Computers, Ergonomics and Schools

are you sitting comfortably?...

by

Lorna J Banks BA(Hons)

Professional Project for:

Moray House College
PGCE (Secondary) Business Studies
1991
I would like to thank all the staff and pupils at Boroughmuir High School, Edinburgh who gave their assistance and co-operation when supplying information for this project. Likewise, I am grateful for the assistance received from computing, technical and business studies staff at St. Columba’s High School, Dunfermline.

Dr Mike Jubber has given (and continues to give) me much needed support and guidance....ie. giving me a rather large kick up the backside to get on and actually produce this document.

Heriot-Watt University and Dundee Institute of Technology should also get a mention for providing a library service which is technologically up-to-date, fast, accurate and above all - open when required!!!

Thank you to the Edinburgh Folk Festival for being there to entertain and encourage me. Sandy Denny you have a lot to answer for...

To save paper this project is printed in single line spacing - trees look better than piles of paper

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Now that computers have been resident and in general widespread use in schools for almost 10 years, I want to investigate the physical environment in which these computers are being used. The motivation behind this study is driven by an interest in human-computer interaction (HCI). Furthermore, an interest in ergonomics relating to computer workplaces. Much research has been done for commercial reasons on workstation design, but are schools taking any notice? Are ergonomic factors taken into account when designing a space for computer use within a school? Are the computers integrated throughout the school or are they simply all put in one room?

The aim of this project is to assess and review the physical environment (workstation environment) in which computers are currently being used in secondary schools and how this may affect a users ability to interact with the computer. Scientific research points to various problems users have when interacting with computers and this project uses this along with discussions with users to suggest some possible solutions.
Material has been gathered from observations and conversations with staff at the 2 High Schools visited during my placements in first and second terms.

This report is divided into 3 main sections:

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Firstly, chapter 1 concentrates on aspects of computer hardware and in particular the physical characteristics affecting the user's interaction with the visual display unit (VDU). This includes a review of technical and psychology research, which is sometimes very detailed purely because this is where my interest lies.

Secondly, a brief look at the psychology behind the way humans read along with the effects the factors mentioned in chapter 1 might have on learning. The types of hardware and software used in schools is also considered and this brings in points highlighted by school users.

Finally, through discussion possible implications and recommendations for improvement are put forward.
Chapter 1

Workstation Ergonomics

1.1 Factors affecting VDU legibility

If pupils are to use, and learn through the use of computers, it is important to look at the factors which affect the interaction between computer and user. This chapter looks in detail at these ergonomic factors such as the level of light in the room, the brightness and contrast of the computer screen, typeface, colour, height and design of furniture etc. Matters of health and safety are also considered.

This project concentrates largely on the reading and input of text to a much greater extent than graphics because in school Business Studies department's text processing is given more attention.

This chapter is particularly technical because I am greatly interested in this aspect of human-computer interaction. I would also like to stress at this point that this has not just come straight out of a book. In fact it is the result of reading a wide variety of psychology and scientific research material and then regurgitating the interesting and relevant bits!

1.1.1 Illuminance

The readability of a VDU screen is affected by the light (or illumination) in a room which falls on its surface. This is called illuminance and is measured in units of Lux(lx). The average level found in workplaces is in the range 300 - 500lx. However, Östberg (1980) recommends levels of 200 - 300lx in workplaces which continuously use display screens. Background light causes problems when reflected back from the glass screen of VDUs, filters producing a matt finish can reduce this.
Figure 1.1  Example of screen reflections obliterating the Image
(From Cakir, Hart & Stewart, 1979)

The user's ability to read the VDU is also affected by its brightness, or more accurately, *luminance*.

1.1.2 *Luminance*

Luminance (in this case) is the light emitting from the displayed characters and/or background on the screen. It is measured by a photometer in units of Candelas per square metre (cd/m²). Bauer and Cavonius (1980) found the approximate average luminance of many raster scan VDUs (which are the only type which concern us here) to be 10cd/m². However Kalsbeck and Umbach (1980) recommend levels greater than 100cd/m² (Television = 100 - 1000cd/m²).

