO. OF ERROR/ COLUMN
Settlement discount code	62		10	N	10
Dissection	63	64	22	N	11
Amount £	65	69	28	N	5.6
Amount p	70	71	121	N	60.5
Trade discount £	72	76	25	N	5
Trade discount p	77	78	117	N	58.5
	79		2		
	80		2		

Table 41 shows where the errors are made on the cards in relation to the information on the document. It was thought it would be worthwhile finding out whether alpha and numeric columns had the same error rate.

Table 41 shows the average number of errors per column, and this shows that alpha columns caused 54.25 errors per column, and numeric caused 21.70 errors/column, e.g. alpha field caused about 2.5 times as many errors as a numeric field.

It is also interesting to compare the first half of the card, i.e. columns 5 - 41 with the second half, i.e. column 42 - 78, since there are two documents/card. See Table 42.

Table 42. A comparison of first and second document.

Field name	First document		Second document	
Branch No.	88		111	
Check letter	32	197	39	203
Customer No.	77		53	
Day (invoiced)	59	100	58	96
Month (invoiced)	41		38	
Invoice serial letter	57	147	89	197
Invoice serial no.	90		108	
Settlement discount code	9	9	10	10
Dissection	15	15	22	22
Amount £	43	141	28	149
Amount p	98		121	
Trade discount £	23	99	25	142
Trade discount p	76		117	
	708		819	

Table 42 shows that slightly more errors occur on the second part of the card, i.e. the second document gives rise to more errors. It can also be seen from the same Table that the proportions of errors for the different fields are about the same on the first and second half of the cards, i.e. it is the same document information that causes difficulties, whether it is in the beginning or the middle of the card.

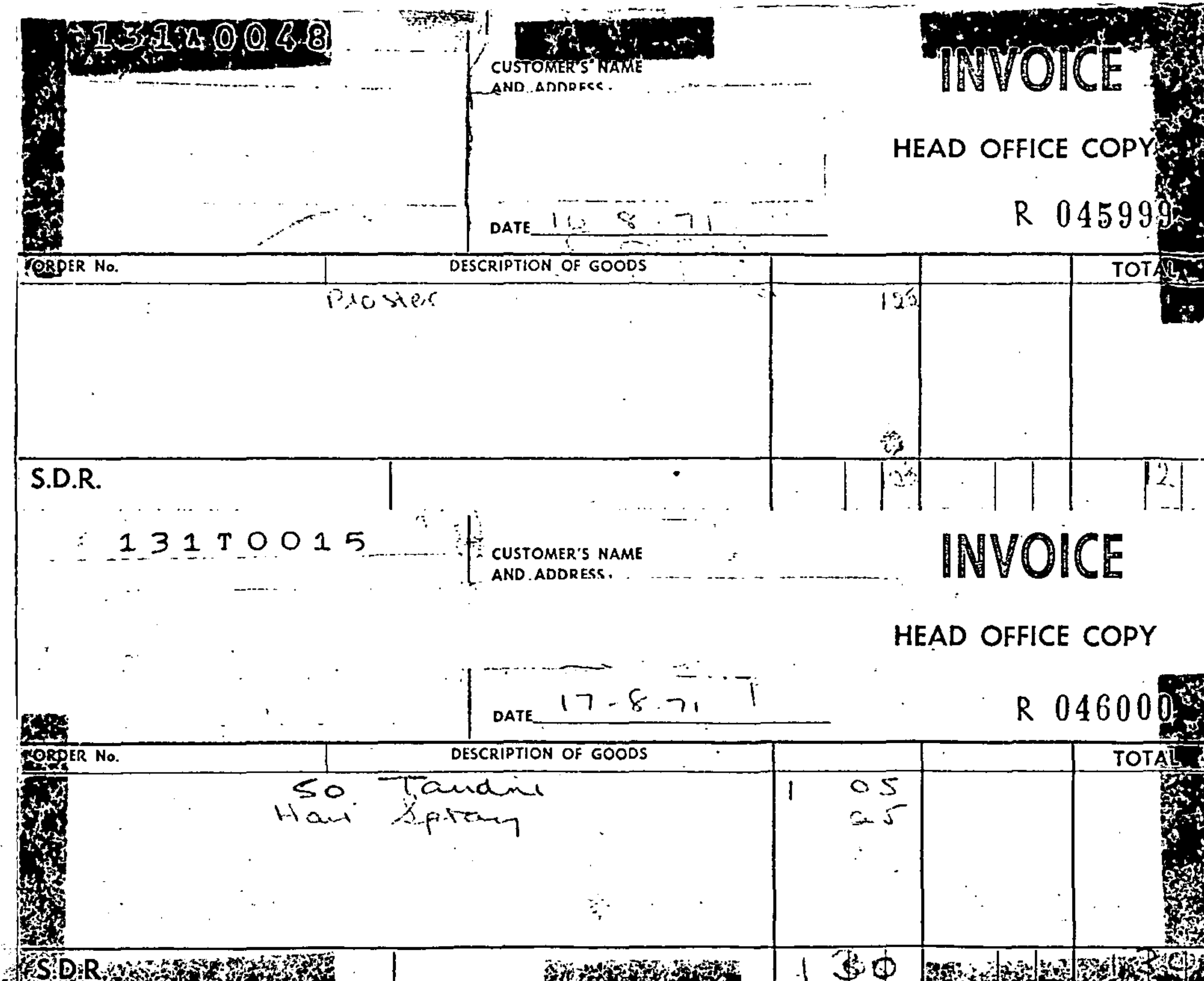
Some of the obvious things that are wrong with the documents, i.e. causes difficulties for the operators, will be briefly mentioned below, together with the complaints and suggestions from people in other sections of the Company who deal with the documents. A photocopied example of each invoice in a complete form have been shown in figures 9, 10 and 11. The name and address of the customer on each invoice has been removed.

1. The branch number, check letter and customer number are impressed in the top left hand corner of the invoices. Very frequently this information overstamps the order number, which makes it difficult to read both the order number, and the branch number, check number and customer number.

2. The invoice number, top right of the invoice, is sometimes a 5 digit, sometimes a 6 digit number. In the latter case the first digit is always a zero and the operators only punch a 5 digit number. This, of course, causes difficulty, since the operators have to omit the 0.

3. Sometimes the invoice serial letter and the invoice number are printed in such a way that the serial letter and the first digit are overprinted, which makes it difficult to read both of them.

4. There is not enough space for the totals, bottom right of invoice that the punch operators have to read.



1311 0048

CUSTOMER'S NAME AND ADDRESS. [redacted]

DATE 16 8 71

INVOICE

HEAD OFFICE COPY

R 045999

ORDER No.	DESCRIPTION OF GOODS			TOTAL
	Poster	125		
S.D.R.				12

131T0015

CUSTOMER'S NAME AND ADDRESS.

DATE 17-8-71

INVOICE

HEAD OFFICE COPY

R 046000

ORDER No.	DESCRIPTION OF GOODS			TOTAL
	50 Tandini Hair Spray	1 05 25		
S.D.R.		1 30		

Figure 9. The figure shows two examples of the small invoice (OM826) that has been used.

132V0002 1

CUSTOMER'S NAME
AND ADDRESS

INVOICE

HEAD OFFICE COPY

DATE 17/8/71

D035905

No. 15098 388

DESCRIPTION OF GOODS			TOTAL
24 Sm STERILISED DRESSINGS	0 96		
12 Med "	0 72		
12 Large "	1 26		
3 ELASTOPLAST FIR. AID OUT.	2-22		
12 TRIANGULAR BANDAGES.	1-68		
6 ASS ADHES. PLASTERS.	1-01		
6 x 1oz STER. COTTON WOOL	0-36		
2 TUBES SULPHACET EYEOINT	0-36		
2 CONST. BANDAGES	0-82		
3 PKS SAF. PINS	0-4½		
1 GALLON DETTOL.	1-92		
10% DISC £10-82	£11-35	1-13	£10 22
	~~11-87~~ ~~11-35~~	~~1-15~~	~~£10-43~~

Figure 10. The figure shows an example of the big invoice (OM830) that has been used.

Figure 11. The figure shows an example of the invoice (OM850) used by the agriculture section of the Company, that has been used.

No 1287 9 HEAD OFFICE COPY

X/ 064264

INVOICE

CUSTOMER'S NAME AND ADDRESS

DATE DELIVERED	CUSTOMER'S ORDER No.	REMARKS, DATE REQD.
30-7-71	—	Ex 9230.

DESCRIPTION OF GOODS	GROSS		DISCOUNT		NET	
5 x 30 lbs Grain Store Dust.	9	75	0	49	9	26

S. D. R.	DATE ORDERED	FIELDSMAN'S No.						
	29-7-71	—	9	75	0	49	9	26

OM 850

SPEEDISET© LAMSON PARAGON

5. The invoices are in general illegible because of being a carbon copy and also because of bad handwriting.

The two main complaints made by people in other branches of the Company who deal with the invoices are as follows:-

(a) On all invoices they want more space between the lines for writing, and (b) in the case of invoices OM826 and OM830 they want one invoice instead of two. They think that the small invoice is far too small and can easily disappear between the bigger invoices.

This is in no way a full analysis of the credit sales invoices, but it gives some indication of the difficulties the operators experience.

5.3.2. Error analysis of PA20 - Local Purchases.

Card type PA20 is used for three documents, (see section 4.0). The layout of these documents is exactly the same and the only variation between them is in respect of colour. (See Appendix 3). PA20 is regarded as a very good document by the punch operators, (see section 2.1) and it has been specially designed for the punch operators.

Two of the documents have the suppliers number pre-printed on them, because the suppliers in question are the main suppliers to the Company. (See Appendix 3). The third document is used for all the other suppliers and the suppliers number is handwritten. The operators only punch one card per document. (See section 4.0). With each batch, the operators receive a punch instruction, (see Figures 12A and 12B and section 4.0).

The number of cards ending in the different columns because of error are shown in Table 43.

PURCHASES ACCOUNTING
LOCAL PURCHASES EDIT

TITLE: TRANSACTION

DEPTL. LETTER: P A

CARD TYPE: 19, 20, 21 or 23.

SEQUENCE:

PROGRAM NO: P A 0 1

PUNCHING DOCUMENT LOCAL PURCHASES LABEL.

FIELD NAME	FROM	TO	TYPE		NOTES
CARD CODE	1	4	AN		1
BATCH NUMBER	5	8	N	L	
CARD NUMBER	9	11	N	LB	2
BRANCH NUMBER	12	15	N	L B	11
SUPPLIER NUMBER	16	20	N	L B	3,11
DOCUMENT NUMBER	21	26	N	LB	11
DOCUMENT DATE	27	32	N	LB	4,11
COST VALUE	33	39	N	B	5,11
PURCHASE TAX	40	45	N	B	6,11
POSTAGE AND CARRIAGE	46	51	N	B	7,11
CREDIT INDICATOR	52		A	B	8,11
RETAIL VALUE	53	59	N	B	9,11
ADJUSTMENT INDICATOR	60		N	B	10,11

NOTES: See Page 2 of 2.

Figure 12a. An example of a punch instruction for Local Purchases (PA20).

PURCHASES ACCOUNTING

LOCAL PURCHASE EDIT

Program PA01 LOCAL PURCHASE LABEL

Notes.

1. a) Punch PA20 for a new transaction
   b) Punch PA21 for an adjustment transaction
   c) Punch PA19 to amend or delete a transaction
   d) Punch PA23 to add a transaction to a batch

2. Blank except for a PA19 and then the card number of the transaction to be amended or deleted.

3. Punch as on label or as on batch card for a summerized batch.

4. Punch in the form DDMMYY ie. 010170, 211269.

5. Punch in the form £££ssd½. (punch '-' for 10d, '&' for 11d).

6. Punch in the form ££ssd½. (punch '-' for 10d, '&' for 11d).

7. Punch in the form ££ssd½. (punch '-' for 10d, '&' for 11d).

8. Punch a 'c' if amounts shown are negative otherwise leave blank.

9. Punch in the form £££ssd½. (punch '-' for 10d, '&' for 11d).

10. Blank for a PA20 transaction otherwise 0 or 1.

11. Leave blank if deleting transaction PA19 only.

Figure 12b. An example of a punch instruction for Local Purchases (PA20)

Table 43. Number of cards ending in the different columns.

Field Name	Column No.	Verified Cards	Non-verified Cards
Card code	1 - 4		
Batch No.	5	0	0
	6	0	3
	7	0	2
	8	0	32
Card No.	9	0	0
	10	0	1
	11	0	0
Batch No.	12	0	5
	13	0	2
	14	0	6
	15	0	4
Supplier No.	16	0	4
	17	0	3
	18	0	3
	19	0	11
	20	3	193

/continued...

Field Name	Column No.	Verified Cards	Non-verified Cards
Document No.	21	0	22
	22	0	10
	23	0	20
	24	0	19
	25	0	30
	26	0	112
Document data	27	0	19
	28	0	13
	29	0	14
	30	0	21
	31	1	11
	32	5	203
Cost value	33	1	12
	34	0	3
	35	0	16
	36	4	25
	37	15	48
	38	160	333
	39	0	3
Purchase tax	40	0	8
	41	0	4
	42	1	4
	43	9	27
	44	76	186
	45	1	0

/continued...

Field Name	Column No.	Verified Cards	Non-verified Cards
Post & Carriage	46	0	3
	47	0	0
	48	0	1
	49	7	6
	50	4	2
	51	0	0
Credit indicator	52	11	29
	53 - 78	0	0
	79	0	1
	80	0	0

As one can expect the majority of the error cards found by the verifier are fully punched, and the majority of them end in columns 38, 44 and 52. The reason for this is that the information punched on the card ends in column 38 if the last information is the 'cost value', in column 44 if it is the 'purchase tax', in column 50 if it is the 'post and carriage', in column 52 if it is the 'credit' and in column 58 if it is the 'retail value'.

The self detected error cards show a slightly different trend. They end fairly evenly in all columns up to column 52.

To determine what features of the document caused errors, a new table was made up in which more details are shown of the document, in particular which columns are alpha and which numeric. (See Table 44).

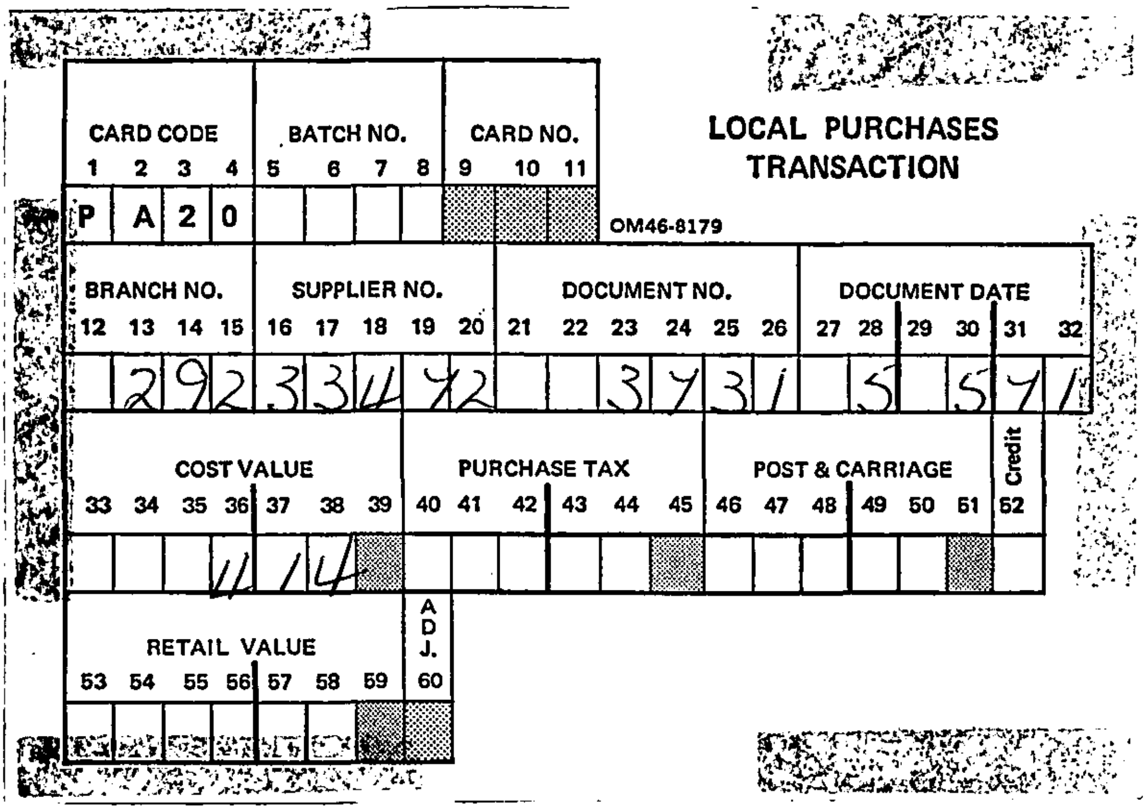
Table 44. Error analysis of PA20.

FIELD NAME	COLUMN NO. FROM	COLUMN NO. TO	NO. OF ERRORS	TYPE	AV. NO. OF ERRORS/ COLUMN
Card code	1	4	3	AN	
Batch No.	5	8	37	N	9.2
Card No.	9	11	1	N	0.3
Branch No.	12	15	17	N	4.2
Supplier No.	16	20	214	N	40.8
Document No.	21	26	213	N	35.5
Document Date	27	32	281	N	46.8
Cost Value	33	39	440	N	62.9
Purchase Tax	40	45	229	N	38.1
Postage & Carriage	46	51	12	N	2
Credit Indicator	52		29	A	29
Retail Value	53	59	0	N	
Adjustment indicator	60		0		
	61	78	0		
	79		1		
	80		0		

From Table 44, the difference between the alpha and the numeric rate is shown. The average number of errors/column for alpha is 29. For numeric it is 26.65. As with the documents previously discussed, alpha information causes slightly more errors than numeric information.

The reason for the high error rate on this document is difficult to explain. It is the author's opinion that there is too much information on the documents for the operators. (An example of a used document is shown in Figure 13). That is to say, the operators see too much irrelevant information which is not related to their punching task. For example, the operators do not need to know that certain columns are associated with Branch No., Supplier No., Document No., Document data and so on. All the punch operators need to know is that certain information is to be punched in certain numbered columns.

The clerical staff who transfer the information from one document onto the documents used for card type PA20 should not really need to have the field names printed on the documents, since the fields come in a logical order and also since they are only doing their task they ought to know it by heart after only a couple of hours practice. It would instead be better to provide them with a basic model they can refer to if necessary.



LOCAL PURCHASES TRANSACTION

OM46-8179

CARD CODE				BATCH NO.				CARD NO.		
1	2	3	4	5	6	7	8	9	10	11
P	A	2	0							

BRANCH NO.				SUPPLIER NO.					DOCUMENT NO.						DOCUMENT DATE					
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	2	9	2	3	3	4	4	2			3	7	3	1		5		5	7	1

COST VALUE							PURCHASE TAX						POST & CARRIAGE						Credit
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
			11	1	4														

RETAIL VALUE							ADJ.
53	54	55	56	57	58	59	60

Figure 13. The figure shows an example of a Local Purchases (PA20) document that has been used.

5.3.3. Error Analysis of 403 - Stock Orders.

Card type 403 is associated with 13 different documents, (see section 4.0). The layout of the 13 documents is exactly the same, and they only differ in respect of colour and a departmental letter, (which occurs in the top right hand corner). (See Appendix 4). The departmental letter is punched in the first column on each card, i.e. it is automatically duplicated together with the card type number on each card. The departmental letter is the letter belonging to the department that indicates an order.

403 is regarded as a difficult document by the operators, (see section 2.1).

There is always only one type of document in a batch. That is to say an operator only deals in one batch with documents arising from one department.

Only trainees are given a punch instruction with each batch. (See Figure 14 and section 4.0). On each document there is room for 40 quantities and item codes, i.e. four columns with ten rows in each, (see Appendix 4). Unfortunately, there is only room for eight quantities and item codes in a card, starting in columns 12, 20, 28, 36, 44, 52, 60 and 68. In other words, if a document is filled, five cards are required to punch the information contained on it.

The work study group found that on average, for all departments, there are four quantities and item codes per document, i.e. on average there are 43 columns punched on each card.

TITLE: KEY PUNCHED ORDERS (& GRADING LIST SELECTION)

CARD TYPE: 402 - 414 (See Notes)

SEQUENCE: CARD TYPE

PROGRAM NO: MJ 110 - EDIT ORDERS ETC.

PUNCHING DOCUMENT ORDER FORMS OR MEMOS

FIELD NAME	FROM	TO	TYPE		NOTES
Deptl. Letter	1		A		1
Card Type	2	4	N	L	
Category Indicator	5		A		2
Branch Number	6	10	N	L	3
Suffix or Grade	11		A		4
Quantity	12	15	N	L	5,6
Item Code	16	19	A		6

NOTES:

1. Punch Book (B), Fancy (F), F&G Props (V), O.Gds Airdrie (N), O.Gds Beeston (G), Photo (P), Staty & Art (S), Sundries (H), Toilet (T). Pzls T(Q)

ORDERS ON FORMS

2. A, B, or Blank
3. 1 - 99999
4. A-Z or Blank
5. 1 - 9999
6. Eight Quantities and Item Codes can be punched for the same Branch starting at columns 12, 20, 28, 36, 44, 52, 60 & 68.

