HUMAN FACTORS IN THE WOOLLEN INDUSTRY - AN INVESTIGATION OF INSPECTION AND MENDING PERFORMANCE WITH SPECIAL REFERENCE TO WORSTED AND TERYLENE / WORSTED CLOTH

by

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submitted for the degree of

Ph.D.

of

LOUGHBOROUGH UNIVERSITY

OF

TECHNOLOGY

FEBRUARY 1970

Acknowledgements

The work described in this thesis, was supported by a grant from the D.S.I.R. (now the Science Research Council), and undertaken while the author was at the Department of Ergonomics and Cybernetics at Loughborough University of Technology. The work was carried out under the general direction of Professor W.F. Floyd and the supervision and guidance of Dr. N.S. Kirk. I wish to thank them for their generous help and advice in all phases of this research. I also wish to thank Mr. F. Hill, the Head of the Wool Industry Training Board and his staff, particularly Mr. K. Wilson and his mending room assessors, for the facilities accorded me during this investigation, Mr. F. Miller, of the Wool Industries Research Association for his help, and the Firms of A.W. Hainsworth, Gledhills, Melfar, Parklands, Oddys, Scotts, Standevens and Yates for their co-operation.

Finally, I wish to thank the British Iron and Steel Research Association for facilities which they provided while I was in their employ and, for valuable technical assistance throughout all the experimentation, Mr. J. Rennocks of the Department of Ergonomics and Cybernetics, Loughborough University of Technology.

Summary

This is an investigation into certain aspects of a process called burling and mending, which is concerned with the inspection and repair of faults in cloth. The females who carry out this task represent a high proportion of the labour force in the textile industry.

Three experiments were undertaken. The first of which established basic information on operator performance by testing the speed and accuracy of burlers and menders in carrying out cloth inspection on an evaluated piece of cloth, under four experimental conditions. The conditions prescribed inspection with (1) eyes only, (2) hands only, (3) both hands and eyes (normal) and (4) hands and eyes plus supplementary angular lighting. A statistical analysis took into account the conditions described, age differences, performance in relation to eight different fault categories and the resultant interactions.

The mean number of faults found overall was well under 60 per cent of those available and even under the most favourable conditions only just over 60 per cent of the faults were detected. Speed and age were found to be non significant factors though a tendency for younger inspectors to rely more on tactual inspection and older women to rely more on visual inspection was noted.

Fault categories differed as to the modality by which they were detected, though numerically faults found tactually were more predominant. It is suggested that inspection performance could be improved if there were a complete overlap of visual and tactual search. Only then could optimum detection be achieved.

The angular lighting condition whilst not producing a significantly better performance than the normal condition was sufficiently promising to suggest a further follow up pilot study.

The results were not dissimilar to the first experiment and though performance as tested with new powerful angular lighting (without taking fault categories into account) was significantly better than that

found under the normal inspection condition of Experiment 1, the findings were not as decisive as had been anticipated. Further investigation was recommended.

A third experiment was undertaken. Here the mending skills of burlers and menders despite problems with the semantics, were evaluated and then related to the inspection results of Experiment 1. No relation was found to exist between the two tasks. This has implications as supervisors (passers) who have essentially inspection functions are generally promoted on the basis of their overall burling and mending skill.

Age differences were observed in that older workers were judged by their supervisors to be more effective workers though their overall scores did not seem to suggest this to be the case.

It was concluded that due to difficulties in recruitment and a potential increase in the number of faults with faster, modern looms, that burling and mending problems (such as representing a production bottleneck) were likely to get worse rather than better. These problems, together with those resulting from the inherent difficulty of the task, and slow feedback to the mending rooms on real performance, lead to the conclusion that a systems approach is required. It is suggested that, simultaneously with improving scanning techniques to allow for more accurate inspection and also improving the feedback system, faults are also tackled at source and the engineering problems critically examined.

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CHAPTER I

INTRODUCTION

1.1 Introduction to the Study

This study is concerned with inspection or more specifically tactual and visual inspection of worsted cloth by burlers and menders. Since the production of cloth became a part of the industrial revolution and was centralised in mills or factories a specialist job has been carried out by female labour, i.e. the mending by hand of faults originating either in the spinning of the yarn or in the weaving of the cloth. The job also incorporates the responsibility for finding the faults in the cloth. As the facility to weave increasingly complex patterns developed so also has the detection and repair of faults increased in complexity. Today, burling and mending as the job is called accounts for the employment of more labour than any other single process in the manufacture of cloth. All in all 13,500 women are employed and this represents nearly 10% of the total labour force in the industry, (Wool and Allied Textile Employers Council Report 1966). However, though the speed of weaving and consequently the production potential have increased there has not been the corresponding increase in the recruitment of burlers and menders. As burling and mending is time consuming, it is expensive and constitutes a production bottleneck. An analysis of the performance of burlers and menders is important in order to assess their efficiency in terms of speed and accuracy, and to determine the areas, if any, where performance may be improved. Also it is necessary to indicate how this improvement may be achieved. In the event of such performance increments being unattainable, it would mean the Industry, of necessity, attempting to eliminate or radically reduce the number of faults at their source. Thus the investigation of the inspection mechanisms employed by these workers it is hoped will represent a contribution in the area of applied science and more particularly a contribution to that part of psychology or ergonomics which is orientated toward problem solving.

1.2 A Brief Historical Note on Attention and Vigilance

The interest of the psychologist in inspection tasks stems from a very early interest in attention which faded for some years only to reappear when vigilance studies became important during the Second World

War. The vigilance studies are considered to be closely allied to work on inspection which has now become more prevalent. To put matters in historical perspective it is proposed to trace broadly the paths pursued by those research workers investigating attention, vigilance, and inspection before considering the present investigation in this dissertation.

Early psychologists grappled with the problems of attention. What made people notice A at the expense of B? For how long could they attend to certain stimuli to the exclusion of others; when attention shifted in direction, where did it pass to next? What were the effects of irrelevant stimuli on attention? How well could two or more things capture and hold attention simultaneously? On how wide an area could attention be focused at any one time?

These problems are discussed by Woodworth and Schlosberg (1954) and described under the headings of (1) determinants of attention, (2) shifting and fluctuation of attention, (3) distraction, (4) divided attention, and (5) span of attention.

Attention was not clearly defined as its properties appeared self evident. James (1890), for example, said "everyone knows what attention is. It is the taking possession by the mind in clear and vivid form, of one out of what seem several simultaneous possible objects or trains of thought. Focalisation, concentration of consciousness are of its essence".

Whilst work on attention flourished initially it leaned heavily on introspective accounts on the contents of consciousness. As the behavioural approach became more fashionable and scientifically acceptable, so introspective psychology and with it "attention" studies fell into disfavour. This is aptly expressed by Woodworth and Schlosberg (1954, p.72) "In spite of the practical reality of attending, the status of attention in systematic psychology has been uncertain and dubious for a long time", and by Broadbent (1958) "It (attention) fell into bad odour because of the inability of introspective psychologists, to agree with one another or to provide objective evidence to back their assertions".

Recently however two volumes have emerged namely "*Attention*" edited by P. Bakan (1966) and "Attention and Performance" edited by Sanders (1967).

1.3 A Note on Vigilance Research

A resurgence of interest in certain of the aspects of attention occurred during the Second World War when studies of vigilance became important.

In war time human beings were called upon to act as monitors, and asked to scan displays associated with electronic detection devices such as radar and asdic for small signals. These were dull displays and they had to be scanned for long periods. Under these circumstances performance was poor, aircraft and submarine echoes appeared and were missed and efforts to improve this performance provoked the experimental examination of what is now variously known as vigilance, monitoring and watchkeeping.

Kirk, (1963) discusses the problem of vigilance and its relation to tasks involving attention. After advancing arguments to show that in man there appears to be no unique defining criteria of attentive behaviour, he points out that more can be achieved when considering attentive tasks.

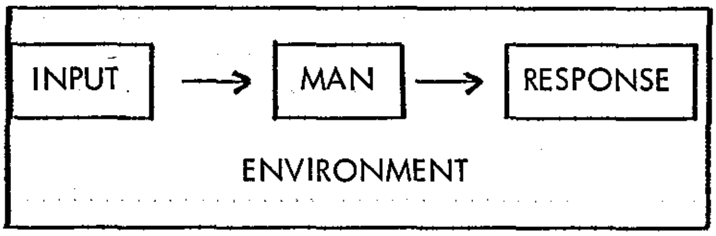
Although all tasks require an element of attention, Kirk regards as specifically attentive tasks only those "in which the subject is required to report changes in his environment". If this is accepted then studies which are discussed in Woodworth and Schlosberg can be broken down into two groups. In the first case there is the free attention situation, in which the properties of environmental factors which are likely to evoke a response without the subject being primed, are considered. In the other situation "which involves controlled attention the subject is specifically asked to report changes in his environment". Kirk then points out that the latter case can be further divided into two sub groups; the first consisting of those cases where a subject is given direct prior warning of the change in the environment (the signal) and the other in which he is not. Vigilance tasks fall into this last sub group, i.e. a controlled attention task where no immediate prior warning is given of an oncoming signal.

Murrell (1965) selects the following vigilance definitions. Firstly that of Fraser (1957) who says that the classical vigilance situation can apply only if (a) the display consists of a series of neutral signals throughout which the significant signals are randomly interspersed, (b) the conditions of the experiment are such as to render it a stress situation in terms of speed, load, and duration etc., (c) knowledge of results is minimal. Secondly, that of Jerison (1959) who defines vigilance as "a probability of detecting rare and near threshold events".

McGrath, Harabedian and Buckner (1959) distinguish between vigilance tasks and monotonous work by pointing out that in the case of the former a search for relatively infrequent signals must be carried out whilst in the latter a repetitive task is carried out without reference to any environmental changes. They say that in a vigilance task the signals to be detected may be added to or taken away from the environment or be represented by a change in a continuously presented stimulus. When the signal occurs it should be possible for an observer or monitor to detect it when alerted without its presentation being disruptive. The time of the signal presentation should not be predictable by the observer though this rule should not necessarily apply to its location. Also the task should be long and continuous and require more than a single momentary judgement.

Kirk has criticised the factors considered in these definitions as being concerned with visual signals at the expense of auditory and other possible sensory modalities. He criticises the vagueness surrounding the frequency of signal occurrence as military situations often demand the detection of single events occurring infrequently, perhaps only once in five or ten years.

Vigilance tasks provoked research into four main areas (summarised by Kirk). In terms of the system below they are :



(1) Input factors would be those related to signal size, rate, location and manner of presentation.

(2) Man factors would be covered by individual differences and would include intelligence, personality, age, experience and training.

(3) Response would refer to manner and type of response.

(4) Environment would refer to physical factors, physiological factors, including whether drugs had been taken, and social and psychological factors including time of day or week, rest pauses, length of watch, isolation, the particular briefing and other pressures.

The classical example of experimental vigilance work is the Mackworth (1950) Clock test which showed the watchkeepers performance to deteriorate after 30 minutes and then to be maintained at a lower level for a further 90 minutes.

Another example is the work of Deese and Ormond (1953) who showed a relationship between rate of signal presentation and probability of detection. This appeared to suggest that an increase of signals (e.g. additional artificial ones) might improve all round detection performance.

In his book "Fundamentals of Skill" (1968), Welford discusses vigilance in terms of the investigation into and the theories proposed to explain decrements in vigilance performance. Drawing on a wide variety of references Welford points out that response decrements occur with both visual and auditory signals. These decrements can be recorded not only in terms of missing signals but also in slower response times.

Failures were not specifically due to omitting to see the source of signals (Mackworth (1964)) as even signals which are fixated are overlooked. Nor were they due to inactivity as decrements occurred in the Mackworth Clock Test even when subjects were forced to respond to every jump making different responses to small and large jumps (Whittenburg, 1956). Nor was it due to a lack of readiness for even when the subject determined when a signal (whether it would require a response or otherwise) would appear, decrements still occurred (Wilkinson, 1961).

These decrements tend to diminish with stronger signals (Mackworth, 1950), or signals of longer duration (Broadbent, 1958), or, when dealing with a series of signals, the wanted to unwanted signals ratio is increased (Colquhoun, 1961, 1966). These factors also appear to interact in that signals of lower intensity can be more readily detected if they appear more frequently (Martz, 1966, 1967).

Of course if signal rate is very high the subject may be overloaded and Poulton (1960) shows there is thus an optimum rate of presentation.

The use of a secondary vigilance task with a primary vigilance task has been tried without achieving a greatly increased detection rate (Wallis and Samuel, 1961, Antrobus and Singer, 1964). Welford suggests this is due to the additional signals detected from the second task being offset by the subject having to divide his attention.

The problem of raising vigilance performance has been tackled in a number of ways. A telephone message during the watch (Mackworth, 1950), changes of activity (Bevan et al, 1967), rest pauses (Bergum and Lehr 1962), the presence of others in the room (Fraser, 1953, Bergum and Lehr, 1963, and Williams et al., 1965), knowledge of results (Mackworth), incomplete knowledge of results (McCormack et al, 1963, McCormack and McElheran, 1963, Wilkinson, 1964), false knowledge of results (Loeb and Schmidt, 1963), or even knowledge of results of a secondary task (Baker, 1961) all serve to favourably affect vigilance performance.

Using the above as well as other findings Welford goes on to discuss the theories proposed to account for observed vigilance performance, obviously with considerable emphasis on the decrements.

(1) Motivation. Mackworth suggested lack of motivation may account for performance decrements, and reduction of the decline of performance, e.g. when army trainees perform a vigilance task in the presence of an officer (Bergum and Lehr, 1963), may be due to an increased motivation.

Welford accepts the above broadly but feels "that a motivation theory of vigilance might be regarded as a sub class of an activation or arousal theory - anything which increases motivation will tend to offset any fall of activation during a prolonged watch".

(2) Expectancy. Several experiments have indicated that performance at vigilance tasks is to some extent related to the expectancy that a subject may have as to the rate at which signals will appear (Broadbent 1958, Colquhoun and Baddeley 1964, 1967).

Welford feels that expectancy can be regarded as "raising or lowering activation level - the rises or falls of activation may anticipate the onset of the task to which they refer", and therefore the expectancy theory would also be "a special case of the activation theory".

(3) Blocking. This theory proposes that there are brief lapses of attention, which increase in frequency throughout a vigilance task, and result in signals being missed. This would explain why signals of greater duration are more readily detected (Broadbent 1968).

Welford points out that the above theory does not readily account for the maintenance of vigilance performance when there is knowledge of results or when there is an increase in the frequency of signals. He goes on to suggest that activation level shows "not only broad changes over relatively long periods but also moment to moment fluctuations during which it might well fall, occasionally to a level at which the system became so insensitive that incoming signals were temporarily blocked". These blocks would increase with frequency as the level of activation declined. This makes the blocking theory again a special case of the activation or arousal theory.

(4) Changes in cut off in signal detection.

Signal detection theory (Tanner and Swets, 1954) suggests that in addition to a frequency distribution of signals plus external and internal noise (the latter being due to randomness in the activity of the sense organ, neural pathways and brain), there exists a frequency distribution of noise alone. If the means of these two distributions differ markedly enough then signals can be readily distinguished. If, however, the two distributions overlap, then depending on the position of the cut off point above which noise will be reported, noise alone can be reported as being perceived as a signal. If the cut off point in the distribution is such that only strong signals need be reported then few false reports will result. If, however, infrequent weak signals need be detected there will be an increase in false reports because of noise exceeding the threshold level.

The current theory proposes that with time, both the detection of signals and false reports decrease in a way which suggests no change in the difference between the means of the two frequencies but rather a change in the criterion level at which signals are detected, (Broadbent and Gregory, 1963, Loeb and Binford, 1963, Taylor 1965, Binford and Loebb 1966, Colquhoun 1967). This too would be explained in terms of the level of activation or arousal moving both frequency distributions to the left of the cut off point as arousal diminishes resulting in fewer responses, and to the right as arousal increases resulting in a greater number of responses.

(5) Activation and Arousal. This theory, which makes use of "a concept of intensity in terms of generalised activation of the organism with the direction of the activity being determined by features of the immediate cognative situation or of past experience", accounts for much of the findings and theories discussed earlier and postulates that vigilance performance decrements result from a lowering of arousal level (Deese, 1955). Naturally, when vigilance performance is maintained arousal level is high.

Welford favours this theory to account for vigilance research and supports it with strong evidence (Mackworth 1950) that the application of benzedrine which has a known stimulating effect on the arousal mechanism prevented a fall in vigilance performance. It is not always as easy to postulate whether a factor which is introduced constitutes an incremental or detrimental effect on the level of arousal.

The arousal theory is hard pressed to account for the decline in vigilance performance in tasks which keep the subjects continuously active (Whittenburg et al 1956, Adams and Boulter 1962, Alluisi and Hall 1963, Wiener et al 1964). Though this activity would normally be thought to raise the level of arousal, Welford cleverly explains this away on the basis of "evidence from fatigue effects" (thought not readily identifiable by Murrell (1965)). He goes on to suggest "that relatively simple, repetitious, actions can be well maintained at a lower level of neural function, and thus at a lower level of arousal or activation, than higher grade and more complex judgements requiring greater channel capacity".

Vigilance work has also been aptly reviewed, summarised and discussed in a book edited by McGrath and Buckner (1963), and in articles by Jerison and Pickett (1963).

Preoccupation with classical vigilance studies, having the characteristics described earlier by Fraser, have been criticised in turn by

Elliott, (1960), who defined broadly a vigilance task as one in which an operator searches for infrequent weak signals, and Kibler (1965). Elliott emphasises the differences between real military situations and the laboratory studies and points out that the results of the latter often cannot be used as a basis for predicting performance on the former.

Elliott feels that more emphasis should have been placed on Mackworth's findings which showed performance levels to be poor at the beginning of a watch rather than on his other principle that is widely quoted viz. detection performance deteriorates with the passage of time. He also goes on to point out that the implications of Deese's findings, i.e. increasing the number of signals, perhaps artificially, in order to improve the overall vigilance performance by maintaining a higher level of expectation, do not apply necessarily to real military vigilance situations.

Kibler (1965) published a paper examining the relevance of vigilance research carried out in the laboratory to actual aerospace monitoring tasks. His arguments also have implications for monitoring tasks other than just those associated with aerospace monitoring. He summarises his conclusions as follows :

(a) "The weak, brief duration signals as typically employed in laboratory vigilance studies are rarely encountered in applied monitoring tasks.

(b) The human monitor typically is required to keep watch over multiple information sources, and frequently more than one type of target or information class is the object of his vigil.

(c) The signals are often complex and multidimensional rather than simple and unidimensional events such as those typically employed in laboratory studies.

(d) In most monitoring tasks, determining the appropriate response to a signal event entails a decision process much more complex than those required in laboratory vigilance studies. Situations which at one time may have required a simple well defined response to an unambiguous signal can be, and often are accomplished entirely by machines".

Vigilance tasks it would seem were naively simulated in the laboratory. The discreet weak signal appears to have been dissociated from the motivating force necessitating its detection. In addition the noise from which the signals had to be sought has been reduced within the experimental situation. It may well be that noise often provided the additional signals that Deese felt would raise performance. The noise could also have provided situations in which critical signals were thought to have occurred only to be discarded as false alarms after consideration.

In broad terms vigilance studies have been applicable to the military, but other situations occur in which monitoring is required, e.g. monitoring of patients by Doctors, the monitoring of processes essential in process control, and the monitoring of a manufactured product or product evaluation by inspectors in industry.

This study is concerned particularly with the inspection of products and the determination of their quality, and also essentially with situations in which judgement has to be exercised by the inspector without the aid of measuring devices such as gauges. That part of inspection covered in statistical quality control and metrology has not been considered.

1.4 Inspection and its Particular Characteristics

Murrell points out that inspection is found in two forms :

(1) paced inspection, where the inspector's work rate is machine controlled, and

(2) unpaced inspection in which no moving belt or similar equipment controls the inspector's work rate and he inspects at his own speed.

Few examples of truly unpaced inspection are found in industry because situations which at first sight appear to be unpaced frequently on closer examination turn out to be paced. This is because often the inspector must make sure that the rate of inspection is at least equal to the rate of production otherwise an inspection bottleneck would occur.

Mention must also be made of operator-inspection. This occurs when the operator responsible for processing or manufacturing a product assumes the additional responsibility of inspecting it. Operator inspection is a task which has no equivalent in military vigilance work. This method may carry incentives in the form of additional pay for the added responsibility. Sometimes a check will be made of operator inspected goods by on line supervisors or by off line quality control personnel. Inevitably the final arbitration of the quality of inspection will be left in the hands of the customer receiving the goods. The advantage of operator inspection is that it may restore some of the lost job satisfaction previously found in craftmanship when complete responsibility for a finished product was invested in one man. Operator inspection is often the inspection strategy found in burling and mending situations.

It is necessary to examine the functions of the inspector more closely.

Colquhoun (1964) develops an analytical model to describe the psychological operation known as inspection. Three stages are postulated :

(1) Detection of discrepancy in the material being examined.

(2) Judgement - does the discrepancy exceed the limits of tolerance (this involves a comparison between immediate perceptual experience and both memory of previous experiences and a standard for comparison).

(3) Decision - accept or reject.

The inspector acquires knowledge of the product he is to inspect. He must know its characteristics and he must understand how these characteristics can deviate from the optimum. He must also be able to recognise when deviations from the optimum are sufficiently serious to render the product defective. Such deviations from optimum may occur for more than one product characteristic, i.e. the inspector may be searching for a multiplicity of fault types, a situation far more common to inspection than vigilance tasks.

The inspector is constantly matching his own mental standard against the materials he is scanning. If the product is nearly perfect in every way the inspector can quickly and confidently pass it, or alternatively, if it is very obviously defective he can equally rapidly reject it. However, often he is working with materials somewhere in between these two extremes and it is necessary for him to scan each product and to make an accept or reject decision, with less than complete confidence.

The inspector is thus involved in processing good (which in this case would constitute noise) and bad (a signal or group of signals) materials, and making decisions on both of them. This kind of task involves constantly holding in mind an image or picture and matching it against a real object. To do this successfully requires a high level of skill.

In the classical vigilance situation, i.e. a man scanning the horizon for enemy vessels or peering at a radar screen for a signal, the processing or comparison to be made between a mental picture and the actual object searched for is negligible. The difficulty of the classical vigilance situation springs from the effort directed to keeping sufficiently alert so as to spot the signal when it arrives. A relatively unambiguous signal must be detected when it arrives on the scene (the unchanging relatively immobile environment which need not over tax the operator's processing abilities). This task involves a somewhat lower level of skill than the inspection task. It is only when the background or noise in a vigilance task requires similar processing characteristics to that of an inspection task that they assume the same level of skill and the tasks become more closely comparable.

In the case of inspection too, the discovery of a signal or fault may only be the first part of the task. Decision making as to the severity of the fault and reaction or response if a rejection procedure is finally required are both essential parts of industrial inspection. Whilst these may also be part of vigilance tasks, rarely are the same time constraints encountered as those experienced on the industrial inspection line.

Quality control has sometimes removed inspection activities from the on line human operator, but despite this human inspection still plays an important role in product quality evaluation in most industrial situations. The question which has to be answered when considering inspection, is what is likely to produce a more efficient performance, a human operator or a machine or a combination of the two? The answer still involves the human operator often enough to warrant serious research effort to be devoted to the industrial inspection in which he plays a large part.

Continued human participation in the face of automation in inspection arises because of the signal criteria often being inprecise and difficult to define. Furthermore several faults may need to be detected and judgement made on their combined severity before an accept/reject decision can be made. These kinds of activities involve a high degree of pattern recognition and it is in this area that automatic fault detecting devices experience most difficulty. Thus the inspection performance of the human operator is likely to be of importance for some time to come and worthy of considerable research effort.

1.5 Inspection Research

Inspection has of course generated a certain amount of research interest over the years. Binns as early as 1934 undertook a study of the visual and tactual inspection of Bradford wool tops from which he concluded that tactile judgement was a fine measuring instrument. As was previously stated (page 6) vigilance research covers a wide field. In inspection, however, studies have concentrated on accuracy, social factors, age and illumination. Intermittent inspection studies have been carried out on the implications of the many aspects of human detection performance in the industrial setting.

Experiments have been undertaken to find out how accurate inspectors really are. An experiment by Bakwin (1945) in which medical practitioners monitored patients, is worth citing as an illustration, albeit not an industrial one, of the frailty of human judgement even in highly skilled operators. Here a thousand eleven year old school children had their throats examined. On first examination, it was found 611 had already had their tonsils removed, and 174 were recommended for operations. The remaining 215 were sent for further examination and 99 were found to require tonsilectomys. After a third examination only 65 children "not requiring" tonsilectomys remained. It cannot be reported that this experiment was pursued to a climax with zero children with infection free tonsils remaining, for a shortage in supply of doctors caused the experiment to be discontinued.

In a study by Jacobson (1953) on quality control inspectors in an electrical plant, he found that the expectation that inspection accuracy was high to be far from true. Test pieces containing two sorts of faults (wiring and solders) were fed to inspectors who performed poorly. A second test run in which connections which should have been soldered were left untouched produced a further poor performance with many of these "obvious" faults overlooked. Jacobson found visual acuity and age to be important factors in detection accuracy.

Inspector accuracy is thus shown to be alarmingly suspect when subjected to experimental study. A close analysis of underlying skills in inspection tasks is necessary if one is to determine the factors which govern inspection accuracy and speed. Only then can one discuss methods of improving operator performance.

Colquhoun (1963) in a paper in "Glass Technology" suggests that accuracy is highly related to an inspector's expectancy of faults occurring. An expectancy of high probability would result in nearly all faults being found, with however, an additional small number of good items being rejected. The reverse would be true if a low probability of expectancy existed, no good items would be rejected but more faults would be missed.

Colquhoun emphasises the importance of the level of arousal in maintaining inspection accuracy. He feels that inspection could be alternated with other tasks, thus maintaining a higher level of arousal and ensuring greater accuracy. Brown (1963) adds a note of caution by stating that if other activities are introduced they must be carefully chosen if the beneficial results thus obtained are not to be offset by delayed adaptation to the former scale of judgement when the first task is recommenced. He also suggests that the frequency with which an inspector is called upon to make absolute judgements positively affects the accuracy of his decisions.

Individual differences, social and psychological pressures from fellow inspectors, supervisors, production department managers, as well as long term customer feed back influence the inspector's criterion level or norms in accept/reject decisions. Colquhoun suggests these norms not only affect his decision making, but also may have profound effects on his judgement of fault severity and even on his perception. A Brunel investigation (1960-61) involving judgement of length, failed to confirm their hypothesis that social influence varies in proportion to the ambiguity of displays, but instead discovered that not only decisions but the perception of "length" itself appeared affected by group pressures.

In another experiment on social effects by Seabourne (1963) on a gauging task, subjects increased their own rejection rate when introduced into a new group with a much higher rejection rate. The conclusions seemed to indicate that :

(a) subjects were unaware of making changes in their judging behaviour;

(b) the extra rejects were all borderline (indicating that standards were raised rather than a random increase in the rejection rate);

(c) subjects incorrectly assumed batches of items given to each worker had the same number of faults present;

(d) subjects considered other members of the group's rejection rates to be more valid than their own.

These results achieved effectively in a working situation seem more typical of real life occurrences than many laboratory experiments.

Colquhoun deals further with matters directly affecting judgement. He discusses Adaption Theory * (Helson 1947) for this purpose. This theory predicts that if a series of stimuli are presented as increasing in magnitude then the respective stimuli will tend to be placed in higher categories of judgement than if in decreasing order of magnitude, because for any stimulus in the ascending series the mean of the stimuli preceding is lower than if presented in the descending order. However, in real inspection situations most faults are random in occurrence and the order is unimportant. Colquhoun feels it would probably be safe to say (1) each judgement influences the next, and (2) the earlier a judgement is made in the series the less its influence on later judgements.

Thomas (1961) has devised a mathematical model (not as yet published) for predicting these judgements and this appears better than Adaption Theory. His assumptions are that judgement is active and changing and is thus best explained using stochastic principles.

He states :

(1) Effect of experience decreases as time passes.

(2) Effect of this decay linked with continuing new experience is to produce systematic variations in the subjective scale which the subject uses for making his judgement.

Brown (1960), Binns (1937) and McKennell(1958) all show evidence that there is little difference in accuracy or for that matter

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* Adaption level is defined as the physical value of the stimulus which would be judged neutral or equal to the standard, and being a weighted geometric mean of the stimuli to which the subject has been exposed. Adaption Theory proposes that the perpetual judgement of any stimulus depends upon the ratio of the physical value of that stimulus to the physical value of the subjects adaption level.

consistency between "skilled" and "unskilled" subjects. As Brown puts it "in the present context skill is governed by experience gained in the immediate past, rather than by previous extensive training".

Colquhoun also deals with the factors affecting detection. He discusses the importance of search patterns and eye movements. Erickson (1964) has shown detection rate to fall off as the speed of movement of the material and also the number of different items in the field increase. Therefore more time may be needed to inspect a complex pattern than a simple one. Also the further a fault lies to the right or left of the centre of the visual field the lower the probability that it would be detected, even for a field 6 inches wide. This may be because scanning is carried out horizontally with too much time spent looking at the centre; if the field is static then Erickson predicts greater success using a circular or spiral method of scanning.

Colquhoun identifies three components in a search task :

(1) For small angles - peripheral vision. It may even be best to keep the eyes fixed and allow the peripheral receptors to function.

(2) For larger angles, eye movements are required.

(3) For still larger angles, head movements are needed.

Sanders (1962) suggests that at certain critical angles where a strategy change is necessary efficiency falls off.

Fixation alone does not guarantee finding a fault, and an experiment by Mackworth (1964) using a newly developed technique for recording eye movements showed signals to be missed despite them being fully fixated.

Colquhoun answers the queries raised by the fixated yet missed signals in terms of "signal detection theory". This work which has been expanded into a statistical theory of perception by Swets (1961) was discussed earlier when considering vigilance research. Briefly it is a theory which postulates that the nervous system which is electro-chemical, contains a certain amount of inherent activity or noise. This varies from moment to moment but is considered to be normally distributed. So if an increase in the activity in the system takes place it can be perceived as either a peak in the internal activity or noise level or as an external signal. How it will be perceived depends on the criterion for signal detection. If the criterion is say at a 5% level, all signals which exceed the mean level of internal noise by 2 std deviations will be reported. Thus in addition to real external signals a small number of internally generated (or false) signals will also be reported. A decrease in the level of acceptance for signal detection say to 1% would reduce the false reports by a small number but also involve a substantial reduction in the number of correct reports. This theory of course eliminates the possibility of human operators inspecting for zero defects.

It must not be forgotten that physiologically based detecting ability plays an important part too in signal detection, but this would be independent of the "decision-criterion". So an operator with poor basic physiological inspection ability within certain limits should be able to detect as many signals as one with excellent physiological detection attributes providing the criterion for acceptance is set low enough. The difference would be in the large number of false detections caused through internally generated signals at the low level criterion for signal acceptance.

Colquhoun comes to some interesting conclusions regarding the application of decision theory to the industrial sphere. He feels the best strategy would be to have two socially separated inspection departments. The first would be given a "risky" rejection criterion and the second a high cautious rejection criterion to salvage all the good material rejected by the first department. This is certainly a theoretically interesting approach and it remains for it to be tried and proven in practice.

The social factors affecting inspector accuracy have also been discussed in some detail by McKenzie (1958). He sees the problems of inspector accuracy being associated with three readily identifiable headings : (1) Individual abilities; (2) formal organisation including training, ergonomic factors and work instructions, and (3) interpersonal and social relations.

He concludes that "inspector consistency is affected by poor definition of standards, by lack of instructions, and by lack of calibration of inspectors with one another". This is also suggested by Cavanagh and Rodger (1962). To maintain adequate performance McKenzie advocates continued training involving supervised practice - a means of conveying quick feed back to the inspector on his own accuracy in short periodical doses.

McKenzie discusses the difficulties caused through varying operator inspector relationships and shows how these social factors can affect the establishment and maintenance of consistent standards of accuracy. He concludes that inspector accuracy, in a working situation, is determined by a wide range of factors, and that 'problems of inaccuracy must then be studied in a wider context than is given by any single approach'. Unfortunately McKenzies' analysis did not have the benefit of the knowledge of "signal detection theory" which would surely have influenced his thinking on inspection accuracy. It would appear that social factors would exercise their greatest influence in the setting up of the abstract standard which forms an inspectors guide, but only partially on the final number of units accepted or rejected.

The effect of age on inspection ability was considered by Jacobson (1953) when trying to account for poor inspection performance in an electrical plant. He found inspection accuracy to increase until the age of thirty-five when average accuracy was 90%. This was followed by a gradual decline to the age of 55, when accuracy was about 75%.

His findings showed that the age group of 30 to 35 years was best but the 25 to 29 age group was only 4% inferior.

Jamieson (1966) conducted an experiment in the telecommunications industry to investigate age and other performance variables, but no age effects were discovered.

Also Griew (1962) conducted an experiment on an auditory vigilance task but could find no age effect.

In a recent review of aging in paced inspection tasks, D.R. Davies (1968) discusses factors which differentiate between paced and unpaced tasks. He suggests, quoting evidence from Brown (Welford, 1958) in which a plotting task was used, that older subjects cope more adequately under unpaced conditions. Little difference was found between subjects' performance under unpaced conditions up to and including those aged in their fifties, though deterioration began in the sixties and seventies. In the paced situation the decline occurs markedly in the fifties with further deterioration in the sixties. Davies explains this difference in terms of a "marked slowing of response in situations where speed is important" by older subjects. The inspection of cloth, which is essentially in the short term an unpaced task, would realistically not be carried out by very many women over the age of sixty.

Cloth inspection would also be considered an extended task. In this case considering paced tasks where it has been suggested older subjects fare worse than in unpaced tasks, "neither the nature of the stimulus to be detected nor the stimulus duration has a greater effect on older subjects than on younger ones in terms of correct detection scores".

Whilst "there appears to be general agreement that there is a decline with age in the ability to receive and transmit information and that the decline in this ability reflects a genuine loss in capacity that has important implications for the maintenance of complex skills" (Welford 1959, 1962; Griew, 1963; Szafran, 1965), Davies concludes his discussion on paced inspection tasks by declaring "in some situations age differences occur, in <u>most</u> they do not".

Although many arguments, such as demands on deteriorating short term memory, have been put forward to account for the deterioration of inspection performance with age, the reasons for this have not been satisfactorily established experimentally. In particular the critical age, at which effective industrial inspection performance begins to fall off has not been satisfactorily identified. Deterioration of performance through age outside the limits normally encountered in an industrial setting is not realistically within the scope of this study.

With the exception of Taylor (1956), and Bellchambers and Phillipson (1962), work on the effect of important variables, such as lighting, has been minimal, though Lion (1964) and Lion, Richardson and Browne (1968) did compare tungsten and fluorescent lighting and found the latter to be superior for inspection type tasks. Taylor investigated the effect of illumination in rayon cloth inspection. He concluded that important differences in standards arose as a result of changing conditions such as the direction, intensity and quality of the light under which the cloth is inspected. Bellchambers and Phillipson reviewed the general principles involved in the use of lighting for inspection.

The above has been an attempt to trace the most important paths pursued by researchers. Firstly a very broad based review of attention and vigilance was undertaken, and then an examination of the relation of vigilance to inspection. This was followed by a more detailed survey of inspection research in particular.

1.6 Research into Tactual Inspection

The preceding review has been concerned with inspection in general terms. The inspection research now discussed is directly relevant to the content of the present dissertation. Firstly the early work of Binns examines tactual and visual performance relating to wool top inspection. Then a further study in similar vein by McKennell is followed by visual and tactual comparisons by Brown in relation to surface inspection of wood, and tactual inspection of fabrics by Stockbridge and Kenchington. All of these papers were given close scrutiny when the methodology of the present research was being considered.

In 1934 Binns examined the visual and tactile performance of various groups of subjects on Bradford wool tops. He had his subjects, ranging from top-makers to arts students, examine six typical Bradford tops. Their task was to grade the samples (1) in order of fineness by sight and (2) in order of softness by touch. It is not completely clear how vision was excluded entirely from (2) or how touch was excluded from (1) but it does appear that subjects were asked to look away, e.g. out of the window, when handling the tops. Five trials were given for each of the above conditions and error scores were obtained. Sight and touch scores were correlated and high correlation coefficients were obtained throughout. Binns, in conclusion, felt that tactile judgement with regard to tops was a particularly fine measuring instrument.

McKennell (1958) also examined the relation between vision and touch with regard to the inspection of wool tops. In this case 'tactivisual', 'vision only' and 'touch only' were the conditions under which each subject had to match a test sample against a series of samples - one for each quality - laid out in order of quality. Five sets of judgements were made by each subject, with three groups of six subjects participating. For the 'vision only' test the subject was not allowed to handle the samples, which were arranged by the experimenter according to the subject's instructions. For the 'touch only' experiment the subject carried out his test in a darkened room, with an additional precaution of lighting the room between judgements to prevent his eyes getting used to the dark. McKennell's findings showed that while the 'vision only' and 'tactivisual' results were similar, the 'touch only' condition showed a significant increase in errors made. The correlation between 'vision only' and 'touch only' was again high.

Brown (1960) examined the problem of visual and tactual judgement of surface roughness of wood. He used the method of paired comparisons, with subjects having to select the rougher of each pair in a total of 36 combinations. The desired roughnesses of wood were produced on 9 flat wooden surfaces. For accuracy the roughnesses were electronically measured. A special experimental apparatus was built with facilities for using normal and oblique lighting. For tactual judgements a shutter in the apparatus sealed off vision. There were five different experimental conditions.

(1) Visual judgement only, in oblique light (V(O))

(2) Visual judgement only, in normal light (V(N))

(3) Tactual judgements only (T)

(4) Tactual judgement plus visual judgement in oblique light (V(O) + T)

(5) Tactual judgement plus visual judgement in normal light (V(N) + T).

Two groups of subjects were tested, 33 unskilled and 8 skilled, and the results showed no significant differences between them.

However, the differences between inspection conditions showed the following results. For skilled subjects significant differences were found between V(O) and V(N), between T and V(N), and between V(O) + T and V(N).

That is, skilled subjects were more sensitive in discriminating roughness, when using visual judgement in oblique light, tactual judgement, and tactual judgement + visual judgement in oblique light than when using visual judgement in normal light.

For unskilled subjects all results other than those between V(O) and V(O) + T and between T and V(N) + T were significant.

That is conditions V(O) and V(O) + T produced more sensitive discrimination than V(N), T, and V(N) + T; and T and V(N) + T a better performance than condition V(N).

The author concluded that skilled operators work almost entirely through tactual cues, though visual inspection with oblique lighting might serve equally as well as tactile information and be used more rapidly. Skilled and unskilled subjects were equally adept under the oblique lighting condition. Brown concluded that this was because neither group had any previous experience with oblique lighting.

In a further experiment using a paired comparison technique Stockbridge and Kenchington (1957) found blind-folded subjects were able to state the relative roughness of various fabrics and also rank them with a significant degree of consistency.

1.7 Discussion

This represents the major research developments in the area of attention, vigilance and inspection. No attempt has been made to cover every detail and only a broad overview has been put forward as an introduction to this study, which is concerned specifically with the working activities of burlers and menders in the woollen industry.

It is the author's contention that far too few inspection and vigilance studies are based on real activities. Heavy reliance is placed on laboratory simulations in which motivation is completely uncontrolled. The difficulty inherent in equating the level of motivation in an experimental situation with on the job performance is nothing new. Yet its importance is far too easily ignored or overlooked. If conclusions from laboratory studies are to be extended into operational principles, then the motivation of the subjects who produced the experimental data must be closely examined and understood.

Very often psychological experimentation is carried out with the intention of varifying or proposing general or universal principles. This is beyond dispute as vital to the progress and furtherance of any science. However, field studies are also significant and in this particular case, an attempt has been made to examine the psychological content of the work activities of burlers and menders. Burlers and menders represent a very large proportion of the manual workers in wool and worsted cloth manufacture. Their work has remained almost unchanged in its essential character for nearly a century without any detailed analysis of its tactual and visual inspection content.

E. Belbin, R. Belbin and Hill (1956) carried out work in the field of training, on mending. They found wide variations in training times, lack of knowledge of the skills involved in burling and mending and an absence of defined levels of attainment at which trainees progress could be evaluated. They concluded that burling and mending "is an inspection process, plus rectification of faults. Usually the skills of rectification were taught more or less effectively but the best method of inspection was less frequently well taught".

They raised certain questions which they felt required answering. Amongst them was a query regarding the sensory modality responsible for detecting faults and another concerning "older people(women over thirty)" their potential as trainees, and the effects on their performance of possibly deteriorating eyesight.

In the course of carrying out their experiments certain observations were made. These included one that suggested that there was a tendency for menders consistently to leave areas of cloth uninspected; also that "some experienced burlers and menders appeared to find burling faults largely by touch, while others appeared mainly to depend on sight"; and that differences in levels of lighting had important implications.

The present study in some senses goes further in that it involves the measurement of tactual and visual performance of the inspection task which precedes the mending. It might be pointed out that some history of task analysis may have been discussed but it also may be argued that each task generates its own specific form of analysis and such was the present case. This study concentrates on inspection, and work in this area has always occupied a niche of its own in ergonomics and psychology.

CHAPTER II

THE BURLING AND MENDING TASK

2.1 An Introduction

In order to manufacture worsted cloth from the raw wool or fleece it is necessary to carry out many varied and diverse processes. These are about twenty in number and include sorting, scouring, carding, combing, spinning, weaving, dyeing, burling and mending, and finishing.

It is necessary to examine these processes briefly in order to understand how and when burling and mending, which is the main interest of this investigation, fits into the worsted manufacturing cycle as a whole.

Sorting — This is the first stage and it involves sorting the fleeces into various qualities.

Scouring — This consists of removing, by scouring, all the dirt, grease and suint from the wool, which is subsequently dried.

Carding — The now clean wool has its tangled fibres separated and opened out to be carded into continuous slivers of wool. These are washed again.

Combing — Next the wool is combed by machines in order to remove the very short fibres from the sliver. The remaining fibres go through several processes in order to obtain uniform worsted tops.

Dyeing — The wool is then carefully dyed.

Weaving — The yarn is now ready to be made into a fabric. Weaving can vary according to the machinery used, but in brief a wide band of threads, the warp, is fitted into the loom, and the weft is then inserted across the warp by means of a shuttle.

Burling and Mending(see figure 1 and figure 2) — The fabric or cloth is then examined for faults, and these are repaired by hand by means of a burling iron or a needle and thread.

Finishing — A certain percentage of oil which has remained in the cloth is now removed and the fabric cropped or treated in a number of ways depending on which type of surface the finished cloth is to have.

2.2 Burling and Mending

If we examine burling and mending more closely, we see that it can be broken down into two parts. Initially the cloth is examined tactually and visually for all faults, the hands being employed to smooth over the cloth surface and to search for any irregularities. The faults are in some cases, such as knots, pushed to the reverse side of the cloth (where they will be removed during the course of the finishing process), picked off the cloth with burling irons, or marked to be repaired a short while later, i.e. when going through the cloth for a second time. Although there are regional differences regarding almost all terminology in the wool and worsted industry, this in fact, is the essence of burling.

The next step is mending which includes repairing with a needle and yarn all faults marked on the initial inspection and also any further faults which may be detected.

It can be seen that both burling and mending have two common factors (1) detecting faults and (2) repairing them. Thus in examining in isolation the inspection task of fault detection one has to take into consideration several facets of both burling and mending.

The material or piece of cloth being processed is usually at least 60 yards in length and 64 inches in width. This leads to quite a large section of the cloth being in view at any one time. Also there are two faces to the cloth and although burling and mending is usually confined to only one side, the reverse side is occasionally examined for cues to aid in making a precise decision regarding mending.

A further decision has to be made on discovering a fault, that is, whether it is worthwhile repairing. The time taken to repair the fault, the difficulty in carrying out the repairs, the probable visibility of the fault after finishing and the quality expected by the customer are the governing factors here.

The faults themselves vary widely ranging from the most obvious, such as felters to fine differences in the twist or the colour.

Most of the major fault types will be found in the following list, though many are known locally by other names.

1. Wrong counts. Weft.
2. Mixed shades.
3. Wrong slayed ends.
4. Wrong draft.
5. Wrong heating.
6. Holes.
7. Felters.
8. Thin places.
9. Heavy places.
10. Picks out.
11. Ends out.
12. Colours crossed.
13. Dobby missings.
14. Weft tails.
15. Weft curls.
16. Rolled ends.
17. Rolled picks.
18. Double picks.
19. Wrong patterns.
20. Loom running without.
21. Tight twist weft.
22. Thick weft bars.
23. Soft twist ends.
24. Thick ends.
25. Tight twist ends.
26. Traps.
27. Knots.
28. Shaft down.
29. Slubs.
30. Shuttle jumps.

31. Ends fast in rods.
32. Open reed.
33. Slack.
34. Snarls.
35. Trailers.
36. Buttons.

Some of the above faults are rather similar, and it is not necessary to discuss all of them in detail, but as an example several of these are briefly described below.

Knots : (Figure 3), are two ends joined together by either weavers, fishermans or dogknots.

Slubs : (Figure 4), thickness created in spinning and drawing.

Slack : results of uneven tension in the yarn.

Snarl : (Figure 5), a long loop of yarn.

Open place : caused through incorrect setting up in the weaving resulting in warp of uneven tension.

Buttons : large slub.

Cracked weft : a loose thread due to tightness of the weave and sharpness of the reed.

Broken picks : (Figure 6) a pick which has broken leaving what appears to be a line across the cloth.

This study seeks primarily to establish a level of basic performance so that realistic comparisons can be made between burlers and menders employed in a wide variety of mills. Factors involving the tactual and visual elements of the inspection part of burling and mending were whenever possible isolated and considered in relation to overall performance. Consideration was given to the different fault types sought, and the sensory factors which made the major contribution to their detection. Age and its relation to all aspects of fault detection was examined, and an attempt was made to relate inspection performance to mending ability. Also special consideration was given to certain aspects of lighting with the objectives always remaining orientated toward problem solving in cloth inspection.

Figure 1 Burlers and Menders at Work Figure 2

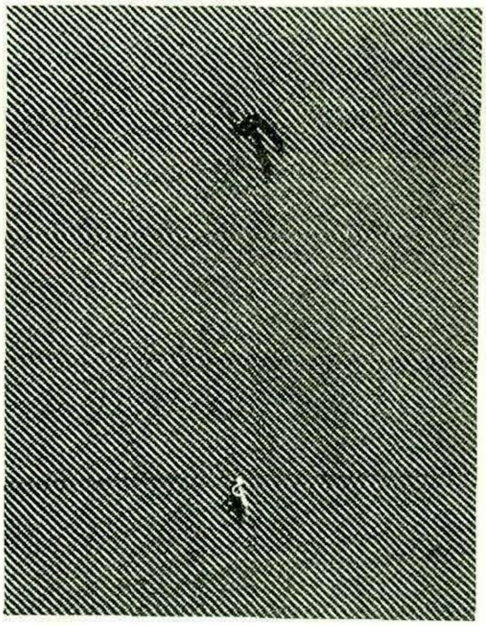


FIG 3

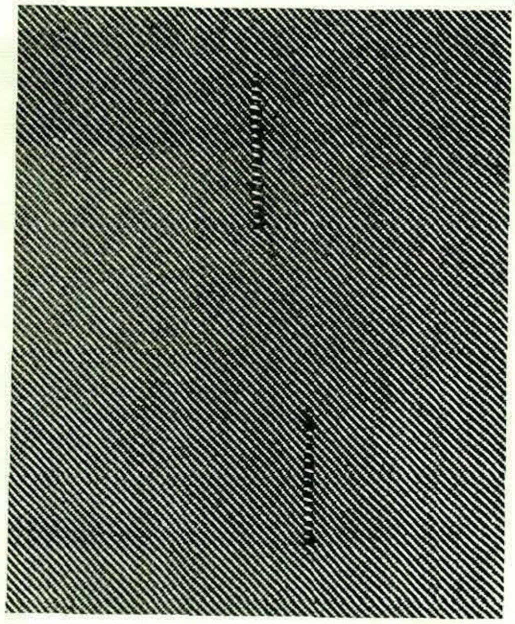


FIG 4

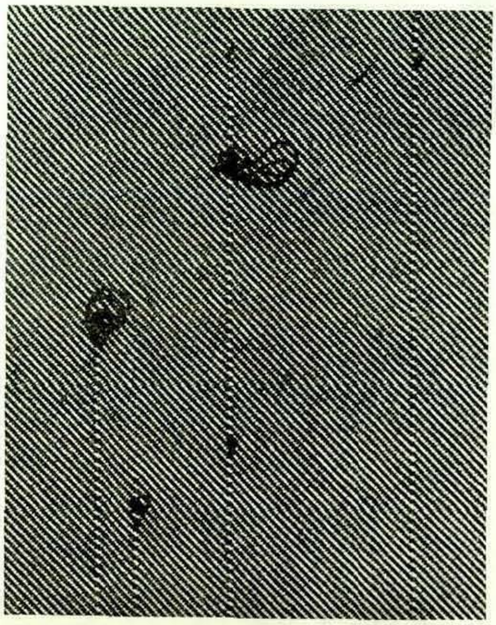


FIG 5

Figure 3 Knots.

Figure 4 Slubs.

Figure 5 Snarls.

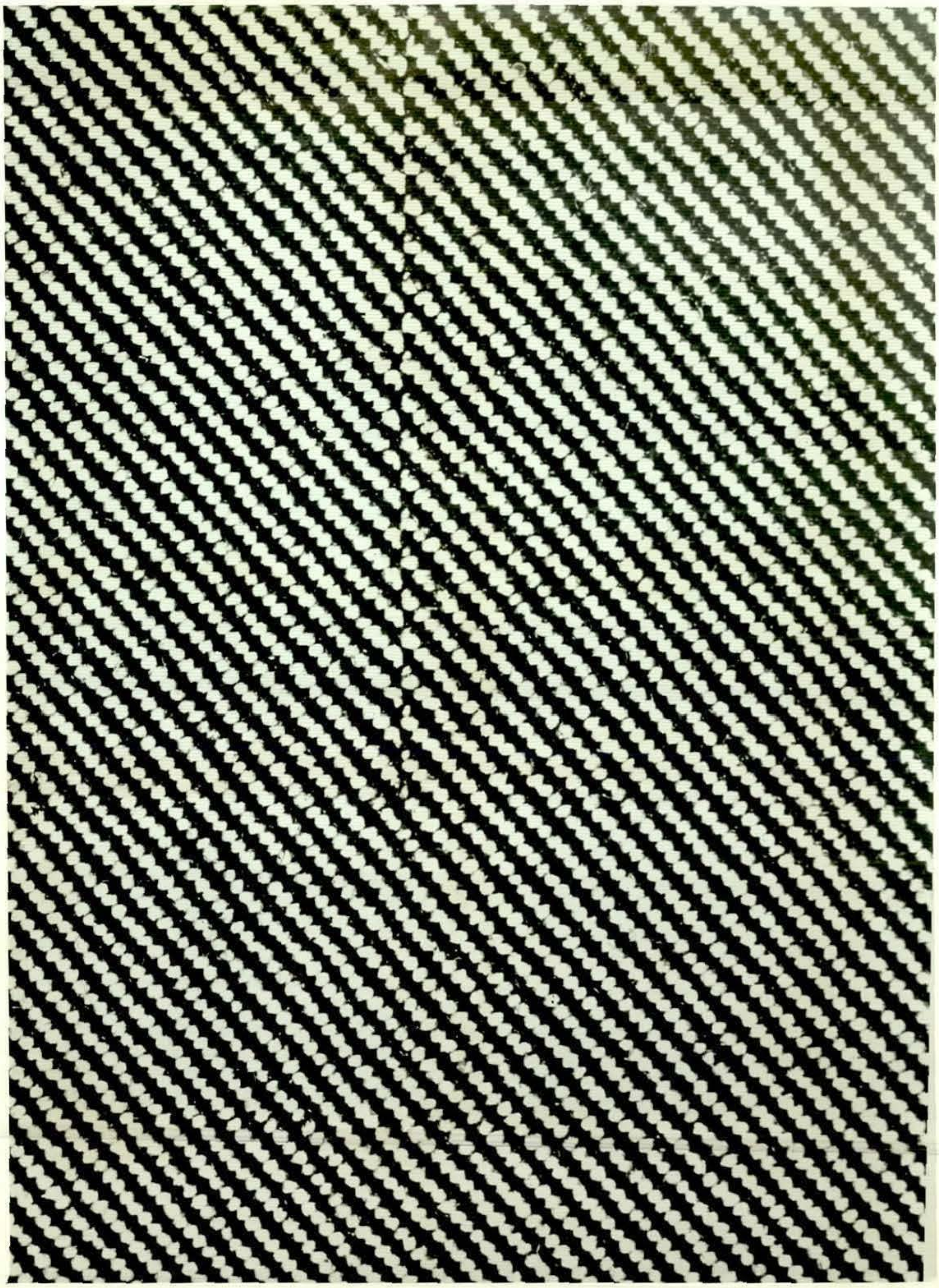


Figure 6 Broken Pick

CHAPTER III

EXPERIMENT I

3.1 Introduction

The first experiment is concerned with the tactual and visual inspection performance of burlers and menders. The intricacies of burling and mending will not be discussed other than to point out that in principle two factors are involved, firstly, detecting faults and secondly, repairing them. This experiment will be dealing essentially with the first factor, i.e. detecting faults.

The objectives, of the experiments which were carried out in 1964, were to obtain basic information regarding the inspection performance of burlers and menders and to evaluate the relative importance of the hands and eyes, when used for detecting faults. It was hoped that the results obtained would have application in aiding and simplifying training programmes as well as indicating how performance might be improved.

3.2 Experimental Preparations

The task of burling and mending involves more complex search patterns and also a greater number of possible responses than those examined in the tactual discrimination studies described earlier. In order to be able to realistically assess inspection performance in burling and mending it is necessary to examine the ability of a person to detect a wide variety of faults, on a large piece of cloth. It is also necessary to have available criteria for judging this performance.

It was therefore important that a piece of cloth of some considerable length, e.g. 25 yards, be made. A suitable piece of cloth was woven by the Wool Industries Research Association at Torridon containing faults which occurred in the normal manufacturing process together with some additional and more unusual faults deliberately added. The cloth was then divided by pieces of white tape into 37 sections of 2 feet in length (later called frames).

In order to determine the type and the location of each fault on the specially woven piece, five experienced passers (supervisors), each from a different mill, examined the cloth. They were asked to point out all the faults that they could find, and were given as much time as they required for this purpose. Three passers simultaneously examined the cloth in 2ft. sections. Each passer covered one third of the area and thereby had an opportunity for thorough inspection. The type and relative position of all the faults were recorded. The remaining two passers then re-inspected the 2ft. section. A keen rivalry between the two groups of passers ensured that all were working to the best of their ability. In all, 29 different fault types were identified. These were later collated into 8 groups (see Table 1).

A number of deliberately woven faults were not discovered despite the passers being informed of their presence. It must therefore be assumed that certain types of faults fall beyond the limits of the discriminating powers of even the most experienced workers working under favourable conditions.

A criterion, on which experimentation could be made on the relatively unassessed tactual and visual discriminatory abilities of burlers and menders, was thus made available.

3.3 Apparatus

A modified work table, see Figure 7, kept at a constant angle, was set up at the headquarters of the Department for Recruitment Education and Training of the Wool (and Allied) Industries in Bradford. The table had two rollers fitted and this allowed the cloth to be drawn over the table surface in a precise and controlled manner, and also to be rewound when necessary.

Some refinements were added to an otherwise ordinary chair of fixed dimensions. These were an adjustable platform on which the chair was placed and an accompanying footrest. This was necessary so as to ensure the subject having the benefit of a good working position in the experimental situation.

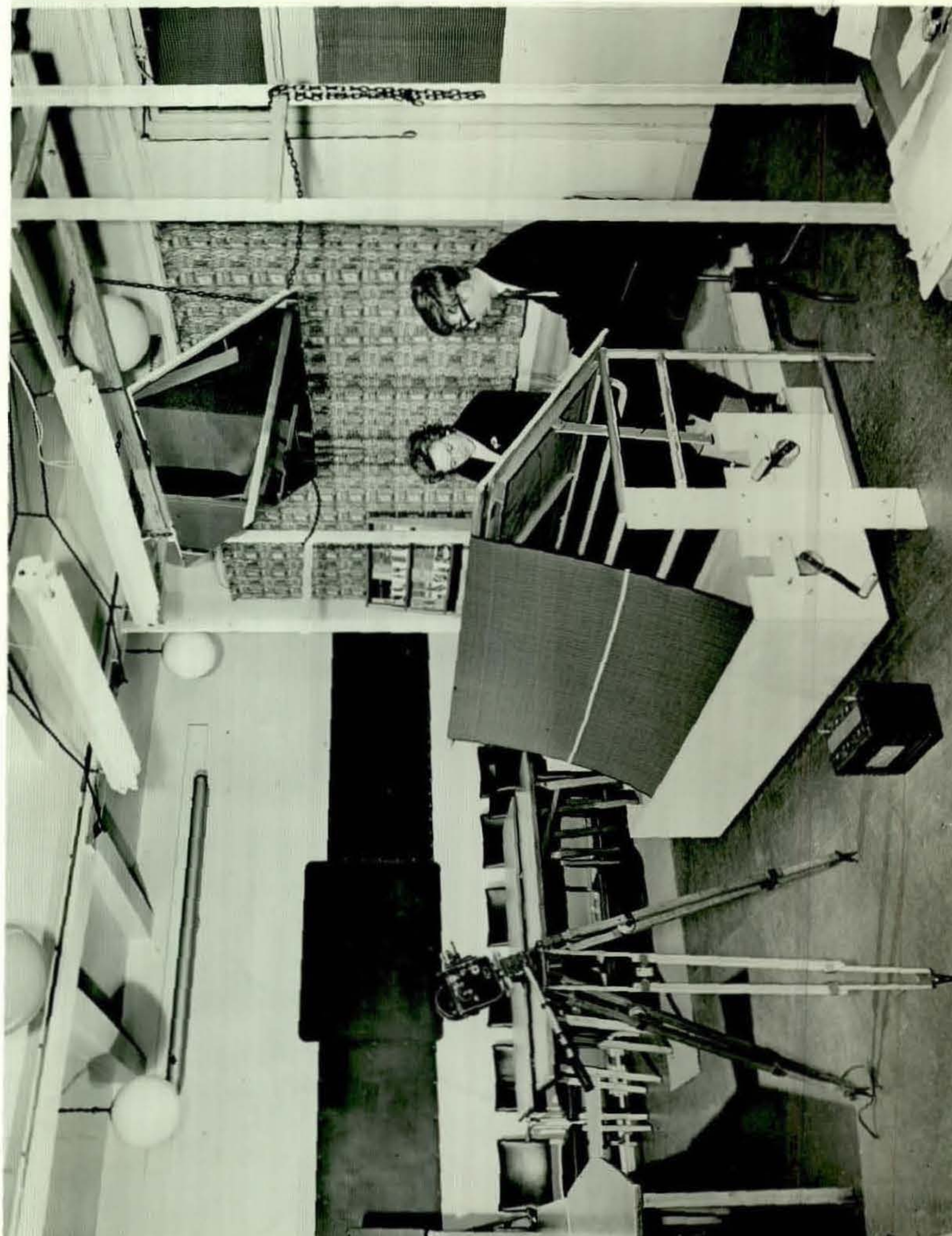


Figure 7 The Experimental room with a subject working under normal (EH) conditions.

The lighting consisted of twin fluorescent lights kept in a constant position at a height of 10 feet above the floor and providing 75 lumens per sq. foot, directly over the table's surface.

A further piece of lighting equipment which was used in one of the experimental conditions was an anglepoise lamp with a shade especially lengthened on the uppermost side so as to shield the subject's eyes from the bright 250 watt bulb used in the lamp. The shade was also polished on its inner surface so as to sharply reflect the beam of light in an oblique downwards direction. This lamp when used was kept in a fixed position throughout the experiment.

A stop watch was acquired to time the subjects on their performance over each 2ft. frame.

Also used were rubber gloves and a wooden pointer; a pair of blackened motor cycle goggles, and printed copies of the plotted faults for each of the 37 frames.

Additional equipment included a camera fitted with a time lapse unit so as to take motion pictures at the rate of 1 frame every 5 seconds. Unfortunately this did not always function satisfactorily and valuable records were thus lost.

3.4 Experimental Method

Thirty skilled burlers and menders, coming from six different mills were used for the first part of the experiment and ten additional girls were used for the oblique lighting experiment. They were divided into two age groups, an over-thirty and an under-thirty group (see Appendix 1). They were randomly allocated so that each group now consisted of 10 subjects, 5 under-thirty and 5 over-thirty. Thus overall, there were 4 experimental conditions each with a group of 10 subjects. These four conditions were as follows :

(1) Inspecting with the hands only (H) (see figure 8)

(2) Inspecting with the eyes only (E) (see figure 9)

(3) Inspecting with both the hands and the eyes (EH)

Figure 8 Inspecting with the hands only (H).

Figure 9 Inspecting with the eyes only (E)

(4) Inspecting with both the hands and the eyes with additional oblique lighting (EHL_1). This last condition will be referred to as the oblique lighting condition.

The subjects were instructed, by means of a standardized tape recording (see Appendix 2), to find and name all the faults on the cloth while working at their normal pace. They were informed that they would be inspecting only one 2 foot section of the cloth at a time and were then told under which experimental condition they would be performing.

At this point the subject would be taken to the work table and placed in a comfortable position on the chair and footrest. Any adjustments which were deemed necessary to the chair platform and footrest were carried out.

The next step was dictated by the experimental condition under which any particular subject would be operating. When working under the condition of hands only, H, in which case it would be necessary to eliminate a subject's visual responses, the pair of blackened motor cycle goggles was worn. In the case of eliminating tactual responses rubber studded gloves and a wooden pointer were used.

The two other conditions had no special requirements except that of an adjustable anglepoise light with a specially designed shade, which was used in conjunction with the oblique lighting condition.

The experimenter was supplied with printed copies of the plotted faults for all 37 frames which were presented to the subjects in a fixed order, i.e. from frame one to frame thirty-seven. The subject upon locating each fault was given feedback by the experimenter who would say "yes", "good" or make an affirmative comment. The time for each subject on each frame was obtained by means of the stop watch.

Two sets of data, other than that concerning time were obtained. Firstly a score for locating a fault and secondly for verbally identifying the fault correctly. In practice, however, only the first category is of any real value. The reason for this is that in the normal course of burling and mending, the worker would be required merely to repair a fault and not to identify it verbally. Thus in order to make the appropriate repairing responses she would have to have understood the underlying nature of the fault. Since all skilled burlers and menders have the ability, with rare exceptions, to repair a fault once they have found it, (suggested by Belbin, Belbin and Hill) though not necessarily with equal skill, the most important criterion to use is the first one, i.e. that of locating the fault. Also it is important to realise that the vast regional differences in the fault nomenclature which may vary even from mill to mill, made scoring an extremely exacting task. Very few false reports were given as each fault could in cases of uncertainty be closely examined. All the "false" reports which were made were checked and the cloth examined for confirmation. In one case an additional fault was located and scores for this were included in the experiment. (For examples of the score sheets with plotted faults, see Appendix 3).

3.5 Treatment of Data

The raw data obtained from this experiment lends itself to four analyses.

(a) The total time taken by each subject to inspect the 37 frames was recorded. An analysis of variance on these times was carried out. No 't' tests were performed as no factor was found to be significant in the analysis of variance.

(b) The total number of faults detected by each subject out of the 735 presented (see Appendix 4) was determined. The total for each subject was converted into a percentage. Thus, in this analysis each of the 735 faults was given an equal weight. An analysis of variance and 't' tests were carried out on these percentages.

(c) The 735 faults which appeared on the cloth were composed of 29 fault types. These were classified into eight groups. Each group consisted of faults which were similar in physical appearance. (see Table 1).

TABLE 1

The 8 fault categories into which the 29 faults were placed

Category	Names of Faults in a Particular Category
1	Knots.
2	Slub, slub weftways and buttons.
3	Slack and slack weft.
4	Thick, thick bar and open places.
5	Drop ends, ends out, weft tails, wrong ends, cross ends, loose ends, stitchings and weft stitchings.
6	Stapples, loops and snarls.
7	Trailers, pick trailers, lashing back, cracked weft and two tails.
8	Stitched pick, pick out, pick and shuttle jumps.

The number of faults in each group that were detected by each subject were recorded. These totals were converted into percentages. Thus, the percentage of faults that each subject detected in each of the eight fault categories was obtained. These percentages were statistically evaluated by means of analysis of variance and students 't' test. In the analysis of this data equal weight was not given to each fault since the number of faults in each category differed substantially. Equal weight was given however to each fault category.

(d) Finally three sets of correlation coefficients were calculated.

(1) Rank order correlation coefficients to determine the effects of the positioning of frames in the cloth.

(2) Product-moment correlation coefficients to investigate overall relationships between factors of speed and accuracy, i.e. faults present per frame, faults detected per frame, inspection time per frame.

(3) Analysis of variance of correlation coefficients, involving accuracy, speed and the number of faults present, and investigating mean differences between experimental conditions and age for the forty subjects.

It will be observed that two of the four statistical analyses described briefly above are concerned with fault detection. These analyses are (b) and (c). In the former, as was pointed out earlier, no account was taken of fault type and thus each of the 735 frames was given an equal weight. An analysis of this data is extremely useful in that it gives an indication of the percentage of faults that may be detected on a typical piece of cloth.

An analysis of fault detection conducted solely in these terms however might be misleading for the following reasons. No account would be taken of fault type and valuable information would be lost. With fault type not taken into account detection results would be heavily weighted in favour of the number of knots and slubs detected as these faults occur far more frequently than any of the others. These particular fault types however which fall in categorys 1 and 2 are reasonably easy to detect. In addition the economic consequences of their being detected and unrepaired are far less important than for most other fault types. Thus faults which occur infrequently but are important are not assigned due weight and their contribution to the whole analysis would be greatly undervalued.

As a result of this consideration a supplementary analysis was carried out which took into account fault type, i.e. analysis (c). This analysis, whilst supplementing analysis (b), leads to other difficulties. For example, in this case the eight different fault categories are given equal weight in the analysis of variance. Because however a different number of faults occur in each fault category, estimates of performance which are averaged over the eight fault categories would not give a true estimate of operators' performance on a typical piece of cloth. The analysis does however have an advantage in that it enables the experimentor to determine which fault categories are associated with good and poor performances so that training schedules for burlers and menders can be rationally based.

As a result of the arguments presented in the previous paragraphs it will be apparent that both analyses (b) and (c) have their advantages and disadvantages and that the correct approach is to consider both analyses simultaneously rather than totally ignore one or the other.

It will be observed that the analysis of the time taken by the subjects to inspect the 37 frames of cloth, i.e. analysis (a), has been carried out in a similar manner to (b) rather than (c). That is to say no account has been taken of fault type. The reason for this lies in the fact that the faults are spread throughout the cloth in a random manner.
The subject, in inspecting the cloth under any one of the four experimental conditions, would start to scan the cloth at any point on the appropriate two foot section in front of her, and point out the first fault that she discovered. Scanning would then continue in any direction that the subject chose leading to another fault being pointed out. This continued until the subject was satisfied that all the faults in that section had been found. The cloth would then be wound on until the next sector was in front of the subject and the same process repeated.

It can be seen that the time taken between the subject discovering any fault A and then fault B might have nothing to do with the characteristic of the fault itself but merely indicate the path that the subject has chosen in her scanning. Since no two subjects would necessarily choose the exact same scanning path from fault to fault, little data on the time taken to detect faults would be available. In any case it would have been immensely difficult to obtain a record of the time and path taken by each subject between any two faults. Furthermore, not every subject necessarily identified a fault verbally immediately upon finding it, but some chose to wait until three or four of them had been located before reporting the information to the experimenter. Thus the only convenient detection time data that can be extracted from this experiment is the time for a subject to scan a section of the cloth with no account taken of fault types.

The last section of the analysis (d) has a logical complement to analyses (a), (b) and (c) since it is concerned with determining the relation between operator speed and accuracy, and the effects of the position and the fault content of the 37 frames.

CHAPTER IV

RESULTS

4.1 Times Taken to Complete Inspection Task

To evaluate the effects of experimental conditions and subject age upon time taken to inspect the cloth the total time taken by each subject to complete the 37 frames was calculated. There were thus forty total times. This follows as there were ten subjects in each of the four conditions, making a total of forty subjects. It will be recalled that each group of ten subjects was composed of five young and five old subjects. The forty total times were subjected to an analysis of variance.

The results of the analysis of variance are given in Table 2. The associated table of means is Table 3. The data are summarised graphically in Figures 10 and 11.

TABLE 2

Analysis of variance on the time taken to inspect the 37 frames of cloth

Source	DF	SS	MS	Variance Ratio	P
Conditions (C)	3	9,153,903.47	3,051,300.69	2.17	$0.1<p<0.2$
Ages (A)	1	364,101.02	364,101.02	-	-
A x C	3	5,406,898.08	1,802,299.36	1.28	$p>0.2$
Residual	32	45,086,227.30	1,408,944.53		
Total	39	60,011,128.77			

It will be seen from Table 2 that no variance ratio is significant at the 0.05 level. Three conclusions may be drawn.