Figure 14. An example of a punch instruction for Stock Order (403).

The number of cards ending in different columns because of errors are shown in Table 45.

Table 45. Cards ending in different columns.

Field Name	Column No.	Verified Cards	Non-verified Cards
Card Code	1 - 4		
Category indicator	5	0	0
Branch No.	6	0	12
	7	0	27
	8	0	23
	9	1	34
	10	1	75
Suffix or Grade	11	0	4
Quantity	12	0	12
	13	0	16
	14	0	20
	15	0	79
Item Code	16	1	90
	17	0	89
	18	6	82
	19	45	166

/continued...

Field Name	Column No.	Verified Cards	Non-verified Cards
Quantity	20	2	21
	21	0	16
	22	0	16
	23	0	63
Item Code	24	1	49
	25	2	51
	26	3	58
	27	78	121
Quantity	28	2	10
	29	0	6
	30	0	9
	31	0	43
Item Code	32	1	40
	33	1	39
	34	2	39
	35	51	87
Quantity	36	1	14
	37	0	10
	38	0	15
	39	0	36
Item Code	40	1	40
	41	1	41
	42	1	44
	43	50	68

/continued...

Field Name	Column No.	Verified Cards	Non-verified Cards
Quantity	44	0	8
	45	0	7
	46	0	8
	47	0	24
Item Code	48	0	38
	49	1	34
	50	0	36
	51	54	63
Quantity	52	1	12
	53	0	5
	54	0	19
	55	0	33
Item Code	56	1	21
	57	1	31
	58	0	22
	59	43	67
Quantity	60	0	3
	61	0	7
	62	0	7
	63	0	15
Item Code	64	0	23
	65	0	20
	66	0	18
	67	47	92

/continued...

Field Name	Column No.	Verified Cards	Non-verified Cards
Quantity	68	0	6
	69	0	6
	70	0	7
	71	0	23
Item Code	72	0	17
	73	0	20
	74	1	23
	75	456	183
	76	0	10
	77	0	1
	78	0	1
	79	0	1
	80	0	0

Table 45 shows that the majority of the error cards found by the verifier end, as one might expect in columns 19, 27, 35, 43, 51, 59, 67 and 75. The reason for this is that the information on the card can end in the above column number, depending upon how many 'quantity' and 'item codes' there are on the document.

It can also be seen that over 50% of the verified cards end in column 75. This means that the average number of quantities and item codes on the documents have increased since the Work Study Report was carried out.

Table 45 also shows the last column punched for the self detected error cards. It can also be seen that the item code seems to cause more errors than the quantity associated with that item. To be able to look into this in more detail, a new table was made up. (See Table 46).

Table 46. Error analysis of 403.

FIELD NAME	COLUMN NO. FROM	COLUMN NO. TO	NO. OF ERRORS		TYPE	AV. NO. OF ERRORS/ COLUMN
Dept. letter	1				A	
Card type	2	4			N	
Category indicator	5		0		A	
Branch No.	6	10	171		N	34.2
Suffix or grade	11		4		A	4
Quantity	12	15	127)	) 554	N	31.7
Item code	16	19	427)		A	106.8
Quantity	20	23	116)	) 405	N	29
Item code	24	27	289)		A	72.2
Quantity	28	31	68)	) 273	N	17
Item code	32	35	205)		A	51.2
Quantity	36	39	75)	) 268	N	18.7
Item code	40	43	193)		A	48.3
Quantity	44	47	47)	) 218	N	11.7
Item code	48	51	171)		A	42.6

FIELD NAME	COLUMN NO. FROM	COLUMN NO. TO	NO. OF ERRORS		TYPE	AV. NO. OF ERRORS/ COLUMN
Quantity	52	55	69)	) 210	N	17.2
Item code	56	59	141)		A	35.2
Quantity	60	63	32)	) 185	N	8
Item code	64	67	153)		A	38.3
Quantity	68	71	42)	) 285	N	10.5
Item code	72	75	243)		A	60.7
	76		10			
	77		1			
	78		1			
	79		1			
	80		0			

Table 46 shows where the errors are made on the document. It shows that the first two quantity and item codes cause more errors than the others.

It can also be seen that the item code in general cause more errors than the quantity. The numbers are 1822 errors for the item code and 576 errors for the quantity, i.e. the item code causes more than three times as many errors as the quantity.

Table 46 shows the average numbers of errors per column. Alpha columns on this document cause 51.03 errors/column, and the numeric causes 19.78 errors/column, i.e. an alpha column causes more than 2.5 times as many errors as a numeric column.

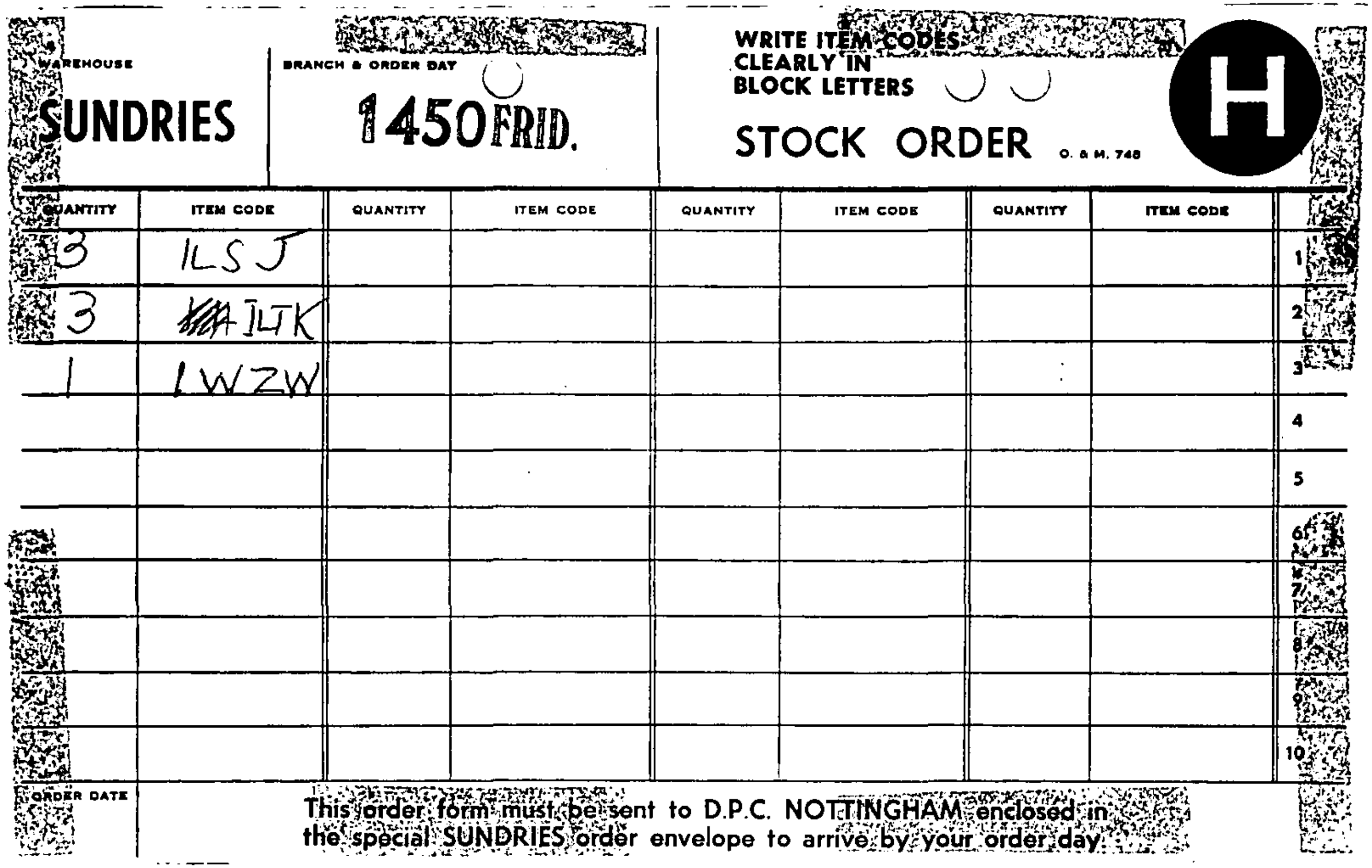
Some of the things which cause difficulties for the operators on this document will be briefly discussed, together with the comments of the people who deal with these documents in the other sections of the Company. An example of a document that has been used is shown in Figure 15.

(a) The item code causes obvious difficulties. It is a four letter code, using all the letters of the alphabet except M, U and D. The branches of the Company have no real complaints about the code.

(b) Since there are four columns with quantities and item codes and ten rows in each column on the document, but only room for eight quantities and item codes on a card, this makes it difficult for the operators to keep track of where they are on the document. If there are more than eight quantities and item codes on a document, the operators have to punch more than one card to a document. The branches have nothing against changing this. It does not make any difference at all to them.

(c) The sequence of punching from the document would be better if the branch number was printed in the top left hand corner.

The shop stationary department of the Company responsible for manually printing the branch number and order day on each document before they are sent to the branches would prefer to locate this information in a corner of the document, and not, as it is on the present one, in the middle at the top of the document.



WAREHOUSE

SUNDRIES

BRANCH & ORDER DAY

1450 FRID.

WRITE ITEM CODES CLEARLY IN BLOCK LETTERS

STOCK ORDER O. & M. 748

H

QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
3	ILSJ							1
3	ILTK							2
1	IWZW							3
								4
								5
								6
								7
								8
								9
								10

ORDER DATE

This order form must be sent to D.P.C. NOTTINGHAM enclosed in the special SUNDRIES order envelope to arrive by your order day.

Figure 15. The figure shows an example of a Stock Order (403) document that has been used.

Since the item code causes more than three times as many errors as the quantity, a brief background is given below to the item code problem.

The present code used on the stock order consists of four letters. It has been in use for about twelve years. The code uses the whole alphabet with the exception of M, U and D. The three first letters in the code are the actual code, the fourth letter is a check letter.

Since 23 letters are in use there are $23^3 = 12167$ possible combinations of letters for the actual code for each department. The biggest department uses about 8000 codes, and altogether for all departments there are about 55000 codes in use.

A summary of the layout of all the documents and a discussion of some of the reasons for the high error rate follows in the next section.

5.4. Critique of the layout of documents and possible reasons for the high error rate.

A commentary on the layout of the documents that have been discussed in the last three sections will be given below, and possible reasons for their high error rates will be discussed.

It is obvious from the last three sections that the layout of the documents is far from satisfactory. To start with only one of them, (the document associated with card type PA20) has been designed for the punch operators and that design does not seem to have been successful. The other documents have not been designed with the punch operators in mind, but mainly for clerical staff. The sequence of presentation of information on the stock order associated with card type (403) and the invoices (C006) could be improved. Instead of having three different invoices associated with card type C006 it would be better to have only one. The spacing between the lines on the small invoice (OM826) and the big invoice (OM830) is not large enough.

The legibility of the documents varies since, for example, credit sales invoices are the second copy and stock order and local purchases are the first copy.

All documents are completed in handwriting and the standard of handwriting is bad in all cases and excessively so for invoices and stock orders. The reason for this is that invoices and stock orders are written under difficult circumstances in the branches of the Company. The personnel who complete these documents are mainly young girls. They do not always have the support of a table or desk when they write in their shop situation. Indeed, the girls primary job is to sell goods in the branches of the Company and they are frequently disturbed by customers when completing invoices and stock orders.

No attempt has been made by the Company to teach all the girls to write in a certain style which is highly legible. There is a further difficulty, and that is that even if this were possible it might be difficult to get the girls to adopt a consistently responsible attitude so that highly legible information was produced, as labout turnover in the branches is high.

A further reason for the high error rate **may possibly be that the** documents are so different, and there are interference effects between them, (leaving aside for the moment problems of incompatibility of layout). Welford (1968) discussed the effects on performance of the order of tasks of varying difficulty, and suggests that, depending on **the order in which the tasks come,** their mutual interference varies. He states that when a more difficult task proceeds an easier task, the transfer effect is positive i.e. performance on the easier task is enhanced. When, however, an easier task proceeds a more difficult task, the transfer effect tends to be negative, i.e. performance on the more difficult task is adversely affected.

Because of what has been said above, a document that has been especially designed for the punch operators (for example PA20) may produce poor performance together with documents that

Arguments about transfer effects should not be over-stressed as the experimental evidence is tenuous and the phenomena poorly understood. As a result it is difficult to make statements even if a qualitative nature which are well justified.

have not been especially designed because of this interference effect. This can be reason for the high error rate on PA20.

This also agrees with an experiment carried out by Klare et al (1957) mentioned in section 3.3, where he compared information written in rectangles across a page or spaced by the insertion of blanks. He found both of them were better than standard printing, but the author concluded that, "It should be emphasised that the advantages of the newer arrangements are best described as potential, since they interfere with strongly developed reading habits. This study indicates, however, that these arrangements may be of value for subjects who have some practice in reading them and/or high ability".

In addition to potential interference effects there are also, almost certainly, effects due to lack of compatibility between the documents. It must be very difficult for an operator to punch from one document with a given design and then to move immediately on to punch from another document of completely different design.

Siebel (1970) states that lack of compatibility slows down the sequwnce of data entry motions, that is to say, that when an operator starts on a new batch of documents with a different layout, she has to re-learn the new document each time she is confronted with it.

It is obvious from what has been discussed in this section that the layouts of the documents conflict with ergonomics ideas.

Design recommendations for documents are discussed in the next section.

Since there was not enough time to re-design all of the documents analysed in detail in this section, (let alone all documents in the Company), it was decided to concentrate only on the stock order (associated with card type 403). Design recommendations for a code for this document were produced, since the code of the stock order caused most errors. These are given in section 7.0.

6.0. Design of Documents

No general ergonomics model has been found describing how documents ought to be designed. The ergonomics of document design appears to be a very important and very large research area for ergonomics which hitherto has been neglected. There are, however, in the Human Factors/Ergonomics literature of today, some data that are useful for designing documents. General ergonomics principles ought also to apply. One principle in Western culture, is that the information to be read and processed should begin at the top left of the document with subsequent information written underneath or from left to right. Ivergard (1969).

Another principle is that the documents should be as clear as possible, i.e. only relevant information that is necessary should be on the document. The document should be designed consistently, i.e. the same information on different documents should be in the same place on each document.

When a document is used as a "punching document", e.g. the document from which information is transcribed on to punched cards, it should be designed to aid:

(a) The person who has to complete by handwriting or typing the document.

(b) The punch operator who has to read the information and record it in the form of punched holes in a card. Sometimes the needs of (a) may be different from (b). Sometimes the document has to be designed to meet other purposes.

The following points, adopted from Great Britain Treasury O and M Division (1962), should be considered in the design of documents from which punching is carried out.

(a) Information should be presented to the punch operator on one side of a single page of the punching document and data not to be punched should be clearly distinguished and separated.

(b) Documents should be kept to a convenient size for handling and for ease of locating the relevant data.

(c) Information should be presented in a straight forward sequence in the order of punching, e.g. in column order on the cards. Information common to a series of cards will normally be positioned first.

(d) It is usually easier to record information set out vertically than horizontally. The eye tends to jump horizontal lines, so causing a rather higher proportion of errors. The report does not provide any evidence for this statement, but it seems likely that vertical arrangements are more effective than horizontal ones.

(e) Boxes can be used with advantage not only to focus the attention of the punch operators on the relevant information, but also to ensure that the information when originally recorded is placed in the correct position of the page.

(f) Shading is a useful device to prevent people recording information in the wrong place or alternatively to obliterate unwanted information.

(g) Legibility is important. Black on white and, where appropriate, certain other colour combinations give good contrasts. It is also essential that sufficiently thick and opaque paper be used to prevent information on the reverse side or from the next document showing through.

6.1. Spacing allowances for entries.

Adequate space must be provided on the document to facilitate easy completion of the entries. Spaces which require people to write smaller than normal can be irritating and will also slow down completion of the document. The recommended amount of space is shown below. The data are adopted from Knox (1952) and Great Britain O and M Division, (1962).

Handwritten entries	5 ch/inch (horizontal)
	4 lines/inch (vertical
Handwritten column of figures	8 figures/inch (crowded)
	6 figures/inch (spaced)

When numeric items are being totalled at the foot of a column, extra space for the total entry will almost certainly be needed.

6.2. Alphanumeric characters.

Alphanumeric characters are used in various contexts, in handwritten or typewritten form. Over the years there has been a great deal of research relating to various facets of the business of communicating by written material, including content, writing style and typography. A summary of the recommendations for letter and digit size and shape is given below. It is assumed that the illumination level is greater than 1 foot candle, that black letters or digits are printed on a white background and that viewing distance is about 28 inches. It is further assumed that the subjects have good eyesight. The data are adapted from McCormick (1970) and Woodson and Conover (1964).

(a) Numerals

Style: Futura medium or Univers 55.

Width/Height ratio: 3:5 except for the digit 1 which is one "stroke width" wide.

Stroke width as a proportion of height: 1:6.

Absolute height of numeral: 0.10" at least, 0.20" preferably.

(b) Letters

Style: Futura demi bold or Univers 55.

Width/Height ratio: 1:1 except for I, J, L and W. Their ratios can be reduced to 2:3 without any appreciable reduction of legibility.

Stroke width as a proportion of height: 1:6.

Absolute height of letter: 0.10" at least, 0.20" preferably.

6.3. Use of colours and other considerations.

Coloured printing ink or coloured paper can help to distinguish documents and will help operators in sorting or selecting documents. There are, however, certain disadvantages. It is well known that defective colour vision is fairly common, about 6% of the men and 2% of the women, have difficulties in differentiating between certain colours, such as between red and green.

Colours have to be chosen after careful consideration of the conditions in which they are to be used, since the light by which work is seen affects colour perception.

Colours can also change in appearance when seen next to another.

Table 47 given below and adapted from Great Britain Treasury O and M Division, shows Le Courier's table of the order of legibility of colour combinations.

Table 47. Legibility of colour combinations.

Order of legibility	Decoration	Background
1	Black	Yellow
2	Green	White
3	Red	White
4	Blue	White
5	White	Blue
6	Black	White
7	Yellow	Black
8	White	Red
9	White	Green
10	White	Black
11	Red	Yellow
12	Green	Red
13	Red	Green

It is essential that the document does not cause glare, and is read in glare free conditions. If the paper or anything on the document causes glare, or there are glare conditions in the visual surrounds, the document will be read with discomfort and performance may be disturbed. Shiny paper should not be used for documents, even if shiny paper produces slightly better print, because this does not balance out the disadvantage of glare.

It is obvious that a document has to be designed in such a way, that it does not hurt the people who deal with it. Paper is often guillotined in such a way that it has very sharp edges and can easily cut the hand. It has been sometimes alleged (Ivergard 1969) that chemicals used in paper and printing can give rise to allergies in the users. Whilst it is not possible to document evidence on this topic, clearly it is a factor which needs to be carefully watched.

It is also essential to keep in mind that the choice of paper should also take into account what type of pen is going to be used. That is to say, when documents are to be completed in pencil it is necessary to use a paper with a matt or rough surface. When pen and ink is used a more polished surface is desirable. Great Britain Treasury O and M Division (1962).

Before a document is completed and put in use, the following things should have been established:

1. What is the purpose of the document?

2. Could the purpose be served by another document?

3. Have all the users been consulted about their needs and asked to comment or offer suggestions?

4. What figures about the use of the form are needed, i.e.:

   (a) Numbers of queries arising from incorrectly completed forms?

   (b) Most frequent source of errors in completion?

   (c) Numbers of copying errors?

   (d) Most frequent source of errors in copying?

5. How is the document used by each person who is handling it?

(a) Are entries made with pencil, pen typewriter or machine?

(b) Would particular features of design help arithmetical or sorting work?

6. What information on the document is copied and how often?

(a) Is the sequence of information convenient for copying and checking operation?

7. Have completed specimens of the document been examined?

(a) For convenience of size?

(b) Adequacy of entry spaces?

(c) Unnecessary entry spaces?

(d) Are alterations of wording needed?

(e) Can entries be simplified by pre-printing?

8. Is the quality of the paper appropriate?

(a) For writing?

(b) For handling?

9. Have any special working conditions been considered?

(a) Outdoor use?

(b) Lighting?

(c) Eye fatigue?

(d) Lack of adequate writing facilities?

10. Can words and printing be removed from the document?

11. Is pre-print of the correct style and size?

12. Can different colours be used?

13. Can the document harm the users in any way?

14. Has the document been tested with the users in all working conditions?

7.0. Design of Codes

In many cases the human operator is a messenger between two machines. In such situations the operator's task is merely one of transmitting a code without errors. The operator does not process the coded information but has simply to render truly the symbolic content and the order in which the symbols appear. The ear and eye can be regarded as the input, and the output is such activities as dialling, writing or speaking.