First it may be concluded that the time taken to inspect the cloth is effectively the same for the experimental treatments eyes only (E), hands only (H), eyes plus hands under normal lighting conditions (EH), and eyes plus hands under special oblique lighting conditions (EHL_1). This is shown by the non-significance of the variance ratio associated with "conditions" (VR = 2.17, $0.1<p<0.2$). Despite the fact that there is no evidence of significant differences existing between the experimental conditions the form of the data

Figure 10

Mean total time in seconds taken to complete 37 frames plotted against experimental condition for young subjects. Each mean is based on five totals. 95% confidence limits are given for each mean. These equal mean total ± (530.84)(2.78), i.e. ± 1,475.74

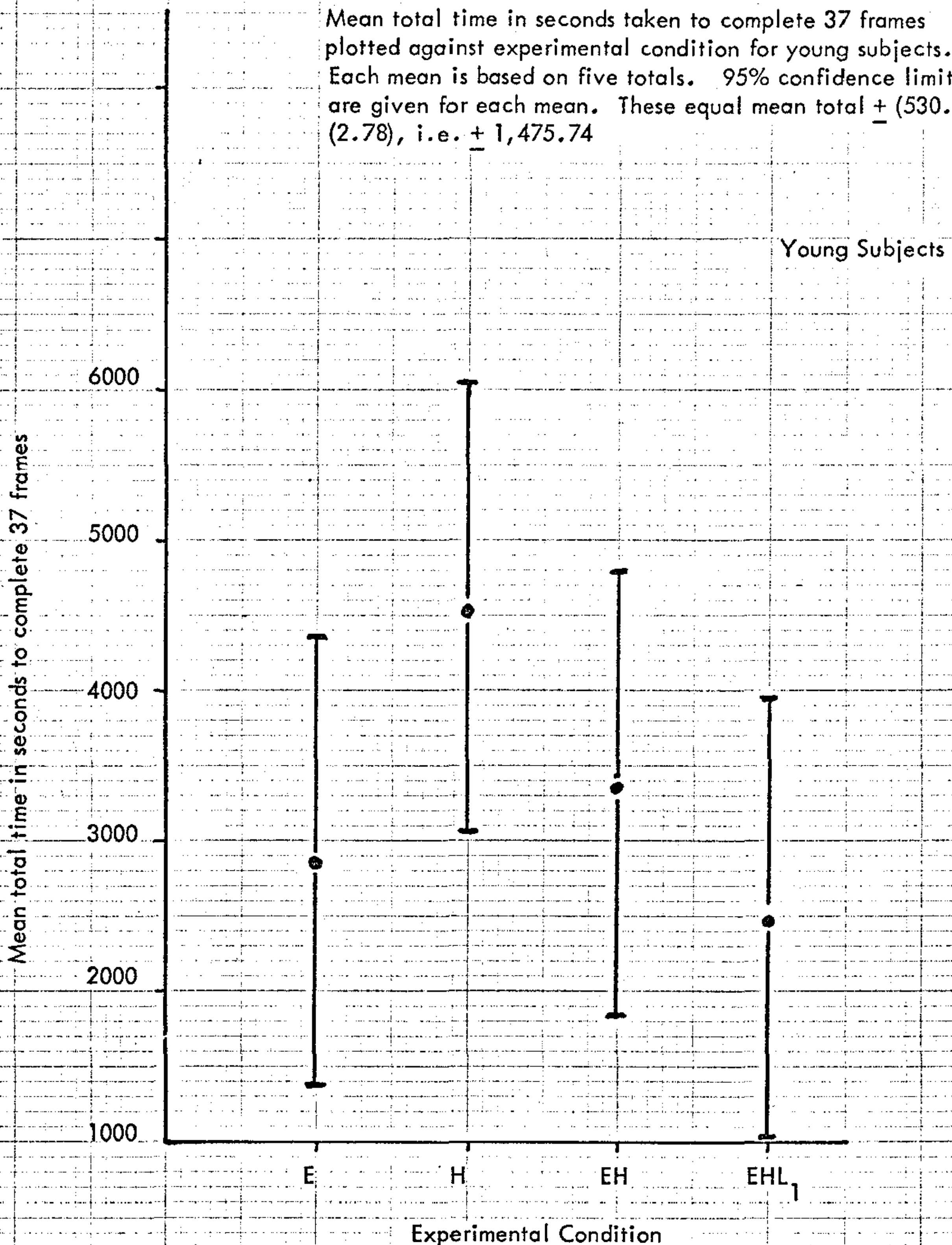
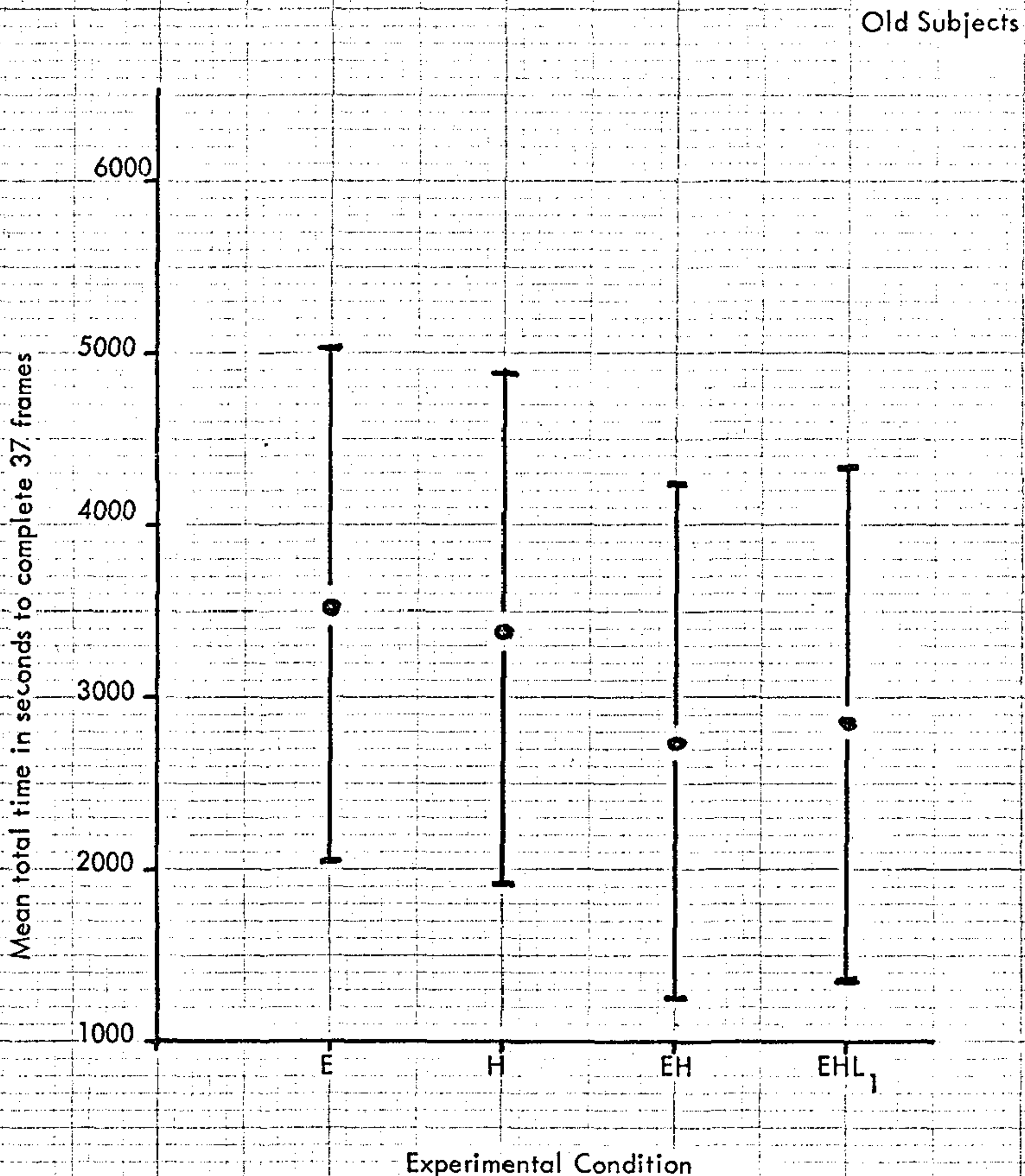


Figure 11

Mean total time in seconds taken to complete 37 frames plotted against experimental condition for old subjects. Each mean is based on five totals. 95% confidence limits are given for each mean. These equal mean total ± (530.84) (2.78), i.e. ± 1,475.74.



is that anticipated.

When two sensory modalities are simultaneously available for fault detection it might be expected that the search time would be less than when only one of the two modalities is available for use. Table 3 shows that this expectation is confirmed in the present experiment.

TABLE 3

Mean total times in seconds to complete the 37 frames by the two age groups working under the four experimental conditions. Each value in the body of the table is the mean of five totals. Values given at the end of a row are based on twenty totals; those given at the foot of a column are based on ten totals.

		Experimental Condition				Experimental Conditions Combined
		E	H	EH	EHL_1	
Groups of Subjects	Y	2,866.80	4,554.40	3,321.60	2,479.80	3,310.65
	O	3,525.00	3,392.60	2,725.60	2,845.20	3,122.10
Groups of Subjects Combined		3,195.90	3,973.50	3,033.60	2,662.50	

The time taken for single modality inspection, in conditions E and H, is greater than that for dual modality inspection, in conditions EH and EHL_1.

It might also be expected that deprivation of visual information is more disorienting for the subject than deprivation of tactual information. In the former circumstance the subject may find it extremely difficult to determine whether she is repeatedly going over the same area of cloth, and on occasion, may even feel that this is a necessary strategy to avoid missing too many faults. Such considerations do not seem to apply to the same extent when the subject can see but is deprived of tactual information. Accordingly it might be anticipated in the single modality case that the time necessary for inspection using touch alone would be greater than that for vision alone. This is shown to be the case in Table 3. The mean total time for condition H is almost four thousand seconds or approximately sixty six minutes. On the other hand the mean total time for condition E is almost three thousand two hundred seconds or approximately fifty three minutes.

This result is open to another explanation. There were a large number of faults present on the cloth which lent themselves to tactual but not visual detection, e.g. knots. As these outnumbered other faults detected primarily by vision it is conceivable that it took longer to inspect the cloth tactually for this reason alone.

It was also thought that in the dual modality case the provision of special oblique lighting should make certain faults, normally detected by touch, susceptible to rapid visual detection. It will be observed in Table 3 that the time taken to inspect the cloth under special lighting conditions (EHL_1) is about two thousand seven hundred seconds or approximately forty four minutes. On the other hand the time taken to inspect the cloth under normal lighting conditions is somewhat more, being about three thousand seconds, or fifty one minutes.

The second principal conclusion which may be drawn from the analysis of variance results shown in Table 2 is that the mean total time for inspection is essentially the same for young and old workers. No variance ratio is shown against "ages" in Table 2. The mean square (MS) associated with "ages" is less than that associated with the "residual" and so clearly cannot be significantly greater than the "residual". Though the mean difference in time for the two groups is not significant in a statistical sense, reference to Table 3 shows that older workers work marginally faster than younger workers. The mean total times are approximately three thousand three hundred and three thousand one hundred seconds respectively, i.e. about fifty five and fifty two minutes.

The third and final conclusion to be drawn is that the time taken to complete the 37 frames by each age group is not differentially dependent upon experimental condition. That is to say that the two groups responded in the same manner to the effect of experimental conditions. This is shown by the non-significance of the variance ratio associated with the A x C Interaction (VR = 1.28, $P \ngtr 0.2$). In Table 3 it will be seen that the greatest difference in mean total time to complete the task occurs when the performances of young and old workers are compared for the tactual situation. The average time taken by older workers is twenty minutes less than the corresponding time taken by younger workers.

In conclusion it should be remembered that no significant effects have been found for experimental conditions, subject age, and conditions x age interaction in this analysis on the time data.

4.2 Percentage of Faults Detected in the Inspection Task with no Account Taken of Fault Categories

To evaluate the effects of experimental condition and subject age upon detection performance the percentage of faults detected by each subject was calculated. For each subject the total number of faults actually found from the total of 735 present was determined. A percentage was calculated by multiplying the number found by $^{100}/_{735}$. These calculations produced forty percentages, as there were ten subjects in each of the four conditions making a total of forty subjects. The forty percentages were submitted to an analysis of variance. The results of this analysis are given in Table 4. Means are shown in Table 5.

TABLE 4

Analysis of variance on the percentage of faults detected over the 37 frames of cloth with no account taken of fault categories.

Source	DF	SS	MS	Variance Ratio	P
Conditions (C)	3	1,231.199	410.399	7.883	$p < 0.001$
Ages (A)	1	43.616	43.616	-	-
A x C	3	152.590	50.863	-	-
Residual	32	1,666.017	52.063		
Total	39	3,093.422			

TABLE 5

Mean percentage of faults detected over the 37 frames by the two age groups working under the four experimental conditions with no account taken of fault categories. Each value in the body of the table is the mean of five percentages. Values given at the end of a row are based on twenty percentages. Those given at the foot of a column are based on ten percentages.

		Experimental Condition				Experimental Conditions Combined
		E	H	EH	EHL_1	
Groups of Subjects	Y	45.50	60.00	55.95	62.67	56.03
	O	46.50	51.92	57.69	59.65	53.94
Groups of Subjects Combined		46.00	55.96	56.82	61.16	

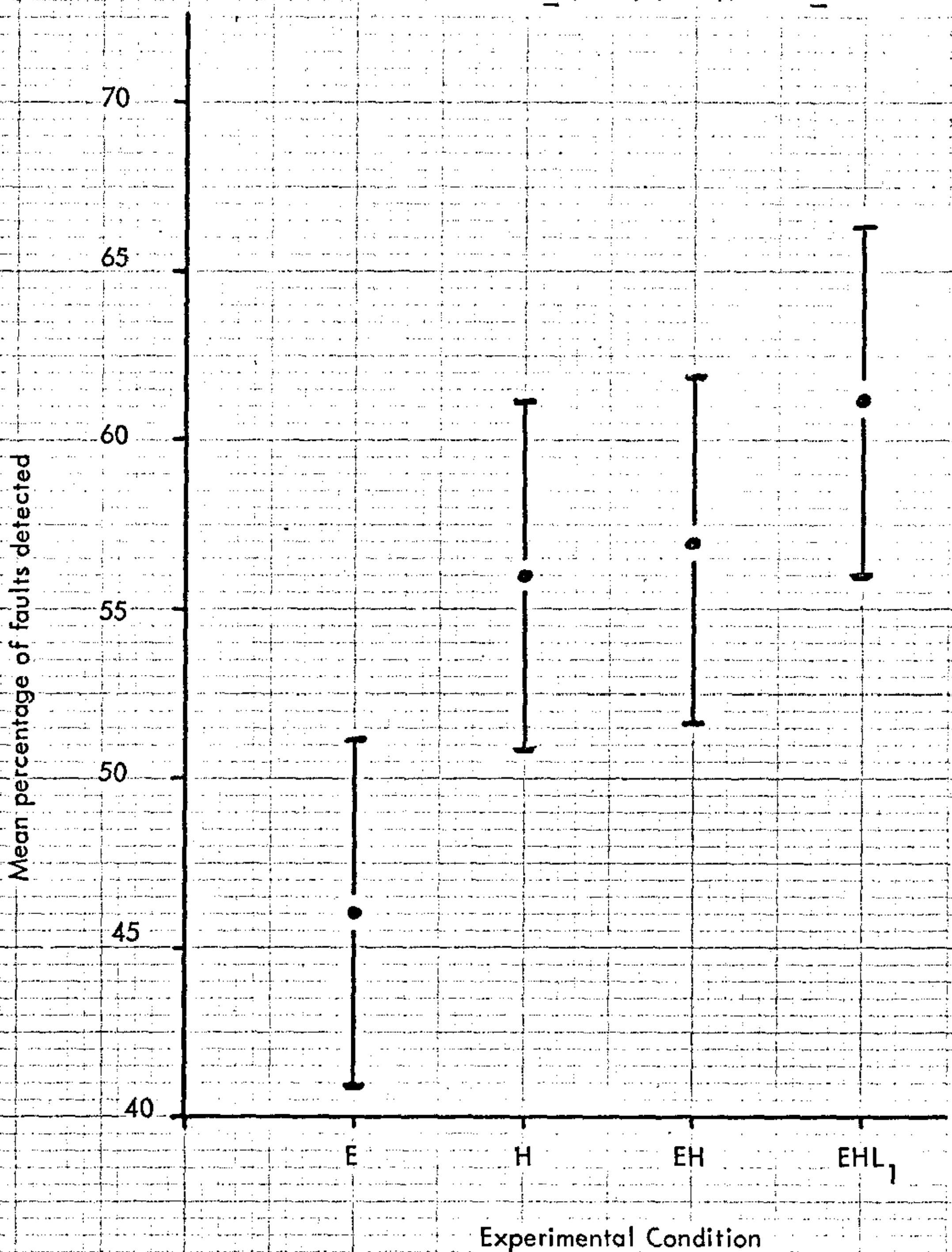
It will be seen from Table 4 that only one variance ratio is significant at the 0.05 level. That is the variance ratio associated with conditions. Three conclusions may be drawn from the analysis of variance table.

First, it may be concluded that experimental condition exerts a considerable effect upon the percentage of faults detected. This is shown by the significance ($p < 0.001$) of the variance ratio (7.883) associated with "Conditions". 't' tests were carried out comparing the mean percentage detection results obtained under each experimental condition. The means on which the 't' tests were carried out are shown in the bottom row of Table 5. These means are also graphically displayed in Figure 12. The results of the 't' tests are shown in Table 6.

Analogous arguments apply here to the likely effects of experimental conditions upon percentage of faults detected as were presented in the previous section when the effects of conditions upon time for inspection

Figure 12

Mean percentage of faults detected in each of the four principal experimental conditions over the 37 frames with no account taken of fault categories. 95% confidence limits are given for each mean. These equal mean percentage of faults detected ± (2.28) (2.26), i.e. ± 5.15



were discussed.

In the present context when fault detection is the criterion of performance, it might be expected that subjects would do better when they can use two sensory modalities simultaneously instead of only one of them at a time.

It will be seen from Table 5 and Figure 12 that this result for visual detection at least has been obtained. The mean percentage of faults detected in condition E is much less than the number detected in conditions EH and EHL_1.

TABLE 6

Comparison by 't' test, of the mean percentage of faults detected under the four principal experimental conditions over the 37 frames of cloth when no account is taken of fault categories.

Conditions Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
EHL_1 - E	15.16	3.23	32	4.69	$p<0.001$	8.57 to 21.75
EHL_1 - H	5.20	3.23	32	1.61	$0.1<p<0.2$	-1.39 to 11.79
EHL_1 - EH	4.34	3.23	32	1.34	$0.1<p<0.2$	-2.25 to 10.93
EH - E	10.82	3.23	32	3.35	$0.001<p<0.01$	4.23 to 17.41
EH - H	0.86	3.23	32	0.27	$0.7<p<0.8$	-5.73 to 7.45
H - E	9.96	3.23	32	3.08	$0.001<p<0.01$	3.37 to 16.55

Table 6 shows that both types of dual modality performances are statistically different from and superior to performances where only the eyes are used. The mean percentage of faults detected in condition H is also less than the numbers detected in conditions EH and EHL. These differences, though in the expected direction, are not statistically significant as Table 6 shows. A possible explanation of the results described in this paragraph is that there was no weighting or correction made for the large number of knots contained in the cloth. It can be observed from the later analysis in which all fault categories are equally weighted, regardless of the number of faults contained in each of them, that Category I, which includes knots, contains faults which are detected primarily by the hands. As the present analysis is in terms of the total number of faults detected regardless of fault type, it will be realised that far more faults were available for tactual rather than visual detection. This may explain why in this analysis detection with the hands alone is as good as detection when the hands are supplemented by the eyes, and also why detection with the hands alone is superior to detection when only the eyes are used.

Turning now to a consideration of the effect of subject age upon percentage of faults detected it will be seen from Table 4 that the mean square associated with ages is smaller than that associated with the residual. Thus the mean difference in detection performance for the two age groups is not significant in a statistical sense. However, the direction of the difference is not what would be expected. As older workers are more experienced at the task than younger workers, they may, as mentioned in the analysis of the time data, be expected to work with greater accuracy. It has been shown in Table 3 that older workers work marginally faster than younger workers. Reference to Table 5 however, shows that the mean percentage of faults detected by older subjects is less than that detected by younger subjects. Older workers detected 53.94% of faults and younger workers 56.03% of the faults presented to them. Thus it would appear that the older workers gain in speed has been obtained at the sacrifice of some accuracy.

The final conclusion to be drawn from Table 4 is that the percentage of faults detected by each age group is not differentially dependent on experimental condition. This is shown by the non-significance of the variance ratio associated with the A x C interaction. Indeed the mean square for this interaction is slightly smaller than that for the residual. This result again throws an interesting light upon the results described in the section concerned with the time data. It will be recalled that Table 3 shows that the average time taken by the older worker to inspect the 37 frames of cloth tactually is almost 20 minutes less than the corresponding time taken by younger workers. Table 5 however, shows that older workers' tactual performance is inferior to that of the younger worker. The mean percentage of faults detected by older workers is 51.92. The corresponding figure for younger workers is 60. Thus it would appear once again that the greater speed of inspection of the older worker has resulted in some sacrifice in accuracy.

In summary of this section it may be said when detection results are analysed and no account taken of fault categories that experimental conditions alone exert a significant effect upon performance.

4.3 Percentage of Faults Detected in the Inspection Task with Fault Categories Taken into Account

To evaluate the effects of experimental conditions, fault type and subject age upon detection performance, the percentage of faults detected in each fault category by each subject was calculated. These calculations produced three hundred and twenty percentages. This follows because there were forty subjects each of whom was exposed to the same faults falling into one of eight categories. Forty multiplied by eight equals three hundred and twenty. It will, of course, be recalled that the forty subjects were divided into four groups of ten, each group being exposed to one of the four experimental conditions. It will also be recalled that each group of ten subjects associated with an experimental condition was divided into two sub-groups comprising five young and five old subjects.

The three hundred and twenty percentages were subjected to an analysis of variance. A split-plot model was used (Cochran and Cox, 1957) as the percentages were correlated in one dimension (fault categories), but not in the other (experimental conditions and subject ages) with different subjects undergoing different experimental conditions and different subjects being in different age groups.

The results of the analysis of variance are given in Table 7.

TABLE 7

Analysis of variance on percentage of faults detected with fault categories taken into account

Source	DF	SS	MS	Variance Ratio Against (a)	Variance Ratio Against (b)	P
Between Subjects	39	24,216.7				
Conditions (C)	3	7,491.8	2,497.3	5.33		0.001<p<0.01
Ages (A)	1	635.6	635.6	1.36		p>0.2
A x C	3	1, 085.3	361.8	-		-
Residual	32	15,004.0	468.9(a)		6.79	p<0.001
Within Subjects	280	108,202.9				
Fault Categories (F)	7	73,552.4	10,507.5		132.88	p< 0.001
F x C	21	16, 515.3	786.4		11.39	p <0.001
F x A	7	1,396.5	199.5		2.89	0.001<p<0.01
F x C x A	21	1,279.5	60.71		-	-
Residual	224	15,459.2	69.0(b)			
Total	319	132,419.6				

It will be immediately observed on consideration of Table 7 that the variance ratio for the comparison of the "residual variation between subjects" and the "residual variation within subjects" is statistically significant (P < 0.001). The former, is significantly larger than the latter. This, of course, is a standard finding in split plot analyses of variance. In this particular context it indicates that when the effects of the main variables ("conditions", "ages", and "fault categories") and their interactions have been partialled out, the residual differences in performance between subjects are greater than those within subjects. This may be expressed otherwise by stating that there is less residual variation between correlated readings than there is between uncorrelated readings.

Each "source" of variance listed in Table 7 will now be discussed in turn with the exception of the residuals which have already been dealt with.

The variance ratio associated with experimental conditions is highly significant ($0.001 < p < 0.01$). This implies that the percentage of faults detected is critically dependent upon the experimental condition under which detection takes place. To provide a better understanding of this result the mean percentage detection for each experimental condition is shown in Table 8. 't' tests comparing these means are given in Table 9. The data are plotted graphically in Figure 13.

TABLE 8

Mean percentage of faults detected under each of the four principal experimental conditions. Each value in the table is based on eighty percentages.

Experimental Condition				Experimental Conditions Combined
E	H	EH	EHL_1	
43.06	43.60	51.78	53.98	48.11

TABLE 9

Comparison by 't' test, of the mean percentage of faults detected under the four principal experimental conditions.

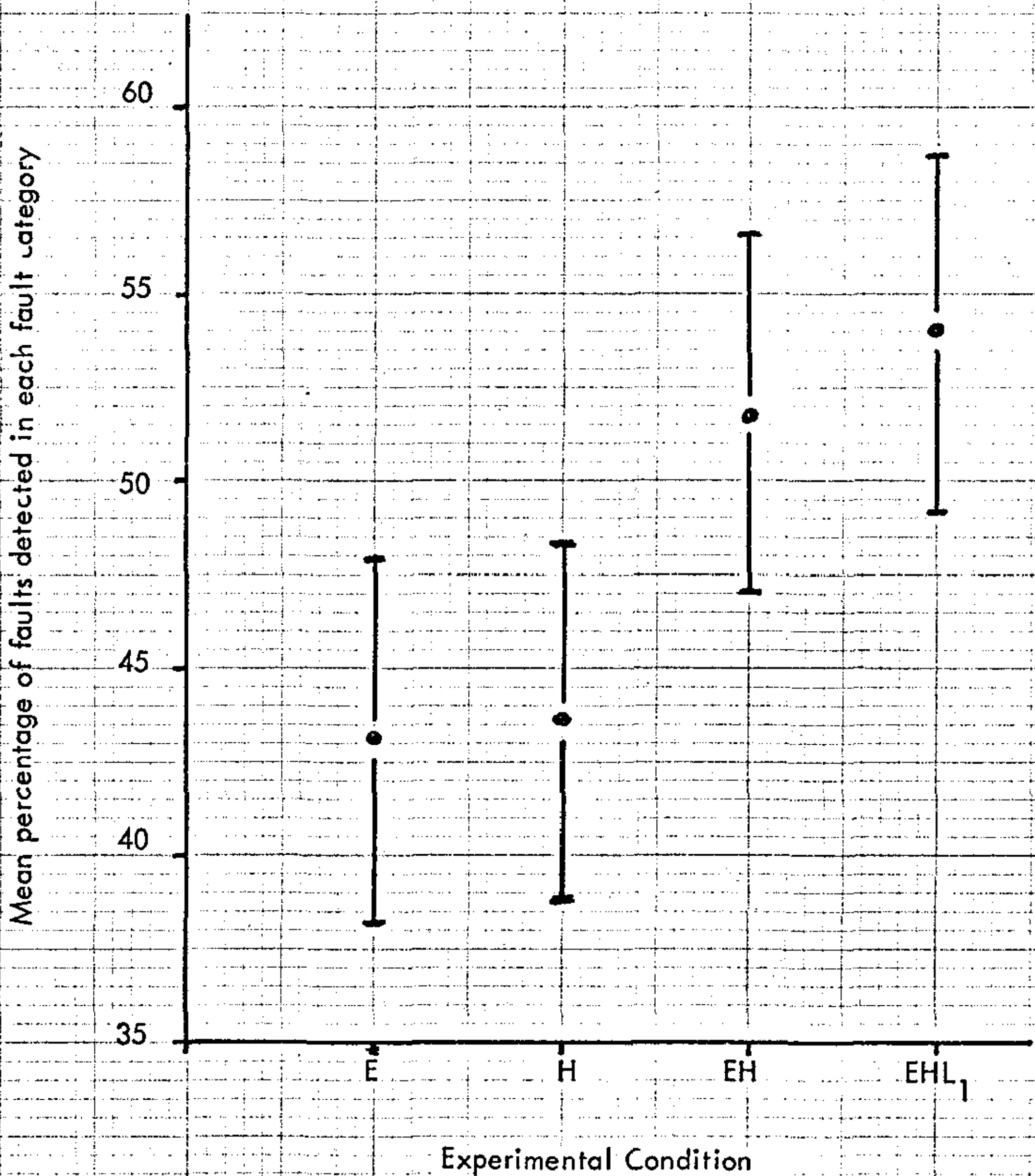
Conditions Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
EHL_1 - E	10.92	3.42	32	3.19	$0.001<p<0.01$	3.94 to 17.90
EHL_1 - H	10.38	3.42	32	3.04	$0.001<p<0.01$	3.40 to 17.36
EHL_1 - EH	2.20	3.42	32	0.64	$0.5<p<0.6$	-4.78 to 9.18
EH - E	8.72	3.42	32	2.55	$0.01<p<0.02$	1.74 to 15.70
EH - H	8.18	3.42	32	2.39	$0.02<p<0.05$	1.20 to 15.16
H - E	0.54	3.42	32	0.16	$0.8<p<0.9$	-6.44 to 7.52

4.3.1 Conditions

Analogous arguments apply here to the likely effects of experimental conditions upon percentage of faults detected as were presented in the two previous sections when the effects of conditions upon (a) time for inspection and (b) fault

Figure 13

Mean percentage of faults detected in each of the four principal experimental conditions. Each mean is based upon eighty percentages. 95% confidence limits are given for each mean. These equal mean percentage of faults detected ± (2.42) (1.99), i.e. ± 4.82



detection with no account taken of fault categories were discussed.

In the present context when fault detection is the criterion of performance it might be expected that subjects would do better when they can use two sensory modalities simultaneously instead of only one of them at a time. It will be seen from Table 8 and Figure 13 that this result has been obtained. The mean percentage of faults detected in conditions E and H is much less than the number detected in conditions EH and EHL_1. Furthermore, Table 9 shows that all comparisons of dual and single modality detection performance (EHL_1 - E, EHL_1 - H, EH - E and EH - H) produce highly significant results.

This result is slightly at variance with that found in the previous section. There, as Table 6 shows, condition H was not significantly different from conditions EH and EHL_1. This discrepancy may be explained by the fact that in the present analysis the large number of tactual faults falling in Category 1 does not exert the effect that it did in the previous analysis on fault detection. This is due to the grouping of the faults into eight categories in the present analysis with equal weight being given to each category irrespective of the number of faults it contains.

It might also be expected as previously stated that deprivation of visual information is more disorienting for the subject than deprivation of tactual information for single modality inspection. In the present context this implies that the mean percentage of detections in condition E should be greater than in condition H. Table 9, however, shows that when these conditions are compared (H - E) there is no significant difference in the results ($0.8 < p < 0.9$). Furthermore, Table 9 and Figure 13 show that the very small difference which does exist is in the unexpected direction. The mean for tactual inspection is 43.60 whilst that for visual inspection is 43.06. This result is similar to, but not so marked as that obtained in the previous section (c.f. Tables 5 and 6)when the large number of tactual faults were given their due weight in terms of their frequency of occurrence.

It was expected in the dual modality inspection situations that the provision of supplementary lighting would improve detection. Table 9 shows that the difference in mean percentage of faults detected in conditions EHL_1 and EH is not statistically significant ($0.5 < p < 0.6$). Table 8 and Figure 13 show, nevertheless, that the difference is in the expected direction. The mean percentage of signals detected in condition EHL_1 is 53.98 which is slightly larger than the corresponding percentage, 51.78, detected in condition EH. This result is similar to that obtained in the previous section (c.f. Tables 5 and 6).

4.3.2 Ages and interactions

Turning now to the effects of "Ages" and "Ages x Conditions Interaction" upon detection performance, it will be seen from Table 7 that neither of the mean squares associated with these factors, i.e. 635.6 and 361.8 is significantly bigger than the appropriate residual mean square, 468.9. It may therefore be concluded that the detection performance of young and older subjects is effectively the same. At this stage too, it appeared that the manner in which young and old subjects respond to the experimental conditions used in these investigations is much the same. These results are the same as those obtained in the two previous sections (c.f. Tables 2 and 4).

For the sake of completeness means for the age groups of subjects, experimental conditions and their interaction are shown in Table 10.

TABLE 10

Mean percentage of faults detected over the 37 frames by the two age groups working under the four experimental conditions, taking into account the eight fault categories. Each value in the body of the table is the mean of forty percentages. Values given at the end of a row are based on 160 percentages. Those given at the foot of a column are based on eighty percentages.

		Experimental Condition				Experimental Conditions Combined
		E	H	EH	EHL_1	
Groups of Subjects	Y	41.65	47.12	52.88	56.40	49.51
	O	44.48	40.08	50.68	51.55	46.69
Groups of Subjects Combined		43.06	43.60	51.78	53.98	

The relations between the figures in this table are very similar to those found in Table 5 in the previous section. It will be noted that the mean percentage of faults detected by older subjects is less than that detected by younger subjects. Older workers detected 46.69% of faults and younger workers 49.51% of faults presented to them. Thus, even with the slightly different form of analysis carried out here, the earlier statement that the older workers' gain in speed has been obtained at the sacrifice of some accuracy would appear to be confirmed. It will also be noted in Table 10 that the tactual performance of younger workers is superior to that of older workers. The mean percentage of faults detected by older workers is 40.08; the corresponding figure for younger workers is 47.12. Once again, the earlier statement made in the previous section that the greater speed of inspection of the older worker in the tacual situation has resulted in some sacrifice in accuracy would appear to be confirmed.

Summarising the "Between Subjects" portion of the analysis shown in Table 7 it may be said when detection results are analysed and account taken of fault categories that experimental conditions alone exert a significant effect upon performance. This is a similar conclusion to that which emerged from the previous section.

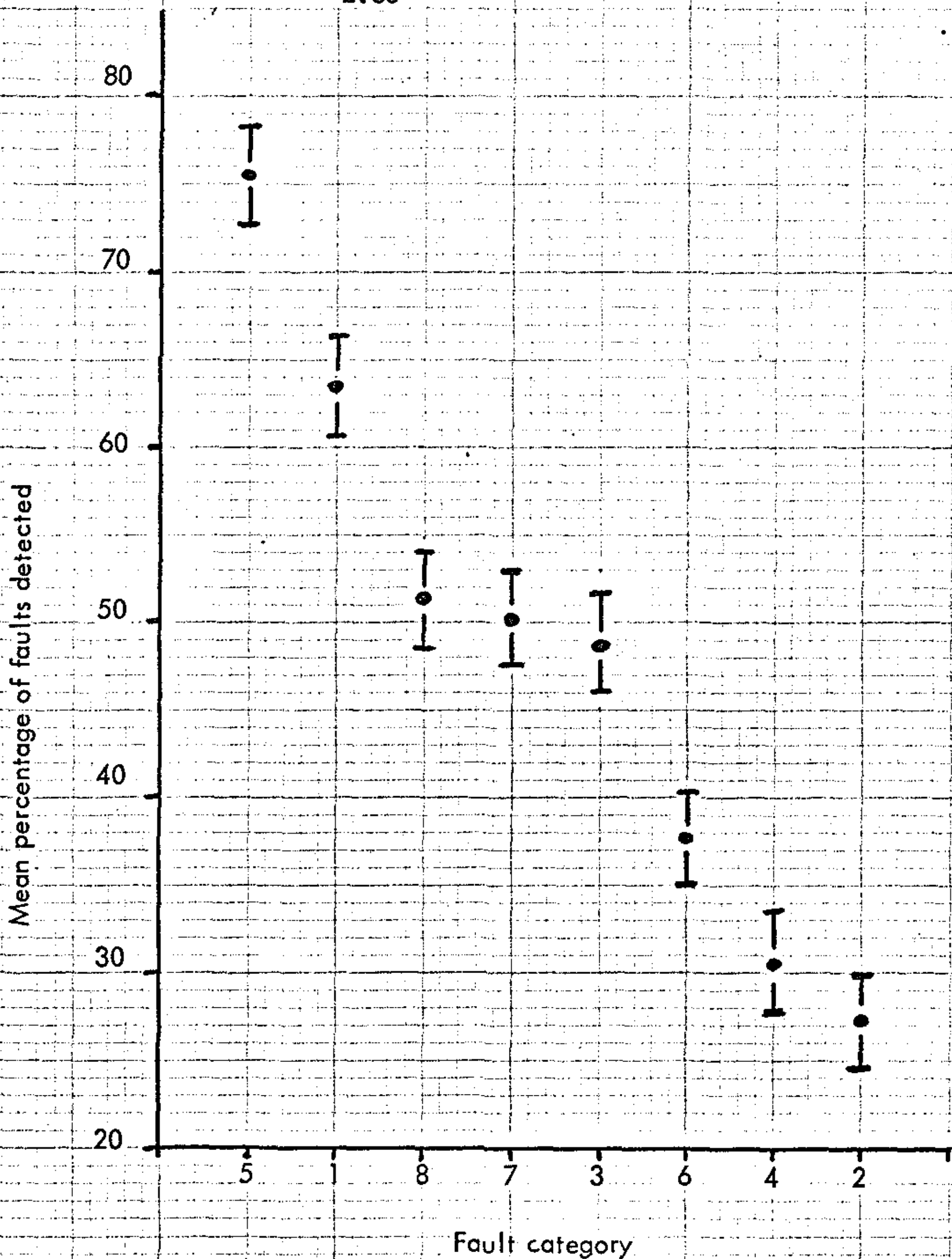
4.3.3 Fault categories and interactions

The second section of the analysis of variance shown in Table 7, the section dealing with variation "Within Subjects" will now be discussed. This portion of the analysis has no counterpart in any of the analyses previously discussed.

The variance ratio associated with fault categories (132.88) is highly significant ($p < 0.001$). This implies that detection performance is heavily dependent upon the type of fault presented to the subject. The mean percentage of detections in each fault category are shown in Table 11. These means are compared by the 't' test in Table 12. The data are plotted graphically in Figure 14 with the fault categories ordered in terms

Figure 14

Mean percentage of faults detected in each of the eight fault categories. Each mean is based upon forty percentages. 95% confidence limits are given for each mean. These equal mean percentage of faults detected $\pm$ (1.31) (2.02), i.e. 2.65



of ease of detection. It will be seen from Table 11 and Figure 14 that there is considerable variation between the fault categories. The worst is category 2 (slubs, slub weftways and buttons). Only 27% of faults in this category were detected. The best is category 5 (drop ends, ends out, weft tails, wrong ends, cross ends, loose ends, stitchings and weft stitchings). Seventy five percent of the faults in this category were detected. Although there is considerable overall variation in detection between fault categories, inspection of Figure 14 suggests that there is no effective difference between fault categories 8, 7 and 3, nor between 4 and 2. This impression is confirmed in Table 12 by 't' tests. On the basis of all the results shown in Table 12 the fault categories can be ordered in terms of effective detection performance. Performance in category 5 is significantly different from, and superior to, performance in all other categories. Hence category 5 may be ranked first. Performance in category 1 is significantly different from performance in all other categories. It is inferior to that in category 5 but superior to that in all other categories. Hence category 1 may be ranked second. Proceeding in this manner through all categories Table 13 was drawn up.

TABLE 11

Mean percentage of faults detected in each fault category. Each value in the table is based on forty percentages.

Fault Category							
1	2	3	4	5	6	7	8
63.45	27.33	48.73	30.73	75.43	37.70	50.20	51.28

TABLE 12

Comparison by 't' test of the mean percentage of faults detected in each of the eight categories

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
5 - 1	11.98	1.86	224	6.44	$p < 0.001$	8.33 to 15.63
5 - 2	48.10	1.86	224	25.86	$p < 0.001$	44.45 to 51.75
5 - 3	26.70	1.86	224	14.35	$p < 0.001$	23.05 to 30.35
5 - 4	44.70	1.86	224	24.03	$p < 0.001$	41.05 to 48.35
5 - 6	37.73	1.86	224	20.28	$p < 0.001$	34.08 to 41.38
5 - 7	25.23	1.86	224	13.56	$p < 0.001$	21.58 to 28.88
5 - 8	24.15	1.86	224	12.98	$p < 0.001$	20.50 to 27.80
1 - 2	36.12	1.86	224	19.42	$p < 0.001$	32.47 to 39.77
1 - 3	14.72	1.86	224	7.91	$p < 0.001$	11.07 to 18.37
1 - 4	32.72	1.86	224	17.59	$p < 0.001$	29.07 to 36.37
1 - 6	25.75	1.86	224	13.84	$p < 0.001$	22.10 to 29.40
1 - 7	13.25	1.86	224	7.12	$p < 0.001$	9.60 to 16.90
1 - 8	12.17	1.86	224	6.54	$p < 0.001$	8.52 to 15.82
8 - 2	23.95	1.86	224	12.88	$p < 0.001$	20.30 to 27.60
8 - 3	2.55	1.86	224	1.37	$0.1 < p < 0.2$	-1.10 to 6.20
8 - 4	20.55	1.86	224	11.05	$p < 0.001$	16.90 to 24.20
8 - 6	13.58	1.86	224	7.30	$p < 0.001$	9.93 to 17.23
8 - 7	1.08	1.86	224	0.58	$0.5 < p < 0.6$	-2.57 to 4.73
7 - 2	22.87	1.86	224	12.30	$p < 0.001$	19.22 to 26.52
7 - 3	1.47	1.86	224	0.79	$0.4 < p < 0.5$	-2.18 to 5.12
7 - 4	19.47	1.86	224	10.47	$p < 0.001$	15.82 to 23.12
7 - 6	12.50	1.86	224	6.72	$p < 0.001$	8.85 to 16.15
3 - 2	21.40	1.86	224	11.51	$p < 0.001$	17.75 to 25.05
3 - 4	18.00	1.86	224	9.68	$p < 0.001$	14.35 to 21.65
3 - 6	11.03	1.86	224	5.93	$p < 0.001$	7.38 to 14.68
6 - 4	6.97	1.86	224	3.75	$p < 0.001$	3.32 to 10.62
6 - 2	10.37	1.86	224	5.57	$p < 0.001$	6.72 to 14.02
4 - 2	3.40	1.86	224	1.83	$0.05 < p < 0.10$	-0.25 to 7.05

TABLE 13

Rank order of fault categories. Magnitude of rank is inversely related to the probability of fault detection. Categories with the same rank are not significantly different from one another. Categories with different ranks are significantly different from one another.

Rank	Fault Category
1st	5
2nd	1
3rd	8, 7, 3
4th	6
5th	4, 2

In Tables 15, 16, 17 and 18, 't' tests relating to the first method of analysis are shown. Each of these tables relates to a different row in Table 14. For example, Table 15 compares means which occur in row E in Table 14. The information contained in Tables 15, 16, 17 and 18 is extremely difficult to digest and is summarised in a more comprehensible form in Table 19. In this table, fault categories are ordered in terms of excellence of detection performance for each of the experimental conditions. Also included in Table 19 is the order in which the fault categories occur when no distinction is made between experimental conditions (see Table 13).

The table shows clearly that faults in categories 6, 4 and 2 (stapples, loops, snarls: thick, thick bar, open place: slub, slub weftways, buttons) are relatively difficult to detect. Similarly faults falling in categories 7 and 3 (trailers, pick trailers: slack, slack weft) are moderately difficult to detect and those falling in category 5 (drop ends, ends out, weft tails) are invariably relatively easy to detect.

The second source of variation in the "Within Subjects" section of the analysis of variance shown in Table 7 is the faults x conditions interaction. The variance ratio, 11.39, associated with this interaction is highly significant ($p < 0.001$). This implies that detection performance for fault categories is differentially dependent on experimental conditions. In other words, if detection performance were plotted against fault category for each of the four experimental conditions the four resultant lines would not be parallel.

The mean percentage of faults detected in each fault category for each of the four principal experimental conditions is shown in Table 14.

Two types of analysis have been performed on these means. In the first 't' tests have been carried out comparing detection performance between different fault categories for the same experimental condition. In the second 't' tests have been performed comparing detection performance between different experimental conditions for the same fault categories.

Analysis in which performance under different experimental conditions for different fault types, for example, performance under condition E for fault type 1 compared with performance under condition H for fault type 2, is considered, is not carried out. This was because the results obtained would have been meaningless in view of the overall significant differences found between respective fault types, and also between respective experimental conditions.

TABLE 14

Mean percentage of faults detected in each fault category for each of the four principal experimental conditions. Each value in the table is based on ten percentages.

Experimental Condition	Fault Category 1	2	3	4	5	6	7	8
E	48.70	19.20	40.90	19.60	80.70	33.00	43.60	58.80
H	69.90	34.20	49.70	29.70	61.10	37.10	45.00	22.10
EH	63.60	25.20	48.80	36.30	82.60	38.00	59.00	60.70
EHL_1	71.60	30.70	55.50	37.30	77.30	42.70	53.20	63.50

TABLE 15

Comparison by 't' test of the mean percentage of faults detected in each fault category for the experimental condition of eyes only (E).

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
5 - 1	32.0	3.71	224	8.63	p<0.001	24.69 to 39.31
5 - 2	61.5	3.71	224	16.58	p<0.001	54.19 to 68.81
5 - 3	39.8	3.71	224	10.73	p<0.001	32.49 to 47.11
5 - 4	61.1	3.71	224	16.47	p<0.001	53.79 to 68.41
5 - 6	47.7	3.71	224	12.86	p<0.001	40.39 to 55.01
5 - 7	37.1	3.71	224	10.00	p<0.001	29.79 to 44.41
5 - 8	21.9	3.71	224	5.90	p<0.001	14.59 to 29.21
8 - 1	10.1	3.71	224	2.72	0.001<p<0.01	2.79 to 17.41
8 - 2	39.6	3.71	224	10.67	p<0.001	32.29 to 46.91
8 - 3	17.9	3.71	224	4.82	p<0.001	10.59 to 25.21
8 - 4	39.2	3.71	224	10.57	p<0.001	31.89 to 46.51
8 - 6	25.8	3.71	224	6.95	p<0.001	18.49 to 33.11
8 - 7	15.2	3.71	224	4.10	p<0.001	7.89 to 22.51
1 - 2	29.5	3.71	224	7.95	p<0.001	22.19 to 36.81
1 - 3	7.8	3.71	224	2.10	0.02<p<0.05	0.49 to 15.11
1 - 4	29.1	3.71	224	7.84	p<0.001	21.79 to 36.41
1 - 6	15.7	3.71	224	4.23	p<0.001	8.39 to 23.01
1 - 7	5.1	3.71	224	1.37	0.1<p<0.2	-2.21 to 12.41
7 - 2	24.4	3.71	224	6.58	p<0.001	17.09 to 31.71
7 - 3	2.7	3.71	224	0.73	0.4<p<0.5	-4.61 to 10.01
7 - 4	24.0	3.71	224	6.47	p<0.001	16.69 to 31.31
7 - 6	10.6	3.71	224	2.86	0.001<p<0.01	3.29 to 17.91
3 - 2	21.7	3.71	224	5.85	p<0.001	14.39 to 29.01
3 - 4	21.3	3.71	224	5.74	p<0.001	13.99 to 28.61
3 - 6	7.9	3.71	224	2.13	0.02<p<0.05	0.59 to 15.21
6 - 2	13.8	3.71	224	3.72	p<0.001	6.49 to 21.11
6 - 4	13.4	3.71	224	3.61	p<0.001	6.09 to 20.71
4 - 2	0.4	3.71	224	0.11	p>0.9	-6.91 to 7.71

TABLE 16

Comparison by 't' test of the mean percentage of faults detected in each fault category for the experimental condition of hands only (H).

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
1 - 2	35.7	3.71	224	9.62	$p<0.001$	28.39 to 43.01
1 - 3	20.2	3.71	224	5.44	$p<0.001$	12.89 to 27.51
1 - 4	40.2	3.71	224	10.84	$p<0.001$	32.89 to 47.51
1 - 5	8.8	3.71	224	2.37	$0.01<p<0.02$	1.49 to 16.11
1 - 6	32.8	3.71	224	8.84	$p<0.001$	25.49 to 40.11
1 - 7	24.9	3.71	224	6.71	$p<0.001$	17.59 to 32.21
1 - 8	47.8	3.71	224	12.88	$p<0.001$	40.49 to 55.11
5 - 2	26.9	3.71	224	7.25	$p<0.001$	19.59 to 34.21
5 - 3	11.4	3.71	224	3.07	$0.001<p<0.01$	4.09 to 18.71
5 - 4	31.4	3.71	224	8.46	$p<0.001$	24.09 to 38.71
5 - 6	24.0	3.71	224	6.47	$p<0.001$	16.69 to 31.31
5 - 7	16.1	3.71	224	4.34	$p<0.001$	8.79 to 23.41
5 - 8	39.0	3.71	224	10.51	$p<0.001$	31.69 to 46.31
3 - 2	15.5	3.71	224	4.18	$p<0.001$	8.19 to 22.81
3 - 4	20.0	3.71	224	5.39	$p<0.001$	12.69 to 27.31
3 - 6	12.6	3.71	224	3.39	$p<0.001$	5.29 to 19.91
3 - 7	4.7	3.71	224	1.27	$0.2<p<0.3$	-2.61 to 12.01
3 - 8	27.6	3.71	224	7.44	$p<0.001$	20.29 to 34.91
7 - 2	10.8	3.71	224	2.91	$0.001<p<0.01$	3.49 to 18.11
7 - 4	15.3	3.71	224	4.12	$p<0.001$	7.99 to 22.61
7 - 6	7.9	3.71	224	2.13	$0.02<p<0.05$	0.59 to 15.21
7 - 8	22.9	3.71	224	6.17	$p<0.001$	15.59 to 30.21
6 - 2	2.9	3.71	224	0.78	$0.4<p<0.5$	-4.41 to 10.21
6 - 4	7.4	3.71	224	1.99	$0.02<p<0.05$	0.09 to 14.71
6 - 8	15.0	3.71	224	4.04	$p<0.001$	7.69 to 22.31
2 - 4	4.5	3.71	224	1.21	$0.2<p<0.3$	-2.81 to 11.81
2 - 8	12.1	3.71	224	3.26	$0.001<p<0.01$	4.79 to 19.41
4 - 8	7.6	3.71	224	2.05	$0.02<p<0.05$	0.29 to 14.91

TABLE 17

Comparison by 't' test of the mean percentage of faults detected in each fault category for the experimental condition of eyes plus hands under normal lighting conditions (EH).

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
5 - 1	19.0	3.71	224	5.12	$p<0.001$	11.69 to 26.31
5 - 2	57.4	3.71	224	15.47	$p<0.001$	50.09 to 64.71
5 - 3	33.8	3.71	224	9.11	$p<0.001$	26.49 to 41.11
5 - 4	46.3	3.71	224	12.48	$p<0.001$	38.99 to 53.61
5 - 6	44.6	3.71	224	12.02	$p<0.001$	37.29 to 51.91
5 - 7	23.6	3.71	224	6.36	$p<0.001$	16.29 to 30.91
5 - 8	21.9	3.71	224	5.90	$p<0.001$	14.59 to 29.21
1 - 2	38.4	3.71	224	10.35	$p<0.001$	31.09 to 45.71
1 - 3	14.8	3.71	224	3.99	$p<0.001$	7.49 to 22.11
1 - 4	27.3	3.71	224	7.36	$p<0.001$	19.99 to 34.61
1 - 6	25.6	3.71	224	6.90	$p<0.001$	18.29 to 32.91
1 - 7	4.6	3.71	224	1.24	$0.2<p<0.3$	-2.71 to 11.91
1 - 8	2.9	3.71	224	0.78	$0.4<p<0.5$	-4.41 to 10.21
8 - 2	35.5	3.71	224	9.57	$p<0.001$	28.19 to 42.81
8 - 3	11.9	3.71	224	3.21	$0.001<p<0.01$	4.59 to 19.21
8 - 4	24.4	3.71	224	6.58	$p<0.001$	17.09 to 31.71
8 - 6	22.7	3.71	224	6.12	$p<0.001$	15.39 to 30.01
8 - 7	1.7	3.71	224	0.46	$0.6<p<0.7$	-5.61 to 9.01
7 - 2	33.8	3.71	224	9.11	$p<0.001$	26.49 to 41.11
7 - 3	10.2	3.71	224	2.75	$0.001<p<0.01$	2.89 to 17.51
7 - 4	22.7	3.71	224	6.12	$p<0.001$	15.39 to 30.01
7 - 6	21.0	3.71	224	5.66	$p<0.001$	13.69 to 28.31
3 - 2	23.6	3.71	224	6.36	$p<0.001$	16.29 to 30.91
3 - 4	12.5	3.71	224	3.37	$p<0.001$	5.19 to 19.81
3 - 6	10.8	3.71	224	2.91	$0.001<p<0.01$	3.49 to 18.11
6 - 2	12.8	3.71	224	3.45	$p<0.001$	5.49 to 20.11
6 - 4	1.7	3.71	224	0.46	$0.6<p<0.7$	-5.61 to 9.01
4 - 2	11.1	3.71	224	2.99	$0.001<p<0.01$	3.79 to 18.41

TABLE 18

Comparison by 't' test of the mean percentage of faults detected in each fault category for the experimental condition of eyes plus hands under special oblique lighting conditions (EHL_L).

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
5 - 1	5.7	3.71	224	1.54	$0.1<p<0.2$	-1.61 to 13.01
5 - 2	46.6	3.71	224	12.56	$p<0.001$	39.29 to 53.91
5 - 3	21.8	3.71	224	5.88	$p<0.001$	14.49 to 29.11
5 - 4	40.0	3.71	224	10.78	$p<0.001$	32.69 to 47.31
5 - 6	34.6	3.71	224	9.33	$p<0.001$	27.29 to 41.91
5 - 7	24.1	3.71	224	6.50	$p<0.001$	16.79 to 31.41
5 - 8	13.8	3.71	224	3.72	$p<0.001$	6.49 to 21.11
1 - 2	40.9	3.71	224	11.02	$p<0.001$	33.59 to 48.21
1 - 3	16.1	3.71	224	4.34	$p<0.001$	8.79 to 23.41
1 - 4	34.3	3.71	224	9.25	$p<0.001$	26.99 to 41.61
1 - 6	28.9	3.71	224	7.79	$p<0.001$	21.59 to 36.21
1 - 7	18.4	3.71	224	4.96	$p<0.001$	11.09 to 25.71
1 - 8	8.1	3.71	224	2.18	$0.02<p<0.05$	0.79 to 15.41
8 - 2	32.8	3.71	224	8.84	$p<0.001$	25.49 to 40.11
8 - 3	8.0	3.71	224	2.16	$0.02<p<0.05$	0.69 to 15.31
8 - 4	26.2	3.71	224	7.06	$p<0.001$	18.89 to 33.51
8 - 6	20.8	3.71	224	5.61	$p<0.001$	13.49 to 28.11
8 - 7	10.3	3.71	224	2.78	$0.001<p<0.01$	2.99 to 17.61
3 - 2	24.8	3.71	224	6.68	$p<0.001$	17.49 to 32.11
3 - 4	18.2	3.71	224	4.91	$p<0.001$	10.89 to 25.51
3 - 6	12.8	3.71	224	3.45	$p<0.001$	5.49 to 20.11
3 - 7	2.3	3.71	224	0.62	$0.5<p<0.6$	-5.01 to 9.61
7 - 2	22.5	3.71	224	6.06	$p<0.001$	15.19 to 29.81
7 - 4	15.9	3.71	224	4.29	$p<0.001$	8.59 to 23.21
7 - 6	10.5	3.71	224	2.83	$0.001<p<0.01$	3.19 to 17.81
6 - 2	12.0	3.71	224	3.23	$0.001<p<0.01$	4.69 to 19.31
6 - 4	5.4	3.71	224	1.46	$0.1<p<0.2$	-1.91 to 12.71
4 - 2	6.6	3.71	224	1.78	$0.05<p<0.1$	-0.71 to 13.91

TABLE 19

Rank order of fault categories for each of the four principal experimental conditions. Magnitude of rank is inversely related to probability of detection. In a given column categories with the same rank order are not significantly different from one another. Categories with different ranks in a given column are significantly different from one another.

		Fault Category for :			
Rank	All Conditions	E	H	EH	EHL_1
1st	5	5	1	5	5, 1
2nd	1	8	5	1,8,7	8
3rd	8,7,3	1,7,3*	3,7	3	3,7
4th	6	6	6,2,4**	6,4	6,4,2
5th	4,2	4,2	8	2	

* Though 1 and 3 occur in the same row they are significantly different from one another, though neither are significantly different from 7.

** Though 6 and 4 and 2 occur in the same row they are significantly different from one another, though neither is significantly different from 2.

A different picture is presented by faults from categories 1 (knots) and 8 (stitched pick, pick out, pick and shuttle jump). Table 19 shows that fault category 1 contains faults which are detected primarily by touch. When touch alone is employed (H) fault category 1 ranks first in case of detection. When sight is combined with touch fault category 1 still comes out well and ranks high for both of the dual modality conditions employed in this experiment. Exposure of faults in category 1 under conditions which do not allow touch to be used result in poor detection. Thus, under condition E this fault category fares relatively badly. Similar statements apply to faults falling in category 8 except that the roles of touch and vision are reversed and the effect is more dramatic than was the case with category 1.

This portion of the analysis is extremely important because it extends that carried out on fault categories when no account was taken of the effect of experimental conditions (see Table 12). It is valuable to know that there are significant differences in detection performance between different fault categories but even more valuable to know that some of these differences and their significance vary according to experimental condition.

Though the above analysis throws considerable light on the source of the faults x condition interaction the second analysis carried out on the data in Table 14 is even more revealing. This analysis consisted, it will be recalled, of a comparison by 't' test of means in the same column. That is to say mean detection performances for different experimental conditions were compared for the same fault category. The results of this analysis are shown in Table 20. On the basis of this analysis the fault categories may be divided into three groups in terms of absolute detection performance. The first group consists of categories 5 and 8. Vision is of prime importance here. Detection performance is the same in conditions EHL_1, EH and E. Performance in these conditions is statistically different from and superior to, that found in condition H where only the sense of touch is employed.

The second group is comprised of categories where touch is of prime importance. Categories 1 and 4 clearly fall in this group. Performance is effectively the same in conditions EHL_1, EH and H. Performance in these conditions is statistically different from, and superior to, that found in condition E, where only the sense of sight is employed. Fault category 2 may also be included in this tactual group though the evidence is slightly less positive. All the statements made in this paragraph apply to category 2, except that relating to the comparison of the condition EH with the condition E. No statistical difference was found between performance under these two conditions.

TABLE 20

Comparison by 't' test of the mean percentage of faults found in each experimental condition for the same fault category.

Fault Category & Experimental Condition Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
H(1) - E(1)	21.2	4.88	57	4.34	p<0.001	11.44 to 30.96
H(2) - E(2)	15.0	4.88	57	3.07	0.001<p<0.01	5.24 to 24.76
H(3) - E(3)	8.8	4.88	57	1.80	0.05<p<0.1	-0.96 to 18.56
H(4) - E(4)	10.1	4.88	57	2.07	0.02<p<0.05	0.24 to 19.86
E(5) - H(5)	19.6	4.88	57	4.02	p<0.001	9.84 to 29.54
H(6) - E(6)	4.1	4.88	57	0.84	0.4<p<0.5	-5.66 to 13.86
H(7) - E(7)	1.4	4.88	57	0.29	0.7<p<0.8	-8.36 to 11.16
E(8) - H(8)	36.7	4.88	57	7.52	p<0.001	26.94 to 46.46
EH(1) - E(1)	14.9	4.88	57	3.05	0.001<p<0.01	5.14 to 24.66
EH(2) - E(2)	6.0	4.88	57	1.23	0.2<p<0.3	-3.76 to 15.76
EH(3) - E(3)	7.9	4.88	57	1.62	0.1<p<0.2	-1.86 to 17.66
EH(4) - E(4)	16.7	4.88	57	3.42	0.001<p<0.01	6.94 to 26.46
EH(5) - E(5)	1.9	4.88	57	0.39	0.6<p<0.7	-7.86 to 11.66
EH(6) - E(6)	5.0	4.88	57	1.02	0.3<p<0.4	-4.76 to 14.76
EH(7) - E(7)	15.4	4.88	57	3.16	0.001<p<0.01	5.64 to 25.16
EH(8) - E(8)	1.9	4.88	57	0.39	0.6<p<0.7	-7.86 to 11.66
EHL_1(1)-E(1)	22.9	4.88	57	4.69	p<0.001	13.14 to 32.66
EHL_1(2)-E(2)	11.5	4.88	57	2.36	0.02<p<0.05	1.74 to 21.26
EHL_1(3)-E(3)	14.6	4.88	57	2.99	0.001<p<0.01	4.84 to 24.36
EHL_1(4)-E(4)	17.7	4.88	57	3.63	p<0.001	7.94 to 27.46
E(5) -EHL_1(5)	3.4	4.88	57	0.70	0.4<p<0.5	-6.36 to 13.16
EHL_1(6)-E(6)	9.7	4.88	57	1.99	0.05<p<0.1	-0.06 to 19.46
EHL_1(7)-E(7)	9.6	4.88	57	1.97	0.05<p<0.1	-0.16 to 19.36
EHL_1(8)-E(8)	4.7	4.88	57	0.96	0.3<p<0.4	-5.06 to 14.46

TABLE 20 (Continued)

Fault Category & Experimental Condition Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
H(1) - EH(1)	6.3	4.88	57	1.29	$0.2 < p < 0.3$	-3.46 to 16.06
H(2) - EH(2)	9.0	4.88	57	1.84	$0.05 < p < 0.1$	-0.76 to 18.76
H(3) - EH(3)	0.9	4.88	57	0.18	$0.8 < p < 0.9$	-8.86 to 10.66
EH(4) - H(4)	6.6	4.88	57	1.35	$0.1 < p < 0.2$	-3.16 to 16.36
EH(5) - H(5)	21.5	4.88	57	4.41	$p < 0.001$	11.74 to 31.26
EH(6) - H(6)	0.9	4.88	57	0.18	$0.8 < p < 0.9$	-8.86 to 10.66
EH(7) - H(7)	14.0	4.88	57	2.87	$0.001 < p < 0.01$	4.24 to 23.76
EH(8) - H(8)	38.6	4.88	57	7.91	$p < 0.001$	28.84 to 48.36
EHL_1(1)-H(1)	1.7	4.88	57	0.42	$0.6 < p < 0.7$	-8.06 to 11.46
H(2)-EHL_1(2)	3.5	4.88	57	0.72	$0.4 < p < 0.5$	-6.26 to 13.26
EHL_1(3)-H(3)	5.8	4.88	57	1.19	$0.2 < p < 0.3$	-3.96 to 15.56
EHL_1(4)-H(4)	7.6	4.88	57	1.56	$0.1 < p < 0.2$	-2.16 to 17.36
EHL_1(5)-H(5)	16.2	4.88	57	3.32	$0.001 < p < 0.01$	6.44 to 25.96
EHL_1(6)-H(6)	5.6	4.88	57	1.15	$0.2 < p < 0.3$	-4.16 to 15.36
EHL_1(7)-H(7)	8.2	4.88	57	1.68	$0.05 < p < 0.1$	-1.56 to 17.96
EHL_1(8)-H(8)	41.4	4.88	57	8.48	$p < 0.001$	31.64 to 51.16
EHL_1(1)-EH(1)	8.0	4.88	57	1.64	$0.1 < p < 0.2$	-1.76 to 17.76
EHL_1(2)-EH(2)	5.5	4.88	57	1.13	$0.2 < p < 0.3$	-4.26 to 15.26
EHL_1(3)-EH(3)	6.7	4.88	57	1.37	$0.1 < p < 0.2$	-3.06 to 16.46
EHL_1(4)-EH(4)	1.0	4.88	57	0.20	$0.8 < p < 0.9$	-8.76 to 10.76
EH(5)-EHL_1(5)	5.3	4.88	57	1.09	$0.2 < p < 0.3$	-4.46 to 15.06
EHL_1(6)-EH(6)	4.7	4.88	57	0.96	$0.3 < p < 0.4$	-5.06 to 14.46
EH(7)-EHL_1(7)	5.8	4.88	57	1.19	$0.2 < p < 0.3$	-3.96 to 15.56
EHL_1(8)-EH(8)	2.8	4.88	57	0.57	$0.5 < p < 0.6$	-6.96 to 12.56

The third group contains categories whose faults seem to be equally detectable by sight or touch separately or in combination. This is certainly true for category 6 where there is no difference in performance between conditions EHL_1, EH, E and H. Categories 3 and 7 present a similar picture except that for the former, performance in condition EHL_1 is superior to that in E, and for the latter, performance in condition EH is superior to that in both E and H.

The results described in the three previous paragraphs based on the 't' tests shown in Table 20 account for the significance of the meaningful part of the "faults x conditions interaction" found in the analysis of variance shown in Table 7. Three other valuable conclusions may be drawn from Table 20. Firstly, in all categories both varieties of dual modality performance are not statistically superior to both varieties of single modality performance. In other words, performance in conditions EHL_1 and EH is never statistically superior to that found in both conditions E and H, though as has already been shown, it is frequently superior to performance in one or the other of the single modality conditions. This result is a valuable extension of that found when the effects on detection performance of experimental conditions alone were examined in the "Between Subjects" portion of the analysis of variance shown in Table 7. (See also Table 9). With no account taken of fault categories both varieties of dual modality performance were better than both varieties of single modality performance. This result is no longer true when fault categories are taken into account.

Secondly, performance in a single modality condition is never statistically superior to that in a dual modality condition though it is frequently much the same.

Thirdly, there is no significant difference between performances in the two dual modality conditions for any fault category. Thus, in no case is it possible to say that oblique supplementary light produced statistically more effective detection performance than standard lighting conditions. Nevertheless, it is perhaps worth noting that in six out of the eight categories, performance was marginally superior in the supplementary lighting condition. This result therefore does little to extend the conclusion reached when experimental conditions alone were examined in the "Between Subjects" portion of the analysis of variance shown in Table 7 (see also Table 9). With no account taken of fault categories no significant difference was found between performances under the two dual modality conditions. The conclusion now is that there is no evidence of a significant difference existing between performances in conditions EHL_1 and EH whether or not account is taken of fault categories.

Turning now to the third source of variation in the fault categories x ages interaction in the "Within Subjects" subdivision of the analysis of variance shown in Table 7, it will be seen that the variance ratio is 2.89 and that the result is highly significant ($0.001 < p < 0.01$). This implies that young and old operators' detection performance is differentially dependent upon the category in which faults occur.

However this result is not as clear cut as it seems for it includes comparisons between young subjects performance on one fault category, e.g. category 1 and older subjects performance on another category, e.g. category 8. In view of the highly significant differences obtained between fault categories little purpose is served in carrying out these types of comparisons.

The mean percentage of faults detected by each age group for each of the eight fault categories is shown in Table 21. These means are graphically displayed in Figure 15. Two types of analysis have been performed which are analogous to those carried out on the means of the fault categories x conditions data. In the first analysis 't' tests have been carried out comparing detection performance between different fault categories for the same age group. In the second 't' tests have been performed comparing the detection performance of the two age groups for the same fault category.

The results of the first set of 't' tests are shown in Tables 22 and 23. To simplify the presentation these tables have been summarised in Table 24. This shows fault categories ordered in terms of excellence of performance for each of the age groups. Included in Table 24 is the order in which fault categories occur when no distinction is made between age groups (see Table 13). The order of difficulty of six of the fault categories is essentially the same for the groups. These are 5, 1, 7, 3, 6 and 2. Two fault categories are differently positioned in the two orders. These are 8 and 4. Old subjects do better relatively speaking on the former while young subjects do better on the latter.

The second analysis, shown in Table 25 and in which 't' tests have been carried out comparing mean detection performance between each age group for the same fault category, largely confirms the results of the first analysis. In seven out of the eight fault categories (5, 1, 7, 3, 6, 4 and 2) the younger group does better than the older group. Nevertheless in six of these seven cases the difference in performance is not significant. In the seventh case, fault category 4, the detection performance of younger subjects is much superior to that of older subjects ($t = 2.80$, $0.001 < p < 0.01$). In the remaining fault category, 8, which depends highly on visual detection skills, older subjects do better than younger subjects. This result, which is contrary to the general trend is almost significant at the five percent level ($t = 1.70$, $0.05 < p < 0.1$).

TABLE 21

Mean percentage of faults detected by each age group for each of the eight fault categories. Each value in the table is based on twenty percentages.

Group of Subjects	Fault Category							
	1	2	3	4	5	6	7	8
Y	63.65	27.95	50.60	35.55	77.35	39.95	52.70	48.35
O	63.25	26.70	46.85	25.90	73.50	35.45	47.70	54.20

Figure 15

Mean percentage of faults detected in each of the eight fault categories by each group of subjects. Each mean is based upon twenty percentages. To keep the graph clear 95% confidence limits have not been drawn. These are, however, equal to mean percentage of faults detected ± (2.44) (2.09) i.e. ± 5.10

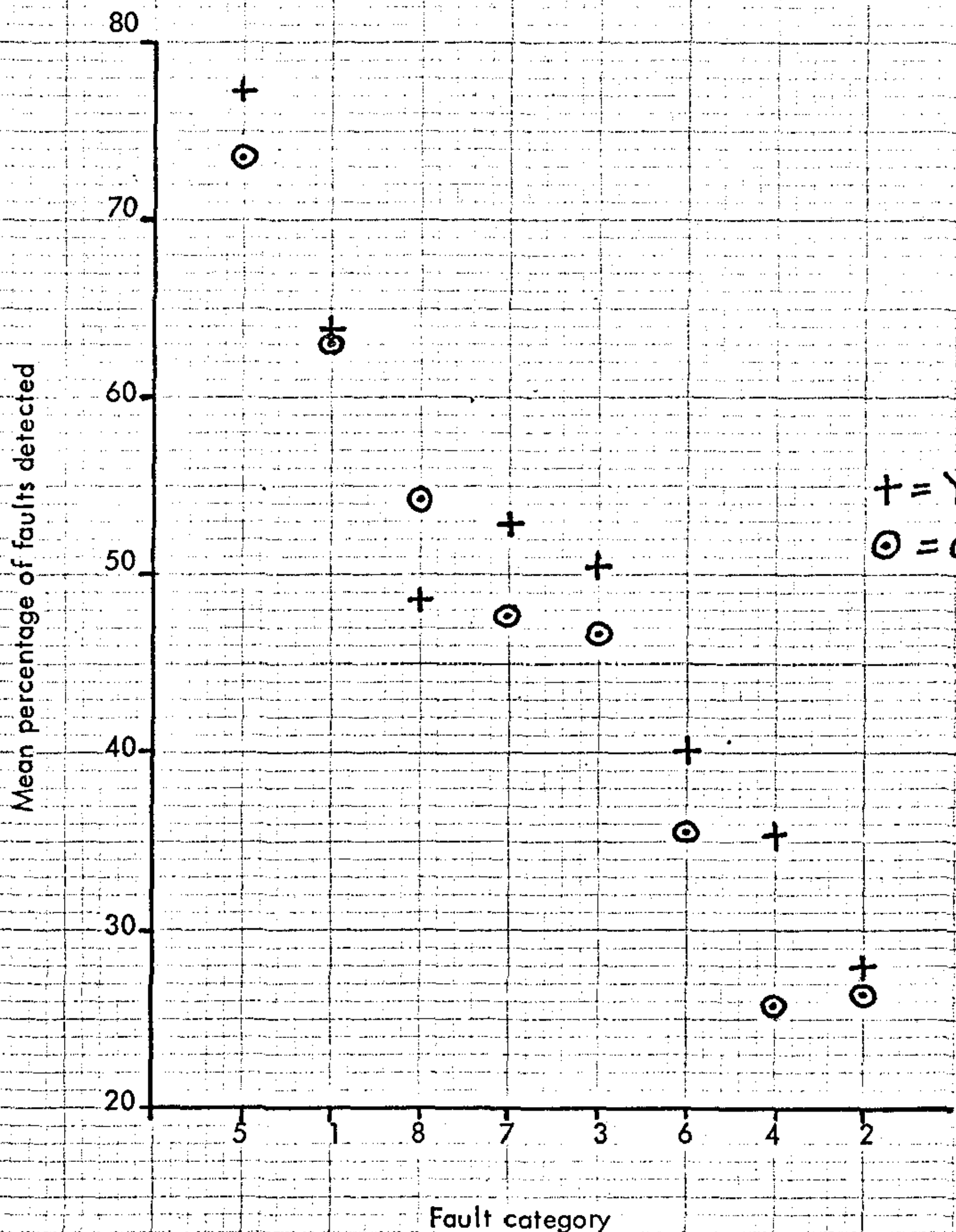


TABLE 22

Comparison by 't' test of the mean percentage of faults detected in each fault category by young subjects.