It is usual to apply the term "immediate memory" to the process involved when information is stored by the human operators for a very limited time, and the data stored is liable to serious damage by intervening extraneous information. In practice it is difficult to distinguish between storing in immediate and in permanent memory. A certain telephone number, for example which has to be dialled many times will ultimately be known by heart, that is to say, will be stored in the permanent memory.

Perhaps the most striking fact about short-term memory is the limited amount of material that can be retained at any one time. Jacobs (1887) quoted in Conrad (1962) first drew attention to the fact that the memory span for letters was smaller than for figures. He offered two explanations. One was that we are more familiar with random figures than with random letter sequences, the other was that there are more letters than figures to choose from. Crannel and Parrish (1957) Warrington, et al (1966) quoted in Welford (1968) also reported that the span obtained with digits was longer than the span obtained with letters. But the evidence is not quite unequivocal. For example, Cardozo andLeopold (1963) found that the span for digits was the same as that for letters when the items were presented visually all at once, but it was longer with auditory presentation.

Broadbent and Gregory (1964) found that lists of alternate digits and letters were less easily recalled than lists consisting of all digits or all letters. The effect of alternation between classes of items has been further shown by Warrington et al (1966) quoted in Welford (1968) who found that although sequences of letters were less well recalled than sequences of digits, they were better recalled than mixed sequences of letters and digits.

The question is, what is the form of code that gives the best guarantee of transmission without errors? The choice is between alpha, numeric and alphanumeric codes.

Both Conrad (1960) and Cardozo and Leopold (1963) state that letters which appear to be logical in context, that is, symbols with meaning are always better than the same number of digits. But letters which appear to be drawn at random from the alphabet are much more difficult to remember than digits.

Conrad (1962) reported an experiment in designing a six-character alpha-numeric code, where two characters had to be figures and four had to be letters. He reported that best performance was found when the figures were in the fourth and fifth positions. He also found that figures attracted fewer errors than letters, and that regardless of the type of characters, positions four and five suffered most error. He also said that "the results can be taken as supporting the view that digits are easier to recall than letters".

Conrad and Hull (1967) reported an experiment where housewives copied alpha-numeric codes by hand. The codes were both grouped and ungrouped. They found that the speed for copying a numeric code was up to 30% faster than a letter code, and the accuracy was up to twice as good for the numeric codes compared with the letter codes.

On the grounds of what has been reported above, it was decided to recommend an all numeric code for the document associated with card type 403. Since there are about 55,000 combinations used of the present code, it was decided that the new code should have at least 100,000 combinations plus a check digit, e.g. five plus one digit = a six digit code.

It is well known that a long code is more difficult to recall, than if the code is grouped. Conrad (1960) stated that for dialing codes the "optimum of the group proves to be 3 or 4 digits", although the evidence cited for this statement was not very definitive.

But since then several experiments have shown that groups of 3 or 4 are best, for example, Severin and Rigby (1963) quoted in Klemmer (1968) reported groups of 3 or 4 best for telephone numbers. Heron (1962) quoted in Klemmer (1969) found rehersal of groups of 4 optimum for eight digit numbers. Wickelgren (1964) quoted in Klemmer (1968) found subjects did best in an immediate memory task when they rehersed groups of 3 or 4. Conrad and Hull (1967) found that groups of 3's were much better than no grouping. There is some support for the motion that people tend to use "natural" groupings of numerals.

Thorpe and Rowland (1965) found that subjects, when asked to repeat orally sets of 7, 8 and 9 numerals that they had previously learned, used groups of 2 and 3 digits most often. They also found evidence of smaller error rates with groups of 3 and 4.

8.0. The Design of the New Document

The size of the new document was slightly bigger than that of the old one, because an A5 (148mm x 210mm) international size paper was chosen (see Figure 16). The A5 size was chosen for two reasons. First the Company would, if designing the new document, choose an 'A' size since it is the international size. The second reason was that A5 was thought to be a convenient size to handle and it would suit most documents that are used in the Data Preparation Section. The shop stationery (see Section 5.3.3.) preferred to have the space for branch number and order day in the one corner of the document, as this would help them when printing this information. In order to accomodate the requirements of the Shop Stationery Department and, more importantly, to improve the punching sequence, the spaces for branch number and order day were placed at the top left hand side of the document (see Figure 16).

Each position in which data could be entered was provided with a box. This is thought to focus the attention of the punch operator on the relevant data, and would space the entries, generally handwritten, in an appropriate way. The width/height ratio of the boxes is 3:5, since this is the recommended ratio for numerals. The new document was designed to take a six item code, see Section 7.0.

The item code was divided up into two groups, with a shadowed space, with a width of 2mm between them. It is necessary to shadow the space providing the groups so no one mistakenly writes a figure in that box. Since the new item code is two

BRANCH & ORDER DAY

STOCK ORDER

WRITE FIGURES AS BELOW

0123456789

WAREHOUSE

SUNDRIES

H

	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
1							1
2							2
3							3
4							4
5							5
6							6
7							7

ORDER DATE

This order form must be sent to D.P.C. NOTTINGHAM enclosed in the special SUNDRIES order envelope to arrive by your order day.

Figure 16. The figure shows an example of the new document.

characters longer than the old one, it is only possible to get seven quantities and item codes on a card. As can be seen from Figure 16, there are only seven quantities and item codes in each column of the document. The operators thus start the next card at the top of the next column. It is thought this would help them to keep track of where they are on the document.

The number of quantities and item codes have been reduced from 40 on the old document to 21 on the new. This should not increase the number of documents, since the average number of quantities and item codes per document is six.

Because of cost, it was not possible to have the new document properly printed. Instead, it was duplicated, which does not give a finish as satisfactory as that obtained with printing.

To determine whether the new document with the new code would reduce the error rate and increase the production rate of punch operators an experiment was carried out. This is described in the next chapter.

9.0. The Experiment

An experiment was carried out to determine whether the new documents and the new code would reduce the error rate and increase the production rate. To see what influence the document and the code had, these conditions were generated for the experiment.

(a) The old document and the old code (0 - 0)

(b) The old document and the new code (0 - N)

(c) The new document and the new code (N - N)

By having these three conditions it is possible to find out how the new code and the new document effect the key and error rate. Comparing (0 - 0) with (0 - N), one can see how the new code affects the key and error rate. By comparing (0 - N) with (N - N) one can see how the new document effects the error rate. The reasons for not having a condition with the new document and the old code are twofold:-

(a) It is possible to determine how the new document and the new code effect the key and error rate by only using the three conditions stated above.

(b) The old code does not fit into the new document since the new document is designed to take a six digit code.

The experimental subjects were divided up into three groups, one group with the old document with the old code (0 - 0), one group with the old document with the new code (0 - N), and one group with the new document with the new code (N - N).

A 5 x 5 latin square design was used for each group. Each operator had five trials. These were spread over a week. See Figure 17 for the layout of the experiment. A, B, C, D and E in Figure 17 are different batches. That is to say, an operator never punched the same batch more than once. The operator punched 200 cards in each trial. The batches with the old document and the old code were made up of real work. The information on the batches in group 0 - N and N - N were exactly the same as the information on the batches in 0 - 0, except for the code which was numeric. The numeric code was made up in the following way. A list of the alphabet was made up, and A was given the number 01, B was given the number 02, etc. See Figure 18. The three first letters in the old code were then used to make up a six digit code. By doing it in this way, all batches in the numeric code corresponded directly to the same batches (i.e. A, B, C, D and E) in the alpha code.

Fifteen punch operators were chosen for the experiment. All of them had more than six months' experience as punch operators. They were divided up into three groups with five operators in each group. The group had the same average performance in terms of "efficiency". This was calculated from the monthly report produced by the Company for the last six months. The first group punched the old document with the old code, (0 - 0). The second group punched the old document with the new code (0 - N). The third group punched the new

GROUP	SUBJECT	TRIAL 1	2	3	4	5
	1	A	B	C	D	E
	2	B	A	E	C	D
O – O	3	C	D	A	E	B
	4	D	E	B	A	C
	5	E	C	D	B	A
	6	A	B	C	D	E
	7	B	A	E	C	D
O – N	8	C	D	A	E	B
	9	D	E	B	A	C
	10	E	C	D	B	A
	11	A	B	C	D	E
	12	B	A	E	C	D
N – N	13	C	D	A	E	B
	14	D	E	B	A	C
	15	E	C	D	B	A

Figure 17. The figure shows the layout of the experiment.

A	=	01
B	=	02
C	=	03
D	=	04
E	=	05
F	=	06
G	=	07
H	=	08
I	=	09
J	=	10
K	=	11
L	=	12
M	=	13
N	=	14
O	=	15
P	=	16
Q	=	17
R	=	18
S	=	19
T	=	20
U	=	21
V	=	22
W	=	23
X	=	24
Y	=	25
Z	=	26

Figure 18. The figure shows how the numeric code was made up.

document with the new code (N - N). All subjects used their own machines under normal conditions.

The following things were recorded for each operator and each branch.

(a) The time taken to punch the batch.

(b) The number of self detected errors made.

(c) The number of errors detected by a verifier, i.e. each batch for all operators was verified by a verifier to determine the number of errors that were undetected by the punch operator.

When an operator had completed five trials, she was asked to fill in a questionnaire, which was developed to try to find out her subjective opinion about the documents. See Appendix 5. The number of characters punched in a batch, the number of characters punched on a self detected error card, the number of characters punched on an error card detected by the verifier were recorded by using the computer facilities in the data preparation section.

Table 48. Split plot analysis of variance on the key rate.

Source	df	ssq	msq	F	Sign
Between subjects	14	5.826180			
Between conditions (c)	2	0.611917	(a)0.305959	$\frac{a}{b} < 1.00$	N.S.
Error between subjects	12	5.214263	(b)0.434522		
Within subjects	60	8.328804			
Between trials (t)	4	4.089137	(c)1.022284	$\frac{c}{e}$ 13.60	$p < .001$
t x c	8	0.632438	(d)0.079055	$\frac{d}{e}$ 1.05	N.S.
Error	48	3.607229	(e)0.075151		
Total	74	14.154984			

Table 48 shows that "Between Trials (t)" was highly significant ($p < .001$). Neither main effect of conditions, (c), nor the interaction t x c was significant at the 5% level. Each of these factors will now be considered in the order in which they occur in the Table. Though "between conditions" did not exert a significant effect, for completeness the average key rate averaged over all trials and subjects for each condition are shown in Figure 19 with 95% confidence limits. It shows what has already been revealed by the analysis of variance, i.e. that the key rate for the different conditions differ only very slightly from one another.

Turning next to the effects of 'trials', which were shown to be highly significant, means were calculated for each trial averaged over subjects and conditions. Figure 20 shows these means together with their 95% confidence limits. As might be expected in general terms performance improved on successive trials, showing evidence of an asymptote on the fourth and fifth trials. Differences between all pairs of means were tested using students 't' test. Those pairs of means which differed significantly at the 5% level are listed below.

Trial	Difference	
1 - 2	0.406	*
1 - 3	0.316	*
2 - 4	0.204	*
3 - 4	0.301	*

* = significant at .05 level.

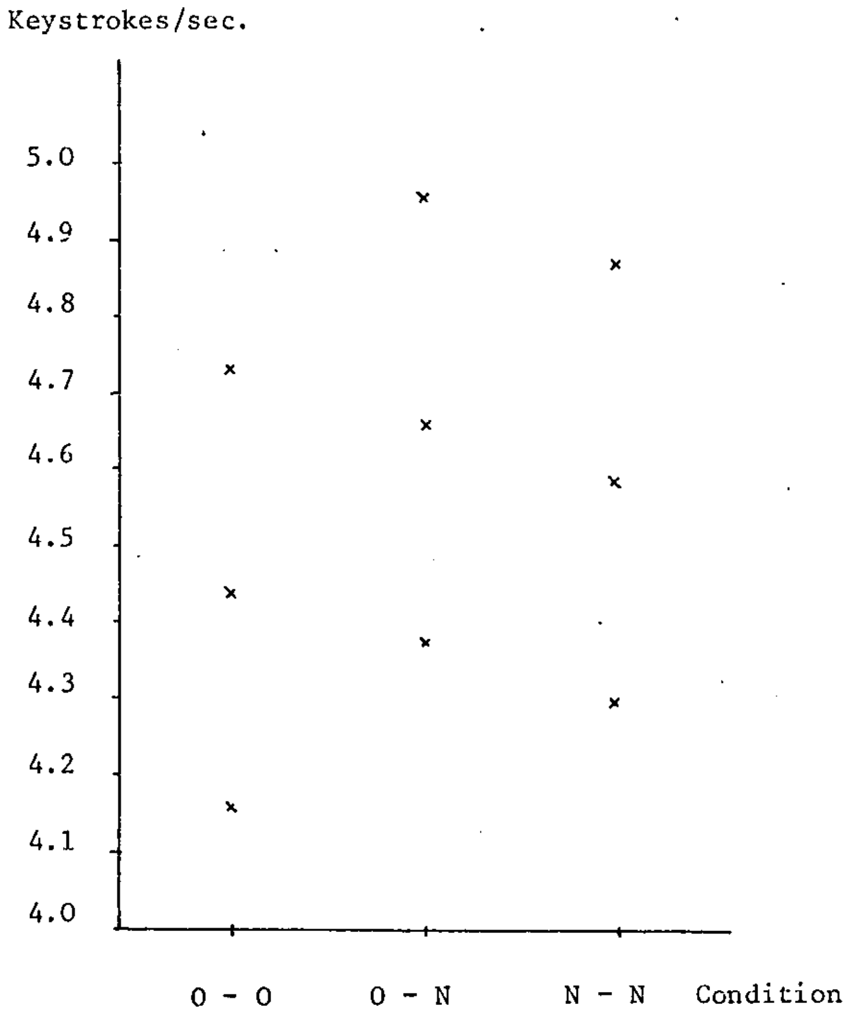


Figure 19. Average numbers of keystrokes per second for each condition, with 95% confidence limit.

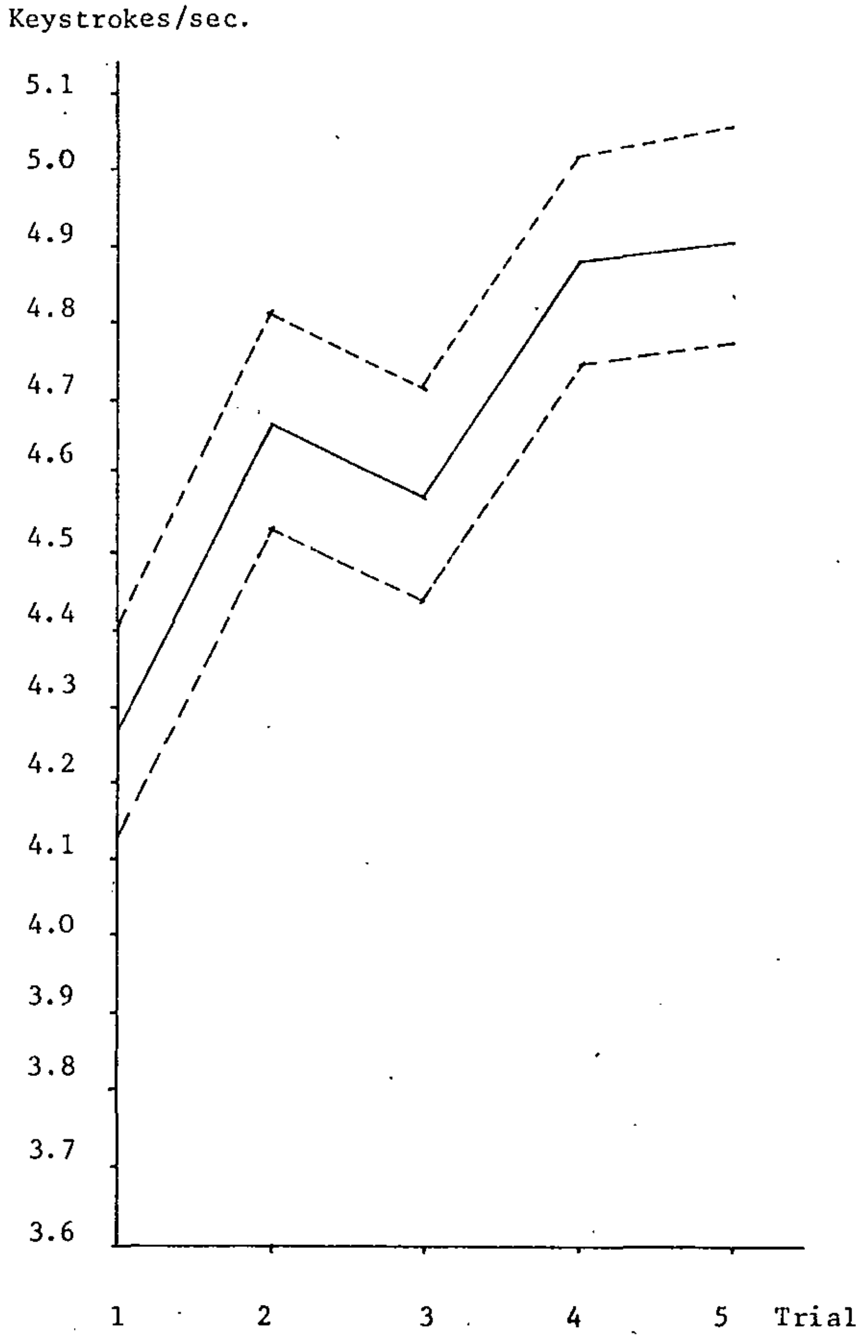


Figure 20. Average number of keystrokes per trial for all subjects, with 95% confidence limit.

The difference between 3 - 5 is significant, since 3 - 4 is significant.

Evidence of improvement in keying rate in early trials is confirmed as is evidence of an asymptote.

No significant effects were obtained for the interaction between trials and conditions. In other words the effect of conditions upon key rate was not differentially dependent upon trials.

Figure 21 shows the average numbers of key strokes per second on each trial for each condition. It can be seen that the key rate on the last trial for both the old document with the new code (0 - N) and the new document with the new code (N - N) is about 4.9 key strokes/second, while for the old document with the old code (0 - 0) the key rate is about 4.6 key strokes/second.

It is interesting to see that the key rate on the first trial for 0 - 0 and 0 - N is the same, but the key rate increases for 0 - N after a couple of trials as presumably the subjects got used to the new code.

The key rate for N - N was lower on the first trial than for 0 - N and 0 - 0. This is not surprising since it was a completely new document, but the effect seems to have disappeared on the second trial.

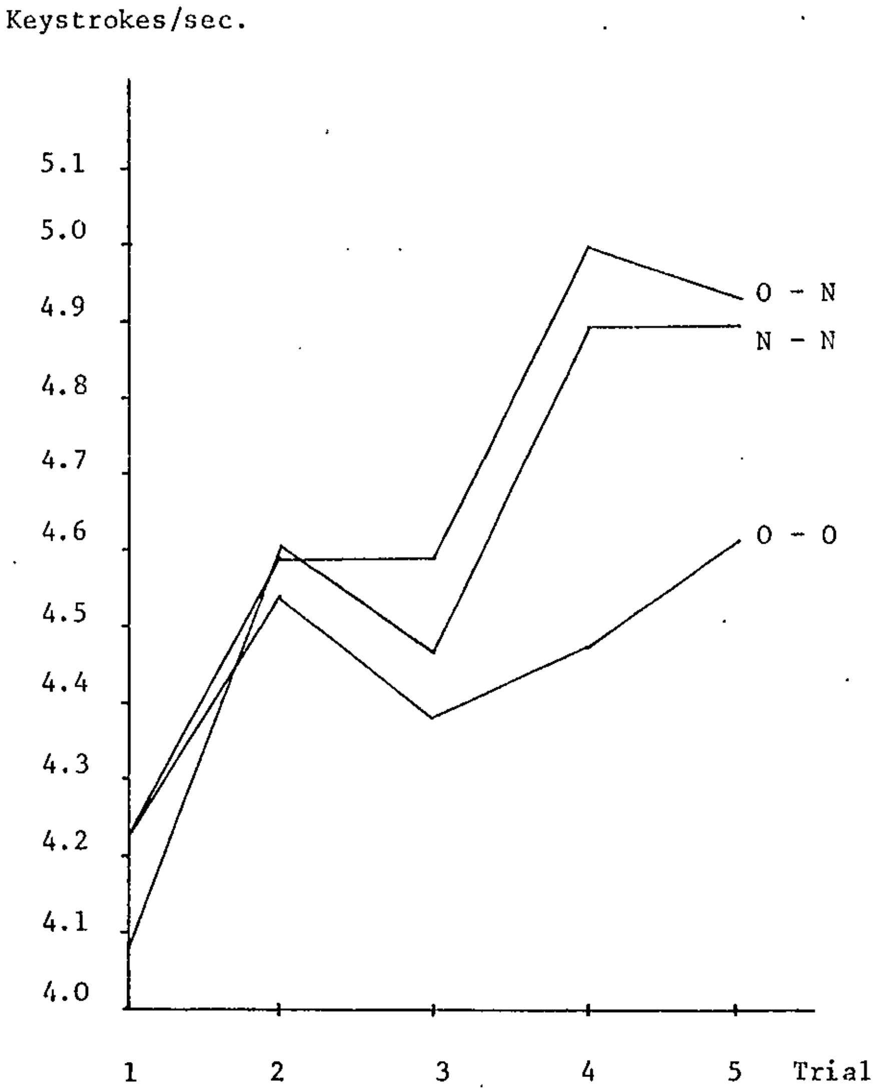


Figure 21. Average numbers of keystrokes per second on each trial for each condition.