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
1 - 2	35.70	2.63	224	13.57	p<0.001	30.55 to 40.85
1 - 3	13.05	2.63	224	4.96	p<0.001	7.90 to 18.20
1 - 4	28.10	2.63	224	10.68	p<0.001	22.95 to 33.25
5 - 1	13.70	2.63	224	5.21	p<0.001	8.55 to 18.85
1 - 6	23.70	2.63	224	9.01	p<0.001	18.55 to 28.85
1 - 7	10.95	2.63	224	4.16	p<0.001	5.80 to 16.10
1 - 8	15.30	2.63	224	5.82	p<0.001	10.15 to 20.45
3 - 2	22.65	2.63	224	8.61	p<0.001	17.50 to 27.80
4 - 2	7.60	2.63	224	2.89	0.001<p<0.01	2.45 to 12.75
5 - 2	49.40	2.63	224	18.78	p<0.001	44.25 to 54.55
6 - 2	12.00	2.63	224	4.56	p<0.001	6.85 to 17.15
7 - 2	24.75	2.63	224	9.41	p<0.001	19.60 to 29.90
8 - 2	20.40	2.63	224	7.75	p<0.001	15.25 to 25.55
3 - 4	15.05	2.63	224	5.72	p<0.001	9.90 to 20.20
5 - 3	26.75	2.63	224	10.17	p<0.001	21.60 to 31.90
3 - 6	10.65	2.63	224	4.05	p<0.001	5.50 to 15.80
7 - 3	2.10	2.63	224	0.79	0.4<p<0.5	-3.05 to 7.25
3 - 8	2.25	2.63	224	0.85	0.3<p<0.4	-2.90 to 7.40
5 - 4	41.80	2.63	224	15.89	p<0.001	36.65 to 46.95
6 - 4	4.40	2.63	224	1.67	0.05<p<0.1	-0.75 to 9.55
7 - 4	17.15	2.63	224	6.52	p<0.001	12.00 to 22.30
8 - 4	12.80	2.63	224	4.86	p<0.001	7.65 to 17.95
5 - 6	37.40	2.63	224	14.22	p<0.001	32.25 to 42.55
5 - 7	24.65	2.63	224	9.37	p<0.001	19.50 to 29.80
5 - 8	29.00	2.63	224	11.02	p<0.001	23.85 to 34.15
7 - 6	12.75	2.63	224	4.84	p<0.001	7.60 to 17.90
8 - 6	8.40	2.63	224	3.19	0.001<p<0.01	3.25 to 13.55
7 - 8	4.35	2.63	224	1.65	0.05<p<0.1	-0.80 to 9.50

TABLE 23

Comparison by 't' test of the mean percentage of faults detected in each fault category by older subjects.

Fault Categories Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
1 - 2	36.55	2.63	224	13.89	$p<0.001$	31.40 to 41.70
1 - 3	16.40	2.63	224	6.23	$p<0.001$	11.25 to 21.55
1 - 4	37.35	2.63	224	14.20	$p<0.001$	32.20 to 42.50
5 - 1	10.25	2.63	224	3.89	$p<0.001$	5.10 to 15.40
1 - 6	27.80	2.63	224	10.57	$p<0.001$	22.65 to 32.95
1 - 7	15.55	2.63	224	5.91	$p<0.001$	10.40 to 20.70
1 - 8	9.05	2.63	224	3.44	$p<0.001$	3.90 to 14.20
3 - 2	20.15	2.63	224	7.66	$p<0.001$	15.00 to 25.30
2 - 4	0.80	2.63	224	0.30	$0.7<p<0.8$	-4.35 to 5.95
5 - 2	46.80	2.63	224	17.79	$p<0.001$	41.65 to 51.95
6 - 2	8.75	2.63	224	3.33	$p<0.001$	3.60 to 13.90
7 - 2	21.00	2.63	224	7.98	$p<0.001$	15.85 to 26.15
8 - 2	27.50	2.63	224	10.45	$p<0.001$	22.35 to 32.65
3 - 4	20.95	2.63	224	7.96	$p<0.001$	15.80 to 26.10
5 - 3	26.65	2.63	224	10.13	$p<0.001$	21.50 to 31.80
3 - 6	11.40	2.63	224	4.33	$p<0.001$	6.25 to 16.55
7 - 3	0.85	2.63	224	0.32	$0.7<p<0.8$	-4.30 to 6.00
8 - 3	7.35	2.63	224	2.79	$0.001<p<0.01$	2.20 to 12.50
5 - 4	47.60	2.63	224	18.09	$p<0.001$	42.45 to 52.75
6 - 4	9.55	2.63	224	3.63	$p<0.001$	4.40 to 14.70
7 - 4	21.80	2.63	224	8.29	$p<0.001$	16.65 to 26.95
8 - 4	28.30	2.63	224	10.76	$p<0.001$	23.15 to 33.45
5 - 6	38.05	2.63	224	14.47	$p<0.001$	32.90 to 43.20
5 - 7	25.80	2.63	224	9.81	$p<0.001$	20.65 to 30.95
5 - 8	19.30	2.63	224	7.34	$p<0.001$	14.15 to 24.45
7 - 6	12.25	2.63	224	4.66	$p<0.001$	7.10 to 17.40
8 - 6	18.75	2.63	224	7.13	$p<0.001$	13.60 to 23.90
8 - 7	6.50	2.63	224	2.47	$0.01<p<0.02$	1.35 to 11.65

TABLE 24

Rank order of fault categories for each group of subjects. Magnitude of rank is inversely related to probability of fault detection. In a given column categories with the same rank order are not significantly different from one another. Categories with different ranks in a given column are significantly different from one another.

Rank	Fault Category for:		
	All Subjects	Young Subjects	Old Subjects
1st	5	5	5
2nd	1	1	1
3rd	8, 7, 3	7, 3, 8	8
4th	6	6, 4	7, 3
5th	4, 2	2	6
6th			2, 4

TABLE 25

Comparison by 't' test of the mean percentage of faults detected by each age group for each of the eight fault categories

Fault Category	Age Groups Compared	Difference	Standard Error of Difference	DF	t	P	95% Confidence Limits of Difference
1	Y - O	0.40	3.45	57	0.12	$p > 0.9$	-6.49 to 7.29
2	Y - O	1.25	3.45	57	0.36	$0.7 < p < 0.8$	-5.64 to 8.14
3	Y - O	3.75	3.45	57	1.09	$0.2 < p < 0.3$	-3.14 to 10.64
4	Y - O	9.65	3.45	57	2.80	$0.001 < p < 0.01$	2.76 to 16.54
5	Y - O	3.85	3.45	57	1.12	$0.2 < p < 0.3$	-3.04 to 10.74
6	Y - O	4.50	3.45	57	1.31	$0.1 < p < 0.2$	-2.39 to 11.39
7	Y - O	5.00	3.45	57	1.45	$0.1 < p < 0.2$	-1.89 to 11.89
8	O - Y	5.85	3.45	57	1.70	$0.05 < p < 0.1$	-1.04 to 12.74

These results, like those for fault categories x conditions, extend in an important way the results which were obtained when only fault categories were considered. It is valuable to know that fault categories influence performance, but even more valuable to know that the influence of fault categories varies according to the age of the subjects.

The results for the fault categories x ages interaction mesh very neatly with other results which have already been described. It was found when the performances of the young and old workers were compared for the tactual situation that the average time taken by the latter was about twenty minutes less than the corresponding time taken by the former. On the other hand, in the analysis of the percentage of faults detected in the inspection task with no account taken of fault categories it appeared that the tactual performance of younger workers was marginally superior to that of older workers. It seemed that the older workers' gain in speed had been obtained at the sacrifice of some accuracy (see page 59). A similar result was obtained for the percentage of faults detected when fault categories were taken into account (see page 66).

In the light of these results it would be anticipated that if certain faults were shown to be detectable primarily by touch then the percentage of such faults detected by younger workers should be greater than the percentage detected by older workers. The relevant data are largely in agreement with this expectation. In the analysis of the fault categories x conditions interaction it was shown (page 77) that there were two fault categories where touch was of prime importance. These were categories 1 and 4. In the analysis of the fault categories x ages which has just been concluded it was shown that for category 4 the performance of young subjects was much superior to that of older subjects. As category 1 refers to knots which are relatively easily detected compared to category 4, the latter is the more searching test of tactual inspection skill. It would appear that older workers are faster but less accurate at inspecting with their hands than younger operators. Where the faults are specifically tactual the detection performance of younger workers is likely to be significantly superior. In this situation no statement can be made about speed.

The final source of variation in the "Within Subjects" portion of the analysis of variance shown in Table 7 is the fault categories x conditions x ages triple interaction. The mean square for this interaction is 60.7 which is slightly less than the residual mean square of 69.0. This signifies that the pattern of detection performance in the fault categories x conditions interaction is similar for the two age groups, and, what amounts to the same thing, that the pattern of detection performance in the fault categories x ages interaction is similar in the four experimental conditions. It would suggest that the variables chosen for investigation were relatively interdependent. The two double interactions fault categories x conditions and fault categories x ages have already been fully discussed and no further elaboration is necessary.

Summarising the results of this rather long section, it may be said that when detection results are analysed with due account taken of fault categories :-

(i) Experimental conditions exert a considerable effect on detection performance. This result is similar to that obtained in section 4.2 where no account was taken of fault categories.

(ii) Fault categories have a marked effect on detection performance.

(iii) The pattern of detection performance in the fault categories varies according to the age of the subjects and the experimental condition experienced.

4.4 Correlation Coefficients

Up to this point the analysis has been concerned with evaluating the results in terms of age and experimental conditions without examining what may be regarded as internal factors such as the possible effects of the order of appearance of a frame in the cloth and the number of faults in individual frames. As thirty seven frames formed the length of cloth and each frame was used as the unit from which measurements such as time taken and faults found originated, possible effect of the frames on performance cannot be ignored. Thus a number of correlation coefficients examining the relationship of "the frame position" and "faults within a frame" with other experimental variables were carried out. In addition a further correlational analysis in which the effects of age and experimental conditions were considered in terms of the internal factors such as frame position, was undertaken.

This involved three series of statistical tests.

(1) Rank order correlation coefficients to determine the effects of the positioning of frames in the cloth.

(2) Product-moment correlation coefficients to investigate overall relationships between factors of speed and accuracy, i.e. faults present per frame, total inspection time per frame and total number of faults detected per frame.

(3) Analyses of variance of correlation coefficients investigating mean differences between experimental conditions and age for the forty subjects.

4.4.1 Rank order correlations

This is the most appropriate technique as the factors being considered are in each case the order of occurence of a frame and its relation to other variables.

1A Rank order correlation coefficient between frame number (order of occurence of a frame) and rank order of the frame in terms of the number of faults appearing in the frame.

$r = 0.078$ $t = 0.48$ df 35 not significant

There is no relation between number of faults present in the frame and the order in which the frame occurs and the faults are in numerical terms therefore randomly distributed throughout the cloth.

1B Rank order correlation coefficient between frame numbers and a rank order from quickest to slowest of the total times taken by the forty subjects for each frame.

$r = -0.458 \quad t = 3.05 \quad df\ 35 \quad p < 0.001$

The subjects as a whole therefore worked faster toward the end of the cloth. This is contrary to the classical vigilance findings which would lead to an expectation of deterioration with time. As the subjects were not informed as to when the experiment would terminate this speeding up effect cannot be accounted for by the subjects anticipating its conclusion and producing an endspurt. Learning and familiarisation with the experimental procedure may account for the significant coefficient.

1C Rank order correlation coefficient between frame number and rank order from greatest to least of the total faults found by the forty subjects in each of the thirty-seven frames.

$r = 0.05 \quad t = 0.296 \quad df\ 35$ not significant

Subjects' perfomance in terms of accuracy (i.e. finding faults) is independent of the order of the frames in the cloth.

Since in 1A it was also shown that faults were randomly distributed it would appear that the traditional vigilance effect, of deterioration of perfomance with time was a non-significant factor. This is probably accounted for firstly in the relative difference between the task of cloth inspection on one hand and the traditional laboratory vigilance task on the other, and secondly in terms of the motivation associated with the respective tasks.

4.4.2 Product moment correlation coefficients

A basic correlation coefficient between the time taken to inspect the 37 frames of cloth and the percentage of faults found by each subject was undertaken for the forty subjects.

$r = .32 \quad t = 2.07 \quad df\ 38 \quad 0.02 < p < 0.05$

As a longer time indicates a slower performance, this significant result establishes that those who took longer to inspect found more faults.

2A Correlation coefficient between the number of faults present in a frame and the total time taken by the forty subjects to inspect each frame over all 37 frames.

$r = 0.739 \quad t = 6.54 \quad df\ 35 \quad 0.01 < p < 0.02$

This is an almost linear relation.

The subjects' performance in terms of speed is significantly related to the number of faults present in a frame, i.e. the more faults there are in the frame the slower the inspection time. There would appear to be two possible explanations. The first, in line with the classical vigilance approach, would suggest that the time a subject spends on any one frame is dependent on feedback. If no further faults appear available for inspection regardless of the number found expectation as to whether any further faults will be found is based on the time which has elapsed since the detection of the previous fault.

This means that after finding a fault the subject will search for another fault. If after a certain time no further faults are found the subject will discontinue the search and move on to the next frame. The termination of the inspection of a frame therefore would bear no direct relation to the number of faults previously detected, unless the time, between the location of the last fault and the discontinuing of the inspection of the frame, is very short indeed.

Alternatively and more likely each subject may scan each frame of the cloth by using a fixed method of scanning which takes a constant time for a given area of cloth. This time is increased by the additional time spent in locating and ascertaining the presence of each fault detected. The latter explanation would require a significant relationship between the overall time taken for the inspection of each frame and number of faults detected. If this held true then it would also necessitate a significant correlation between faults present in a frame (which, 2A, correlates with total time taken) and the overall number of faults found. This is seen to be the case in 2B and 2C.

2B Correlation coefficient between the total number of faults detected in each frame and the total time taken by the forty subjects to inspect each frame over all 37 frames.

$r = .861 \quad t = 9.98 \quad df\ 35 \quad p < 0.001$

The coefficient is almost linear and shows that the more faults there are found the longer the time taken for the inspection of any frame.

This result agrees with hypothesis proposed in 2A and shows a relationship between the number of faults detected and the time taken. It would appear to imply that the detection of each fault consumes a small increment in time in addition to that required for scanning the cloth.

2C Correlation coefficient between the number of faults present in a frame and the total number of faults detected in each frame by the forty subjects for each of the 37 frames.

$r = .84 \quad t = 9.20$ with 35 df $\quad p < 0.001$

There is a highly significant and nearly linear relationship between the number of faults available for detection in any one frame and the number detected in that frame. This result is dependent on the correlation coefficients discussed in 2A and 2B, and the highly significant result serves to confirm the explanation put forward in 2A. This proposes that each subject has a similar scanning pattern for all frames which takes a given time. Additional periods of time are expended in the detection of each fault. Thus any subject would have a probability of detecting a certain proportion of faults available. The value of the proportion detected would depend on scanning techniques. This indicates a proportional relationship between faults in the cloth and faults detected which is confirmed above.

4.4.3 Analysis of variance of the correlation coefficients calculated for each of the forty subjects.

TABLE 26

3A Analysis of variance of the correlation coefficients of faults present in a frame and the time taken to inspect that frame over the 37 frames by each of the forty subjects.

Source	SS	df	M.S.	F.	P.
Ages	0.01	1	0.010	0.37	N.S.
Conditions	0.20	3	0.067	2.48	N.S.
A x C	0.04	3	0.013	0.48	N.S.
Residual	0.86	32	0.027		
Total	1.111	39			

This analysis examines the hypothesis that the actual numerical value of the number of faults within each frame had no disproportionate effects on the time taken to scan that frame. Age differences, experimental condition differences and the interaction between the two are examined without the occurence of any significant differences.

What has been examined is the relationship between time taken per frame and the number of faults available for detection. Had differences been found it would have indicated that certain groups of subjects (age group or experimental condition group) spent disproportionate time inspecting certain of the frames. Since this did not occur one can assume that each subject maintained a similar kind of internal consistency in the time they spent in scanning each frame related to the number of faults present and they were sufficiently true to this pattern to produce correlations coefficients which show no fundamental differences when subjects were compared.

This would support the hypothesis advanced in 2A that each subject has a consistent scanning technique for the frames requiring a relatively constant time. Increases in this time can be related to extra time spent in locating faults which in turn has been shown (2C) to be dependent on the number of faults present.

TABLE 27

3B Analysis of variance of the correlation coefficients between the number of faults detected in a frame and the time taken to inspect that frame over the 37 frames by each of the forty subjects.

Source	SS	df	M.S.	F.	P.
Ages	0.01	1	0.01	0.5	N.S.
Conditions	0.03	3	0.01	0.5	N.S.
A x C	0.02	3	0.01	0.5	N.S.
Residual	0.74	32	0.02		
Total	0.80	39			

Here the hypothesis that the number of faults found within a frame has no disproportionate effects on the time taken to scan that frame is examined. No significant differences have been found and the hypothesis suggested in 3A (i.e. that subjects have a consistent scanning pattern requiring a constant time which is increased through time spent in locating a fault) is given further confirmation. It would also support the proposition, which is implied by the above, and substantiated in 2C that there is a strong overall relationship between faults found and faults present in the cloth.

TABLE 28

3C Analysis of variance of correlation coefficients between number of faults found in a frame and number of faults in that frame over the 37 frames for each of the forty subjects.

Source	SS	df	M.S.	F.	P.
Ages	0	1	0	0	N.S.
Conditions	0.139	3	0.046	9.2	$p<0.01$
A x C	0.03	3	0.01	2	N.S.
Residual	0.149	32	0.005		
Total	0.318	39			

This analysis examines the hypothesis that the actual numerical value of the number of faults within each frame had no disproportionate effect on the number of faults detected. In the analysis of variance (Table 4) in which subjects performances are compared it is the differences between scores which is being discussed. Here, however it is the relationship between performance achieved and possible performance. A subject who consistently finds 80% of the faults per frame throughout the cloth would have an almost identical correlation coefficient as a subject who consistently finds 60% of faults per frame. If, however, such consistency were not achieved, i.e. under certain circumstances a subject would find nearly all the faults within one frame but very few in another containing a similar number of faults then a low correlation between faults present and performance would be achieved. Inconsistencies of this kind occur in the analysis of variance of the correlation coefficients for conditions.

TABLE 29

Comparison by 't' test of the mean of the correlation coefficients (for faults found/faults present) for each of the four principal experimental conditions.

	Mean Diff	Std Error	df	t	P
EHL - E	0.153	0.038	32	4.02	$p<0.001$
EHL - H	0.019	0.038	32	0.05	N.S.
EHL - EH	0.056	0.038	32	1.47	N.S.
H - EH	0.037	0.038	32	0.97	N.S.
H - E	0.134	0.038	32	3.53	$p<0.001$
EH - E	0.097	0.038	32	2.55	$0.0125<p<0.025$

Whilst the significance of the results discussed above are not apparent from the correlation coefficient (faults present in each frame/ faults detected in each frame) in 2C, as the results of the subjects were totalled regardless of under which condition they worked, an examination of the 't' tests for the mean differences between conditions clarifies this situation. Significant differences occur between on the one hand conditions H, EH, EHL_1, and condition E on the other. As there are more faults which are inspected tactually than visually it would seem that when inspection is carried out by vision only then the faults which can potentially be detected are significantly less than the faults which can potentially be detected when the hands are involved. This results in a significantly different mean faults detected / faults per frame ratio (i.e. correlation coefficient) for condition E as against condition H, EH, and EHL_1. It highlights the importance of scanning the cloth completely with both senses when inspecting and indicates the kind of discrepancy which can occur when this is not carried out.

4.5 Summary of Results

No significant differences in speed of performance were found for experimental conditions, age differences or the interaction between the two.

2. Significant differences in the percentage of faults detected with no account taken of fault categories between conditions were found, showing EH and EHL_1, the dual modality conditions to produce a better performance than when the eyes (E) alone, but not when the hands (H) alone were used for inspection.

3. Significant differences in faults detected with fault categories taken into account were found between :

(i) conditions showing the dual modalities to produce better performance than the single modalities;

(ii) fault categories showing different kinds of faults to require different methods of detection;

(iii) the fault categories and conditions interaction showing certain faults are easier to detect than others and that these differences become more apparent when specific experimental conditions are used for inspection.

4. More faults rely on tactual rather than visual detection.

5. No significant age differences were found.

6. Subjects as a whole inspect faster as they reach the end of the cloth.

7. There is an almost linear relation between faults present in a frame and the total time taken to inspect that frame by the forty subjects.

8. There is an almost linear relation between the total number of faults detected in each frame and the total time taken by the forty subjects to inspect each frame.

9. There is an almost linear relation between number of faults present in a frame and the total number of faults detected in that frame.

10. Significant differences were found between the conditions; in this case E, and the three remaining conditions, H, EH, and EHL_1 respectively, when considering the analysis of variance for the correlation coefficients between faults found and faults present in the cloth for each of the forty subjects.

4.6 Discussion

Performance in cloth inspection which previously had been the subject of guesswork and estimation can now be considered more objectively. Knowledge of inspection performance had not embodied the number of occasions a piece of cloth required to be scanned before it could be said to be reasonably burled and mended.

Performance on a single inspection of twenty five yards of cloth under unrestricted conditions reveals the following:-

TABLE 30

	Mean % of faults detected as calculated from the raw total number of faults.	Mean % of faults detected as calculated from taking the mean of the % faults detected in each fault category.
EH	56.81	51.78
EHL_1	61.16	53.98

This means only a little over half the faults are detected, which is surely a disappointing performance when it is realised that no mending was involved. Perhaps the inherent difficulty of the task could have been predicted from casual observation of the care and concentration which had been displayed by the specially selected passers who participated in the experimental preparations. (This it will be recalled was part of the activity involved in setting up the experimental standard piece of cloth).

In fact it might be argued in the case of certain faults, that their detectability lies at or beyond the threshold level of human inspection performance. These faults whose presence could not necessarily be guaranteed were deliberately woven into the cloth yet despite the knowledge of their nature and approximate position, they could not be located. Their existence was later confirmed by the specialists responsible for the weaving and their position pointed out to the experimenter.

A second factor responsible for the level of performance obtained is thought to be associated with scanning techniques. Experimentally it has been demonstrated that certain faults are discovered essentially by the use of the hands, whilst others are detected primarily by the use of the eyes. Unless both sensory modalities are used to scan the entire area of the cloth, faults can be missed simply by employing the "wrong" modality to search the area in which they occur.

A third factor may also hamper inspection performance. Normally the success of inspecting and subsequently mending a fault is not revealed in real terms until after the finishing process. This would lead to a system of slow feedback to the mending room. Also the condition of the cloth after finishing would be very different to that found in the mending room and Taylor (1956) has suggested that this would result in different judgements being made with regard to the amount of mending required. Generally it is suspected that cloth is overmended and this general information would be passed on. It is possible that this could influence inspection performance. It is worth noting that very few errors of commission were recorded. This was probably because the subject had control over the duration of the task and in cases of uncertainty could spend additional time in conducting her search. Thus in terms of Swets decision theory this would have been a case in which the overlap between the distributions for noise and noise + signals would have been minimal. It is of course possible that certain errors of omission may have occured when faults such as wrong twists, which, it is suggested, lie at the threshold of human perceptual ability, may have been detected and subsequently lost as the angle of vision momentarily altered. No report may have been given under such circumstances.

The mean times taken to inspect the twenty five yards of cloth under unrestricted conditions were as follows :-

EH	EHL_1
50.5 minutes	44.4 minutes

As a full piece of cloth is about 75 yards in length, this means a range of inspection time of approximately two to two and a half hours would be required. As has already been pointed out, this would certainly not result in all the faults being detected. Further inspection would be necessary and in practice, on many occasions the same piece of cloth would be inspected up to five times. An independent survey carried out by the Woollen Industries Research Association shows that an average of 19 hours is spent mending a piece. As automation of burling and mending is extremely unlikely in the foreseeable future and a persistent female labour shortage makes this process a bottleneck it is indeed necessary that performance in this sphere is improved.

The age dividing line of 30 years is a meaningful one in terms of burling and mending. Most menders begin training and working upon leaving school. They continue for a number of years, get married and eventually stop working finally in order to have children. When the children reach school going age the women often return to the mending rooms and put in many more years of work. This does tend to mean a bimodal population with a low frequency about the age of thirty. This was exactly the case in the sample used in the experiment.

The results found, serve to emphasise the difficulties that lie in trying to draw conclusions and create generalisations regarding the effect of age on performance. No significant differences were found except those concerning fault category and age interaction and here many factors other than age had to be accounted for. Several clear trends, although not always significant, did tend to emerge and these were later confirmed in Experiment 2. Older women tended to rely less on their hands for inspection and more on their eyes (postulated by Belbin, Belbin and Hill, 1956). Consequently less tactual search meant that they were marginally quicker. However, as more faults required tactual rather than visual modality detection they tended to find less faults overall. This difference in approach implied that older women due to the effects of practice would perform better than younger women when using their eyes only for inspection whereas the reverse would apply for younger women. This was found to be the case.

Performance however did not show any wider age discrepancies and though the known effects of physiological deterioration, of e.g. eyesight would be bound to result in performance decrements at some stage, this could not be concluded in respect of the experiments described.

Traditional vigilance theory suggests that as the frequency of signals increases so the proportion of signals detected increases. Some evidence of this was found in the investigation (4.4.2 correlation coefficient 2C), where a significant correlation was found between the number of faults present and the number detected.

Deese and Ormond (1955) also postulated an hypothesis in which they stated "the feedback from the search task determines what the observer expects from further participation in the task in a simple proportional relationship and his vigilance will vary accordingly". This feedback would maintain the arousal level of the subject. In one sense this would seem to be confirmed by the high correlation between the faults found and the time taken. However another factor must be considered. In terms of the total times taken by subjects, though significantly less faults were found under the condition of E, more time (though not significantly more time) was taken than inspection under the EH and EHL_1 conditions. (As the H condition contains elements of balance and orientation as the subjects were blindfolded this cannot be considered in the same way). Finding less faults under condition E in theory should lead to less feedback and an earlier termination of the inspection task resulting in faster inspection, yet this is not the case! It would appear more likely that a fairly fixed pattern of scanning takes place regardless of the number of faults found. It is postulated that normally a certain area of the cloth is scanned independently by the hands or the eyes without any overlapping. The longer period of time required for the E condition might simply be a reflection of the additional scanning that is required when the eyes are forced to scan a greater area of the cloth than would normally be their practice.

It was for this reason that the correlation between the faults present in a frame and the time taken to inspect the frame (see 4.4.1 correlation coefficient 2A) was thought to be less likely to depend on feedback, i.e. the termination of the inspection of a frame depending on the amount of time that has elapsed since the last fault was located.

The explanation proposed involved a constant scanning time for any given area of cloth. This time is increased by the additional time spent in locating and ascertaining the presence of each fault detected.

Thus it would appear that in circumstances where the quantitative aspects of a detection task are known and feedback is relatively plentiful the dependence on the feedback in terms of performance becomes less important whilst the dependence on the quantitative aspects of the task become more so. Thus whilst in principle the theory of arousal would still apply the need for feedback in terms of signals is not critical and the level of arousal is maintained by the knowledge of the magnitude or duration of the task. These circumstances are more applicable to industrial inspection tasks than to those examined in terms of classical vigilance.

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Before any experimental work was initiated considerable liaison had taken place with Woollen industry personnel, and a great deal of information gathered. It was found that there were differences of opinion as to the nature of several factors affecting inspection performance. One of these factors concerned the value of angular lighting.

Certain mills took tremendous care with lighting, and, particularly in the case of new premises, made certain that they had good conditions of illumination. However, though Bellchambers and Phillipson (1962) suggested that "surface texture and faults which are comparatively small depressions or projections of the surface material should be examined with light falling at grazing inclination", angular illumination has not of late been formally introduced. By altering the angle at which cloth is held in relation to overhead lighting the burlers and menders themselves introduce an element of angular lighting though this is not supplemented with additional lighting apparatus.

There is nothing new about angular lighting, which in the past has been used in several mills with varying opinion as to its worth. With the means to gain objective measures available, it seemed opportune to clarify the contribution that angular lighting might make to the inspection performance of burling and mending. It would be true to say that a fault once located by means of angular lighting could then be repaired in accordance with the menders ability. The key use of the angular lighting would therefore lie in the inspection content of the task.

Once the results of the first experiment had been presented to members of the woollen industry, request for further experimentation and clarification were made and with this co-operation forthcoming it was possible to carry out another experiment specifically in the area of angular lighting.

CHAPTER V

EXPERIMENT 2

5.1 Introduction

This experiment is in many ways a facsimile of the earlier experiment though it fulfills a different purpose. In duplicating the circumstances and apparatus under which the first experiment was carried out, it was planned thus to overcome the difficulties encountered in obtaining skilled subjects and to make use of the basic data already gathered. This data was incorporated in the present exercise, and used to assess the value of angular lighting in the inspection of cloth.

The previous equipment used represented a very tentative approach to evaluating angular lighting as an inspection aid, and while it is recognised that a sophisticated series of experiments examining variations in the levels of lighting, the types of lighting, and the positioning of the lighting, would be required before any final conclusion could be reached, it was considered worthwhile attempting to improve on the first evaluation attempt. In this case a far more powerful battery of lighting was used, with the object of testing the possible effect of really strong lighting on inspection performance.

It is recognised that there may be an optimum value of lighting somewhere between the two extremes discussed in this thesis, however thisstudy, it was felt, would prove to be an important step, in objectively determining the value of angular lighting for cloth inspection.

The Woollen Industries Training Board (W.I.T.B.) agreed to collaborate and do their best to make the necessary facilities available to allow the experiment to take place.

5.2 Experimental Design

This was based entirely on Experiment 1. There were three experimental conditions : (1) the normal condition, EH; (2) the angular lighting condition, EHL_1 in which a 240 Watt bulb and shade were used. Both of these were part of the earlier experiment and the results obtained then were used for comparative purposes with (3) the new angular lighting condition EHL_2, which made use of five 500 Watt photoflood lights.

Ten subjects participated in Condition EHL_2. They were divided into two age groups, an over 30 group and an under 30 group. This is all in accordance with the design of the earlier experiment. Thus the experimental design is again of the split plot analysis of variance form and simple to analyse.

5.3 Apparatus

Unfortunately due to administration difficulties the room in which the previous experiment was held was not available, but the W.I.T.B. provided space in their mending rooms which allowed a reasonable facsimile of the previous work place to be constructed.

Whereas previously a conference room, which had a quiet and undisturbed atmosphere, was used, on this occasion a room at the W.I.T.B. mending school was employed. In the latter the normal intake of trainees were at work near the experimental site. Thus a different atmosphere prevailed.

Most of the equipment used in the present investigation was also used in Experiment 1 and will be only briefly described here. This includes the experimental table, the seating arrangements, the cloth, the photographic and other recording apparatus. The principle exception involves the new angular lighting apparatus which will be discussed in some detail.

It is readily appreciated that good overhead lighting is necessary to see a large number of faults which are actually in the cloth. Certain classes of faults which lie in the cloth and all classes of faults which protrude above the cloth surface are difficult to see with simple overhead lighting. It was thought possible that these faults could be perceived by using supplementary oblique lighting.

The use of this procedure gives rise to a number of problems.

Firstly, the level of illumination received on the surface of the cloth from the angular lighting must be relatively intense particularly if substantial overhead lighting is being used. Otherwise no shadow effect occurs and the angular lighting fails to make its presence felt. Secondly, there is the problem of locating the angular lighting. As the level of illumination falls off with distance according to the Inverse Square Law, it will be appreciated that the experimental cloth which measures six feet across would have a higher level of illumination on one side than the other if the supplementary light source was placed on one side of the table. Alternatively if two angular light sources were used, one at each side of the table they would partially interfere with each other. As the practical aim of the experiment was to produce some sort of portable angular lighting which might be adopted by the industry which initiated the experiment, a single source of illumination was considered more suitable. Its limitations were therefore accepted and the objectives were aimed at attaining lighting which would provide a shadow or contrast effect where faults existed throughout the width of the cloth. The arbitrary method of deciding what constituted a contrast was an observed difference of a minimum of five lumens per square foot, at the edge of the width of the cloth furthest from the angular lighting, between readings taken with the overhead lighting operating alone and the overhead and angular lighting on simultaneously (see Appendix 5).

Several other difficulties presented themselves with the choice of angular lighting equipment. Firstly in order to get the contrast just described it was necessary to have a light source of considerable intensity - this could have been achieved with photoflood lamps, however, these give off sufficient radiant heat to cause a great deal of discomfort to anyone in close proximity.

Standard manufactured fluorescent lighting did not present this problem. However, the size of fluorescent lighting made it difficult to construct a battery of these lights, which would be sufficiently intense for the purposes of the experiment, without becoming completely unwieldy. The output of standard manufactured two-feet fluorescent tubes and even four-feet and five-feet tubes do not provide sufficiently strong light sources to compensate for their awkward size in the context of the experiment.

Consequently five photoflood lamps each of 500 Watts were used in a specially constructed reflector. This was placed at an angle of 30° to 35° to the near edge of the work table, four and a half to five feet away from the table (see Figures 16 and 17) and slightly behind a line continuing from the edge of the work table nearest a subject.

This position was found by a process of trial and error in which the illumination requirements of the experiment were met with minimum accompanying radiant heat and glare.

The subjects were provided with a green eye shade to help shield their eyes from any glare from the powerful angular lighting.

5.4 Experimental Procedure

The subject was taken to the experimental work table and given instructions to find and name all the faults on the cloth in each two-feet frame whilst working at her normal pace. In fact these instructions were the appropriate sections of the original instructions given in the first experiment (see Appendix 2).

The subject was then placed in the seat at a comfortable height in relation to the table. The footrest was also adjusted accordingly. It was preferred that the subject should remain seated throughout the experiment, however one or two subjects were difficult to restrain in this way since they explained they normally preferred to stand at work and they were allowed to have their way.

The subjects inspected the cloth frame by frame using their hands and eyes and were timed and scored by the experimenter who also turned on the cloth from one frame to the next. This continued until the 37 frames had been completed.

5.5 Treatment of Data

This follows largely the procedure used in Experiment 1 (see page 44) and makes use of the data on conditions EH, EHL_1, and condition EHL_2 of the present experiment.

Figure 16 The experiment in progress under the angular lighting condition EHL_2.

Figure 17 Another view of the experimental lay out.

This resulted in three sets of analyses :

1. Analysis of Variance for total time taken by each subject.

2. Analysis of Variance for total faults found by each subject.

3. Analysis of Variance for faults found after account had been taken of fault category.

CHAPTER VI

RESULTS

In discussing the results attention will be specifically directed toward evaluating the new condition and no effort will be made at restating or rediscussing results solely involving the two conditions from the earlier experiment.

6.1 Time Taken to Complete Inspection Task

TABLE 31

Analysis of variance on the time taken to inspect the 37 frames of cloth

Source	DF	SS	MS	Variance Ratio	P
Conditions(C)	2	728,954.07	364,477.04	0.43	NS
Ages (A)	1	92,296.54	92,296.54	0.01	NS
A x C	2	1,234,218.46	617,109.23	0.73	NS
Residual	24	20,234,810.40	843,117.10		
Total	29	22,290,279.47			

It can be seen that the non-significant differences intime taken previously found are again repeated and it seems that skilled subjects do not vary significantly in the time required to inspect cloth.

TABLE 32

Mean total times in seconds to complete the 37 frames by the two age groups working under the three experimental conditions. Each value in the body of the table is the mean of five totals. Value given at the end of a row are based on fifteen totals, those given at the foot of a column are based on ten totals.

Experimental Conditions		EH	EHL_1	EHL_2	Total
Groups of	Y	3342.50	2479.80	2973.60	2931.97
Subjects	O	2716.40	2845.20	2901.40	2821.00
	Total	3029.45	2662.50	2937.50	

The EHL_1 condition produced fastest inspection and the EHL_2 only slightly quicker inspection than the EH normal condition. However, since none of these differences vary significantly from zero not too much should be read into them. It was disappointing to find no increase in speed as the previous trend suggested that this might occur with improved lighting.