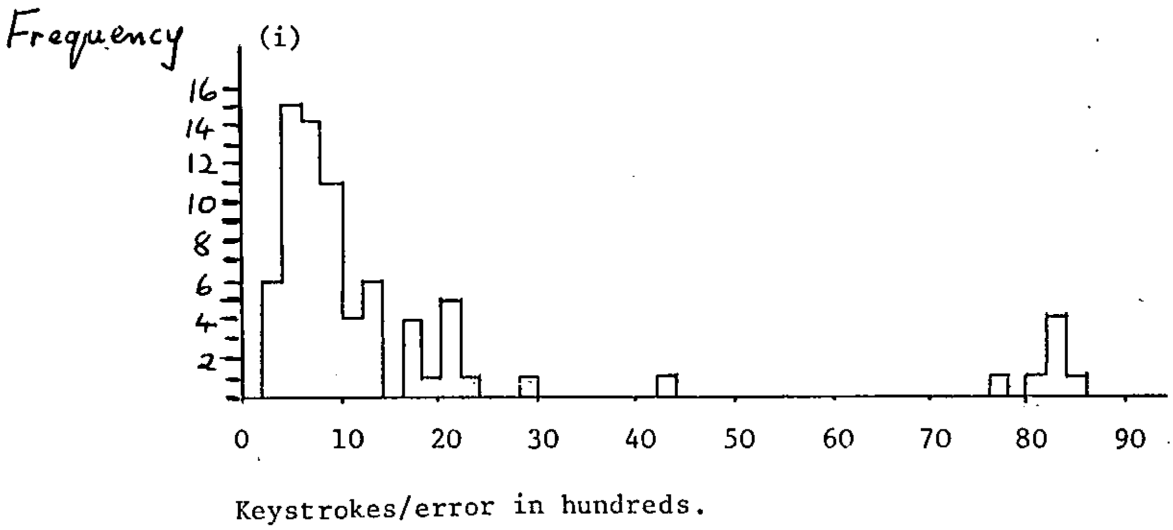
9.1.2. Self detected error rate.

An analysis of variance was carried out on self detected errors and a summary of this is reported in Table 49.

Table 49. Split plot analysis of variance on the self detected error rate.

Source	df	ssq	msq	F	Sign
Between subjects	14	252,460,539.39			
Between conditions (c)	2	79,365,169.15	(a) 39,682,584.57	$\frac{a}{b}$ 2.75	N.S.
Error between subjects	12	173,095,370.24	(b) 14,424,614.19		
Within subjects	60	107,692,952.80			
Between trials (t)	4	6,415,573.40	(c) 1603,893.35	$\frac{c}{e} < 1$	N.S.
t x c	8	15,391,297.24	(d) 1,923,912.16	$\frac{d}{e}$ 1.08	N.S.
Error	48	85,886,082.16	(e) 1,789,293.38		
Total	74	360,153,492.19			

Table 49 shows that no factor was significant. However, the author was doubtful about the form of the data. When a closer inspection was made it was found, in particular, that the data were bimodally distributed. See Figure A. The second mode which was small occurred in the long tail of high self corrected error values. In order to make the data meet better, the assumptions of the analysis of variance a logarithmic transformation was applied. A further analysis of variance was then carried out on the transformed data. The results of this are shown in Table 50.



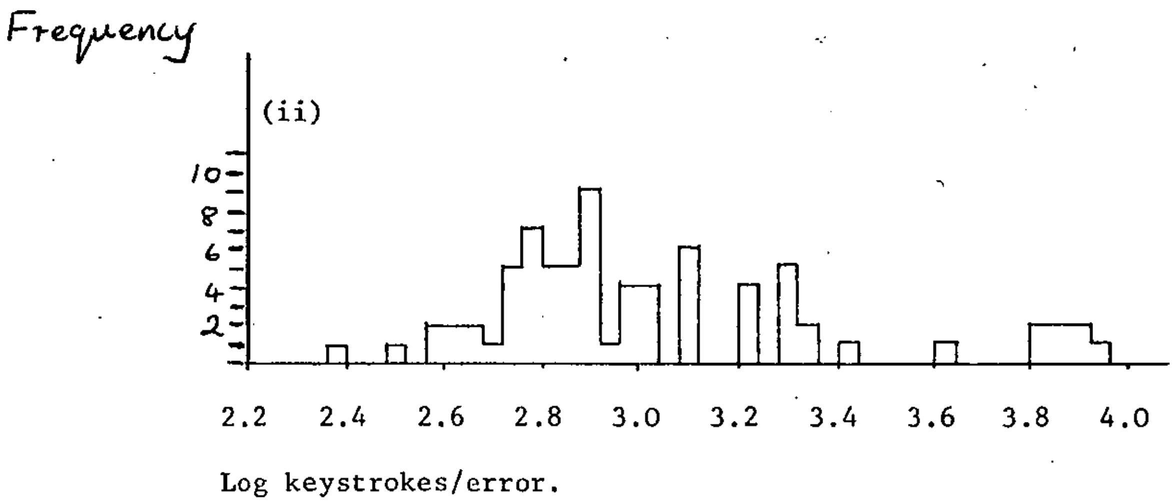


Figure A. The figure shows the distribution of the self-detected error rate, before (i) and after (ii) the logarithmic transformation.

Table 50. Split plot analysis of variance on the self detected log error rate.

Source	df	ssq	msq	F	Sign
Between subjects	14	7.108448			
Between conditions (c)	2	3.505426	(a)1.752713	$\frac{a}{b}$ 5.837	$.01 < p < .025$
Error between subjects	12	3.603022	(b)0.300252		
Within subjects	60	2.868678			
Between trials (t)	4	0.321648	(c)0.080412	$\frac{c}{e}$ 2.156	N.S.
t x c	8	0.757137	(d)0.094642	$\frac{d}{e}$ 2.538	$.01 < p < .025$
Error	48	1.789893	(e)0.037289		
Total	74	9.977126			

It shows that the effect of "Between Conditions (c)" and the interaction "t x c" is significant ($.01 < p < .025$ in each case). The effect of "Between Trials (t)" is non significant.

Figure 22 shows the average number of log key strokes/error for each condition, with the 95% confidence limit. A t-test was carried out to find out which pairs of means differed significantly. Results that were significant are shown below:

Conditions	Difference	
O-O - O-N	0.527	*
O-N - N-N	0.306	*

* = significant at .05 level.

It will be seen that the self detected error rate is less for the new code and old document than in the other two conditions.

Figure 23 shows the average number of log key strokes/error on each trial for all subjects, with the 95% confidence limits.

Figure 24 shows the average number of log key strokes/error on each trial for the different conditions. It shows that the self detected error rate improved after the third trial for condition N - N, but that it was more or less the same on each trial for conditions O - N and O - O.

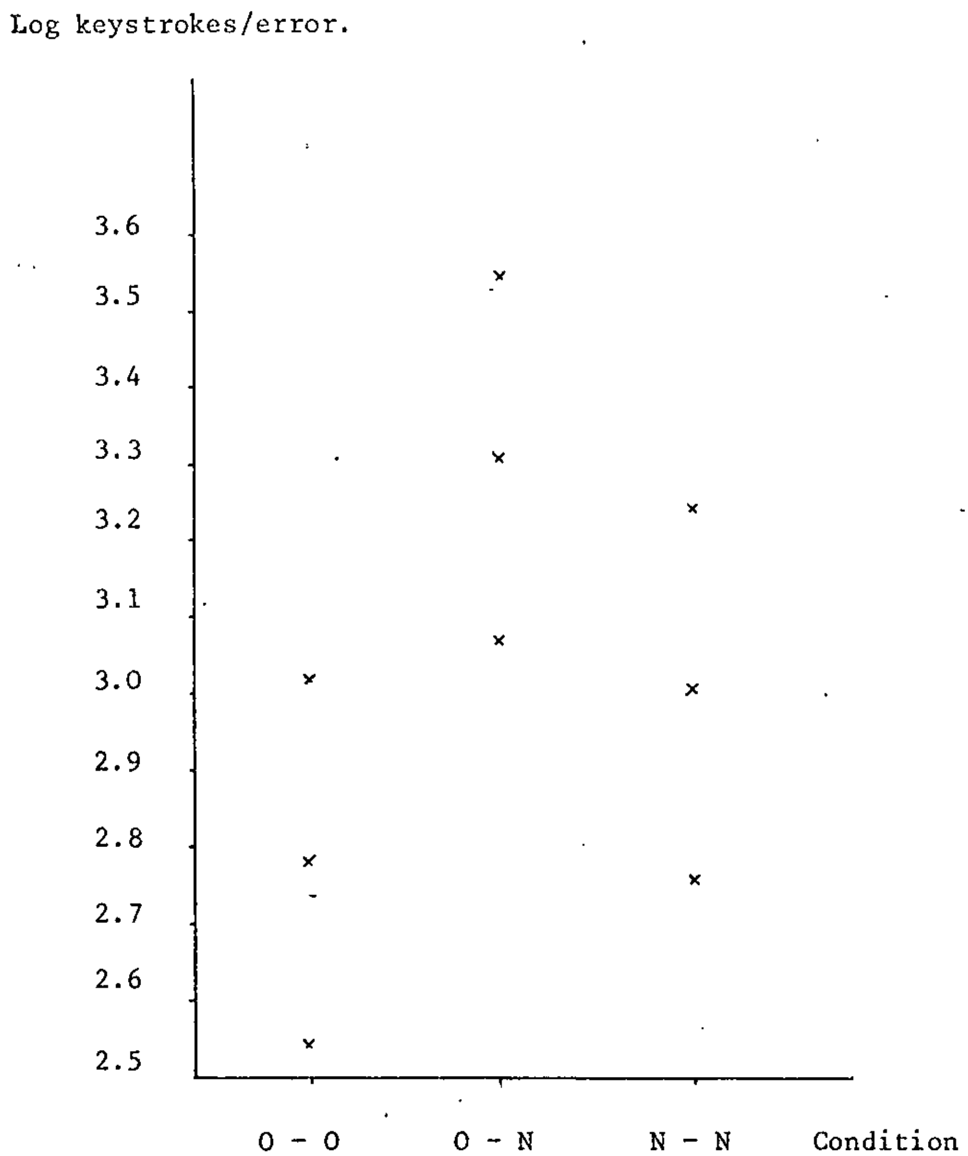


Figure 22. Average number of log key strokes per error for each condition for the self detected error, with the 95% confidence limit.

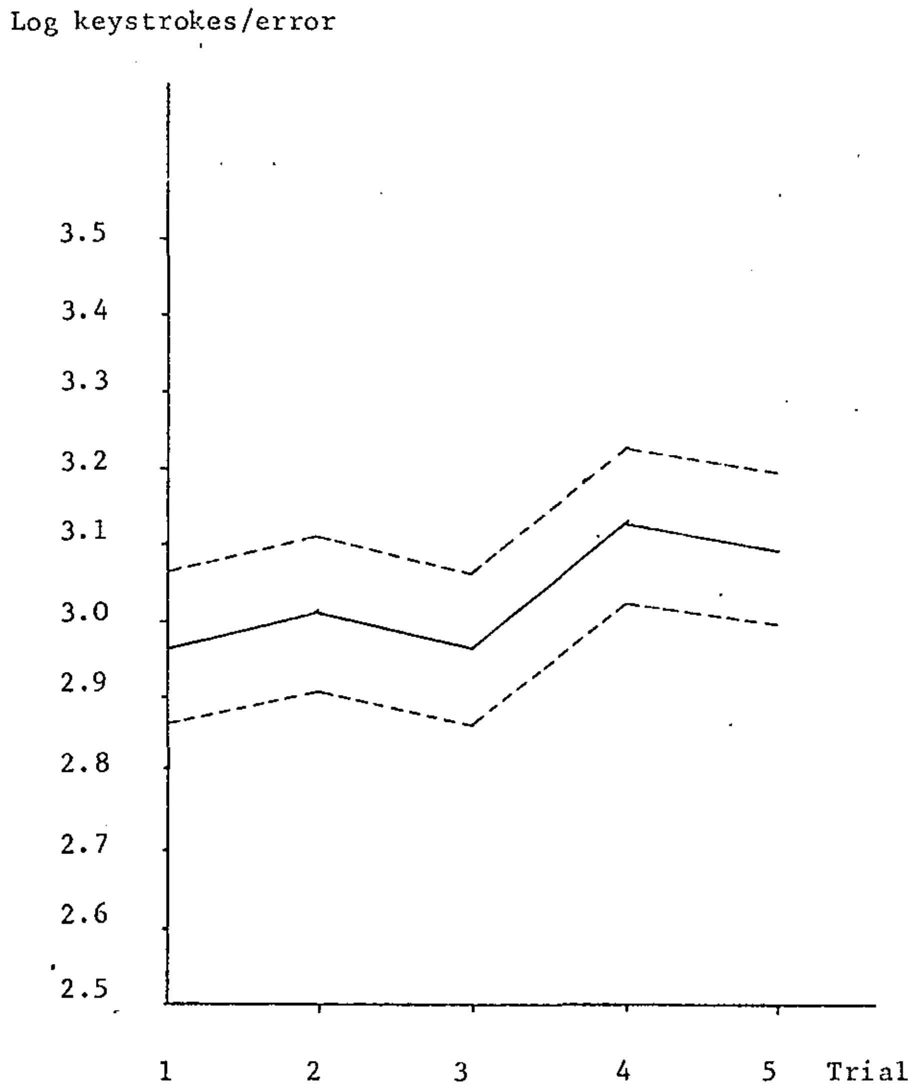


Figure 23. Average number of log keystrokes per error on each trial for all subjects on the self detected error, with the 95% confidence limit.

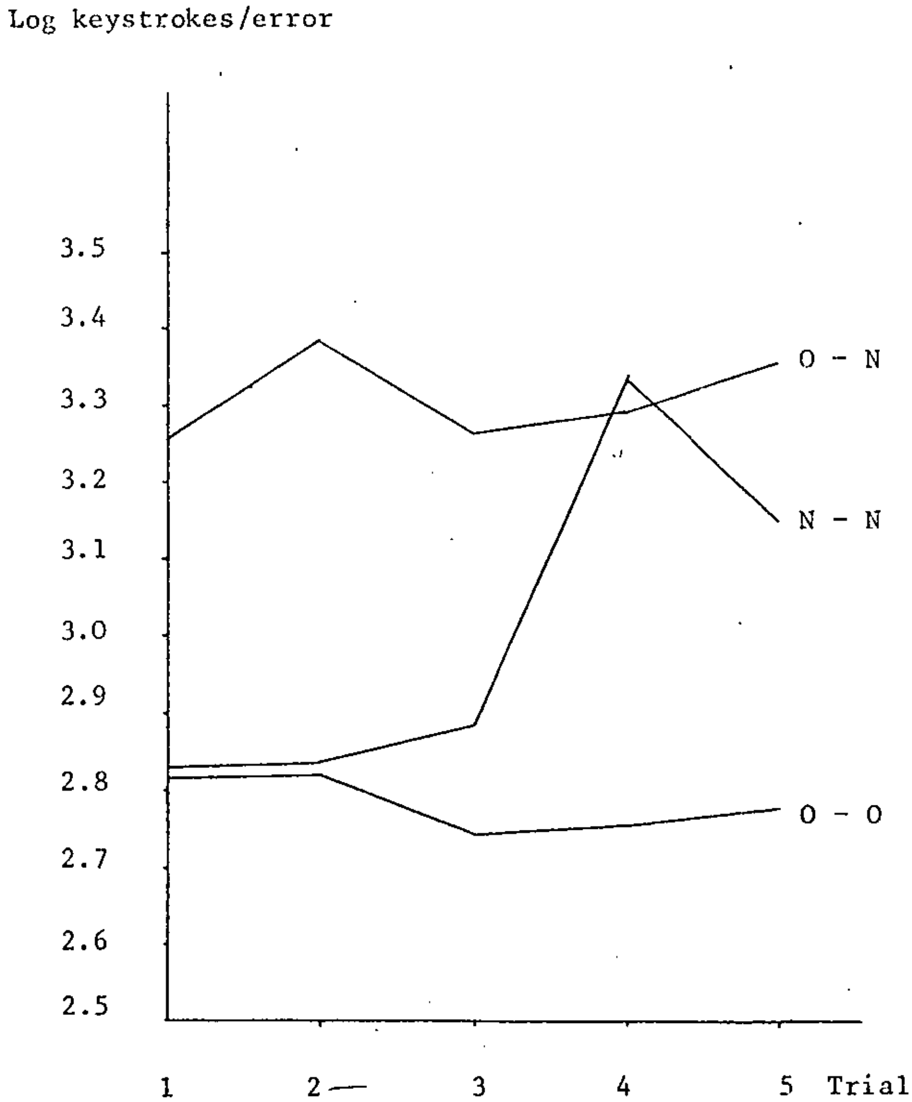


Figure 24. Average numbers of log key strokes per error on each trial for self detected error on each condition.

9.1.3. Verified error rate.

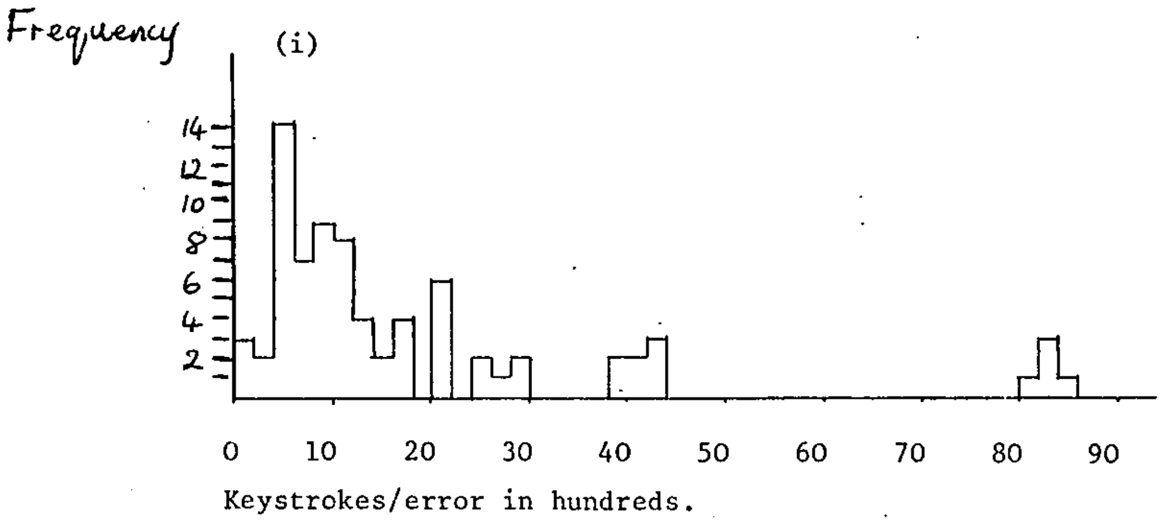
An analysis of variance was carried out on the verified errors, and a summary of this is reported in Table 51.

Table 51. Split plot analysis of variance on the verified error rate.

Source	df	ssq	msq	F	Sign
Between subjects	14	137,069,296.75			
Between conditions (c)	2	61,811,074.43	(a) 30,905,537.22	$\frac{a}{b}$ 4.92	$.025 < p < .05$
Error between subjects	12	75,258,222.32	(b) 6,271,518.53		
Within subjects	60	135,133,193.80			
Between trials (t)	4	11,357,710.22	(c) 2,839,427.56	$\frac{c}{e}$ 1.27	N.S.
t x c	8	17,166,508.10	(d) 2,145,813.51	$\frac{d}{e} < 1$	N.S.
Error	48	106,608,975.48	(e) 2,221,020.32		
Total	74	272,202,490.55			

Table 51 shows the "Between Conditions (c)" was significant ($.025 < p < .05$) while "Between Trials (T)" and the interaction t x c were non significant.

Unfortunately as was the case with self detected errors the form of the data was bimodal, **(see Figure B), with the second small mode** in the right hand **tail**, which was very long. In order to better meet the assumption of the analysis of variance the logarithm of the verified error rate was calculated and a new analysis of variance carried out. This is shown in Table 52.



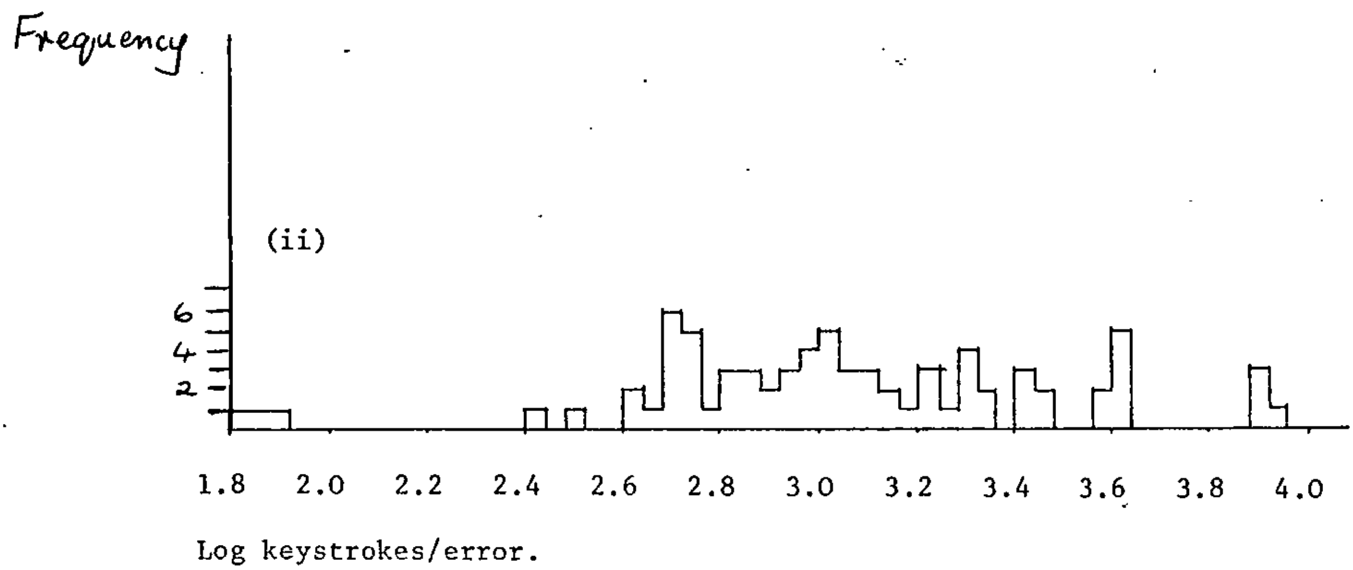


Figure B. The figure shows the distribution of the verified error rate, before (i) and after (ii) the logarithmic transformation.

Table 52. Split plot analysis of variance on the verified log error rate.

Source	df	ssq	msq	F	Sign
Between subjects	14	9.913163			
Between conditions (c)	2	3.608185	(a)1.804093	$\frac{a}{b}$ 3.433	N.S.
Error between subjects	12	6.304978	(b)0.525415		
Within subjects	60	3.691194			
Between trials (t)	4	0.566025	(c)0.141506	$\frac{c}{e}$ 2.470	N.S.
t x c	8	0.375324	(d)0.046916	$\frac{d}{e} < 1$	N.S.
Error	48	2.749845	(e)0.057288		
Total	74	13.604357			

Table 52 shows that everything was non significant. Figure 25 shows the average number of log key strokes/error for each condition, within 95% confidence limit. It shows that the error rate for the new document and the new code (N - N) is better than the error rate for the old document, and the old code (O - O) and the old document and the new code (O - N), but as stated earlier the differences are not significant.

Figure 26 shows the average numbers of log key strokes/error on each trial with 95% confidence limits.

Figure 27 shows the average numbers of log key strokes/error on each trial for each condition. It shows that condition N - N is better on all trials compared with condition O - O and condition O - N, though the differences are not significant.

9.1.4. Total error rate.

An analysis of variance was carried out on the total error rate, i.e. self detected and verified errors combined, and this is reported in Table 53. The data for the total error rate were close to normally distributed. See Figure C.

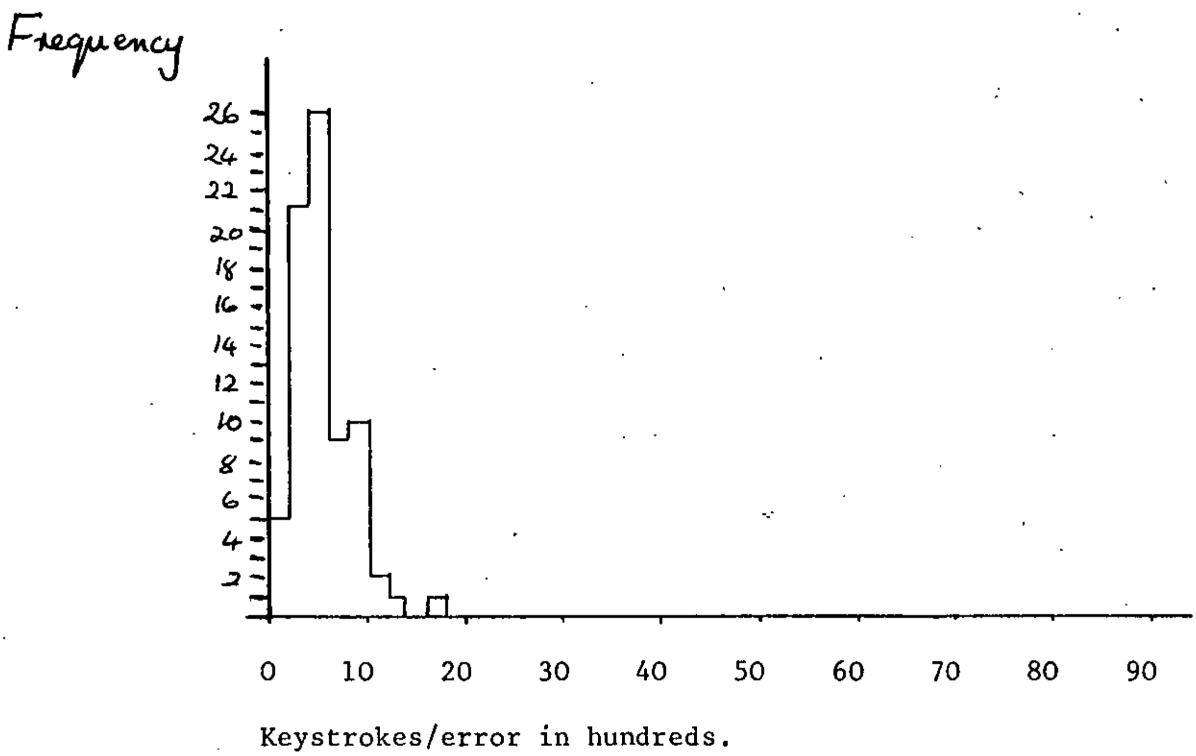


Figure C. The figure shows the distribution of the total erro

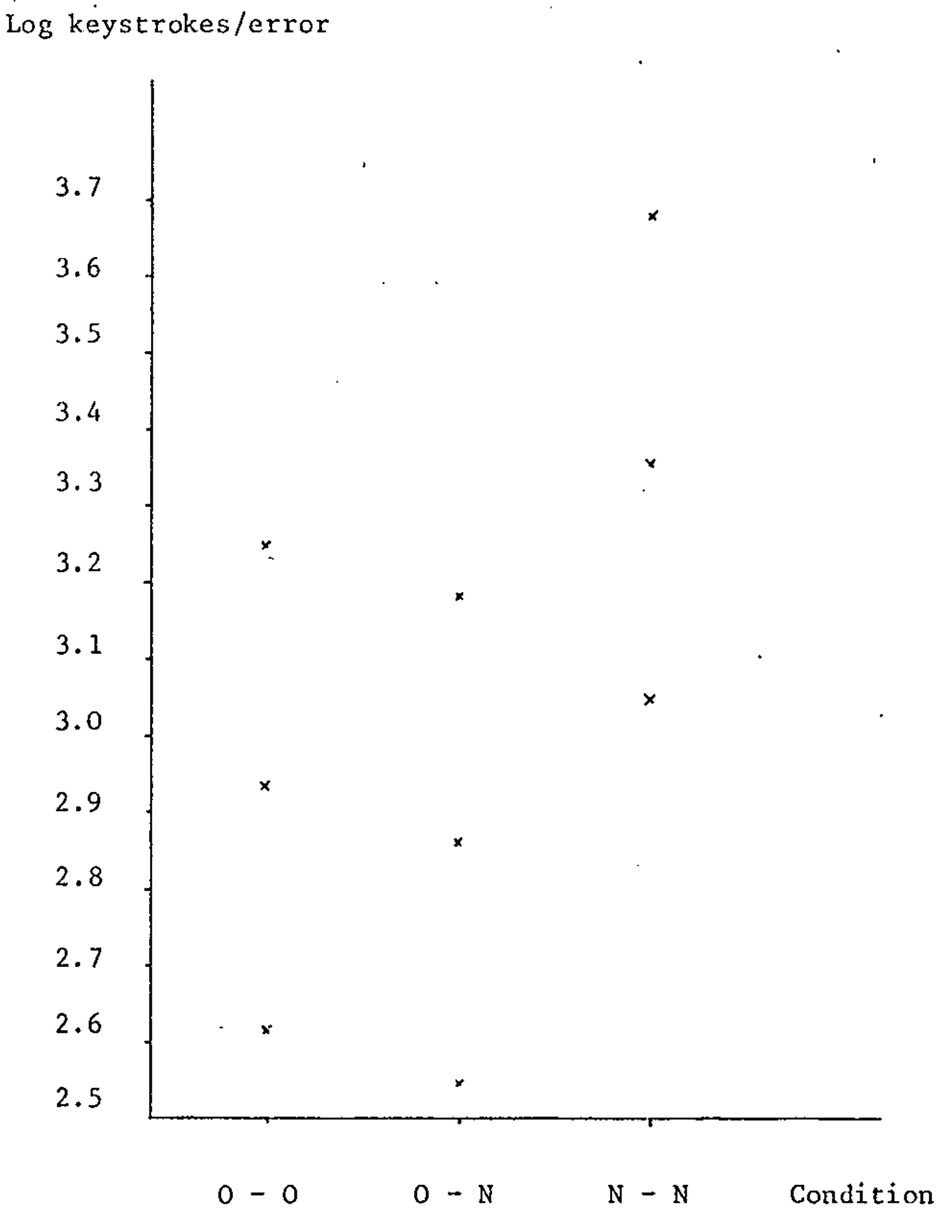


Figure 25. Average numbers of log key strokes per error for each condition for verified errors, with 95% confidence limit.

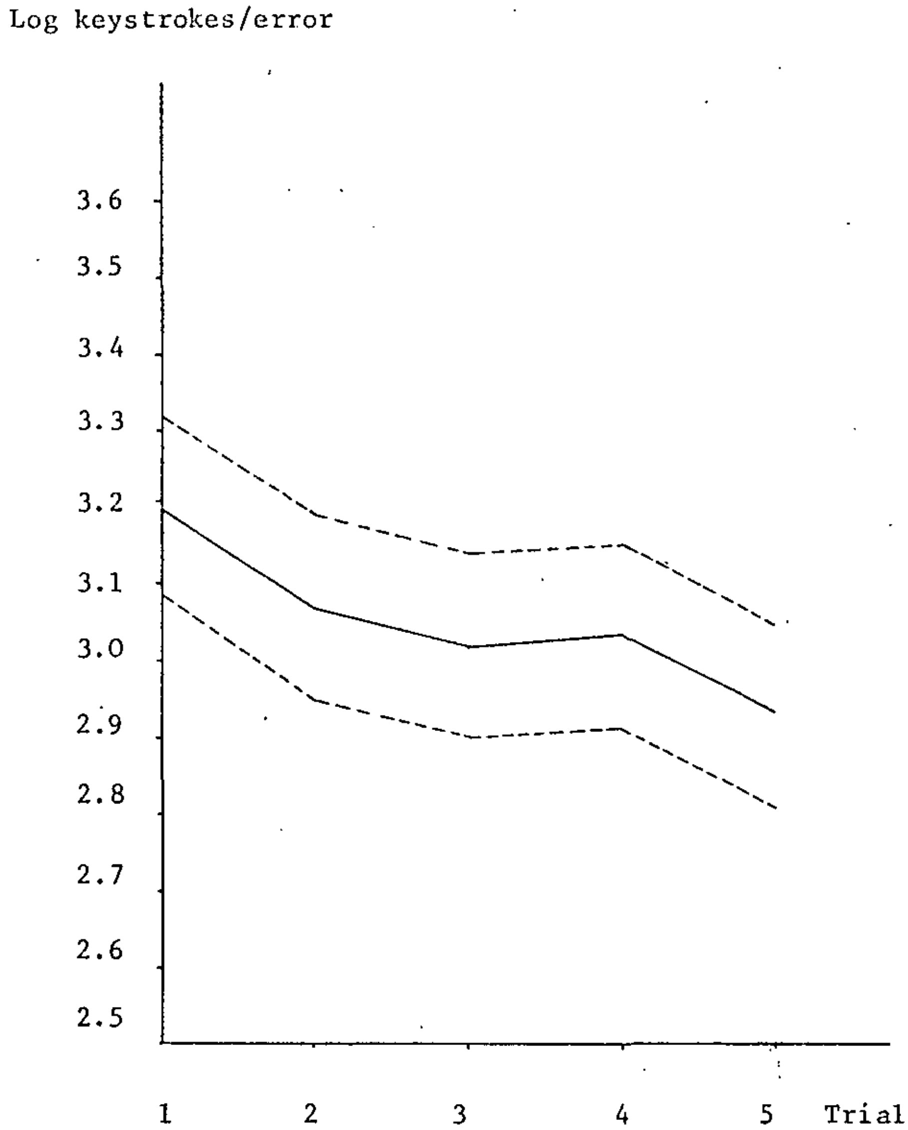


Figure 26. Average numbers of log key strokes per error on each trial for all subjects for verified errors with the 95% confidence limit.

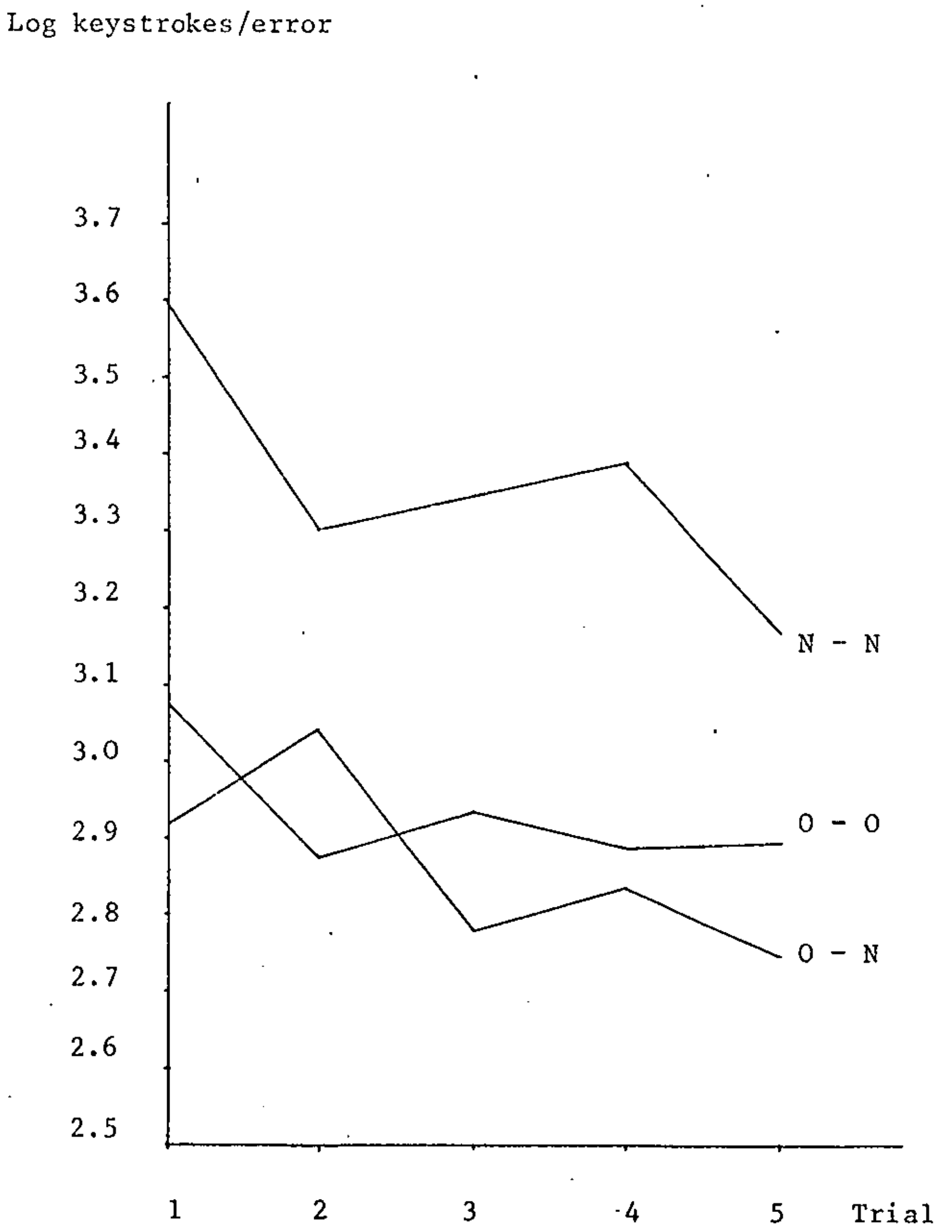


Figure 27. Average numbers of log keystrokes per error on each trial for verified error on each condition.

Table 53. Split plot analysis of variance on the total error rate.

Source	df	ssq	msq	F	Sign
Between subjects	14	3,608,361.39			
Between conditions (c)	2	1,452,076.19	(a) 726,038.10	$\frac{a}{b}$ 4.04	$.025 < p < .05$
Error between subjects	12	2,156,285.20	(b) 179,690.43		
Within subjects	60	2,902,516.20			
Between trials (t)	4	159,296.47	(c) 39,824.12	$\frac{c}{e}$ 1.19	N.S.
t x c	8	1,135,711.93	(d) 141,963.99	$\frac{d}{e}$ 4.24	$p < .001$
Error	48	1,607,507.80	(e) 33,489.75		
Total	74	6,510,877.59			

Table 53 shows that "Between Conditions (c)" was significant ($.025<p<.05$), while "Between Trials (t)" was non significant. Interaction t x c was highly significant ($p<.001$). Figure 28 shows the average number of key strokes/error for each condition, with the 95% confidence limit for the total error rate. A t-test was carried out to see what conditions differed significantly from each other. Significant differences are reported below.

Condition			Difference	
0-0	-	N-N	338.04	*

* = significant at .05 level.

It will be seen that the total error rate is less for the new document with the new code, that in the other two conditions.

Figure 29 shows the average numbers of key strokes/error on each trial, with the 95% confidence limits.

Figure 30 shows the average numbers of key strokes/error on each trial for each condition. It shows that the total error rate for condition N - N decreases after the third trial, and that the error rate for condition 0 - N and condition 0 - 0 do not vary much on the different trials.

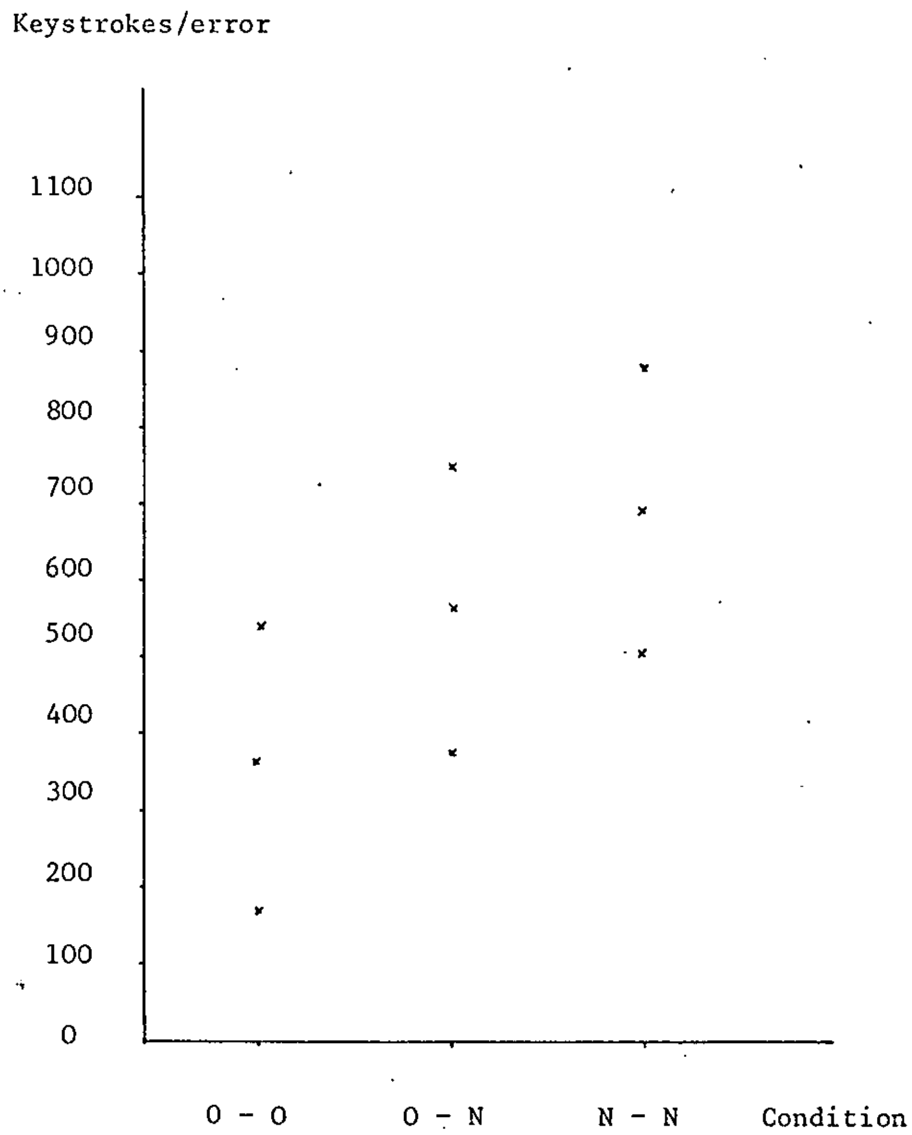


Figure 28. Average number of keystrokes per error for each condition for total errors, with 95% confidence limit.