It is interesting to note that the original difference in speed which showed older subjects to be quicker than the younger subjects has been maintained. Also no interaction occurs between age and conditions which means groups of subjects are affected in the same way by conditions.

6.2 Percentage of Faults Detected in the Inspection Task with no Account Taken of Fault Categories

TABLE 33

Analysis of variance on (the percentage total of) faults detected over the 37 frames of cloth with no account taken of fault categories.

Source	DF	SS	MS	Variance Ratio	P
Conditions (C)	2	420.77	210.39	6.79	$p<0.01$
Ages (A)	1	19.76	19.76	0.64	NS
A x C	2	43.78	21.89	0.71	NS
Residual	24	743.76	13.99		
Total	29	1228.07			

A significant result between conditions was obtained and this was an important factor fundamental to the findings of the experiment. The variance ratios associated with the ages and ages x conditions interaction are non-significant and this ties up with the results achieved previously.

TABLE 34

Mean percentage of faults detected over the 37 frames by the two age groups working under the three experimental conditions with no account taken of fault categories. Each value in the body of the table is the mean of five percentages. Values given at the end of a row are based on fifteen percentages. Those given at the foot of a column are based on ten percentages.

Experimental Conditions		EH	EHL_1	EHL_2	Experimental Conditions Combined
Groups of Subjects	Y	55.95	62.67	67.75	62.12
	O	57.69	59.65	64.22	60.52
Groups of Subjects Combined		56.82	61.16	65.98	

The performance of the subjects under the enhanced lighting condition EHL_2 further reflects the trend towards improved performance suggested by the condition EHL_1 (see figure 18).

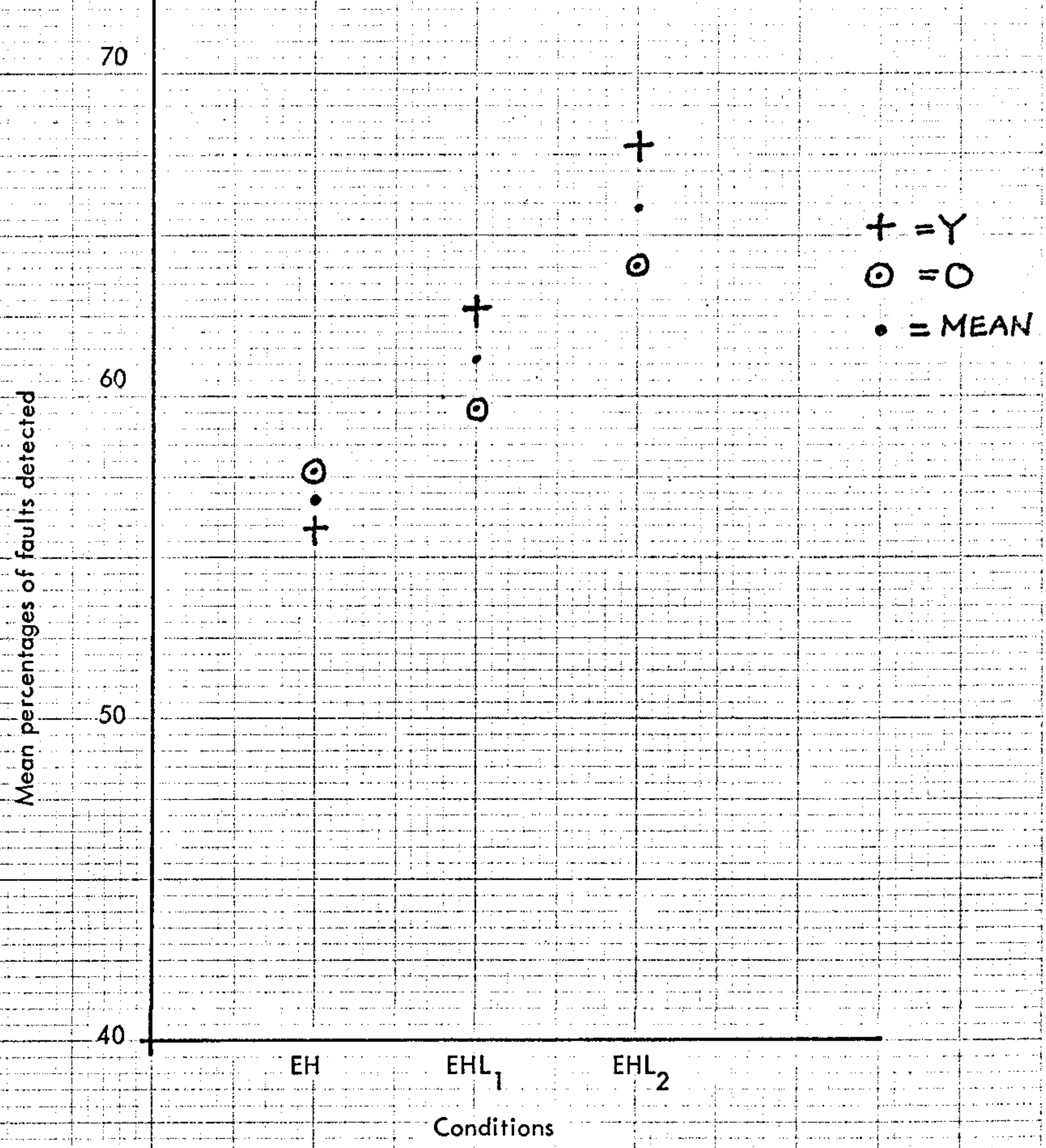
TABLE 35

Comparison by 't' test of the mean percentage of faults detected under the experimental condition of EHL_2 with the EHL_1 and EH conditions over the 37 frames of cloth when no account is taken of fault categories.

Conditions Compared	Difference	Std. Error of Diff.	DF	t	P	95% Confidence Limits of Difference $t \pm 5.13$
EHL_2-EHL_1	4.82	2.49	24	1.94	$0.05<p<0.1$	-0.31 to 9.95
EHL_2- EH	9.16	2.49	24	3.68	$0.001<p<0.01$	4.03 to 14.29
EHL_1-EH	4.34	2.49	24	1.74	$0.05<p<0.1$	-0.79 to 9.47

Figure 18

Mean percentage of faults detected in each of the three experimental conditions with no account taken of fault categories. The 95% confidence limits for each mean are not shown. They are, however, equal to the mean percentage of faults detected ± (1.75) (2.06), i.e. ± 3.63. Also shown are the mean values for the two age groups.



This is a most important result for it shows a significant difference in performance between EHL_2 and EH the normal working condition, an improved detection performance of just over 16%. Since all other aspects of the experiment were controlled and the subjects randomly selected and matched on age, the main purpose of this experiment was thus broadly achieved and it remains for further refinement and experimentation to produce a prototype of an optimum portable side light which could be used by the industry.

6.3 Percentage of Faults Detected in the Inspection Task with Fault Categories Taken into Account

TABLE 36

Analysis of variance on percentage of faults detected

Source	DF	SS	MS	Variance Ratio Against (a)	Variance Ratio Against (b)	P
Between Subjects	29	10,325.49	356.05			
Conditions (C)	2	1,720.14	860.07	2.61		NS
Ages (A)	1	437.41	437.41	1.33		NS
A x C	2	251.89	125.99	0.38		NS
Residual	24	7,916.05	329.84			
Within Subjects	210	90,537.50				
Fault Categories (F)	7	53,742.45	7,677.49		41.84	$p < 0.001$
F x C	14	4,125.00	294.64		1.60	NS
F x A	7	556.26	79.47		0.43	NS
F x C x A	14	1,257.44	91.96		0.50	NS
Residual	168	30,826.35	183.49			
Total	239	100,862.99				

This analysis with the exception of 'fault categories' has no significant results, and 'fault categories' were dealt with earlier in great detail.

This was mildly surprising as "conditions" had proved a significant factor in the analysis of variance in Table 31, when no account was taken of fault categories. This would appear to indicate that the differences in fault detection found between conditions has been distributed amongst the fault categories in a manner which reveal only small differences.

Fault categories which showed significant differences at the .001 level have already been dealt with in great detail during the results of the first experiment.

6.3.1 Conditions and ages

TABLE 37

Mean percentage of faults detected under each of the three principal experimental conditions. Each value in the table is based on eight percentages.

Experimental Conditions			Experimental Conditions Combined
EH	EHL_1	EHL_2	
51.78	53.98	58.23	54.66

The overall result showed no significance, and as this was contrary to the result achieved when fault types were not considered it seemed worthwhile examining these means. Certainly the EHL_2 condition shows the sort of increment over EH (normal) that would be expected in light of the results shown for the total percentage faults found.

TABLE 38

Comparison by 't' test of the mean percentage of faults detected under the four principal experimental conditions.

Conditions Compared	Diff.	Std. Error of Diff.	DF	t	P	95% Confidence Limits $t \pm 5.91$
EHL_2-EHL_1	4.25	2.87	24	1.48	$0.1<p<0.2$	-1.66 to +10.16
EHL_2- EH	6.45	2.87	24	2.25	$0.02<p<0.05$	+0.54 to +12.36
EHL_1-EH	2.20	2.87	24	0.77	NS	-3.71 to 8.11

A significant difference too, is found between the means for EHL_2 and EH when results are based on fault types. The improvement in detection performance against that achieved whilst working under normal conditions is over 12%. However too much should not be read into this result for conditions were overall not a statistically significant factor.

TABLE 39

Mean percentage of faults detected over the 37 frames by the two age groups working under the three experimental conditions, taking into account the eight fault categories. Each value in the body of the table is the mean of forty percentages. Values given at the end of a row are based on 120 percentages. Those given at the foot of a column are based on eighty percentages.

		Experimental Condition			Experimental Conditions Combined
		EH	EHL_1	EHL_2	
Groups of Subjects	Y	52.88	56.40	58.75	49.51
	O	50.68	51.55	57.70	46.69
Groups of Subjects Combined		51.78	53.98	58.23	

These results are essentially similar to those obtained, without fault categories being considered, in Table 32. In this case, no 't' test analysis has been carried out as a non significant result was obtained for the "Ages" and the "Ages x Conditions" interaction.

6.3.2 Fault categories and interactions

TABLE 40

Mean percentage of faults detected in each fault category. Each value in the table is based on thirty percentages.

Fault Category							
1	2	3	4	5	6	7	8
70.20	31.37	54.27	40.20	81.00	45.73	53.27	60.73

TABLE 41

Comparison by 't' test of the mean percentage of faults detected in each of the eight principal fault categories.

Fault Categories Compared	Diff	Std. Error of Diff	D.F.	t	P	95% Confidence Limits t ± 6.90
5 - 1	10.80	3.50	168	3.09	<0.001	3.80 to 17.70
5 - 2	49.63	3.50	168	14.18	<0.001	42.73 to 56.53
5 - 3	26.73	3.50	168	7.64	<0.001	19.83 to 33.63
5 - 4	40.30	3.50	168	11.50	<0.001	33.40 to 47.20
5 - 6	35.27	3.50	168	10.08	<0.001	28.37 to 42.17
5 - 7	27.73	3.50	168	7.92	<0.001	20.83 to 34.33
5 - 8	20.27	3.50	168	5.79	<0.001	13.37 to 27.17
1 - 2	38.83	3.50	168	11.09	<0.001	31.93 to 45.73
1 - 3	15.93	3.50	168	4.55	<0.001	9.03 to 22.83
1 - 4	29.50	3.50	168	8.43	<0.001	22.60 to 36.40
1 - 5	24.47	3.50	168	6.99	<0.001	17.57 to 31.37
1 - 7	16.93	3.50	168	4.84	<0.001	10.03 to 23.63
1 - 8	9.47	3.50	168	2.71	0.001< p<0.01	2.57 to 16.37
8 - 2	29.36	3.50	168	8.39	<0.001	22.46 to 36.26
8 - 3	6.46	3.50	168	1.85	0.05<p<0.1	-0.44 to 13.36
8 - 4	20.03	3.50	168	5.72	<0.001	13.13 to 26.93
8 -6	15.00	3.50	168	4.82	<0.001	8.10 to 21.90
8 - 7	7.46	3.50	168	2.13	0.025<p<0.05	0.56 to 14.36
3 - 2	22.90	3.50	168	6.54	<0.001	16.00 to 29.80
3 - 4	13.57	3.50	168	3.87	<0.001	6.67 to 20.47
3 - 6	8.54	3.50	168	2.44	0.01<p<0.025	1.64 to 15.44
3 - 7	1.00	3.50	168	0.29	p>0.50	-5.90 to 7.90
7 - 2	21.90	3.50	168	6.26	<0.001	15.00 to 28.80
7 - 4	12.57	3.50	168	3.59	<0.001	5.67 to 19.67
7 - 6	7.54	3.50	168	2.15	0.025<p<0.05	0.64 to 14.44
6 - 2	14.36	3.50	168	4.10	<0.001	7.46 to 21.26
6 - 4	5.03	3.50	168	1.44	p>0.25	-1.87 to 11.93
4 - 2	9.33	3.50	168	2.67	0.001<p<0.01	2.43 to 16.23

TABLE 42

Faults	
1st Category	No. 5
2nd Category	No. 1
3rd Category	No. 8, 7, 3 (1)
4th Category	No. 6, 4
5th Category	No. 2

(1) 8 is significantly better than 3.

Table 42 simplifies the results obtained in Table 41. The table has been set out so as to show significant differences between overall performance on fault categories. If a fault category has been placed first it means that performance on those faults was statistically significantly better than all others. Faults placed second indicate a statistically significantly better performance than on the remaining fault categories and so forth. Any categories placed in the same rank show no statistically significant differences.

Differences between Experiment 1 and Experiment 11 are minimal. This is not surprising as both have conditions EH and EHL in common. Also all the significant differences shown between fault categories may not be real as 28 't' tests were carried out and by chance alone one or even two results could be expected to be significant at the .05 level.

TABLE 43

Mean percentage of faults detected by each age group in each of the eight fault categories. Each value in the table is based on fifteen percentages.

	Fault Categories							
	1	2	3	4	5	6	7	8
Under 30	69.83	32.33	56.00	44.87	81.80	46.13	56.07	59.87
Over 30	70.47	30.50	52.53	36.47	80.20	44.33	50.47	61.60

This was a non-significant factor and an examination of mainly very small differences, for only in category 4 where the under 30 group are 8.4% better and in category 7 where they are 5.6% better do differences exceed 4%. The under 30 group score marginally better in six categories, i.e. categories 2, 3, 4, 5, 6 and 7 whereas the over 30 group do better in two categories, namely 1 and 8, but these sort of differences would be expected by chance alone.

TABLE 44

Comparison by 't' test of the mean percentage of faults detected by each age group in the eight fault categories. O is the over 30 group and Y the under 30 group.

Fault Category and Age Group	Diff.	Std. Error of Diff.	DF	t	P	95% Confidence Limits $t \pm 10.33$
No. 1 O - Y	0.64	5.19	between 60 & 120	0.12	$p > 0.50$	-9.69 to 10.97
No. 2 Y - O	1.83	5.19	"	0.35	$p > 0.50$	-8.50 to 12.16
No. 3 Y - O	3.47	5.19	"	0.67	$p > 0.50$	-6.86 to 13.80
No. 4 Y - O	8.40	5.19	"	1.62	$.10 < p < 0.25$	-1.93 to 18.73
No. 5 Y - O	1.50	5.19	"	0.29	$p > 0.50$	- 8.83 to 11.83
No. 6 Y - O	1.80	5.19	"	0.35	$p > 0.50$	-8.53 to 12.13
No. 7 Y - O	5.60	5.19	"	1.08	$.25 < p < 0.50$	- 4.73 to 15.93
No. 8 O - Y	1.73	5.19	"	0.33	$p > 0.50$	- 8.60 to 12.06

As expected from the analysis of variance Table 36, none of the mean differences for between age groups for each fault category show any statistical significance. An examination of age differences between different fault categories, e.g. comparisons between performances of over 30 subjects (O) on category No. 1 with under 30 subjects (Y) on category 2 would be quite meaningless.

TABLE 45

Mean percentage of faults found in each fault category under the three experimental conditions. Each value in the table is based on ten percentages.

Experimental Conditions	Fault Categories							
	1	2	3	4	5	6	7	8
EH	63.20	25.20	48.80	36.30	82.60	38.00	59.00	60.70
EHL_1	71.60	30.70	55.50	37.30	77.30	42.70	53.20	63.50
EHL_2	75.40	38.20	58.50	48.50	83.10	56.50	47.60	58.00

Performance under condition EHL_2 is better than for the condition EH and EHL_1 for fault categories 2, 4 and 6 and marginally better for categories 1, 3 and 5. Only for categories 7 and 8 are performances under EH and EHL_1 better (see figure 19).

Figure 19

Mean percentage of faults found in each fault category by each group of subjects under the three experimental conditions. Each mean is based upon ten percentages. The 95% confidence limits for each mean are not shown. These are, however, equal to the mean percentage of faults detected. ± (4.284) (2.202), i.e. ± 8.65

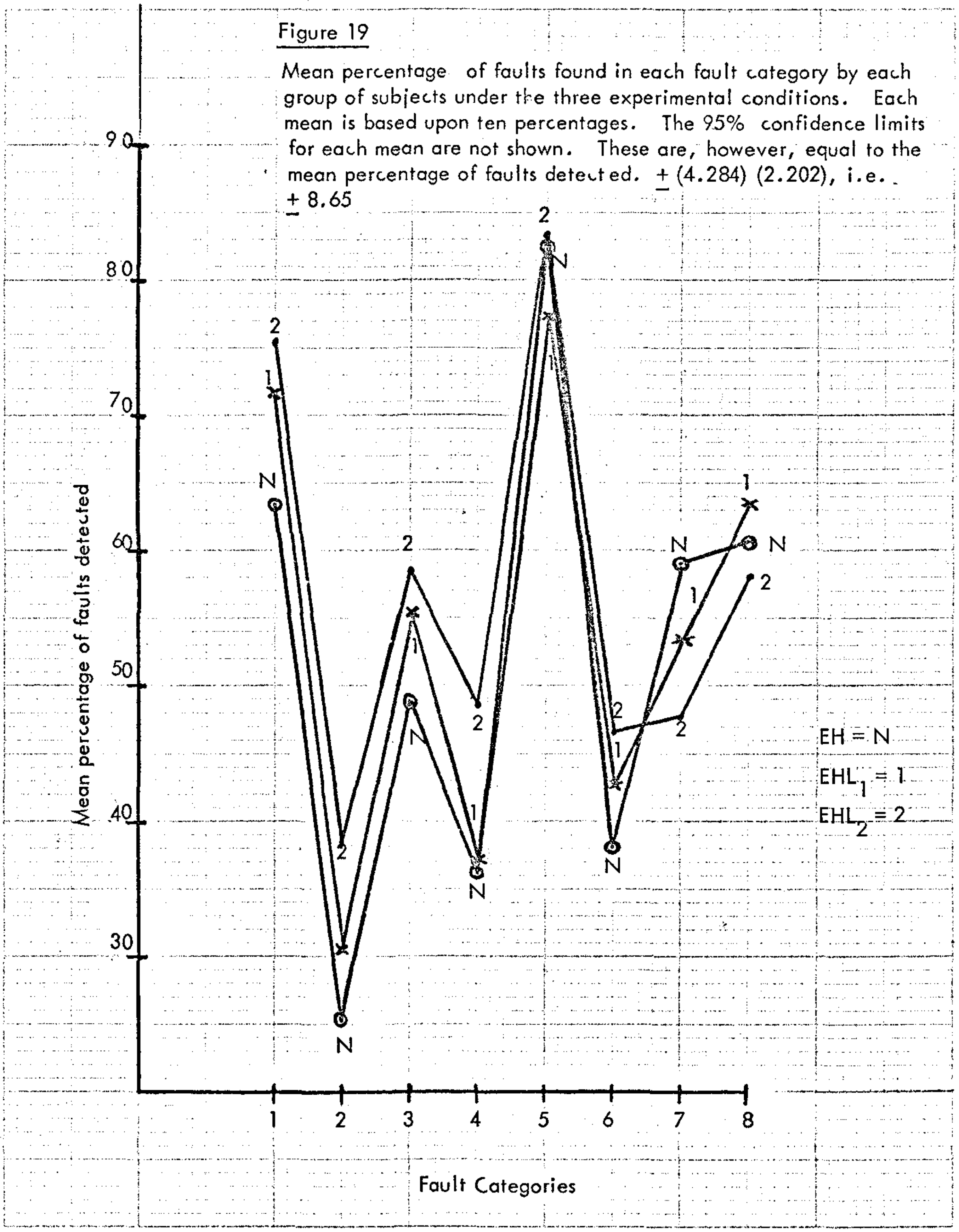


TABLE 46

Comparison by 't' test of the mean percentage of faults found in the EHL_2 condition with those in the same fault categories in the EHL_1 and EH conditions. EHL_1 and EH were compared in Experiment 1 together with the E and H conditions.

Fault Category & Experimental Condition	Diff.	Standard Error of Diff.	DF	t	P	95% Confidence Limits $t \pm 8.94$
EHL_2(1)-EH(1)	11.80	4.49	Between 60 & 120	2.63	$0.01<p<0.025$	2.86 to 20.74
EHL_2(2)-EH(2)	13.00	4.49	"	2.90	$0.001<p<0.01$	4.06 to 21.94
EHL_2(3)-EH(3)	9.70	4.49	"	2.16	$0.025<p<0.05$	0.76 to 18.64
EHL_2(4)-EH(4)	12.20	4.49	"	2.72	$0.001<p<0.01$	3.26 to 21.14
EHL_2(5)-EH(5)	0.50	4.49	"	0.11	$p>0.50$	-8.44 to 9.44
EHL_2(6)-EH(6)	18.50	4.49	"	4.12	$p<0.001$	9.56 to 27.44
EH(7)-EHL_2(7)	11.40	4.49	"	2.54	$0.01<p<0.025$	2.46 to 20.34
EH(8)-EHL_2(8)	2.70	4.49	"	0.60	$p>0.50$	-6.24 to 11.64
EHL_2(1)-EHL_1(1)	3.80	4.49	"	0.85	$0.250<p<0.50$	-5.14 to 12.74
EHL_2(2)-EHL_1(2)	7.50	4.49	"	1.67	$0.10<p<0.25$	-1.44 to 16.44
EHL_2(3)-EHL_1(3)	3.00	4.49	"	0.67	$p>0.50$	-5.94 to 11.94
EHL_2(4)-EHL_1(4)	11.20	4.49	"	2.49	$0.01<p<0.025$	2.26 to 20.14
EHL_2(5)-EHL_1(5)	5.80	4.49	"	1.29	$0.10<p<0.25$	-3.14 to 14.74
EHL_2(6)-EHL_1(6)	13.80	4.49	"	3.07	$p<0.001$	4.86 to 22.74
EHL_1(7)-EHL_2(7)	5.60	4.49	"	1.26	$0.10<p<0.25$	-3.24 to 14.54
EHL_1(8)-EHL_2(8)	5.50	4.49	"	1.22	$0.10<p<0.25$	-3.34 to 14.44

EHL_2 conditions produce a better performance on all fault categories except on categories 7 and 8, than conditions EH and EHL_1. In the most important applied comparison, that is, between EHL_2 and EH, for fault categories 1, 2, 3, 4 and 6 performance under EHL_2 is significantly better, and only on category 7 is performance under EH significantly better. This represents a general improvement in performance, particularly with the faults thought to require tactual skill. With fault category 8 a fault requiring visual detection skill the angular lighting has proved a source of interference and a decrement in performance has occurred.

Differences between the two angular lighting conditions, except for categories 4 and 6 where performance under EHL_2 is significantly superior are not exceptionally great though scores on EHL_2 are usually better by a small margin. The improvement brought about by the angular lighting is shown to be a general one spread throughout most of the eight fault categories with few decremental effects.

TABLE 47

Comparison by 't' test of the mean percentage of faults found in each fault category under the experimental conditions of EHL_2. (Already done for EH and EHL_1, as well as E and H in Experiment 1).

Fault Category	Diff.	Std. Error of Diff.	DF	t	P	95% Confidence Limits of Difference value ± 11.93
5 - 1	7.70	6.058	168	1.27	0.10<p<0.25	-4.23 to 19.63
5 - 2	44.90	6.058	168	7.41	p<0.001	32.97 to 56.83
5 - 3	24.60	6.058	168	4.06	p<0.001	12.67 to 36.53
5 - 4	34.60	6.058	168	5.71	p<0.001	22.67 to 46.53
5 - 6	26.60	6.058	168	4.39	p<0.001	14.67 to 38.53
5 - 7	35.50	6.058	168	5.86	p<0.001	23.57 to 47.43
5 - 8	25.10	6.058	168	4.14	p<0.001	13.17 to 37.03
1 - 2	37.20	6.058	168	6.14	p<0.001	25.27 to 49.13
1 - 3	16.90	6.058	168	2.79	0.001<p<0.01	4.97 to 28.83
1 - 4	26.90	6.058	168	4.44	p<0.001	14.97 to 38.83
1 - 6	18.90	6.058	168	3.12	p<0.001	6.97 to 30.83
1 - 7	27.80	6.058	168	4.59	p<0.001	15.87 to 39.73
1 - 8	17.40	6.058	168	2.87	p<0.001	5.47 to 29.33
3 - 2	20.30	6.058	168	3.35	p<0.001	8.37 to 32.23
3 - 4	10.00	6.058	168	1.65	0.05<p<0.10	-1.93 to 21.93
3 - 6	2.00	6.058	168	0.33	p>0.50	-9.93 to 13.93
3 - 7	10.90	6.058	168	1.80	0.05<p<0.10	-1.03 to 22.83
3 - 8	0.50	6.058	168	0.08	p>0.50	-11.43 to 12.43
8 - 2	19.80	6.058	168	3.27	p<0.001	7.87 to 31.73
8 - 4	9.50	6.058	168	1.57	0.10<p<0.25	-2.43 to 21.43
8 - 6	1.50	6.058	168	0.25	p>0.50	-10.43 to 13.43
8 - 7	10.40	6.058	168	1.72	0.05<p<0.10	-1.53 to 22.33
6 - 2	18.30	6.058	168	3.02	p<0.001	6.37 to 30.23
6 - 4	8.00	6.058	168	1.32	0.10<p<0.25	-3.93 to 19.93
6 - 7	8.90	6.058	168	1.47	0.10<p<0.25	-3.03 to 20.83
4 - 2	10.30	6.058	168	1.70	0.05<p<0.10	-1.63 to 22.23
4 - 7	0.90	6.058	168	0.15	p>0.50	-11.03 to 12.83
7 - 2	9.40	6.058	168	1.55	0.10<p<0.25	-2.53 to 21.33

TABLE 48

A summary of the basic information obtained by comparing fault categories within each condition is given below. In addition to the results of the EHL_2 condition from Experiment II the E, H, EH and EHL_1 results from Experiment I are given.

Rank	E	H	EH	EHL_1	EHL_2
1st	5	1	5	5, 1	5, 1
2nd	8	5	1, 8, 7	8	3,4,6,7,8(3)
3rd	1, 7, 3(1)	5, 7	3	3, 7	4, 2(3)
4th	6	6, 2, 4(2)	6, 4	6, 4, 2	
5th	4, 2	8	2		

(1) Though 1 and 3 are not significantly different from 7 they are significantly different from one another.

(2) Though 6 and 4 are not significantly different from 2 they are significantly different from one another.

The differences between fault categories is less clear cut for EHL_2 than under the other conditions which were discussed earlier. Whereas previously several clear cut categories of significantly different performance emerged, this is now less obviously the case.

Performance is best for fault categories 1 and 5 but there are no significant differences between performances on fault categories 3 and 4, 6, 7 and 8, nor between 8 and 4, 6 and 7, and again no differences emerge between category 6, and categories 4 and 7 or between any combination of 4, 7 and 2(3). So performance differences between categories have become less noticeable and with further changes in lighting it may be possible for a general plateau in performance to be reached. Though this would fall short of any aim to inspect for zero possible defects it would nonetheless represent some improvement in overall inspection performance.

6.4 Summary of Results

1. No significant differences in speed of performance were found for experimental conditions, age differences or interaction between the two.

2. Significant differences in faults detected with no account taken for fault categories between normal conditions and those with the new angular lighting result in more faults being found under the latter condition.

3. There were no significant differences in the number of faults detected, when account was taken of fault categories, between conditions, ages or their interaction.

4. Significant differences were found, much in the same way as Experiment I between fault categories, but not however in any of the associated interactions.

6.5 Conclusions and Discussion

This experiment was carried out in order to determine if any further change in angular lighting would result in more significant differences than those observed in an earlier experiment. Differences have emerged between normal working conditions and the condition EHL_2 as has been demonstrated in Table 34 and discussed following Table 35. These differences occurred in the analysis which took no account of fault categories. When fault categories were considered (see Table 36) these differences were not repeated, but, because of the first analysis, the results were more closely analysed (see Table 38) and a significant difference between the EHL_2 and EH conditions was found. It must be understood that this further analysis was only prompted by the significant result achieved in the analysis in which fault categories were not being taken into account.

The results were not as decisive as was initially anticipated, but the difficulties involved in setting up a really searching experiment in which the many facets of lighting, angular and otherwise, are tested, was not possible. However, so very few controlled experiments on inspection in the wool industry are carried out, that the results demonstrated here do give valuable information. Previous angular lighting experiments have been uncontrolled stabs in the dark at solving the problem on-line. Conflicting opinions exist on the value of lighting. The present experiment should help to clarify some of these opinions.

Hecht (1928) and Lythgoe (1932) suggest that an increase in lighting will always produce an increase in acuity up to a certain optimum. Although the relationship is not clear, nevertheless it does exist. Whether any increase in performance over and above a certain level due solely to lighting could be detected is doubtful, what is certain is that lighting differences do affect inspection performance and faults which cannot be detected cannot be mended. It is possible through a programme of controlled experimentation to determine the type and level of lighting which would give the most economic return in inspection performance.

The results show two interesting effects. Firstly with regard to speed, once again no significant increase in speed of performance per frame could be observed (see Table 31). This leads one to believe that regardless of age differences, conditions ranging from tactual or visual inspection alone to those involving variations in lighting, or for that matter any age x condition interaction, no differences in speed occur. This information coupled with the high correlation coefficients (4.4.2, 2A and 2B) between speed and faults present and speed and faults found in Experiment 1 leads one to suspect that speed of performance is a limiting factor depending on the fault content of the cloth. This would perhaps account for the slight decrease in speed for condition EHL_2 when compared with EHL_1 in terms of the greater (though non-significant) number of faults detected.

The results pertaining to the latest experimental condition showed not the dramatic improvement that was partially anticipated but a general levelling of performance throughout the eight fault categories.

CHAPTER VII

EXPERIMENT 3

7.1 Introduction

The studies carried out in this thesis have been concerned with tactual and visual inspection performance, and had burling and mending been concerned solely with the inspection of cloth the measurements obtained experimentally would have been directly related to work place performance.

However, inspection is only one skill which is brought to bear by the subjects when at work. Mending is the end product of their efforts; and a combination of inspection, in the sense that relevant faults should not be left unrepaired, and mending are what burlers and menders are judged by.

To consider measurements obtained from one portion of the task without accounting for the influence of mending would have been to present an incomplete picture. Thus, although mending represented even greater problems than inspection in respect of the semantics involved, detailed research in the area was regarded as essential to this study.

Burling and mending can loosely be divided into two tasks. In burling the cloth is drawn over a table and searched for faults. Basically on the detection of a fault one of three things may occur :

(a) the fault is pushed to the reverse side of the cloth where it will be later removed during the course of the finishing process;

(b) the fault may be picked off the cloth with burling irons. Burling irons which give their name to the burling process are simply a small pair of tweezers which are somewhat similar in appearance to those used for cosmetic purposes by women;

(c) the fault may be marked to be repaired a short while later.

The second step is mending. This involves repairing with a needle and yarn all faults marked on the initial inspection, and also any further faults which may be detected. It can be seen that both burling and mending have too common factors - detecting faults and repairing them. Inspection predominates in burling whilst repairing predominates in mending.

As was stated earlier, it was thought to be highly desirable to examine and assess the performance of operatives on the production side of the task and so a study of mending was undertaken, particularly that part of mending concerned with repair. It was also thought worthwhile to determine the relation between inspection and repairing performance so that a rational basis would exist for the organisation of burling and mending work. At present these two tasks are combined into a single job and are carried out by the same person.

Several difficulties present themselves in carrying out an accurate assessment of mending skill. Firstly it is necessary to have a representative sample of an operative's work to evaluate her skill. As there are a large number of different kinds of faults which may arise on any one piece of cloth, it is important to examine the expertise of the burlers and menders on several different fault types. This is particularly important as the skill required to mend a piece has to be above a certain minimum level. This involves the repair of some, though not necessarily an exceptional quantity, of the more difficult fault types. The skill of all but the very poorest of operatives is such that it would be extremely difficult to differentiate between them when a simple fault is burled or mended. (This factor, in the course of the experiment, lead to one piece of cloth being rejected as unsuitable before presentation to the subject because it was too good!). Secondly there is an endurance factor in mending. This occurs in two ways. The operator has to repair a variety of faults on a piece of cloth. Furthermore, occasional faults (e.g. thick or a wrong twist etc.) require mending to be carried out over several yards of yarn. This entails the operative maintaining a high standard of work for a long period. Thus, in an experiment it is important to ensure that a large sample of operators' work be examined to allow for this consistency factor. A brisk artificial experiment which allowed a high standard of work, which could not be maintained, would give invalid results. This ruled out any possibility of repair work on a short length of cloth being used as a criterion for mending skill. The minimum requirement was judged after consultation within the woollen industry to be one full piece, approximately 70 to 75 yards in length and about 2 yards wide.

In the previous inspection experiments the location of faults in one piece of cloth was carefully recorded before the cloth was submitted to various groups of subjects for inspection. Inspection performance for each subject was measured by relating the number of faults detected to the total number present in the piece of cloth. This was only possible because the state of the cloth was constant. Inspection did not result in any changes in the composition of the fault content of the cloth. This of course is not the case with mending and gives rise to a third difficulty. Once a piece of cloth has been mended its fault content has been markedly altered and no useful purpose would be served by allowing a second subject to mend any fault which remained through having been deliberately left or overlooked by the first subject. Neither could the cloth be "unmended" or restored to its initial state quickly or economically. Thus it did not seem to be possible to use a single piece of cloth.

A solution to this difficulty is to have a number of pieces of cloth specially made up so that each subject has an identical mending task. A single 70 yard length of cloth may however cost well over £100 even in its unfinished state with all its faults present. The provision of specially manufactured cloth at this pricefor each subject was not economically possible. The procedure outlined above would have been expensive in other respects. If identical pieces of cloth had been specially made up it would have necessitated the subjects being released from their firms for at least the length of time that the mending process takes. This is of the order of 8 to 10 hours for a well woven piece of cloth. In some cases mending may take 40 or more hours. It was not possible to obtain the release of skilled subjects to do unproductive work (from their employers point of view) for this length of time away from their mending rooms. A further point is that even with specially woven cloth, the pieces would only be identical as regards the quality and type of yarn used, the pattern on the cloth, and, the type and tightness of the weave. By their very nature faults are not possible to duplicate.

Most of the above difficulties were solved by the Mills in which subjects were employed. The managers of the Mills very kindly and generously agreed to do their best to supply pieces woven in a 2 and 2 twill of worsted or worsted-terylene yarn. Thus, the type of weave and yarn were similar for all subjects. It was not however, possible to control the quality of the yarn, the pattern on the cloth, the tightness of the weave or the precise type, frequency and location of faults.

Two and two twill is a form of weave that is reasonably common and readily available from normal production in Spring time when the experiment was carried out. In every case the cloth was supplied to a subject employed in the mending room of the same mill which produced the piece of cloth. This ensured that the subject was being usefully employed on familiar pieces of cloth and did not suffer under any handicap of being presented with unusual or different material. Furthermore, the piece of cloth would have had to be processed in this very way sooner or later and so did not constitute a loss to the mill.

The fourth principal difficulty related to the standardization of the work place and the environmental conditions, particularly the lighting for mending. Both of these were controlled in the previous experiment on inspection. As implied earlier it was not practical to assemble all the subjects under identical conditions at a single location away from their work and in this experiment they remained at their work place in their own mills and participated in the experiment almost as part of the normal day's work.

It is thus immediately conceded that the subjects were not working under controlled or uniform conditions. However, they did have the advantage of being on very familiar ground and their experimental performance should not have differed substantially from that normally found in the mending room.

7.2 Data from the Inspection Experiment

As stated in the introduction the main purpose of this study was to obtain information on mending performance and on the relation between the inspection and mending skills of burlers and menders. It was thus highly desirable to use subjects who had taken part in the inspection experiment. Scores for inspection ability had been obtained for all the subjects used in that experiment and were thus readily available for comparative purposes.

Forty women had served as subjects. They had been equally divided into four groups of ten. Each group had carried out inspection under one of four conditions. These were inspection with :

(a) Hands only (H),

(b) Eyes only (E),

(c) Eyes and Hands together (EH), and

(d) Eyes and Hands together under supplemented lighting conditions (EHL_1).

The first two conditions (E) and (H) were artificial when compared with the subject's everyday working situation, as the subjects had been forced to inspect with only one of the two important contributing sensory modalities available to them. Thus, the scores obtained for these conditions would not give a complete picture of the subjects' inspection ability. These two groups were thus discarded for present purposes.

The second two conditions, (EH) and (EHL_1), realistically simulated normal working conditions in that both the hands and eyes were simultaneously available for inspection. Furthermore as no statistically significant differences in speed or accuracy of inspection performance were found between the two groups of subjects who underwent conditions (EH) and (EHL_1), it seemed appropriate that the twenty subjects in these groups should be regarded as homogeneous and suitable for the mending experiment.

This is confirmed in Appendix 6, in which subjects have been divided into two groups. 1 - the group which underwent condition EH, and 2 - the group which underwent condition EHL_1. The groups are tested for Mean differences by student 't' tests for all the scores examined in the present experiment. In no case was the difference between means significant at the .05 level or better.

As a comparison with the inspection experiment was of prime importance, it was necessary to extract the appropriate data from it. This consisted of :

(a) Inspection Speed: the time in seconds that each subject took to inspect the cloth.

(b) Inspection Accuracy (1) : the percentage of faults detected by each subject.

(c) Inspection Accuracy (2) : in (b) no account was taken of fault types. A second inspection accuracy was calculated in the following manner. Faults were grouped into 8 categories. The percentage of faults detected in each category was recorded. The average of the resulting eight percentages was then calculated for each subject.

(d) Inspection Skill (1) : this is Inspection Accuracy (1) divided by Inspection Speed, the resulting quotient was multiplied by 1000. This gives a convenient index of inspection accuracy per unit time.

(e) Inspection Skill (2) : this is Inspection Accuracy (2) divided by Inspection Speed, the resulting quotient was multiplied by 1000. This, like, (d) gives a convenient index of inspection accuracy per unit time.

Of the twenty subjects who underwent conditions (EH) and (EHL_1) in the original experiment, only seventeen were available for use in the mending experiment. Their inspection performance as measured by the indices (a) to (e) described above is given in Table 49.

The data given in Table 49 were converted to rank scores in Table 50. For each index of inspection performance the best person was ranked first and the worst last.

TABLE 49

The inspection performance of 17 subjects who underwent conditions (EH) or (EHL_1) in the original inspection experiment.

Subject	Inspection Speed(secs)	Inspection Accuracy(1)	Inspection Accuracy(2)	Inspection Skill(1)	Inspection Skill(2)
A	2380	60.68	57.38	25.50	24.11
B	2428	58.23	56.25	23.98	23.17
C	2365	47.89	41.75	20.25	17.65
D	4101	69.52	61.63	16.95	15.03
E	2071	49.80	41.50	24.05	20.04
F	5150	61.90	60.88	12.02	11.82
G	2970	67.07	61.38	22.58	20.67
H	2407	62.59	52.75	26.00	21.92
I	3030	57.28	47.63	18.90	15.72
J	2435	71.02	64.25	29.17	26.39
K	2046	63.13	55.88	30.86	27.31
L	3198	53.33	46.13	16.68	14.42
M	2588	55.51	44.13	21.45	17.05
N	2814	56.46	50.00	20.06	17.77
O	3049	54.15	46.50	17.76	15.25
P	3330	50.07	51.63	15.04	15.50
Q	3052	66.53	60.38	21.80	19.78

TABLE 50

Rank scores for each of the inspection performance indices presented in Table 49.

Subject	Inspection Speed(secs)	Inspection Accuracy(1)	Inspection Accuracy(2)	Inspection Skill(1)	Inspection Skill(2)
A	4	8	6	4	3
B	6	9	7	6	4
C	3	17	16	10	10
D	16	2	2	14	15
E	2	16	17	5	7
F	17	7	4	17	17
G	10	3	3	7	6
H	5	6	9	3	5
I	11	10	12	12	12
J	7	1	1	2	2
K	1	5	8	1	1
L	14	14	14	15	16
M	8	12	15	9	11
N	9	11	11	11	9
O	12	13	13	13	14
P	15	15	10	16	13
Q	13	4	5	8	8
	No ties	No ties	No ties	No ties	No ties

7.3 The Mending Experiment

7.3.1 Subjects

As previously stated, of the twenty subjects used in the inspection experiment only seventeen could be traced and all of these women participated in the present mending experiment.

7.3.2 Apparatus

One piece of cloth was provided for each subject. Each piece was about seventy yards in length and about two yards in width. Twelve pieces were 2 and 2 twills, and 5 were fancy weaves all of which were woven from worsted or worsted-terylene yarn.

Time and score sheets were provided. (See Appendix 7). Each sheet accompanied a particular piece of cloth. On the sheet were listed the faults occurring on the cloth. Space was provided for the subject to record the length of time taken to repair each of the faults.

Subjects were provided with stop clocks to record these times.

7.4 Experimental Method

The process of the experiment began by obtaining from a mill a piece of cloth which satisfied the requirements of the experiment, i.e. a two and two twill. The cloth was then checked and marked with chalk for all mending faults. The length of all mending faults was specified. An assessment of the number of burling faults was made by counting a sample of them (e.g. knots) in two yards at the beginning of the piece, two in the middle and two at the end. In this way a good estimate of the amount of mending work involved was obtained. This evaluation was carried out by Mr. K. Wilson, the Head of the Wool Industry Training Board Mending School and his team of supervisors, Miss Pullen and Miss Smith.

All the faults found were recorded in their order of appearance on a special time and score sheet (see Appendix 7). The cloth was then returned to the mill and the subject who was designated to undertake its repair was given a stop clock, the appropriate time and score sheet, and a set of written instructions (see Appendix 8). The latter was explained to the subject and she was given the opportunity to ask questions.

The subjects used the clock to :

(i) time themselves for the overall period needed to attend to the piece of cloth in question;

(ii) time themselves for the period taken for burling;

(iii) record the individual times needed to mend each of the other faults marked on the cloth;

(iv) record the times taken for mending carried out on any additional faults found, which did not appear on the time and score sheet. This precaution was taken as it was possible that a few faults might have escaped the original assessment. As the subject was instructed to record all these faults, nothing was thereby lost.

All but one subject carried out the timing task extremely meticulously.

The subjects were instructed to burl and mend the cloth in the usual way and not to attend to any faults which they would not normally be required to repair. This situation often occurs in the industry as certain faults take too long to mend to be considered an economic proposition. These are left in the cloth and conceded when the cloth goes to the retailer or clothing manufacturer. When it was necessary for a subject to leave a fault for the above reason, this was marked on the time and score sheet as "not done". Faults which were marked on the time and score sheet but which could not be located by the subject were differentiated from the above and marked "not found".

Subjects were told that they would be paid ten shillings for participating in the experiment and a further ten shillings for accurately timing themselves and neatly filling in the time and score sheet. They were also told that a further £1 would be given to the person who was judged to have done the best of all the subjects on the latter task. The subject was left to start the experiment on her own immediately after she had completed the work occupying her at the time.

As soon as a subject completed her piece of cloth, it was returned to the Wool Industry Training Board Mending School, together with its time and score sheet. The cloth was then carefully re-examined by Mr. Wilson and his team. They assigned a mark, out of twenty, to each subject for the following :

(a) Mending Speed : this mark was arrived at by relating the actual time recorded by the subject for mending the piece, to an estimated time obtained in the initial evaluation of the cloth. In the marking of mending speed account was taken of any extra faults which the subject found but which were not discovered in the initial evaluation of the cloth. Account was also taken of faults which the subject missed.

(b) Mending Neatness : a mark was assigned to the subject for the neatness in repairing faults. The closer the repair work came to being invisible the better was the mark assigned.

(c) Mending Inspection : a mark was given for inspection performance during the mending process. It was based on two factors :

(i) Extra faults found by the subject which were not marked on the time and score sheet.

(ii) Faults missed by the subject which were indicated on the time and score sheet.

The mending inspection mark cannot be considered equal in its accuracy to the inspection accuracy scores obtained in the original inspection experiment. In the mending experiment, as previously indicated, the great majority of faults were marked on the cloth for the subject. The prime aim of the mending experiment was to assess mending and not inspection skill. Thus it was important that subjects had an easy passage in locating faults rather than subjecting them to a further searching inspection test.

It is important to note that Mr. Wilson and his team of assessors did not know the results of the inspection experiment when they were giving marks for Mending Speed, Mending Neatness and Mending Inspection. Nor were they aware of other scores which are described later in this section. It should also be noted that at no time did Mr. Wilson or his assessors meet any of the subjects. Marking was done entirely on the basis of firstly, examining the cloth before it was mended and, secondly, examining the cloth after the subject had completed her work on it with the guidance of the time and score sheet. Judgements of subjects' work was thus entirely impersonal. It was thereby hoped to eliminate any personality or "halo" effects which may have contaminated the results.

It must be pointed out that several practical difficulties presented themselves at this point. Firstly, the services of Mr. Wilson and his team, who are normally concerned with running the Woollen Industry Training Board Mending School, were only available for a limited period of time, which was officially three weeks. The prospects of obtaining an extension of their services or for that matter, the use of the mending room a further length of time were non-existent. Also it was necessary to pay a fairly substantial fee in order to obtain the services and even if Mr. Wilson and his team had been available for longer, it is doubtful if the necessary funds could have been obtained to allow the experiment to proceed for a much lengthier period of time.

It must be understood, that during the course of the present experiment in which the Assessors tackled their task in unison, they were fully occupied, for the whole three-week period. In fact the experiment ran overtime by several days, giving the assessors, during other duties, the task of finishing the last of their functions associated with this experiment, and there can be little doubt that a considerable extension of time would have been necessary if alterations had been made in the experimental design. For example, it would have been desirable in the interests of ascertaining the validity of the results for each of the three judges to score each piece of cloth separately for Mending Neatness, Mending Speed and Mending Inspection. This would have necessitated each judge assessing each piece of cloth on three occasions and would have involved a great deal of additional time. Similarly, though less so, extra time would have been necessitated if each judge had worked independently in scoring each piece of cloth once and obtaining individually Mending Neatness, Mending Speed and Mending Inspection scores.

Also it would have been desirable in the interests of reliability to have Mr. Wilson and his two assistants re-assess the cloth on one or more occasions but the time and the money were not available.

Another method to establish validity which would have undoubtedly improved the experimental design would have involved separate teams being used to make independent judgements on Mending Speed, Mending Neatness and Mending Inspection. However, once again this was not possible. Firstly experts other than the Mending School team were not readily come by, and it would have been indeed unlikely that the key personnel who would have been required to act as judges, would have been allowed to leave their work for the necessary three weeks. Secondly extra funds would have been necessary to pay for the services of the additional judges, and once again the mending room and the cloth would have been required for a longer period of time.

Unfortunately, it was not possible for the above reasons to fulfil all the requirements to ensure the validity and reliability of the experiment. However, it was felt that the experiment was still worth carrying out, and that the exceptional experience of Mr. Wilson and his adjudicators, as well as their independence and their remoteness from the subjects, would ensure that the experiment would produce results which would be of value, and which could be readily interpreted.

Three further scores were obtained from the mending experiment. The first of these is termed Mending Skill.

(d) Mending Skill : this was defined as Mending Speed x Mending Neatness. This score is the mending counterpart of those scores defined as Inspection Skill(1) and Inspection Skill(2) in the previous experiment. It represents an attempt to produce a unitary score for mending based on "speed" and "accuracy".

The second of the remaining scores which was obtained was defined as a Time Utilization score.

(e) Time Utilization : this was calculated by summing the times recorded for mending each fault and the time required for burling. This constituted the total time involved in repair work. This time was then related to the total time that the piece of cloth was with the subject. Thus ,

$$TU = \frac{(t + b)}{T}$$

where TU = Time Utilization

T = Total time taken from starting work on the piece of cloth to completing work on it.

t = Sum of the times spent on mending each fault.

b = Time spent burling the cloth.

The final score which was used was termed a Mending Room Effectiveness score.

(f) Mending Room Effectiveness: this was obtained by asking the Mill Managers or the Supervisors of the mending rooms to give ranks to the subject (or subjects) whom they employed in relation to other employees in the same mending room. Managers and Supervisors were not aware of any of the other scores obtained in the inspection and mending experiment. The ranks were given for mending performance. It should be recalled however that with the present organisation of work the *same person inspects and repairs a given piece of cloth.* As good inspection is a pre-requisite of good mending performance in the normal working situation the Mending Room Effectiveness ranks are judgements based on an amalgam of performance at both inspection and repair. In mending rooms where there were only a few employees ($<$20) it was relatively easy for the Mill Managers and Supervisors to produce a rank for the subject who was in their employ. In some cases, however, subjects came from large firms which employed over a hundred women in their mending rooms. In these cases the Managers or Supervisors based their judgement of rank on average earnings per hour. These earnings are, of course, based on mending performance. A fraction was then obtained for each subject by calculating the ratio of her rank to the total number of women in her own mending room. These fractions were then standardized in the form of percentiles as different mending rooms employed different numbers of subjects.

In summary, the following scores were obtained from the mending experiment.

(a) Mending Speed
(b) Mending Neatness
(c) Mending Inspection
(d) Mending Skill
(e) Time Utilization
(f) Mending Room Effectiveness

Subjects scores on each of these measures of performance are given in Table 51. It will be observed that in the Time Utilization column there is no entry against subject E. Her data was excluded as there was evidence that her timing of her work was not accurate. It will also be observed that there is no entry in the Mending Room Effectiveness column against Subject N. This particular subject was employed in a mending room where all the menders worked in pairs. It was therefore not possible to obtain data on her Mending Room Effectiveness in relation to the rest of the menders with whom she worked.

The data given in Table 51 were converted into rank scores. These are shown in Table 52. For each index of mending performance the best person was ranked first and the worst last. Ties occurred between some subjects on all indices. The frequency and extent of the ties is indicated at the foot of each column.

TABLE 51

The mending performance of 17 subjects who underwent conditions (EH) or (EHL_1) in the original inspection experiment.

Subject	Mending Speed	Mending Neatness	Mending Skill	Mending Inspection	Time Utilization	Mending Room Effectiveness
A	19.0	19.5	370.50	19.5	0.698	71.094
B	17.0	20.0	340.00	19.5	0.755	16.667
C	16.0	19.5	312.00	19.0	0.747	50.000
D	18.5	19.5	360.75	19.0	0.869	95.833
E	18.0	18.5	333.00	19.0	No score	99.206
F	18.0	19.0	342.00	19.0	0.910	83.333
G	19.0	19.0	361.00	18.0	0.733	69.118
H	17.0	19.0	323.00	18.0	0.624	16.667
I	18.0	19.0	342.00	18.0	0.783	64.815
J	18.0	18.0	324.00	16.0	0.708	53.906
K	17.0	16.0	272.00	16.0	0.994	47.642
L	15.0	19.0	285.00	17.0	0.853	71.094
M	18.0	16.0	288.00	14.0	0.997	99.206
N	16.0	17.0	272.00	14.0	0.908	No score
O	18.0	16.0	288.00	13.0	0.688	62.698
P	17.0	15.0	255.00	14.0	0.783	35.185
Q	16.0	12.0	192.00	14.0	0.893	83.333

TABLE 52

Rank scores for each of the mending performance indices presented in Table 51

Subject	Mending Speed	Mending Neatness	Mending Skill	Mending Inspection	Time Utilization	Mending Room Effectiveness
A	1.5	3	1	1.5	14	6.5
B	11.5	1	6	1.5	10	15.5
C	15	3	10	4.5	11	12
D	3	3	3	4.5	6	3
E	6.5	10	7	4.5	-	1.5
F	6.5	7	4.5	4.5	3	4.5
G	1.5	7	2	8	12	8
H	11.5	7	9	8	16	15.5
I	6.5	7	4.5	8	8.5	9
J	6.5	11	8	11.5	13	11
K	11.5	14	14.5	11.5	2	13
L	17	7	13	10	7	6.5
M	6.5	14	11.5	14.5	1	1.5
N	15	12	14.5	14.5	4	-
O	6.5	14	11.5	17	15	10
P	11.5	16	16	14.5	8.5	14
Q	15	17	17	14.5	5	4.5
Ties	1 of 2	2 of 3	3 of 2	2 of 2	1 of 2	4 of 2
	1 of 3	1 of 5		1 of 3		
	1 of 4			2 of 4		
	1 of 6					

7.5 Age Differences

A statistical examination of differences in performance with age was undertaken. This utilised all the scores obtained in the experiment. In the inspection experiment the subjects were grouped into two age groups - an over thirty group and an under thirty group. Here the differences between these two age groups is calculated for all the scores examined in the present experiment. This includes scores which were previously examined in the inspection experiment to take into account present conditions in which there were eight subjects under 30 and nine over 30, rather than ten of each. The statistical test which was applied was the normal scores test of Kendall. The subjects are identified in terms of age in Table 53. All the scores and ranks which apply are the same as those shown for each subject in tables 51 and 52.

TABLE 53

The subjects in over and under thirty age groups.

Subjects	
Under 30	Over 30
B	A
C	D
F	E
G	I
H	K
J	L
N	M
P	O
	Q

CHAPTER VIII

RESULTS

Kendall rank order correlation coefficients (tau) were calculated for the data from both the inspection and mending experiments. This correlation coefficient (Kendall, 1955) was used in preference to Pearson's product moment correlation coefficient because much of the data from the mending experiment was only ordinal information. For the sake of consistency non parametric correlation coefficients were used throughout. For convenience of presentation the correlations have been arranged into three main groups. These are :

(1) Correlations between indices of performance obtained solely from the inspection experiment.

(2) Correlations between indices of performance obtained solely from the mending experiment.

(3) Correlations between indices of inspection and mending performance.

8.1 Rank Correlations from the Inspection Experiment

The rank correlations from the inspection experiment are shown in Table 54.

TABLE 54

Rank order correlations from the inspection experiment

	Inspection Speed	Inspection Accuracy (1)	Inspection Accuracy(2)	Inspection Skill (1)	Inspection Skill (2)
Inspection Speed	X	-0.03	-0.21	Not Calcul.	Not Calcul.
Inspection Accuracy (1)		X	+ 0.79 ($p<0.001$)	Not Calcul.	Not Calcul.
Inspection Accuracy (2)			X	Not Calcul.	Not Calcul.
Inspection Skill (1)				X	+0.85 ($p<0.001$)
Inspection Skill(2)					X

It will be seen that no coefficients were calculated between Inspection Speed, Inspection Accuracy(1) and Inspection Accuracy (2), on the one hand and Inspection Skill(1) and Inspection Skill(2) on the other. These coefficients were not calculated because Inspection Skill(1) and Inspection Skill(2) are compounded from the remaining indices of inspection performance. If, therefore, a significant correlation had been obtained in these cases, their interpretation would have been trivial.

It will be seen from Table 54 that only two coefficients are statistically significant. The correlation of Inspection Accuracy (1) and (2) produced a tau of +0.79 ($p < 0.001$). This indicates that inspection accuracy when no account is taken of fault type is a good predictor of inspection accuracy when account is taken of fault type and conversely. This result may be alternatively interpreted by stating that when faults which are very easy to detect are eliminated from consideration the rank order of subjects inspection accuracy remains the same. The correlation between Inspection Skill (1) and Inspection Skill (2) produced a tau of +0.85($p < 0.001$). This result is not surprising in view of significant correlation which has just been discussed. It may be interpreted in the following manner. Inspection accuracy with no account taken of fault type per unit time is a good predictor of inspection accuracy with account taken of fault type per unit time, and conversely.

The remaining coefficients in the Table, -0.03 and -0.21 are not statistically significant. Nevertheless, they suggest that fast inspectors tend to be poor fault detectors and slow inspectors good fault detectors, for both indices of inspection accuracy.

8.2 Rank Correlations from the Mending Experiment

The rank correlations from the mending experiment are shown in Tables 55, 56 and 57. The tables are distinguished from one another because the number of subjects involved in the correlations varies from one table to another. In Table 55, data for all 17 subjects was available.

In Table 56, however, no rank score was available for Subject E on Time Utilization and no rank was available for Subject N for Mending Room Effectiveness. In Table 57 where Mending Room Effectiveness and Time Utilization were correlated with each other, the same holds true and the correlation in this case was therefore based on only 15 subjects.

It will be seen in Table 55 that no correlations were calculated between Mending Speed and Mending Neatness on the one hand, and Mending Skill on the other. This was because the latter is compounded from Mending Speed and Neatness and the interpretation of any significant correlations which might be obtained here would have been trivial. Two correlations are significant in Table 55. Tau for *Mending Neatness and Mending Inspection is +0.78* ($p < 0.001$). This result is not entirely unexpected. Good mending inspection is a pre-requisite of mending being neat.

It is possible that a meticulous mender having an easy task as far as inspection was concerned (because of the large number of marked faults), found herself with slightly more time available than usual (note the positive correlation with mending speed) and has utilised her time in more than usual careful inspection.

The other correlation which is statistically significant is that between Mending Skill and Mending Inspection. Tau in this case is +0.57($0.001 < p < 0.01$). This result follows from the one that has just been discussed for two reasons. First, Mending Neatness is one of two components of Mending Skill. As Mending Neatness is correlated with Mending Inspection one would therefore expect Mending Skill to correlate with Mending Inspection. Secondly, the other component of Mending Skill, which is Mending Speed, also correlated with Mending Inspection. The correlation between Mending Skill and Mending Inspection may be interpreted in the following way. When simultaneous account is taken of Mending Speed and Neatness so that a unitary measure of Mending Skill is produced, rank scores on this measure may be predicted from rank scores which depend upon the carefulness with which subjects repaired faults which have already been pointed out to them and the carefulness with which they search for other faults which have not been previously pointed out to them.

Neither of the remaining correlation coefficients is statistically significant.

There is a suggestion however that subjects who are good at being neat menders are also fast menders and that subjects who are not neat tend to be slower menders. Tau in this case equals +0.22. There is also a suggestion that subjects who inspect carefully when mending are fast menders, and that subjects who inspect carelessly are slow menders. Tau in this instance is +0.24.

TABLE 55

Rank correlations from the mending experiment

(Each correlation is based on 17 subjects)

	Mending Speed	Mending Neatness	Mending Skill	Mending Inspection
Mending Speed	X	+0.22	Not Calcul.	+0.24
Mending Neatness		X	Not Calcul.	+0.78 ($p<0.001$)
Mending Skill			X	+0.57 ($0.001<p<0.01$)
Mending Inspection				X

TABLE 56

Rank correlations from the mending experiment

(Each correlation is based on 16 subjects. For correlations involving Time Utilization no rank was available for Subject E. For those involving Mending Room Effectiveness no rank was available for Subject N.)

	Mending Speed	Mending Neatness	Mending Skill	Mending Inspection
Time Utilization	-0.16	-0.22	-0.24	-0.10
Mending Room Effectiveness	+0.29	-0.05	+0.15	+0.04

TABLE 57

Rank correlations from the mending experiment

(The correlation is based on 15 subjects. No ranks were available for Subjects E and N for Time Utilization and Mending Room Effectiveness respectively)

	Time Utilization
Mending Room Effectiveness	+0.38 ($0.05 < p < 0.10$)

None of the correlations shown in Table 56 is statistically different from zero. This means, strictly speaking on the basis of the data presented here, that there is no evidence of a relation between Time Utilization and Mending Room Effectiveness scores on the one hand, and Mending Speed, Mending Neatness, Mending Skill and Mending Inspection on the other. Despite this interpretation it is interesting to note that there is a hint that :

(a) Those who waste little time overall when mending are the slower menders, and those who waste more time overall are the faster menders (tau = -0.16).

(b) Those who waste little time overall when mending tend to be the more careless menders, whereas those who waste more time overall when mending tend to be the more careful menders (tau = -0.22).

(c) Those who waste little time overall when mending tend to be the less skilled menders and those who waste more time overall when mending tend to be the more skilled menders (tau = -0.24). This result, of course, follows from (a) and (b).

There is also a suggestion in the data that :

(d) Those who are ranked as effective mending room operators by their supervisors tend to be the fast menders, whilst those ranked as ineffective tend to be the slow menders (tau = +0.29).

(e) Those who are ranked as effective mending-room operators by their supervisors tend to be the more skilled menders, whilst those ranked as ineffective tend to be the less skillful menders (tau = +0.15).

Too much emphasis, however, should not be put upon the above interpretations. If (c) and (e) are accepted as true then it would be expected that those who waste little time would be ranked as ineffective in the mending room, and that those who waste more time would be ranked as effective. It will be seen from Table 57, however, that a different result has been obtained. Subjects who wasted little time in the mending experiment are highly regarded in their mending rooms, whilst those who were less gainfully employed in the experiment are not so highly regarded in their mending rooms. Tau in this case is +0.38 and is almost significant at the 0.05 level.

If any overall impression can be successfully gained from the above data at all, it is that less skilled workers need more time to mend, whereas more skillful menders can mend quickly or slowly as is their want. However, it does appear that the time gained through swift work is not used productively.

8.3 Ages

It will be observed in Table 58 that the sums of the normal scores are given in two columns, headed Under 30 and Over 30. The original ranked scores have been changed into proportion scores and these again converted to the areas they represent under the normal probability curve. Thus a subject whose rank is 1st out of 17, in tables 50 or 52, has a score midway between 0 and 1, i.e. 0.5. This represents 0.030 as a proportion of 17 and when converted to normal scores is -1.89. Thus a high rank would be represented by a negative normal score, whilst a low rank would have a positive score. All the normal scores of the Young group are added and all the normal scores of the Old group are also summed. These two totals should be nearly numerically equal though one total will be positive and one negative. One of the normal score totals is then tested to see if there is a significant difference between the distribution of the scores of the old and of the young subjects. A negative total would indicate that, that group (i.e. either Young or Old) had achieved a larger proportion of high rank scores than the group with a positive total.

The results show three significant differences. Firstly, the older women were thought by their supervisors to be more effective in the mending room than the younger women ($p \leq 0.0001$ for Mending Room Effectiveness). Also the older women were less wasteful of time overall, than the younger women ($p = 0.04$, for time utilisation). Thus it would appear that the older subjects are more highly valued in the mending rooms and are also the people who spend most time on productive activities. The third significant result confirms the findings of the first experiment on inspection, in which it was found that the young subjects did better than older subjects when inspection accuracy was considered without a weighting for fault categories ($p = 0.02$). This result in the earlier experiment however was not significant and since the present result is based on the same data and is unaffected by the mending experiment, it does appear that in this case the scores of the three subjects who participated in the first experiment but not in the second have by their absence tended to add emphasis to this result. It must be remembered however, that whilst the earlier result was not a significant one it was nevertheless in the same direction as the present findings.

In brief the remaining results though not significant suggest : Younger subjects to be better than older subjects at (1) mending neatness (Y = - 1.76), (2) mending skill (Y = -0.28), (3) mending inspection (Y = -1.09), (4) inspection accuracy(1) (Y = -0.48), and (5) inspection skill(2) (Y = -0.61); and older subjects to be better than younger subjects at (1) mending speed (O = -0.92), (2) inspection speed (O = -0.63), and (3) inspection skill(1) (O = -1.14).

Though the above results cannot be interpreted without reservations it would appear at first sight that whilst the younger subjects seemed to excel at the tasks requiring skill, the older subjects worked faster. One wonders whether these trends may not appear because of the better eyesight and tactual sensitivity of the younger subjects as against experience, which allows older workers to work at speed and use short cut methods, both in fault inspection and mending.

TABLE 58

A comparison of the performances of the over 30 age group and the under 30 age group by means of Kendalls normal scores test for each of the scores examined in this experiment.

Type of score	Under 30 Std. deviation units	Over 30 Std. deviation units	Sig. value	
Mending Speed	+0.89	-0.92	p =0.38	N.S.
Mending Neatness	-1.76	+1.78	p =0.08	N.S.
Mending Skill	-0.28	+0.27	p =0.61	N.S.
Mending Inspection	-1.09	+1.10	p =0.28	N.S.
Time Utilization	+ 2.08	-2.08	p = 0.04	Sig.
Mending Room Effectiveness	+4.42	-4.42	p = 0.0001	Sig.
Inspection Speed	+0.63	-0.63	p =0.53	N.S.
Inspection Accuracy(1)	-0.48	+0.48	p =0.63	N.S.
Inspection Accuracy(2)	-2.26	+2.26	p = 0.02	Sig.
Inspection Skill(1)	+1.14	-1.14	p =0.23	N.S.
Inspection Skill(2)	-0.61	+0.61	p =0.54	N.S.

8.4 Rank Correlations Between Indices of Inspection and Mending Performance

Rank correlation coefficients obtained by relating inspection and mending performance are shown in Tables 59 and 60. Those correlations shown in Table 59 are based on 17 subjects, those in Table 60 on 16 subjects. There is no evidence that any correlation shown in these tables is significantly different from zero. This means, strictly speaking, that there is no evidence of any index of inspection performance being correlated with any index of mending performance.

TABLE 59

Rank order correlations obtained from the comparison of the results from the inspection and mending experiments. (Each correlation is based on 17 subjects)

	Inspection Speed	Inspection Accuracy(1)	Inspection Accuracy(2)	Inspection Skill(1)	Inspection Skill(2)
Mending Speed	-0.02	+0.25	+0.27	+0.09	+0.09
Mending Neatness	+0.11	+0.05	+0.07	0.00	+0.03
Mending Skill	+0.07	+0.20	+0.19	+0.07	+0.07
Mending Inspection	+0.18	+0.04	+0.12	+0.12	+0.13

TABLE 60

Rank order correlations obtained from the comparison of the results from the inspection and mending experiments. (Each correlation is based on 16 subjects. For those correlations involving Time Utilization, no rank was available for Subject E. For those involving Mending Room Effectiveness no rank was available for Subject N).

	Inspection Speed	Inspection Accuracy(1)	Inspection Accuracy(2)	Inspection Skill(1)	Inspection Skill(2)
Time Utilization	-0.21	-0.04	-0.08	-0.23	-0.23
Mending Room Effectiveness	-0.22	+0.03	-0.03	-0.19	-0.27

Nevertheless, in Table 59, there is a faint hint that :

(a) Those who tend to be quick at mending are good at fault detection whereas those who tend to be slow at mending are poor at fault detection (tau = +0.25 and +0.27).

(b) Those who are skilled at mending tend to be good at fault detection whilst those who are less skilled at mending tend to be poor at fault detection (tau = +0.20 and +0.19).

(c) Those who are good at inspection in the mending experiment tended to be fast at inspection whereas those who are poor at mending inspection tended to be slow at inspection (tau = +0.18).

There is also a suggestion from Table 60 that :

(d) Those who waste little time overall when mending tend to be slow at fault detection, whereas those who waste more time overall when mending tend to be fast at fault detection (tau = -0.21).

(e) Those who waste little time overall when mending tend to be the less skilled inspectors whereas those who waste more time overall when mending tend to be the more skilled inspectors (tau = -0.23 and -0.23).

Mending Room Effectiveness appears to relate to Inspection Speed, Inspection Skill(1) and (2) in the same manner as Time Utilization (tau = -0.22, -0.19 and -0.27 respectively).

It should be remembered once again, however, that the probability of observing rank correlation coefficients of this magnitude when *tau is zero is quite high.*

8.5 Summary of Results

1. A significant correlation coefficient was found between *Mending Neatness and Mending Inspection.*

2. A significant correlation was found between Mending Skill and Mending Inspection.

3. A relatively high but not significant correlation was found between Time Utilization and Mending Room Effectiveness.

4. The women over 30 achieved significantly better scores for Mending Room Effectiveness.

5. The women over 30 achieved significantly better scores for Time Utilization.

6. The women under 30 achieved significantly better scores for Inspection Accuracy.

7. Overall no significant relation would appear to exist between those skills required for the inspection task and those required for mending.

8.6 Discussion

Of forty seven correlations computed, only four were significantly different from zero in a statistical sense. On a purely chance basis two or three might be expected to be significant. It is probable, nevertheless, that the two significant correlations shown in Table 54 do indicate a true relation. That is to say firstly a rank score on one measure of inspection accuracy may be reliably predicted from a corresponding rank score on the other measure, (tau = +0.79) and secondly, a rank score on one measure of inspection skill may be reliably predicted from a corresponding rank score on the other measure (tau = +0.85).

More doubt, however, attaches to the significant correlations obtained between Mending Inspection on the one hand, and Mending Neatness and Mending Skill on the other. These are shown in Table 55. It is possible that these results do indicate true relations which may be explained in the way already described in the previous results section. It is also possible that the highly significant results are an artefact of the procedure used in the evaluation of the subjects' mending performance. It will be recalled that the team of experts at the Wool Industry Training Board Mending School were not aware of the results of the inspection experiment. Nor were they aware of Time Utilization or Mending Room Effectiveness scores. When, however, a subject had mended a piece of cloth, it was returned to Mr. Wilson and his team of experts. It was then marked for Mending Speed, Mending Neatness and Mending Inspection. Since marks for these factors were given, of necessity, in temporal contiguity by the same group of evaluators it is possible that some contamination of results took place. Thus, if a subject was initially given a good mark for neatness it is possible that the evaluators' subsequent judgements on speed and inspection were also good - simply because the initial impression persisted.

As Mending Skill is an amalgam of Mending Speed and Mending Neatness this is also subject to contamination. Thus, all the results in Table 55, but no others, could be explained in this way.

As was discussed earlier, it would of course have been better to have obtained separate teams of experts to evaluate Mending Speed, Mending Neatness and Mending Inspection independently. It would, also, have been even more desirable to have had several independent teams evaluating performance on each measure of mending.

These remarks are prompted not only by the doubts expressed in the previous paragraph but also by certain other features of the data. For example, in Table 54 negative correlations were obtained between speed and accuracy of inspection in the inspection experiment (tau = -0.03 and -0.21). When, however, speed from the inspection experiment was related to accuracy of inspection (Mending Inspection) in the mending experiment the correlation was positive (see Table 59, tau = +0.18). It is true, of course, that none of these correlations was found to be significantly different from zero and it may be that the apparent discrepancies are not real. More disturbing perhaps is the lack of correlation between accuracy of inspection in the mending experiment and accuracy of inspection in the inspection experiment (see Table 59, tau = +0.04 and +0.12). This result is more difficult to explain. It may be argued that the team of experts was not primarily concerned with inspection in the mending experiments and that more attention was given to the judgements on Mending Speed, and Neatness. If, however, a group or individual's judgements are shown to be at variance with an objective criterion, a residual doubt remains about the validity of that group or individual's judgements on other matters when no objective criterion is available.