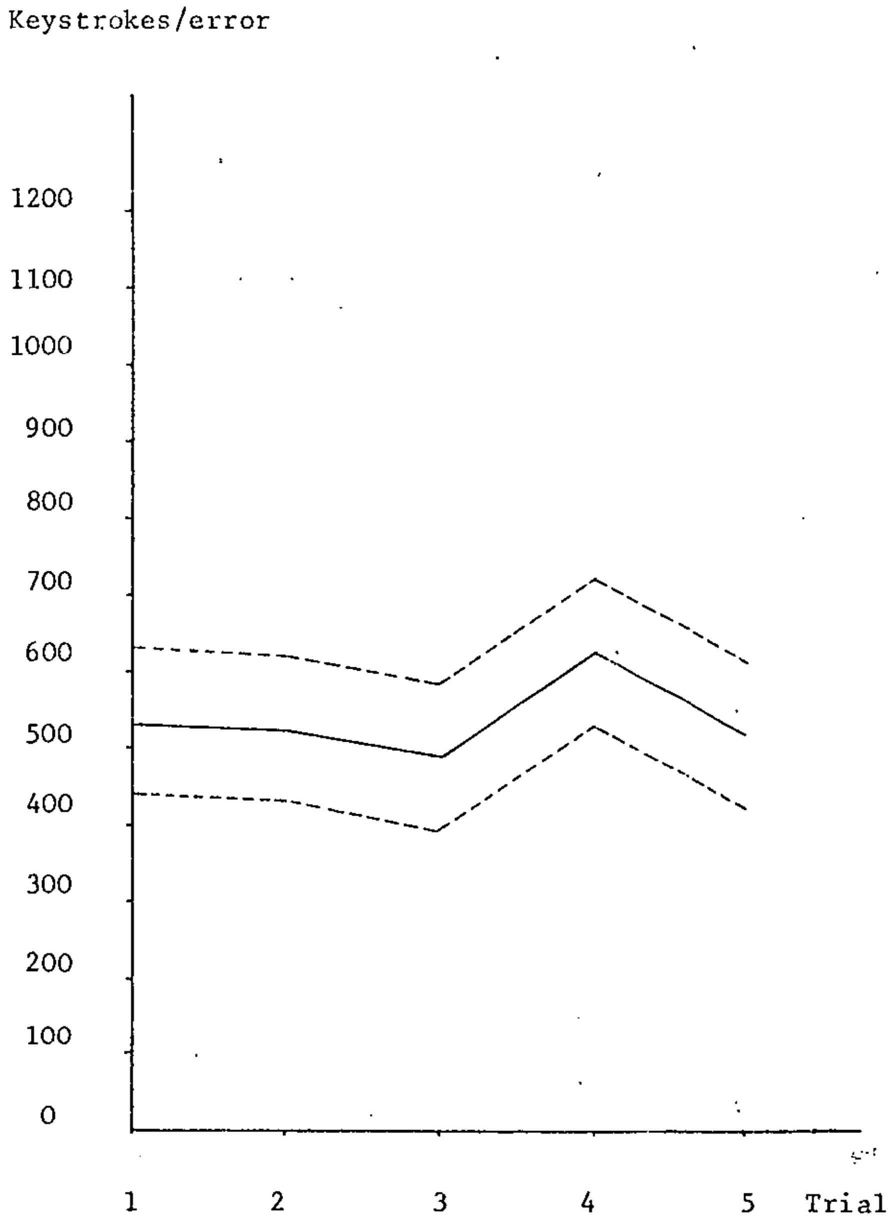


Figure 29. Average number of keystrokes per error per trial for trial error for all subjects, with 95% confidence limit.

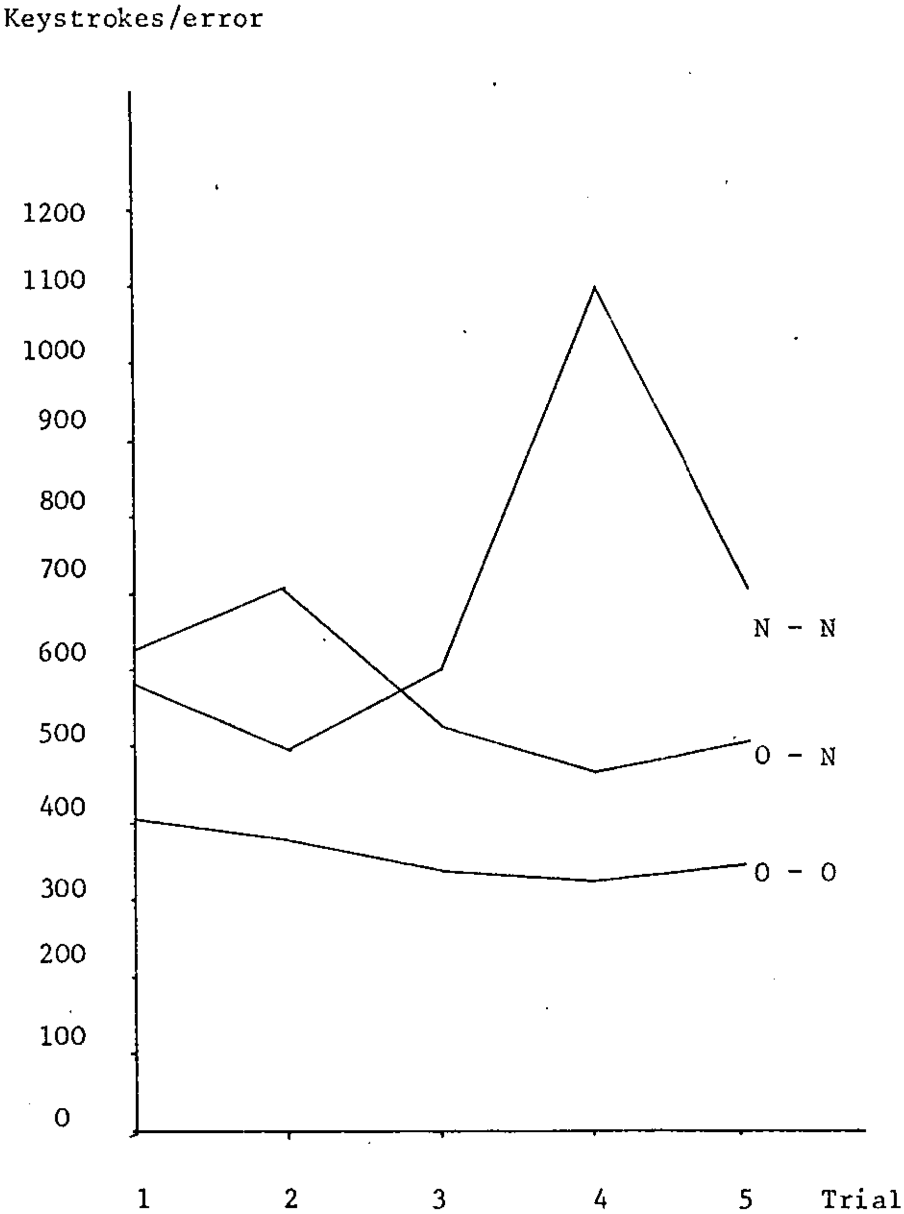


Figure 30. Average number of keystrokes per error on each trial for the total error on each condition.

9.1.5. Summary of results on keying and error rate.

From the results of the experiment reported above, it seems that the new document and the new code do not effect the key rate very substantially, but do seem to effect the error rate, particularly the total error rate.

9.1.6. Comparing of the error rates and ratio between the self detected error rate and the verified error rate for all conditions.

Since the self detected and verified error rate seem to be the reverse for condition O - N and N - N, (see Figure 22 and Figure 25), it was decided to make up a table with the error rates for all three conditions. Table 54 shows all the error rates in percentage form.

Table 54. Error rate for all three conditions in percentage form.

Condition			
	Self detected error rate	$\frac{1}{673}$	x 100 = 0.148%
0 - 0	Verified error rate	$\frac{1}{946}$	x 100 = 0.105%
	Total error rate	$\frac{1}{358}$	x 100 = 0.279%
	Self detected error rate	$\frac{1}{3108}$	x 100 = 0.032%
0 - N	Verified error rate	$\frac{1}{1333}$	x 100 = 0.075%
	Total error rate	$\frac{1}{564}$	x 100 = 0.177%
	Self detected error rate	$\frac{1}{1327}$	x 100 = 0.075%
N - N	Verified error rate	$\frac{1}{3036}$	x 100 = 0.032%
	Total error rate	$\frac{1}{696}$	x 100 = 0.143%

It can be seen in Table 54 that the total error rate for 0 - 0 is nearly twice as high as for N - N.

It is interesting to note that the self detected error rate and the verified error rate for condition 0 - N is completely reversed, compared with condition N - N, i.e. the operators on condition N - N detected and corrected more errors themselves and because of this they let fewer errors through to the verifier compared with the operators on condition 0 - N.

It can also be seen in Table 54 that the ratio between self detected error rate and the verified error rate is not 4:1 which it was found to be in the "analysis of the error cards", (section 5.1). In fact the ratio is about 1.5:1 for condition O - O, 1:2.3 for condition O - N and 2.3:1 for condition N - N. The ratio is even in the reverse direction from what would be expected for condition O - N.

9.1.7. Key rate versus error rate for the different operators.

Klemmer and Lockhead (1960) reported that the operators who are fast punchers also make fewer errors. Figure 31 shows the relation between key rate and error rate for each subject.

A correlation coefficient was carried out on the data reported in Table 31 to determine the relationship between speed and error rate for the 15 subjects. The result of this is shown below.

$$r = 0.39$$

It indicates a linear relationship in which the value of y increased as r increases, i.e. a fast operator makes a small number of errors and a slow operator makes a large number of errors. This agrees with Klemmer and Lockhead (1960).

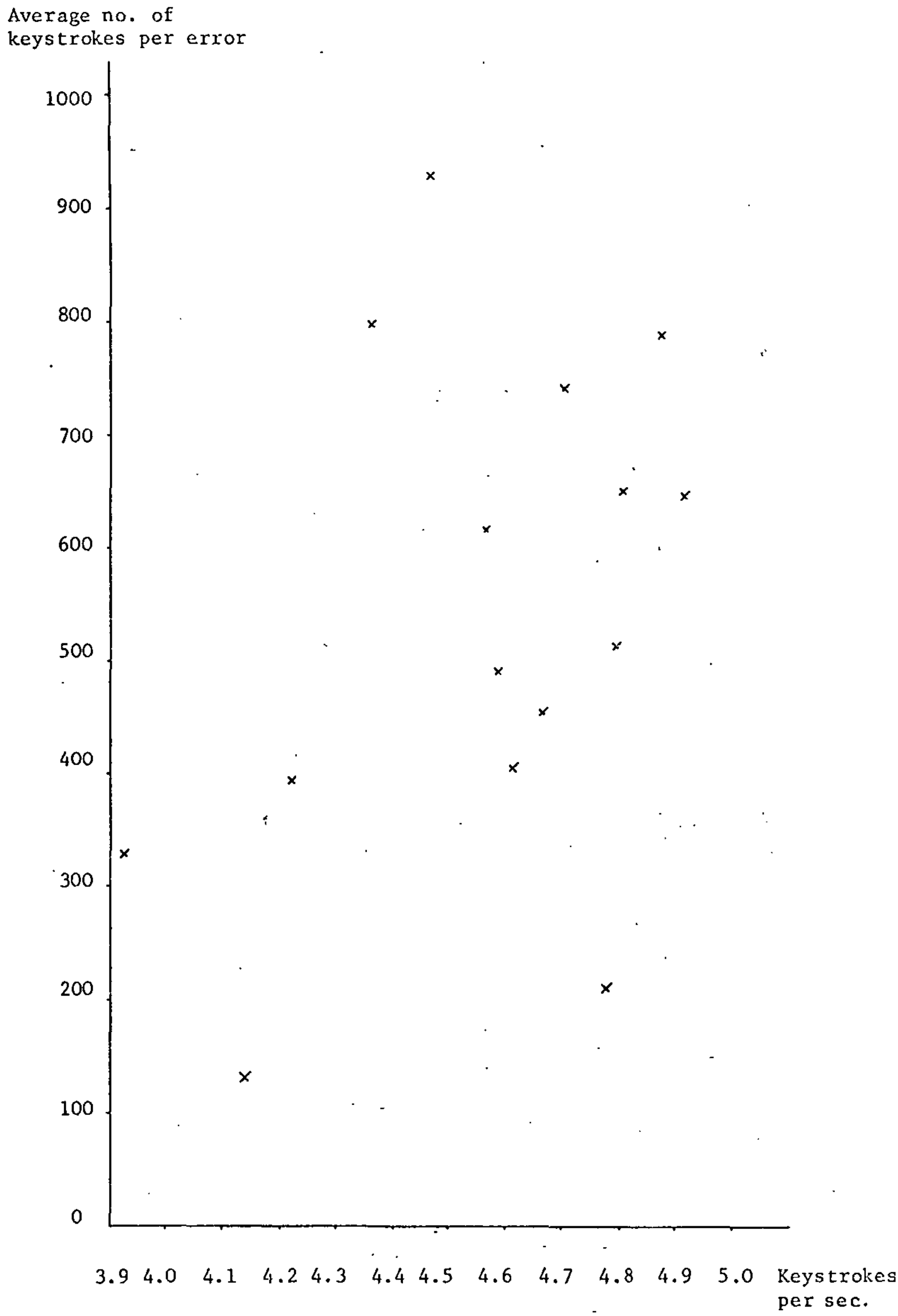


Figure 31. The relation between key rate and total error rate for each subject.

9.1.8. Results of the questionnaire.

The results from the questionnaire that was given out to subjects after they had completed the five trials are shown below.

Table 55. Subjects responses to the question "How easy is it to read the data on the document?".

Scale	% Condition O - O	% Condition O - N	% Condition N - N
Very easy			
Easy		40	20
Satisfactory	100	40	80
Difficult		20	
Very difficult			
Total	100	100	100

Table 56. Subjects responses to the question "Do you think there is sufficient space between data on the same line?".

Scale	% Condition O - O	% Condition O - N	% Condition N - N
Plenty			
Enough	100	80	100
Barely enough		20	
Not enough			
Total	100	100	100

Table 57. Subjects response to the question "Do you think there is sufficient space between the lines of the data?".

Scale	% Condition O - O	% Condition O - N	% Condition N - N
Plenty		20	
Enough	100	80	100
Barely enough			
Not enough			
Total	100	100	100

Table 58. Subjects response to the question "Do you ever lose track on where you are on the document?".

Scale	% Condition O - O	% Condition O - N	% Condition N - N
Often			
Sometimes	80	60	80
Rarely	20	40	20
Never			
Total	100	100	100

Table 59. Subjeets response to the question "How good is the layout of the document?".

Scale	% Condition O - O	% Condition O - N	% Condition N - N
Very good			
Good	20	20	20
Satisfactory	80	80	80
Poor			
Very poor			
Total	100	100	100

The subjects were also asked if they had any comments about anything that had not been mentioned in the questionnaire and in that case to write them down. The only comment thay had was that the data should be typed instead of handwritten and this was said by several of the subjects.

The results of the experiment are discussed in the next section together with the discussion for the whole project.

10.0 Discussion

This project set out to try to determine whether operators in the data preparation section experienced any difficulties or discomfort, and if so what were the causes. The results from the questionnaire administered at the beginning of the study will be discussed first. It will be recalled that no measurements were made on the environment, to see whether the operators' complaints are valid or not.

The reason for this is that the second part of the project concentrated on the documents. The questionnaire can be seen in Appendix 1 and the results are reported in Section 2.1. The possible effect on the operators' performance of all the things that have not been examined, e.g. the machine, work-place and environment, is not known.

Another project that looked into the visual, auditory and thermal environments in detail was carried out in the spring of 1971 by a postgraduate student from the Department of Ergonomics in another section of the same building. He administered a questionnaire about the environment, the answers to which contained many complaints about environmental conditions, even though his objective measurements indicated that the conditions were within the comfort limits. He concluded that the complaints were probably of psychological and social nature, and that this ought to be looked into. Whether this is the same for the data preparation section is not known. It seems unlikely that the visual and thermal unlikely that it should effect her performance to any great extent. The only comment the operators had on the layout of the office was, that the position of the supervisor led to unfair distribution of work. This is probably more a problem of a social nature, than anything else.

The keyrate and error rate found in the literature, the workstudy, the monthly report and survey are discussed below. The average data from the different reports are shown in Table 60.

Table 60. Key and error rate from the literature, workstudy, monthly report and survey.

	Literature	Work Study	Monthly Report	Survey
Keyrate (Keystrokes/min)	168	181.8		
Error rate (Keystrokes/error)				
Self detected				216.68
Verified	1600 - 4300		1575	851.44
Total				188.63

It can be seen in Table 60 that the data from the different reports differs considerably, especially the error rates. The difference between the keyrate reported in the literature and the workstudy is small and can probably be disregarded. The differences between the error rates are more interesting. The error rate reported in the monthly report is slightly below the error rates reported in the literature. But it was established that the monthly report did not give a true picture of the error rate, and the correct error rate for the data preparation section was established in the survey. The difference between the error rate in monthly reports and the survey is probably due to the way in which the errors are recorded. The difference between the error rate found in the survey and the error rate established in the literature is considerable. It can be argued that the reason for the high error rate is poor operator performance. However, this seems unlikely because the operators error rate in percentage of cards has to be less than 2% after three weeks training for them to be accepted by the Company. Furthermore, it is known that both speed and accuracy improves during the first year on the job. See section 3.2. It seems more likely that the reasons for the high error rate should be blamed on the large number of different documents, their layout, the lack of compatibility between them, and their legibility.

If one compared the error rate for 403 (Stock Order) obtained in the survey, see Tables 37, 38 and 39 in chapter 5.3., environment in the data preparation section should be different from the other sections of the building, since the whole building has the same type of lighting and is air-conditioned. It was stated in Section 2.1. that it is the author's subjective opinion that it would be worthwhile investigating the auditory environment, since the noise is sometimes disturbing. However, it seems unlikely that the noise could reduce the operators' performance to any great extent, since it is only really disturbing when all machines are in use, and this is very seldom.

It also seems unlikely that the machines used in the data preparation section could reduce the operators' performance to any great extent, if any, since the machines are capable of operating up to rates of about 20 keystrokes per second. That is to say, the maximum keyrate which the machine can deal with is about the same as the maximum keyrate at which an operator is capable of working, but an operator can only come near to this rate at short bursts, (see section 3.1). If a machine ever delays an operator, it will probably be in a situation when the machine skips a card that only has about 40 columns punched, but since this normally happens when the operator also has to turn over a source document, it seems unlikely that this would delay the operator, and reduce the performance. It also seems unlikely that the workplace could influence the operators performance to any great extent. A majority of the operators complained when an adjacent machine is under repair, but since this only effects an operator for a relatively short time, it seems

Unfortunately in the data preparation section, it is difficult to envisage the possibility (even if the present recommendations are taken up) that all documents will contain only numeric data. This means that recommendations relating to numeric keyboard design (such as those contained in Yllo (1962) cannot be utilized.

with error rates obtained in the experiment, see Table 54, chapter 9.16, especially conditions 0 - 0, one realises that the error rate obtained in the experiment for condition 0 - 0 is below the error rate obtained in the survey. The reason for this is probably that the operator took extra care and tried to do their obsolute best since they knew they were taking part in an experiment. But the error rates for condition 0 - 0 obtained in the experiment are still well above the error rates quoted in the literature.

The total error rate for the new document with the new code (N - N), is significantly better than the total error rate for the old document with the old code (0 - 0), while the total error rate for the old document with the new code (0 - N) is better than the total error rate for condition 0 - 0, though not significantly so. The total error rate for N - N is better than the total error rate for 0 - N, but it is not significant. That is to say, both the layout of the new document and the new code helped to reduce the error rate. The error rates for the new document with the new code (N - N) are well within the range quoted in the literature. This agrees with the argument that was put forward earlier, i.e. it is not the operators fault that the error rate in the data preparation section is high, since the error rate for a well laid out document is well within the limits quoted in the literature.