One of the critical difficulties in evaluating mending performance, particularly Mending Neatness, is that no ultimate objective criterion of satisfactoriness exists. What constitutes satisfactory workmanship so far as the finished piece of cloth is concerned is purely subjective. Fundamentally two questions may be asked in such a situation :

(a) Do experts agree amongst themselves when they make judgements independently of one another?

(b) Do experts agree with their own judgements from one occasion to another?

The first question relates, in the circumstances discussed here, to the problem of validity of judgements, the second to the consistency of judgements.

As has been discussed earlier in 7.4 – Experimental Method, there can be no doubt about the desirability of determining these aspects of validity and reliability, but as was pointed out there were overwhelming practical difficulties, such as the limited time for which the present assessors and the mending room were available, the need for additional funds, and the scarcity of available teams of experts. Also the length of time for which the pieces of cloth were available was limited and an extension would have involved dislocating the delivery schedules which the firms participating in the experiment had to meet.

Another possible weakness in the experiments relates to the subjects used. If it is desired to generalise from such experiments to the normal working situation then it must be assumed, inter alia, that the subjects are truly representative of the population of burlers and menders found in the woollen industry. Unfortunately, it was not possible to exercise control over the selection of subjects. This had to be left in the hands of the Mills. No random selection techniques were employed. Mills simply nominated personnel whom they were prepared to allow to take part in the experiments and all such nominees were accepted. It is possible, however, that rather superior burlers and menders took part in the experiments as a result of this procedure. This is implied by the Mending Room Effectiveness percentiles given in Table 51. These range from the 17th to the 99th percentile with a median value of about 67. These figures suggest that the subjects were of higher than average ability with some constraint on spread of ability, particularly at the lower levels.

Bearing in mind the weaknesses outlined above what conclusions may be drawn if the experiments are regarded as pilot investigations requiring fuller confirmation?

The principal purpose of the present studies was to examine the relation between performance at inspection and mending tasks. No evidence of a relation was found. In the Introduction to this paper it was stated that the inspection and mending tasks are combined into one job which is carried out by the same person. The first conclusion is that the present results suggest that this organisation of the work in the woollen industry is far from optimal. Good mending performance in the current working situation is conditional upon good inspection performance. The chances, however, of obtaining high quality cloth, once it has been mended, may be extremely low because :

(a) There is a high probability that a person who is skillful with a needle and yarn has overlooked a large number of faults. This will mar the mended cloth.

(b) There is a high probability that a person who is a good inspector will not be skillful with a needle and yarn. This will also mar the mended cloth.

The results of the present investigations imply that the two tasks of inspection and mending should be separated into independent jobs which are carried out by different people. Thus, inspectors would not mend and menders would not inspect. Each group would carry out the task to which it was best fitted. This should ensure a higher quality of cloth leaving the mending room.

Unfortunately, such a re-organisation of work would bring a number of problems in its train. If inspection and repair were separated which group of operatives should deal with burling faults? Many of the faults found in the course of inspection can be dealt with by burling irons almost as swiftly as they can be marked by chalk.

A second problem relates to the determination of the optimal inspector/mender ratio to achieve the maximum satisfactory work output. One possible approach is to determine the relative time that each task consumes on standard lengths of cloth, and to make the allocation ratio directly proportional to time. If, for example, it transpires that inspection takes one third of the time that mending requires, then inspectors and menders should be employed in the ratio 1/3, i.e. one inspector for every three menders.

Once a decision has been made on what this ratio should be it would be extremely interesting to determine experimentally whether splitting the inspection and mending tasks in the way suggested produces better results than current practice.

A problem closely related to that of how to organise the burler and mender's job is that of selecting the 'passer'. In each mending room there is invariably a person, generally female, who has the final responsibility of determining whether a piece of cloth is of sufficient quality to go on to the next stage in the manufacturing process. The person with this responsibility is the passer, and it will be readily appreciated that her job is almost entirely composed of inspection. In view of the lack of correlation found between mending and inspection in the present investigations, it is suggested that it should be ascertained that a person who is employed as a passer is in fact a good inspector and not merely a good mender. Observations made in a number of mills by the author suggests that promotion to passer is sometimes based on mending performance alone.

Two final conclusions are offered. The first is that it is possible that the present pay structure in the woollen industry does not relate in the way that it ought to measures of inspection and mending performance. This is suggested by the lack of correlation between Mending Room Effectiveness ranks, which were closely tied to employees' hourly earning rates, and ranks for inspection and mending performance. There is in fact some evidence that Mending Room Effectiveness ranks, and hence pay, are inversely related to excellence of inspection performance. When these results are simultaneously considered with the relatively high positive correlation found between Mending Room Effectiveness and Time Utilization ranks one is tempted to conclude that payment is made for the proportion of time worked and not for quality of inspection or mending.

Finally, the large number of negative, though non-significant, correlations between Time Utilization ranks and ranks on almost all other indices of performance lead to the conclusion that with more controlled observation Time Utilization may be a useful index of stress. The idea would be that a person who has plenty of time to spare on a job is not under stress whereas a person with little or no time to spare is being pushed to the limit.

CHAPTER IX

CONCLUSIONS AND DISCUSSION

9.1 The Experiments Considered

Burling and mending as has been explained consists of two components, inspecting cloth and repairing faults. E. Belbin et al. (1957) devoted considerable effort to analysing the repairing of faults. She translated her findings into training methods and devised a scheme to aid new operatives in understanding the elements of mending. This is achieved by presenting trainees with enlarged and simplified models of various patterns of weaving. The trainee thereby gains a rapid appreciation of the intricacies of weaving and the requirements of mending. The models can be reduced in size and increased in complexity until the stage is reached when the trainee is ready to tackle the normal kinds of cloth. This type of training is amongst the methodology used at the Wool Industries Training Board's Training School in Bradford where, traditionally a period of several years training, has been reduced to a matter of weeks. Also the new methods allow middle-aged women to learn a job traditionally believed to be suitable only for young school leavers, Belbin (1958).

Before the benefit of this scheme can be translated into actuality and faults burled and mended it is necessary to locate the faults. This study has examined the inspection of cloth with the intention of gaining greater understanding of the processes involved. This, it was hoped, would lead to findings which could be adapted to selection and training techniques and particularly to helping retrain existing burlers and menders.

Prior to this study real objectivity had never been applied to assessing and comparing inspection performance in the woollen and worsted industry. Teams of highly skilled supervisors concerned with inspecting cloth solely, rather than as part of an integrated burling and mending activity examined an experimental piece of cloth inch by inch, checking and confirming each other's findings in order to establish a standard. Yet even under these circumstances certain faults, specially woven into the cloth in order that a reasonable variety might be introduced into the experiment, were not detected. This was despite the women being informed of the presence, type and location of the faults. Faults such as these, e.g. a wrong twist, might well appear more obvious after the cloth has been finished and made into a garment, but it would be fair to conclude that some faults are not within the range of human detection ability at the inspection stage of cloth manufacture, since even supervisors with many years of experience at inspection could not detect them.

The establishment of this standard enabled experimentation to be objective and allowed valid comparisons to be made between individuals and groups. The relative importance of the two contributing senses, visual and tactile were examined and compared with normal working conditions and similar conditions supplemented with angular lighting. As a result of the findings in a first experiment designed to establish a baseline of performance, a further experiment on inspection under angular lighting conditions was carried out. The effects of age, and different fault types on the speed and accuracy of perfomance were evaluated.

It was recognised that under normal circumstances inspection did not take place in isolation but was part of a process which also included operative inspection whilst carrying out repairs on the cloth. Thus performance, in which inspection was minimised and the repairing of faults the foremost task, was measured and compared with the same subjects' performance on the inspection task.

The details of the results have been fully discussed in the respective chapters on each experiment but a summary of the important findings and the conclusions proposed is necessary to gain understanding of the wider implications.

Under working conditions a single piece of cloth may be inspected on anything up to five occasions before it finally goes on to the finishing process. The cloth is inspected once while it is burled and chalk may be used to mark faults for later repair. When this second inspection is carried out faults not found on the initial inspection may be located and also mended. Finally a third check is carried out before the cloth is then handed in as mended to the passers or supervisors. The cloth is then inspected by the passer or supervisor and if faults are located then it may be again handed to the mender for further repair during which it may be examined for a fifth time. It is interesting to contemplate that since approximately 60% of the faults are being located with one inspection it would require five inspections to be arithmetically certain of eliminating 99% of all faults, if of course 60% of the faults were also detected on each subsequent inspection. Interesting though this supposition may be it is not possible to draw any wider conclusions. In the course of the experiments pertaining to inspection ability opportunity for only a single inspection of the cloth was possible. This was a particularly thorough inspection of the cloth under conditions of minimal distraction and without mending responsibility. Only twenty-five yards of cloth, approximately a third of that normally inspected at one time, were involved and yet for the relatively normal conditions of EH and EHL_1 an average of 47 minutes and 28 seconds per inspector was taken and only 58.99 per cent of the total faults found. Since no other objective measure of inspection perfomance in this context has been undertaken, this result must stand as testimony to certain inspection inadequacies. Inspection of cloth is not easy but training places a great deal of emphasis on mending and assumes inspection skills are readily acquired. Perhaps an explanation to inspectors of scanning techniques which pointed out that certain faults are unlikely to be discovered by means other than tactual whilst others are dependent on visual detection would lead to a complete overlap of tactual and visual search, i.e. the whole of the surface of the piece of cloth being inspected both tactually and also visually and not merely partially tactually and partially visually. It was hoped that an analysis of the time lapse motion pictures would throw light on this matter but unfortunately mechanical failure of the time lapse unit on both Experiments I and II disrupted the systematic data collection and rendered what was collected inadequate for detailed analysis. This was regrettable as casual observation of the subjects suggested most strongly that manual and visual scanning was haphazard. This is perhaps not surprising when it is realised that the task emphasis on mending leads to constant interruption of inspection (often for long periods of time) to facilitate mending. Thus it became all the more important for inspection while it is being carried out to be based on systematic scanning.

Expectation of performance in unpaced inspection tasks (Botwinnick and Schock, 1952) leads one to expect older workers to be more accurate, with younger operators exhibiting perhaps less skill and (Welford, 1962) probably more speed. Davies (1968) says "in general they (older subjects) appear to attach more importance to accuracy than speed of response". In the present experiment, though not significantly so, a complete reversal of this expectation was observed. Younger subjects were slower 55 minutes and ten seconds on average for the four conditions of the first experiment as against 52 minutes and two seconds for the older subjects. In the woollen industry opinion often is expressed that older women are less dependent on tactual cues and use mainly vision to carry out their inspection. Younger women through lack of experience in detecting by means of visual cues rely far more on feeling the cloth. There is some confirmation of this in the results of these experiments. For example, younger women perform better tactually, with 60.00% of the total faults found as against 51.92% and the older women are marginally better at visual detection, i.e. 46.50% as against 45.50% for the younger group.

The differences become more apparent when the analysis takes account of fault categories. Here younger subjects detect 47.12% as against 40.08% for condition H whereas older subjects are better under E detecting 44.48% as against 41.65%.

This appears more critical when it is realised that more faults are detected by means of the hands than by means of vision. This is demonstrated quite clearly for in all but fault categories 5 and 8 in which visual performance is significantly better than the tactual, tactual scores are better, and significantly so, in categories 1, 2 and 4. Categories 1 and 2 in fact contain more faults than any of the other categories. It now becomes clear that some younger subjects are inspecting predominantly with the hands and older subjects with the eyes, and that with the majority of the faults requiring tactual inspection, a better performance from the younger age group is only to be expected.

With regard to speed the results at first glance show younger women to be both faster inspectors with their eyes, 47 minutes and 46 seconds, on average as against 58 minutes and 42 seconds for the older group, and slower with their hands (75 minutes and 54 seconds as against 56 minutes and 32 seconds on average) though overall the older women are the quicker. Once again however these results are not significantly different and in terms of inspection performance it cannot be considered that any real age differences have been found.

Correlation coefficients show there to be a significant relationship between the total time required to inspect a frame of cloth and the number of faults found in that frame. It has been proposed that this occurs because there is a fixed scanning time devoted to an area of cloth by each subject regardless of how thoroughly or otherwise the area is inspected. Added to this scanning time is the time taken to perceive, decide, and in the case of the experiment, verbally react to each fault found. But for this, scanning time would bear a random relationship to the number of faults found in any frame. If for example it was assumed that an expectancy of locating a constant number of faults in each frame existed then in frames with very few faults for example, subjects in anticipation of finding more would carry on scanning and similarly in a fault ridden frame once a certain number of faults had been detected subjects would feel they had found as many as could be expected. That this does not occur is substantiated by the high positive correlation referred to and also high positive and significant correlations between faults present in a frame and faults found in that frame and between faults present in a frame and the time taken to inspect that frame.

Alternatively traditional vigilance theory suggests that the feedback from the search task determines what the observer expects for further participation in the task and again evidence somewhat to the contrary emerges from the investigation. Under the condition of "eyes only" more time was taken to inspect than under EH or EHL_1 though significantly less faults were found. Here the H or "hands only" condition does not represent a valid comparison as the subject, being blindfolded, was involved in factors such as the maintaining of balance and orientation. Detecting less faults under condition E should mean less feedback and thus the abandonment of the search at an earlier stage, but this was not found to be the case.

It is postulated that in circumstances where the quantitative aspects (in this case the area of the frame being scanned) of a detection task are known and feedback is relatively plentiful then the dependence upon feedback to maintain the level of arousal and thereby improve performance becomes of less importance whilst the quantitative aspects of the task become more so. It is suggested that these circumstances are more applicable to industrial inspection tasks than to those originally examined in terms of classical vigilance.

In examining an analysis of variance of the correlation coefficients, between the number of faults in a frame and the time taken for inspecting that frame for each of the 37 frames for each of the 40 subjects, a significant result is obtained for differences between conditions. In each case the correlation between faults found and time taken is less for the vision only condition than any of the other conditions and subjects in scanning by means of vision, a frame that has a high content of tactual faults, will not score highly on faults found. Since there are many less visual faults available for detection than tactual faults an imbalance will occur.

It is therefore perhaps not surprising to find the younger subjects scanning for faults visually (condition E) and detecting less of them, through lack of experience, than the older subjects and thus scanning faster, with the opposite effect under condition H in which the younger subjects do better. Overall of course, there being less visual faults available for detection the older subjects in finding fewer faults would be less likely to consume the time required for perceiving, identifying and reacting to detected faults and would thus be quicker.

The need for complete overlap of the tactual and visual senses in scanning cannot be overemphasised if improvements in inspection performance are to be brought about.

The investigations into the effect of angular lighting on inspection performance were really no more than two pilot studies. In order to determine the optimum type, source and power of illumination required to elicit maximum inspection performance a more sophisticated apparatus and further careful investigation would be necessary. Nevertheless it is interesting to note that the two forms of angular lighting tested, one very weak and the other a particularly powerful source of 2,500 Watts coupled with a special reflector, both produced results in the same direction. This showed performance increments when compared to performance obtained with overhead lighting alone. It would not be correct to deduce a linear relationship or any other from these results but the way does appear to be open for further research to stipulate whether even more powerful sidelighting is required or whether a less powerful light source would be equally or even more effective.

It is interesting to note in the special lighting condition that older subjects are again quicker and younger subjects more accurate in fault detection. Older subjects do, however, improve somewhat in their accuracy and it is worthwhile noting that this improvement occurs particularly with faults which are usually detected tactually. Brown (1960) in an experiment on the judgement of the surface roughness of wood thought his skilled subjects to be dependent on tactual rather than visual skills. This would appear to be contrary to the findings of the experiments described here, however he too found visual inspection with oblique lighting even without the aid of tactual inspection, to be highly advantageous for both skilled and unskilled subjects. It seems likely that less tactual scanning is required when angular lighting is used, the purpose of the side-lighting being to cast shadows from raised portions of the cloth, thus making faults easy to detect. Even then, however, only 58.23% of the total number of faults in the cloth were detected when fault categories are taken into consideration.

The attempt to predict inspection ability from scores from the various aspects of mending performance did not produce decisive results. This in intself is of some importance. Mending ability proved difficult to assess. Measures of mending speed, mending neatness and a combined score of mending skill were obtained by assessors. This was carried out as objectively as possible with the assessors examining the cloth before and after it was repaired and never having any contact with the subjects. An attempt to gain more objective measures was also made by getting the times taken for mending and burling and trying to relate this to the total time spent working on the cloth. Also management assessments, e.g. of relative earnings, were used to obtain estimates of Mending Room Effectiveness. This latter score correlated positively though not significantly with mending speed and time utilization, though not with neatness, which is not entirely surprising as under most incentive and piece-rate schemes speed is the more likely to affect earnings positively than accurate and neat mending.

Inspection correlations with mending are also not significant and an overall conclusion can only serve to emphasise that the two tasks demand relatively different skills. This makes the selection of "passers" critical. Whilst further research would be required to compare the inspection performance of passers with the cross section of menders who participated in this experiment, in order to determine whether practice at inspection rather than mending plus inspection, improves the inspection performance, nevertheless the question is raised as to whether the more skilled inspectors should be promoted to passers (usually the supervisory position) rather than the best all-round mender. It may well be that a good mender will have her skills poorly utilised as a passer. At present no direct measures of the two separate tasks are obtained in mending rooms though it would not be exceptionally difficult for supervisors to check work on two criteria (1) on the quality of the burling and mending repairs, and (2) on the number of faults requiring mending which have been overlooked. Once records are kept some idea of the relative abilities of a mender over a period of time could be obtained and more objective selections made for the position of passers. This could lead to more effective deployment of a working group into which it is at present difficult to recruit. An examination of age differences provides interesting information. Differences in speed again show the older group to be quicker whilst the mending neatness or accuracy scores show the younger inspectors to be superior though in neither case were the results obtained significant. It is interesting to note that differences found between age groups in both inspection and mending are in the same direction for speed and accuracy.

Time utilization scores would normally reflect the time spent inspecting rather than mending. In this experiment, however, nearly all the faults were marked so that subjects were only occupied with mending. Thus a poor time utilization score indicates time wasted non-productively with the younger group at fault.

It would appear that it is speed and persistency which gives the older group their highly significant superiority in mending room effectiveness. It is possible though, that assessment by supervisors in individual mending rooms is influenced, e.g. by a halo effect which favours the older women. The results found in both inspection and mending experiments would not lead one to expect such noticable differences in earning power or working ability. One may hypothesize on reasons for this but it would appear that younger menders are not working at their full potential. It may be possible that piece work and incentive schemes with their emphasis on speed do not offer the necessary encouragement to younger menders whose work appears to be orientated to careful inspection and slower mending.

Unfortunately, previous research in the area covered by the present investigation has been negligible and neither reassurance nor contradiction can be found to support or negate the results proffered. It is hoped that implementation of the recommendations made in this thesis into training schemes, and, the examination of the results obtained will serve to stimulate further research effort not only into the field of inspection but into related areas in cloth production as well.

9.2 Future Developments

It is perhaps worth considering that even the best subject in the experiment inspecting under the most favourable conditions located only 70% of the available faults. The reasons for this have been discussed in terms of task difficulty, scanning deficiencies, and the remoteness of real feedback. It is also possible that the suggestions proposed regarding improved lighting and better scanning techniques may still leave the inspector with too much to do. In addition the recruitment of female menders represents a persistent problem and the burling and mending process is thus very often a production bottleneck. A recent survey by the Wool Industries Research Association of 12 mills found that greasy mending of a piece of cloth took an average of nineteen hours. Obviously the industry would like to reduce this mending time and the scope to do so does exist, as it is generally believed that there is a tendency to overmend. Small faults can be particularly troublesome as if they are not mended they may be apparent in the finished cloth, and yet often if mended this too may leave a mark.

If this problem is to be tackled at the cloth/mender interface then the question of feedback becomes a vital one.

The decision to mend or otherwise which has to be made in the mending room, receives no real verification as the ultimate result is not known until a considerable while later, i.e. after the cloth is "finished". Thus the real criteria of whether a fault should be mended or not rests not on whether this would be a sound decision in light of the condition of the grey or greasy cloth, but whether it would still be a good decision after the cloth has undergone further processing. Feedback on mending performance in the absolute sense is thus rarely if ever received, for a mender only in exceptional circumstances works on the cloth in its finished state and even then it would usually not be the same person who carried out the original mending.

Research is required in the identification and tracing of faults through the mending process and then through the finishing process with a parallel study of a similar fault left unmended. The fault should be located on the cloth's surface and its position accurately plotted on record sheets so that it can be easily traced and evidence is unambiguous. Analytical photographic records must also be collected of the fault through the stages of before mending, after mending and after finishing. A similar record for comparative purposes must also be kept of the control faults, i.e. the one that is not mended.

By selecting a range of levels of severity for each fault and taking account of variables such as the type of weave and the type of yarn, it might be possible to establish at which point a fault should or should not be repaired. This would be (1) because of a fault being too small and that both fault and repair would leave equal blemishes, or (2) because of the fault being too large and mending thus too time consuming, without necessarily achieving the objective of completely concealing the fault.

The photographic record and the information collected could be fed back to the mending rooms in the form of a manual and also used in the training school of the Wool Industries Training Board. That this training methodology would be successful is suggested by Chaney and Teel (1967). They found diagrams of faults to be an effective aid to the training of industrial inspectors. Thus whilst it is possible that neither inspection nor mending performance would be improved if measured by means similar to those used in the present study, the ultimate effectiveness of the menders would be improved in real terms and the time and therefore the cost of mending a piece of cloth reduced.

Further problems however exist for with engineering technology developing new looms which will be capable of weaving cloth faster than ever before, reaching over 200 picks per minute compared with perhaps an average of little more than 100 per minute now, burling and mending problems threaten to multiply rather than diminish.

At present one man may be supervising as many as six looms. He also maintains a vigil on possible faults which may emanate from the bobbins of yarn or in the weaving, and seeks to correct these at the time of their detection, thereby reducing the eventual effort of the menders. With the future increase in speed of picks the load on the weaver is greatly increased, as will be the subsequent load on the menders.

A systems approach to these problems is of the utmost importance if optimal results are to be achieved. Merely tackling the problem at the mending room and inspection interface represents sub-system optimisation and ignores the real sources of the fault production. These can usually be traced to the state of the yarn leaving the spinning process and subsequent weaving.

It seems likely that faults such as slubs resulting from changes in yarn thickness may soon be eliminated. An electronic yarn clearer machine (slub catcher) has been developed to inspect yarn during the winding process. The machine can be set so as to consider two criteria. The first is thickness and the second is the length of the thickness. It is necessary to measure for both because it would be uneconomic to eliminate very short lengths of all but exceptionally thick yarn. The yarn runs through a condenser, the capacitance of which depends on the mass of the material. When the mass exceeds the limit which is set the yarn is cut away and knotted, knots being easier faults to mend. It is possible that the next generation machine will be able to consider a second set of limits and eliminate thin as well as thick yarn.

Consideration also needs to be given to shuttle speed and yarn strength. It is known that certain mills have to modify their own looms regarding shuttle speed, particularly when mohair is used, as the loom manufacturers do not give them the engineering end products they require.

Knots arising due to the technique of joining yarns too need further investigation and modification. W.I.R.A. developed an adhesive to overcome this problem, but unfortunately its use is limited as it requires skillful hand application. This tends to reduce production and makes the removal of knots at the mending room stage still a more attractive proposition.

Factors such as ensuring the correct setting up of the loom should not be overlooked and "wrong twists" might be avoided by colour coding bobbins for left or right handed twists.

Where concentrated effort should be made is not absolutely clear but a cost benefit study should determine the critical areas. Thus whilst every effort to improve the inspection and mending performance of burlers and menders should be encouraged, a systems approach to the whole problem area with particular reference to the engineering components should be pursued. Present difficulties in obtaining suitable mending room personnel should serve to emphasise the predictable problems of the future and the importance of obtaining solutions in areas where maximum impact will be gained.

APPENDICES

APPENDIX 1

Experiment 1

The sample for Experiment 1 consists of twenty subjects under the age of thirty and twenty subjects over the age of thirty. A subject of the age of thirty is included in the older group.

	Under 30	Over 30
Range	17 to 28 years	30 to 58 years
Mean Age	21.4 years	40.8 years

APPENDIX 2

Text of a Tape Recording Played to all Subjects in Experiment I

This is an introduction to explain to you what you are going to do here, so please listen closely.

You are participating in an experiment which is attempting to find out exactly how often you use your hands to help you find faults in a roll of cloth and also how often you use your eyes to help you find faults. In order to work this out accurately some people during the experiment will use their eyes only and will not be allowed to touch the roll of cloth directly with their hands. Others will wear special glasses and will only be allowed to use their hands and a third group will be allowed to use both their hands and their eyes. The gentleman in charge of the experiment will tell you which of these groups you are in.

Once you have been told which group you are in the gentleman will adjust the height of the chair and footrest at the work table so that you are in a correct position. You will then either be fitted with the special glasses or you will be given a pointer and some rubber gloves or alternatively nothing extra at all if you are in the last group.

On the work table you will see a roll of cloth. This is divided into two foot sections with pieces of white tape.

What we want you to do now is to find all the faults in each two foot section of the roll of cloth. When you find a fault point out exactly where the fault is and then say what kind of fault it is. When you are satisfied that you have found all the faults in one section tell the gentleman and he will wind the cloth onto the next section.

You will then do the same thing again and so on and so forth. Remember there is no mending involved, and all you have to do is point out and name the faults. There is no rush but please do try to work at your normal pace.

If you have any questions please ask me as I am here to assist you.

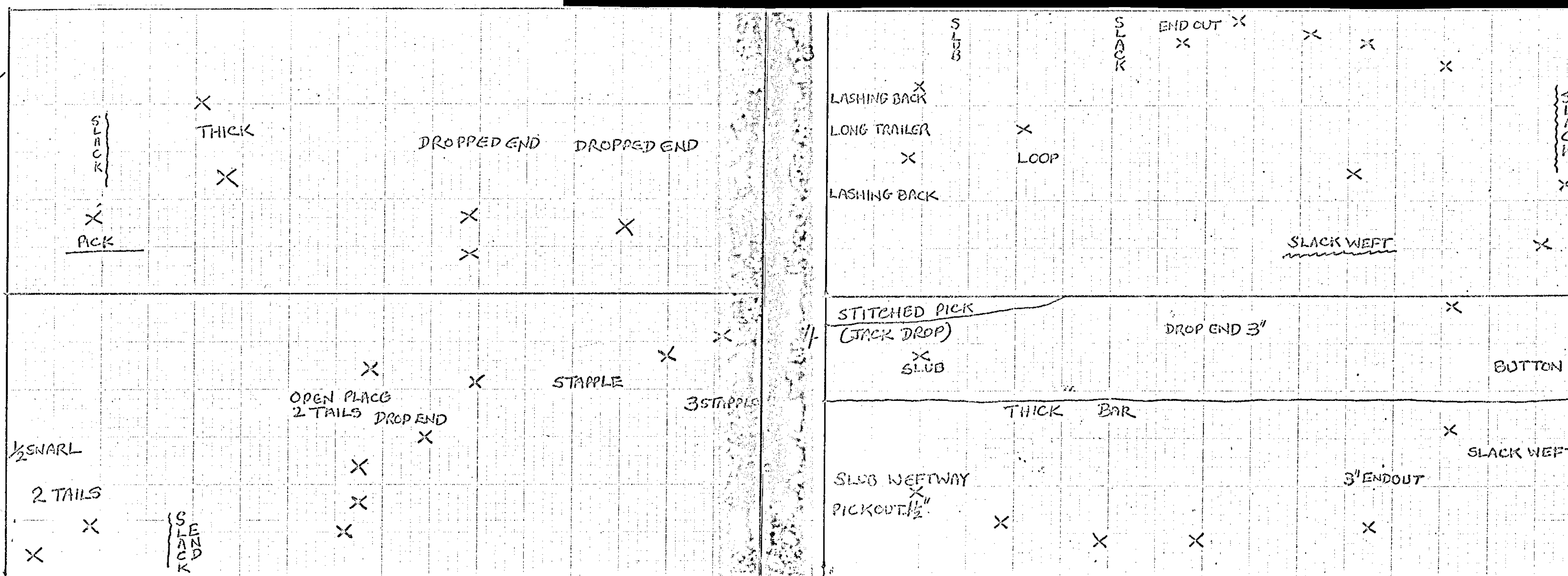
Thank you very much for coming along and helping with this experiment.

Thank you.

APPENDIX 3

eriment 1

Attached are typical examples of the score sheets with the tted faults. The numbers on the left indicate the frame numbers on the th.



APPENDIX 4

Experiment 1

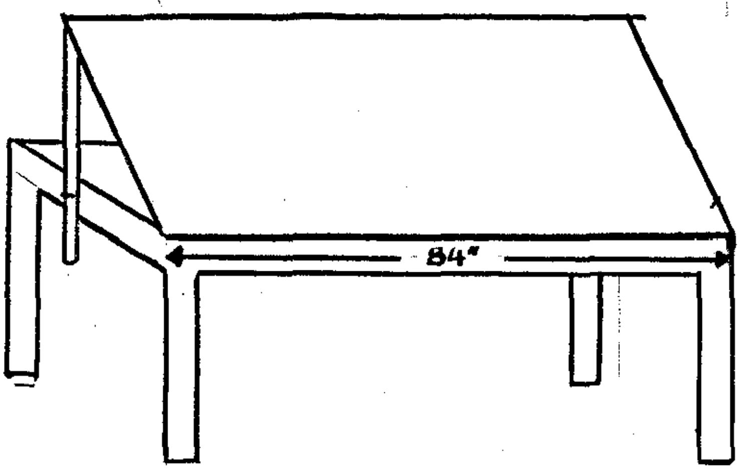
Total Number of Faults in the Cloth

	Faults Present
Fault Category 1	335
Fault Category 2	93
Fault Category 3	66
Fault Category 4	24
Fault Category 5	83
Fault Category 6	66
Fault Category 7	38
Fault Category 8	30
TOTAL	735

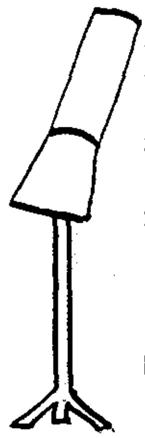
APPENDIX 5

Experiment II

Levels of lighting on the experimental table with and without angular lighting. All the measurements relate to light falling on the surface and are given in lumens per square foot.



Experimental table



angular light source

Readings in lumens/sq. ft.

	far side	middle	near side
Overhead + angular lighting	55	85	145
Overhead lighting alone	50	50	50

APPENDIX 6

Experiment 3

A test for mean differences by Students' t test between the following groups of subjects.

(1) The nine subjects who participated originally in the EH group of Experiment 1.

(2) The remaining eight subjects who participated originally in the EHL_1 group in Experiment 1.

The Mean differences of the seven major sets of scores used in Experiment 3 were considered.

Score	Means EH	Means EHL_1	Mean Difference	t	P
Inspection Speed(scores in seconds)	2983.88	2819.87	164.01	0.424	N.S.
Inspection Accuracy(scores are a total of 8 percentages)	412.33	436.12	-23.79	0.803	N.S.
Mending Speed (scores are out of 20 marks)	17.44	17.31	0.13	0.138	N.S.
Mending Neatness(scores out of 20 marks)	17.61	17.94	-0.33	0.031	N.S.
Mending Inspection(scores out of 20 marks)	17.22	16.50	0.72	0.628	N.S.
Time Utilization[1](in terms of a fraction of the total mending time)	0.781	0.814	-0.033	0.493	N.S.
Mending Room[2] Effectiveness (percentile scores)	65.68	64.10	1.58	0.113	N.S.

1. only 8 subjects in the EH group - one score not considered in Experiment 3.
2. only 7 subjects in the EHL_1 group - one score not considered in Experiment 3.

It may be argued that the distributions of the above scores are not normal. This is because of the appearance of skewness in the distribution and the consistently low t scores obtained for all seven tests.

These persistent low scores may be indicate of :

(a) greater variation within a group than between groups

(b) skewness in distribution.

The first of these possibilities is rejected for a priori reasons and in the case of the second it must be realised that a non-parametric technique would be less powerful than the t test used and even less likely to reveal any significant differences between means.

APPENDIX 7

Time and Score Sheet

The subject was required to enter the time spent on each fault of a particular type, frequency and length in the space provided. If the fault could not be located then the subject recorded "not found" against that fault instead of the repair time. If extra faults were found their length and time for repair were recorded in the appropriate columns.

KNOTTING AND TRIMMING EDGES		THICK WARP DRAWN		THICK WEFT DRAWN		SLACK ENDS		DROP ENDS		WARP MENDS	
	TIME SPENT	AMOUNT	TIME SPENT	AMOUNT	TIME SPENT	AMOUNT	TIME SPENT	NUMBER	TIME SPENT	LENGTH	TIME SPENT
		48 ins		62 ins							
		4 ins		9 ins							
		4 ins		8 ins							
		9 ins		6 ins							
		6 ins		7 ins							
		5 ins		6 ins							
		6 ins		6 ins							
		4 ins		9 ins							
				12 ins							
		86 ins		6 ins							
				7 ins							
				6 ins							
				6 ins							
				6 ins							
				156 ins							

WEFT MENDS		STITCHINGS		FELTERS		CURLS AND SNARLS		TRAILERS		DOUBLE ENDS	
LENGTH	TIME SPENT		TIME SPENT		TIME SPENT		TIME SPENT	NUMBER	TIME SPENT	LENGTH	TIME SPENT
15 ins								40			
46 ins											
20 ins											
50 ins											
48 ins											
57 ins											
49 ins											
285 ins											

APPENDIX 8

Instructions to Subjects

Although this is for an experiment I want you to burl and mend this piece at your normal speed. However, I would like you to do certain things especially for this experiment.

To begin, first burl the cloth on the back.

Put down the following information on the sheet handed to you.

1. Put at the top of the sheet the total time for burling and mending the whole piece.

2. Using the clock given to you for the experiment accurately record the following on the sheet in the correct place.

(a) The time taken to burl the back of the cloth.

(b) Do not forget to put down the time taken when going over the cloth at the end for your final burling.

THESE TWO ITEMS MUST BE ENTERED IN THE FIRST COLUMN ON THE LEFT HAND SIDE OF THE SHEET.

(c) The separate times taken to repair each of the faults listed on the sheet e.g. *if 36 drop ends are listed time yourself for each of these with a clock and put down the figure in the correct column, e.g.*

45 seconds

30 seconds

1 minute and 10 seconds.

THERE IS NO NEED TO ADD UP THE TIMES YOURSELF.

If any of these faults are ones which you would not normally repair then leave it and write "not done" on the sheet in the correct place.

If you cannot find any of the faults marked on the sheet , then write "not found" in the correct place.

If any additional faults are found which are not marked on the sheet write them down in the correct column and accurately record your time for this work.

NOTE : In addition to your normal wages for participating in this experiment, and for the time lost in the process of carrying out the instructions you will receive 10 shillings. If all the time and other information requested are accurately, neatly and well recorded on the sheet supplied, you will receive a further 10 shillings bonus.

There are about twenty ladies in mending rooms in several mills taking part in the experiment and the one who is judged to have been best at timing herself and completing the sheet provided with the most accurate detail as well as being the neatest will receive an additional £1.

PLEASE TAKE CARE OF THE CLOCKS PROVIDED.

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