The keyrates obtained in the experiment are shown in Figure 21, the keyrates on the last trial for conditions (O - N) and (N - N) are about 4.9 characters/second and for (O - O) they are 4.6 characters/second. If one converted these to keystrokes/min one gets 294 and 276 keystrokes/min. Siebel (1970) says that the keyrates in an experiment are twice the keyrate during a working day, i.e. to be able to **compare** the keyrates in the experiment with the keyrates in the literature, we have to divide them by two. That is to say, the keyrate for O - N and N - N is then equal to 147 keystrokes/min and O - O is equal to 138 keystrokes/min. Although this gives only a very rough figure, it is then possible to compare it with the data in the literature. The figures obtained from the above calculations are less than the figures given in the literature. (See Table 60). Too much should not be made out of this, since it is a very rough way to compare data. But the keyrates in the experiment show that all numeric documents, i.e. O - N and N - N have a higher keyrate than the document with mixed alpha and numeric.

Since the new code is two characters longer than the old code, one may ask whether the reduced error rate justifies the slightly longer time taken to punch the new code. A reduced error rate saves the following things:

1. The time taken for a punch operator to correct self corrected errors.

2. The time taken for a verifier to determine whether she or the punch operator has made an error.

(It should be noted that the new document with numeric data provides marginally faster punching which, unfortunately, does not completely compensate for the longer code which it engenders compared with the alpha code).

3. The time taken for the punch operator to correct the errors detected by the verifier.

4. The time taken for the verifier to verify the cards that have been corrected by the punch operator.

5. The number of cards wasted.

The reduced error rate is also probably encouraging for an operator from a psychological point of view. As a result of these consideration the author thinks that a reduced error rate can justify a slightly longer time taken to punch a document.

The purpose of the experiment was to determine whether the new design of the document and the new code would increase the operators performance. One has to remember when looking at the results of the experiment that several things were working against the new document. The operators were not used to it, and they did not have training sessions before the experiment. However, they were used to the condition 0 - 0, i.e. the old document with the old code, since this condition was made up of real work they do every day. The new documents are different from the majority of the documents used in the data preparation section, i.e. there are interference effects between them. See section 5.4. That is to say, depending upon what type of work the operators did immediately before the experimental session, the performance in the experiment could have been enhanced or adversely effected. In addition to potential interference effects, there are almost certainly effects due to incompatibility in the layout between the documents. See section 5.4. All of these factors work against the new document. In order to avoid all of these effects it would have been necessary to carry out an experiment over several months, with the operators using only one type of document. It was not possible to do this in the time available. Also the cost of running an experiment over such a long time would have been prohibitive. However, the results of the experiment indicates that a properly designed document will increase the operators performance. But it is difficult to say how much the operators performance would increase if all documents were redesigned in a similar way. It has been shown that it is possible to reduce the total error rate about 50 %, see Table 54, because of this it should be possible to get a substantial increase in performance and output if all the documents were redesigned.

Since it has been established that it is possible to increase the operators' performance by redesigning the documents, the new practical problem is to get enough evidence to convince the Management that it is important for them to redesign the documents. It is unfortunately not possible to state exactly how much the redesigning of all the documents would increase the data preparation section output. The only way to get more evidence for this would be to do a much bigger and elaborated experiment.

If the Management want to get a higher output and increased performance in the data preparation section, the first thing they might do would be to start looking at what sort of new data preparation equipment is available on the market, and by how much it could increase their output. However, if they buy new data preparation equipment, the output might increase only slightly. This is because the error rate will still be the same, but the errors might be slightly easier to correct on new, more sophisticated equipment. But the source documents will still be the "bottleneck" to an efficient system, i.e. the data preparation section will not be able to take full advantage of more sophisticated machinery because the source documents will always limit the operators performance. That is to say, to optimize the data preparation section, the source document has to be redesigned. This would certainly be a much cheaper way to increase the output than for example, to buy new data preparation equipment.

11.0 Conclusion

From what has been discussed in this project, it is clear that there are several things that can cause discomfort and difficulties for operators in a data preparation section, and certain things, such as the documents can reduce their performance to a great extent.

It has been shown that the error rate that is usually recorded in a data preparation section, i.e. the errors found by the verifier, does not give a true picture of the error rate. Because of this it is apparent that a system that records the keyrate and the total error rate, i.e. both the self detected errors and the errors found by a verifier, for each document and operator is needed in a data preparation section.

This would also be advantageous to the people who are designing new documents for the data preparation section. Since the cost per unit of through-put for data preparation by key punch machines has increased compared with the cost per unit of through-put for the computer system itself, the keypunch has begun to appear as a "bottleneck" to efficiency. Thus, it is necessary for a data preparation section to try to increase their output without increasing the cost. It has been shown that one way to do this is to redesign the documents that cause difficulties for the operators. This is certainly a much less expensive way to increase the output than for example to buy new data preparation equipment. As previously stated, new equipment would not reduce error rates, it would only make them slightly easier to correct.

This project has shown how it is possible to reduce the cause of difficulties experienced by the operators by applying human factors/ergonomics data, while at the same time reducing the operators' error rate.

A brief list of the recommendations for change, arising from the investigation is given below:

1. A system that records the keyrate and total error rate for each document and operator is needed.

2. Documents of different sizes should not be mixed in a batch.

3. The documents used in the data preparation section ought to be re-designed to achieve the following:

   a) clearer layout in general.

   b) more compatibility between the documents.

   c) correct punching sequence.

   d) standardized sizes.

4. Codes ought to be all numeric.

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REFERENCES

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APPENDIX 1

Punch operator questionnaire

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

INSTITUTE FOR CONSUMER ERGONOMICS

PUNCH OPERATOR QUESTIONNAIRE

I am making a study of the working conditions in your office, including such things as the documents, the workstations, the layout of the office and the environment, in order to give recommendations for improvement.

I would like you to answer the questions on this reply sheet in order to get your opinion of the working conditions. You may rest assured that anything you say will be treated in the strictest confidence.

Remember that any information you can give will be valuable, so do not hesitate to say just what you think.

It is essential that you do not discuss with others your replies to the questions posed in this investigation, as I want your own uninfluenced personal opinion.

Please answer questions by putting a tick (√) in the appropriate box.

Finally, please answer every question.

GENERAL QUESTIONS

1. Sex: Male ☐ Female ☐

2. Age: Under 18 ☐ 18-21 ☐ 22-25 ☐ 26-30 ☐
31-35 ☐ 36-40 ☐ 41-45 ☐ Over 45 ☐

3. Are you married ☐ or single ☐ ?

4. Shift: Day ☐ Evening ☐ Night ☐

5. How long have you been working as a punch operator, both in Boots and elsewhere?

_______ years _______ months

6. How did you come to take up this work?

____

____

____

7. Did you get your training in this Company?

Yes ☐ No ☐

8. How easy is your job to carry out?

Very easy ☐ Easy ☐ About average ☐

Neither easy nor difficult ☐ Difficult ☐ Very difficult ☐

9. If you think your job is difficult or very difficult, try to specify why.

____

____

____

10. How tiring do you find your work?

Very tiring ☐ Fairly tiring ☐

Not particularly tiring ☐ Not tiring at all ☐

11. If you think your work is very tiring or fairly tiring, try to specify why.

____

____

____

12. How frequently do you get headaches?

Often ☐ Sometimes ☐ Rarely ☐ Never ☐

13. How frequently do you suffer from eyestrain?

Often ☐ Sometimes ☐ Rarely ☐ Never ☐

QUESTIONS ABOUT THE ENVIRONMENT

For each aspect of the environment listed, put a tick against the numbers which best describes your impression. For example, if for question 14 you feel that the typical temperature of the office in winter is about right, you should tick (4). If for question 15 you feel that the typical temperature of the office in summer is too hot tick (7), and so on.

Use your experience to make an overall judgement rather than rating things as they are this moment.

14. Typical temperature of office in winter, from 'too cold' (1) to 'too hot' (7).

(1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6) ☐ (7) ☐

Too cold Too hot

15. Typical temperature of office in summer, from 'too cold' (1) to 'too hot' (7).

(1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6) ☐ (7) ☐

Too cold Too hot

16. Typical impression of ventilation of office in winter, from 'stuffy' (1) to 'fresh' (7).

(1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6) ☐ (7) ☐

Stuffy Fresh

17. Typical impression of ventilation of office in summer, from 'stuffy' (1) to 'fresh' (7).

(1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6) ☐ (7) ☐

Stuffy Fresh

18. Typical lighting in office, from 'dim' (1) to 'too bright' (7).

(1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6) ☐ (7) ☐

Dim — Too bright

19. Typical noise in office, from 'very quiet' (1) to 'intolerably noisy' (7)

(1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ (6) ☐ (7) ☐

Quiet — Intolerably noisy

20. Where is your machine situated (from the windows)?

1st row ☐ 2nd row ☐ 3rd row ☐

4th row ☐ 5th row ☐ 6th row ☐

21. Do you find the artificial light glaring?

Not noticeably ☐ Hardly noticeably ☐

Just noticeably ☐ Very noticeably ☐

QUESTIONS ABOUT THE WORKSTATIONS

22. How much space is there on the working surface of your machine to set out documents from which you work?

Plenty ☐ Enough ☐

Barely enough ☐ Not enough ☐

23. How easy is the machine to operate?

Very Easy ☐ Easy ☐ Satisfactory ☐

Difficult ☐ Very Difficult ☐

24. How easy is it to place documents and cards so that they are readily to hand?

Very Easy ☐ Easy ☐ Satisfactory ☐

Difficult ☐ Very Difficult ☐

25. How well can you see the cards when they are in the machine?

Very well ☐ Well ☐ Satisfactorily ☐

Badly ☐ Very badly ☐

26. How much space is there around your machine for normal movement?

Plenty ☐ Enough ☐ Barely enough ☐ Not enough ☐

27. How much space is there around your machine while an adjacent machine is under repair?

Plenty ☐ Enough ☐ Barely enough ☐ Not enough ☐

28. Are there any other particular difficulties connected with the space around your machine?

____

____

____

29. What type of shoes do you wear at work?

Low heel ☐ Medium heel ☐ High heel ☐

30. Do you like ☐ or dislike ☐ the type of chair you are using?

31. How easy is it to adjust the seat height?

Very Easy ☐ Easy ☐ Satisfactory ☐

Difficult ☐ Very Difficult ☐

32. How easy is it to adjust the backrest?

Very Easy ☐ Easy ☐ Satisfactory ☐

Difficult ☐ Very Difficult ☐

33. How comfortable is the seat to sit on?

Very comfortable ☐ Comfortable ☐ Satisfactory ☐

Uncomfortable ☐ Very Uncomfortable ☐

34. Can you keep your feet comfortably flat on the floor when you are working?

Yes ☐ No ☐

35. How good is the support which the backrest of the seat provides?

Very good ☐ Good ☐ Satisfactory ☐

Poor ☐ Very poor ☐

36. How frequently do you get muscular pains (pain in the back or legs, etc), while working?

Often ☐ Sometimes ☐ Rarely ☐ Never ☐

37. If you get pain often or sometimes, please tick (✓) on the figure to show where you get pain. (Woman - Figure 1, Man - Figure 2).

38. Is there anything else you would like to say about your chair?

____

____

____

QUESTIONS ABOUT THE LAYOUT OF THE OFFICE

39. How much space is there in the office (your section) as a whole?

Plenty ☐ Enough ☐ Barely enough ☐ Not enough ☐

40. How good is the layout of the date preparation section?

Very good ☐ Good ☐ Satisfactory ☐

Poor ☐ Very poor ☐

41. If you think the layout could be improved, what changes would you suggest?

____

____

____

FIGURE 1 (WOMAN)

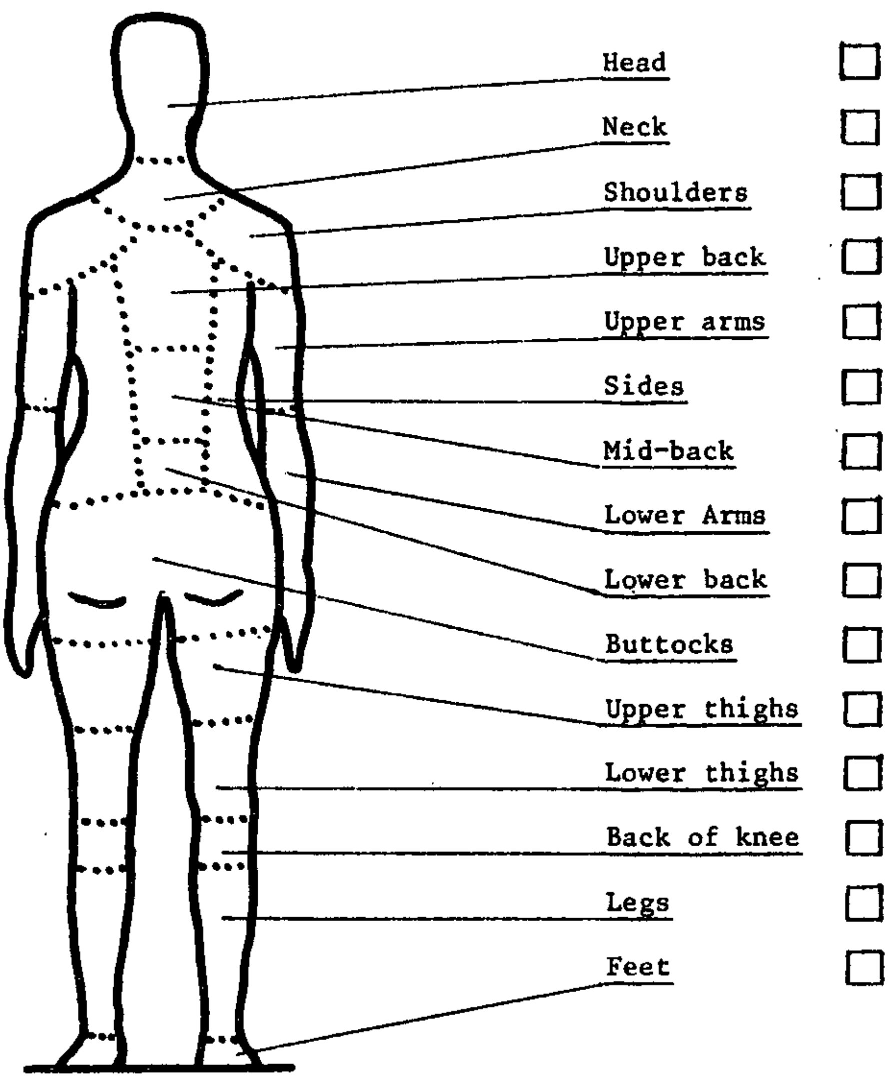
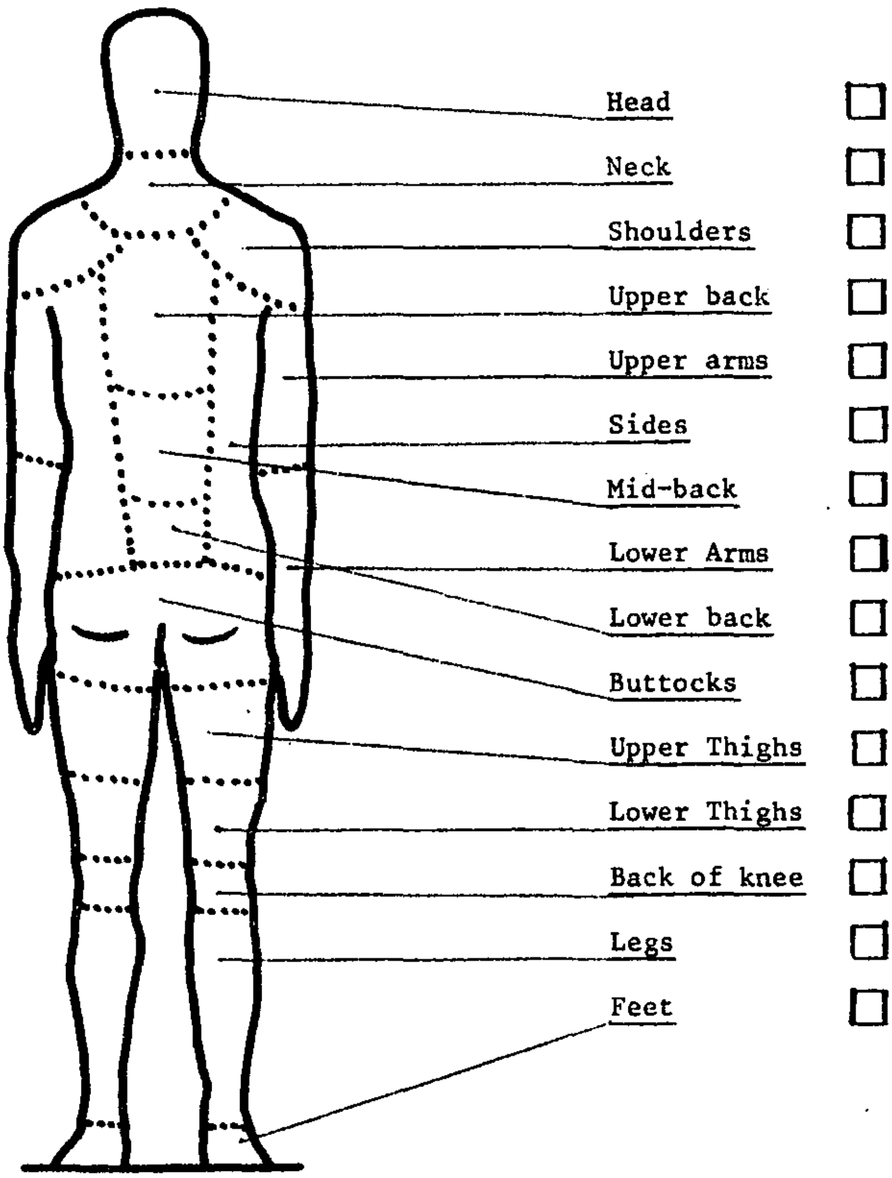


FIGURE 2 (MAN)


Head
Neck
Shoulders
Upper back
Upper arms
Sides
Mid-back
Lower Arms
Lower back
Buttocks
Upper Thighs
Lower Thighs
Back of knee
Legs
Feet

QUESTIONS ABOUT THE DOCUMENTS

42. Which five documents (invoices, etc.) do you think are most difficult to read. Try to put the most difficult first, the next most difficult second, and so on.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

43. Try to specify why you find them difficult to read.

____

____

____

44. If you think they could be improved, what changes would you suggest?

____

____

____

45. Which five documents (invoices, etc.) do you think are easiest to read? Put the easiest first, and so on.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

46. Try to specify why you find them easy to read.

47. Is there anything not mentioned in this reply sheet that you feel you would like to say about your office?

48. Is there anything not mentioned in this reply sheet that you feel you would like to say about your job?

APPENDIX 2

Credit Sales Invoices

PLEASE REMIT TO ADDRESS BELOW

↑ BRANCH ADDRESS STAMP MUST BE USED ↑

CUSTOMER'S NAME AND ADDRESS:

DATE

INVOICE

Boots THE CHEMISTS LTD.
HEAD OFFICE
NOTTINGHAM
NG2 3AA

P 46095

ORDER No.	DESCRIPTION OF GOODS			TOTAL

S.D.R.

PLEASE REMIT TO ADDRESS BELOW

↑ BRANCH ADDRESS STAMP MUST BE USED ↑

CUSTOMER'S NAME AND ADDRESS:

DATE

INVOICE

Boots THE CHEMISTS LTD.
HEAD OFFICE
NOTTINGHAM
NG2 3AA

P 46096

ORDER No.	DESCRIPTION OF GOODS			TOTAL

S.D.R.

CUSTOMER'S NAME
AND ADDRESS:

INVOICE

HEAD OFFICE COPY

P 46095

DATE

ORDER No.	DESCRIPTION OF GOODS			TOTAL
S.D.R.				

CUSTOMER'S NAME
AND ADDRESS:

INVOICE

HEAD OFFICE COPY

P 46096

DATE

ORDER No.	DESCRIPTION OF GOODS			TOTAL
S.D.R.				

An example of the small invoice OM826.

[redacted]

CUSTOMER'S NAME
AND ADDRESS:

[redacted]

INVOICE

BRANCH COPY

P. 46095

DATE

ORDER No.	DESCRIPTION OF GOODS			TOTAL

S.D.R.

CUSTOMER'S NAME
AND ADDRESS:

INVOICE

BRANCH COPY

P. 46096

DATE

ORDER No.	DESCRIPTION OF GOODS			TOTAL

S.D.R. [redacted]

PLEASE REMIT TO
ADDRESS BELOW

CUSTOMER'S NAME
AND ADDRESS

DATE

INVOICE

Boots THE CHEMISTS
NOTTINGHAM
NG2 3AA

D 038348

ORDER No.

DESCRIPTION OF GOODS			TOTAL

S.D.R.

An example of the big invoice (OM830)

An example of the invoice (OM850) used by the agricultural section of the Company.

To Remove Carbons

This is a Multipart Set Please use a Ball Point Pen

INVOICE

W/ 085806

BOOTS FARM SALES LIMITED

HEAD OFFICE : NOTTINGHAM, NG2 3AA

TELEPHONE 56111

CUSTOMER'S NAME AND ADDRESS

DATE DELIVERED	CUSTOMER'S ORDER No.	REMARKS, DATE REQD.

DESCRIPTION OF GOODS	GROSS £	GROSS p	DISCOUNT £	DISCOUNT p	NET £	NET p

S. D. R.	DATE ORDERED	FIELDSMAN'S No.

OM 850

SPEEDISET LAMSON PARAGON

APPENDIX 3

Local Purchases Documents

CARD CODE				BATCH NO.				CARD NO.		
1	2	3	4	5	6	7	8	9	10	11
P	A	2	0							

LOCAL PURCHASES TRANSACTION

OM46-8179A

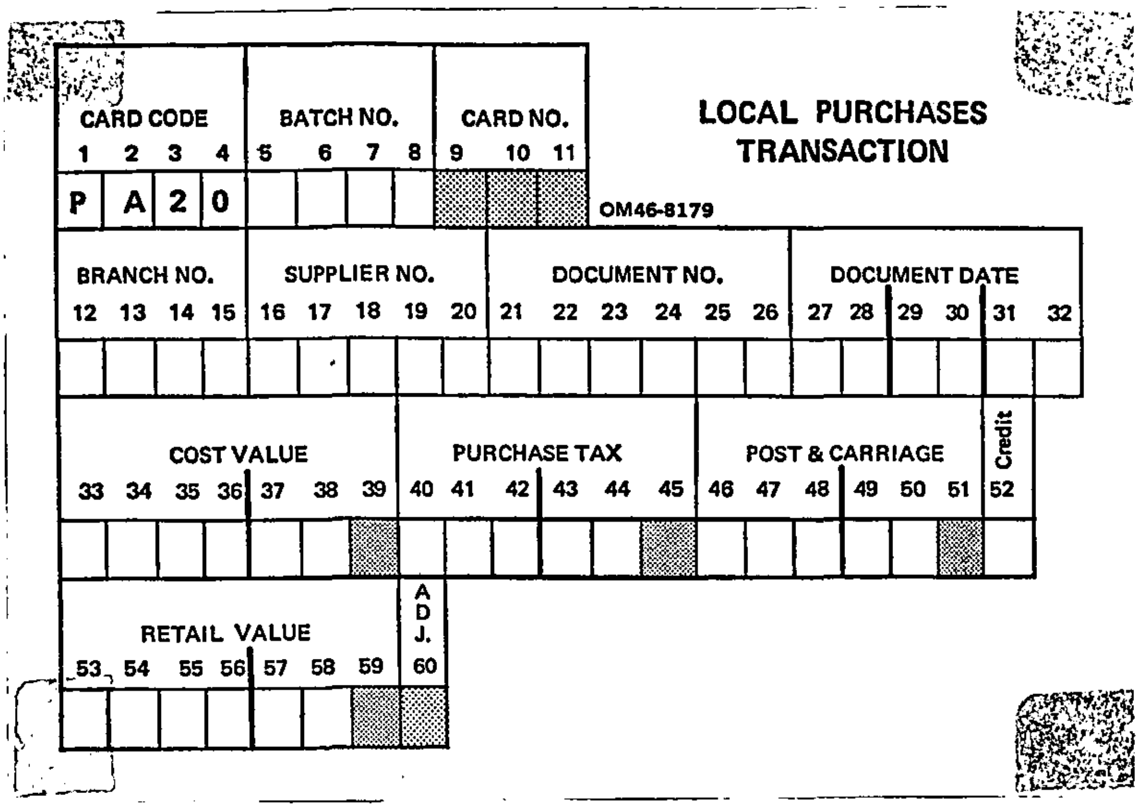
BRANCH NO.				SUPPLIER NO.					DOCUMENT NO.						DOCUMENT DATE					
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
				5	0	0	0	8												

COST VALUE							PURCHASE TAX						POST & CARRIAGE						Credit
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52

RETAIL VALUE							ADJ.
53	54	55	56	57	58	59	60

MACARTHY

An example of the Local Purchases (PA20) document.



LOCAL PURCHASES TRANSACTION

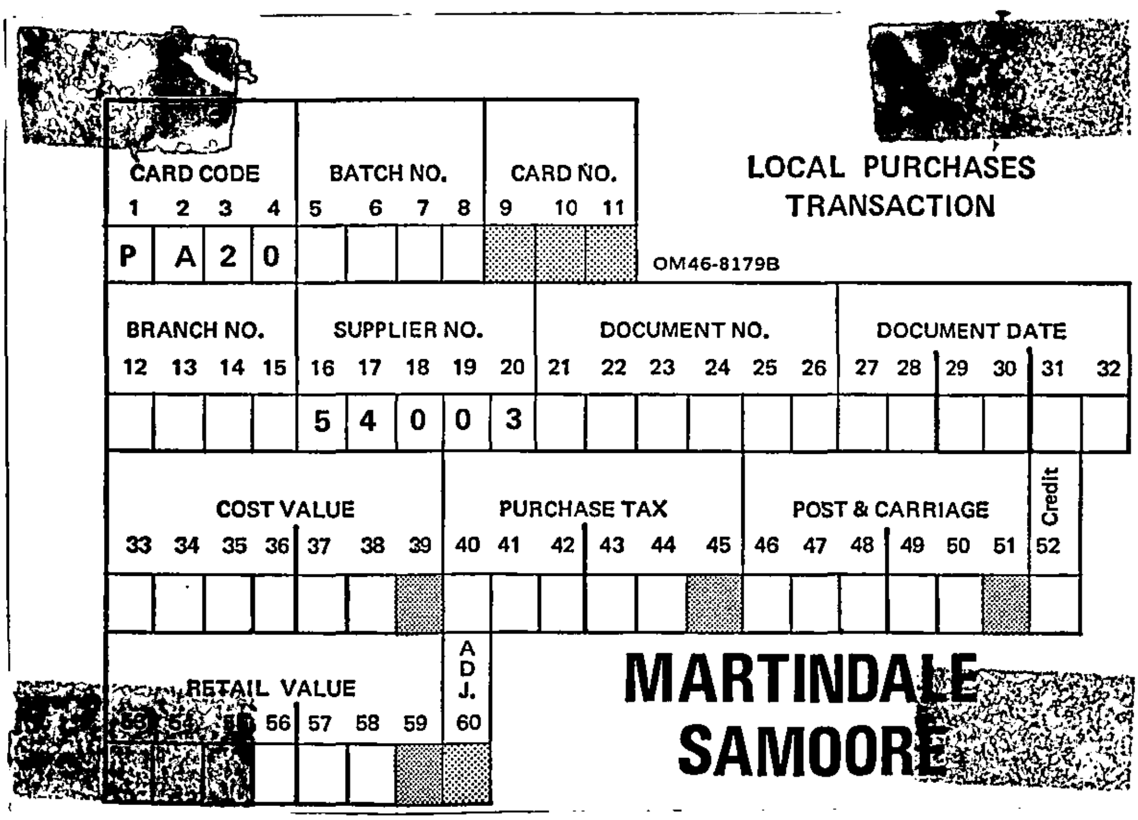
OM46-8179

CARD CODE				BATCH NO.				CARD NO.		
1	2	3	4	5	6	7	8	9	10	11
P	A	2	0							

BRANCH NO.				SUPPLIER NO.					DOCUMENT NO.						DOCUMENT DATE					
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

COST VALUE							PURCHASE TAX						POST & CARRIAGE						Credit
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52

RETAIL VALUE							ADJ.
53	54	55	56	57	58	59	60



LOCAL PURCHASES TRANSACTION

OM46-8179B

CARD CODE				BATCH NO.				CARD NO.		
1	2	3	4	5	6	7	8	9	10	11
P	A	2	0							

BRANCH NO.				SUPPLIER NO.					DOCUMENT NO.						DOCUMENT DATE					
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
				5	4	0	0	3												

COST VALUE							PURCHASE TAX						POST & CARRIAGE						Credit
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52

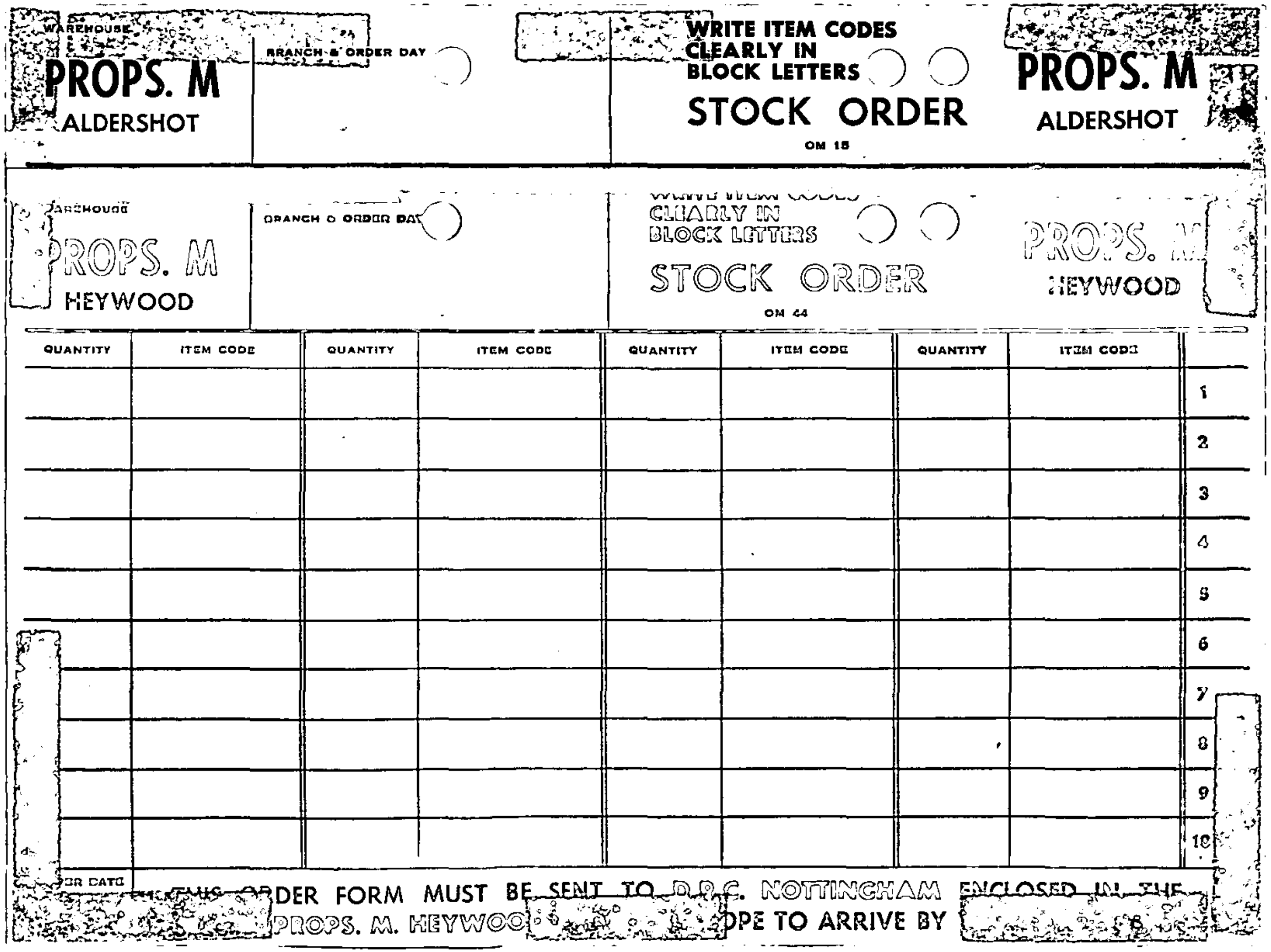
RETAIL VALUE							ADJ.
[illegible]	[illegible]	[illegible]	56	57	58	59	60

MARTINDALE SAMOORE

Examples of the Local Purchases (PA20) document.

APPENDIX 4

Stock Order documents


WAREHOUSE
PROPS. M
ALDERSHOT
BRANCH & ORDER DAY
WRITE ITEM CODES CLEARLY IN BLOCK LETTERS
STOCK ORDER
OM 15
PROPS. M
ALDERSHOT

WAREHOUSE
PROPS. M
HEYWOOD
BRANCH & ORDER DAY
WRITE ITEM CODES CLEARLY IN BLOCK LETTERS
STOCK ORDER
OM 44
PROPS. M
HEYWOOD

QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

ORDER DATE
THIS ORDER FORM MUST BE SENT TO D.P.C. NOTTINGHAM ENCLOSED IN THE PROPS. M. HEYWOOD ENVELOPE TO ARRIVE BY

Examples of the Stock Order (403) documents, only the headings are shown on some of the documents, since the layout of them is the same.

Examples of the Stock Order (403) documents, only the headings are shown on some of the documents, since the layout of them is the same.

WAREHOUSE	BRANCH & ORDER DAY	
PROPS. M. LONDON		WRITE ITEM CODES CLEARLY IN BLOCK LETTERS STOCK ORDER OM 820

M PROPS

LONDON

WAREHOUSE	BRANCH NUMBER	ORDER DAY	INVENTORY SECTION	
HOUSEWARE (PART 1)				WRITE ITEM CODES CLEARLY IN BLOCK LETTERS STOCK ORDER OM 177

HOUSEWARE (PART 1)

QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

ORDER DATE

THIS ORDER FORM MUST BE SENT TO **D.P.C. NOTTINGHAM** ENCLOSED IN THE SPECIAL **HOUSEWARE (PART 1)** ORDER ENVELOPE FOR THE CORRESPONDING INVENTORY SECTION TO ARRIVE BY YOUR ORDER DAY FOR THIS SECTION

Examples of the Stock Order (403) documents, only the headings are shown on some of the documents, since the layout of them is the same.

WAREHOUSE **STATIONERY & ART** | BRANCH & ORDER DAY | WRITE ITEM CODES CLEARLY IN BLOCK LETTERS | **STOCK ORDER** O. & M. 789 | **S**

WAREHOUSE **TOILET** | BRANCH & ORDER DAY | WRITE ITEM CODES CLEARLY IN BLOCK LETTERS | **STOCK ORDER** O. & M. 770 | **T**

WAREHOUSE **SUNDRIES** | BRANCH & ORDER DAY | WRITE ITEM CODES CLEARLY IN BLOCK LETTERS | **STOCK ORDER** O. & M. 748 | **H**

QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

ORDER DATE

This order form must be sent to D.P.C. NOTTINGHAM enclosed in

Examples of the Stock Order (403) documents, only the headings are shown on some of the documents, since the layout of them is the same.

WAREHOUSE
PROPS. T.
BEESTON

BRANCH & ORDER DAY

WRITE ITEM CODES
CLEARLY IN
BLOCK LETTERS

STOCK ORDER

OM 767

PROPS T

WAREHOUSE
BEESTON
OWN GOODS

BRANCH & ORDER DAY

WRITE ITEM CODES
CLEARLY IN
BLOCK LETTERS

STOCK ORDER

OM 847

OG
BEESTON

WAREHOUSE
H & G/BFS
PROPS

BRANCH & ORDER DAY

WRITE ITEM CODES
CLEARLY IN
BLOCK LETTERS

STOCK ORDER

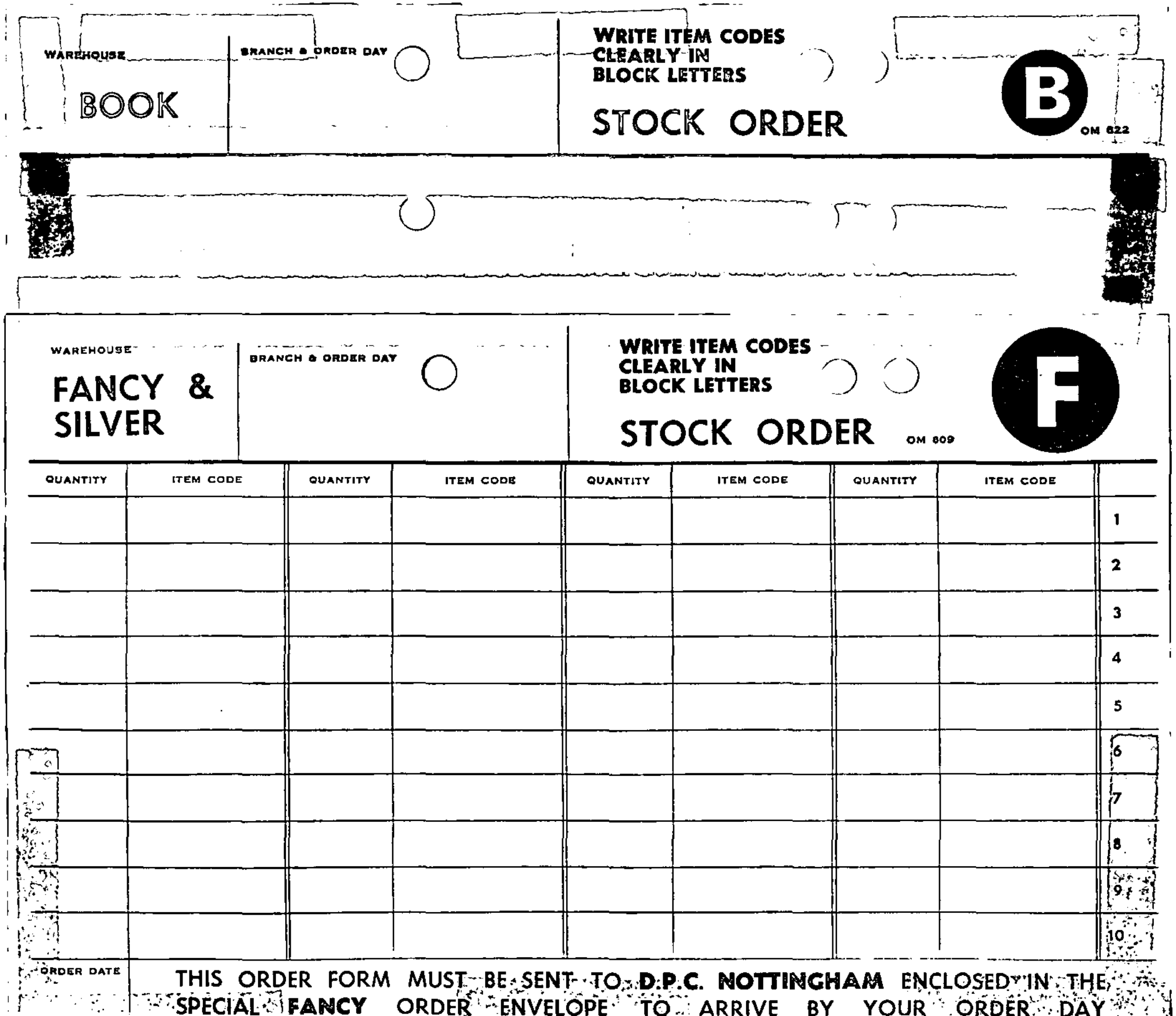
H & G/BFS PROPS

OM 878

QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

ORDER DATE

THIS ORDER FORM MUST BE SENT TO **D.P.C. NOTTINGHAM** ENCLOSED IN THE SPECIAL **H & G/BFS** ORDER ENVELOPE TO ARRIVE BY YOUR ORDER DAY



WAREHOUSE BOOK | BRANCH & ORDER DAY

WRITE ITEM CODES CLEARLY IN BLOCK LETTERS

STOCK ORDER

B

OM 822

WAREHOUSE FANCY & SILVER | BRANCH & ORDER DAY

WRITE ITEM CODES CLEARLY IN BLOCK LETTERS

STOCK ORDER

OM 809

F

QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	QUANTITY	ITEM CODE	
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

ORDER DATE

THIS ORDER FORM MUST BE SENT TO **D.P.C. NOTTINGHAM** ENCLOSED IN THE SPECIAL **FANCY** ORDER ENVELOPE TO ARRIVE BY YOUR ORDER DAY

Examples of the Stock Order (403) documents, only the headings are shown on some of the documents, since the layout of them is the same.

APPENDIX 5

Punch Operator Reply Sheet

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

INSTITUTE FOR CONSUMER ERGONOMICS

PUNCH OPERATOR REPLY SHEET

I would like you to answer the questions on this reply sheet in order to get your opinion of the document. You may rest assured that anything you say will be treated in the strictest confidence.

Remember that any information you can give will be available, so do not hesitate to say just what you think.

It is essential that you do not discuss with anyone else your replies to the questions posed in this investigation, as I want your own uninfluenced opinion.

Please answer questions by putting a tick (✓) in the appropriate box.

Finally, please answer every question.

1. How easy is it to read the data on the document?

Very easy ☐ Easy ☐ Satisfactory ☐

Difficult ☐ Very difficult ☐

2. Do you think there is sufficient space between data on the same line?

Plenty ☐ Enough ☐ Barely enough ☐ Not enough ☐

3. Do you think there is sufficient space between the lines of data?

Plenty ☐ Enough ☐ Barely enough ☐ Not enough ☐

4. Do you ever lose track on where you are on the document?

Often ☐ Sometimes ☐ Rarely ☐ Never ☐

5. How good is the layout of the document?

Very good ☐ Good ☐ Satisfactory ☐ Poor ☐

Very poor ☐

6. If you think the layout is poor or very poor, try to specify why.

____

____

____

____

7. Is there anything that has not been mentioned in this reply, that you would like to say about the document.

____

____

____

____