Thompson (1984) states the following reasons for having high display luminance:

(i) visual acuity increases (up to a limit)
(ii) less optical distortion and improved depth of field
(iii) discomfort from reflected glare may be reduced.
However, if luminance is too high, discomfort from direct glare may increase and cause reduced acuity because, characters become blurred, bright and dazzling (as subjects complained of in Bauer and Cavonius, 1980).

Figure 1.2 shows how different designs of VDU have different characteristics as far as luminance and character design are concerned.

Figure 1.2  Comparison of 2 characters on different VDUs, at 4 different luminance levels  
(From Cakir, Hart & Stewart, 1979)

Legibility of text on VDUs is affected by the relationship of contrast which exists between the luminance of the characters and their background. This is referred to as luminance contrast.

1.1.3  Contrast

Contrast between the luminance of the character and the background can, if too high (>15:1), produce glare, and if too low (<3:1), result in reading difficulties. In an attempt to get the contrast (sharpness) correct the following equations are used to gain measures.
The International Lighting Commission (CIE) definition of the luminance contrast relationship between an object and its background (the most widely quoted definition) is:

\[
\text{Contrast} = \frac{L_o - L_b}{L_b}
\]

where:

- \(L_o\) = object luminance
- \(L_b\) = background luminance

Thus the contrast of the printing on this page produces a negative value (\(L_o < L_b\)), and is referred to as having negative contrast. Conversely, light characters on a dark background is positive contrast, the most commonly used on VDUs.

Scientists use a different measure to define contrast over an area of screen - the Michelson Contrast. Thus, you can see there is a need for a standard measure to enable easy comparison.

The greater the contrast between characters and background, the easier it is to read. This is important as it affects visual acuity, contrast sensitivity, visual reading field and speed of recognition. Low contrast (little difference between luminance of characters and background) impedes reading (Timmers et al, 1980 & Bouma, 1980).

*Figure 1.3*: Effect of decreased paper brightness upon readability

(From Cakir, Hart & Stewart, 1979)

However, this still occurs in common public display presentations like Viewdata and Teletext, where bad (luminance levels too similar) combinations of text and background colour are made ie. green on yellow (Radl, 1980).
Many researchers have turned their attention to the question of whether positive or negative contrast is better for interaction with VDUs (Bauer & Cavonius, 1980; Peterson & Tinker, 1931; Radl, 1980 etc). The latter study reported reading speeds increased by 10% on negative contrast screens. Bauer & Cavonius found that the success rates for recognising nonsense words and overall recognition speeds increased by 23% and 8% respectively. In a questionnaire, all but one of their subjects favoured the negative contrast. The reason for this being it was easier to read and more comfortable to use. The effects of reflective glare are also reduced on a negative contrast screen.

However, if you are looking between a positive contrast (dark screen, light text) screen and a negative contrast book (light page, dark text), this can cause eye strain because the eyes have to adjust to different light levels.

1.1.4 Resolution and Font Design

The resolution of a VDU screen is dependant mainly on the number of scan lines used to make up the picture. The more lines, the greater the resolution. The principle method of alphanumeric character generation on VDUs is the dot matrix. Each dot in the matrix is called a pixel (or elementary picture element). Figure 1.4 shows how the display is generated.

![Diagram of TV line raster and Stripe raster](image)

**Figure 1.4** Building up a character (a) horizontal or (b) vertical scanning of the electron beam “lighting” up the phosphor pixels of the display

*(From Cakir, Hart & Stewart, 1979)*
Minimum resolution, from the point of view of character discrimination, especially in mixed upper and lower case displays, is regarded to be $5 \times 7$ matrix (standard DIN 66234). The more pixels the greater the detail and resolution, eg. good photograph = $2000 \times 2000$ pixels, high resolution VDU = $640 \times 400$ pixels. However, this is being improved all the time and graphics screens (eg. on Apple Mac's) tend to have better resolution.

Computers offering word processing facilities tend to have more typeface or font varieties available.

The interrelationship between resolution, legibility, viewing distance and character size (height) is discussed next.

1.1.5 Character size and Viewing Distance

Older VDU technology dictates that there are fixed character sizes which therefore denotes a reasonably fixed number of lines per screen, eg. BBC or Amstrad computers. Newer technology, eg. Apple Mac, have variable character sizes and therefore variable lines per screen. However, there have been a number of studies directed at determining the optimum character size matrix (Vartabedian 1971, 1973; Huddleston 1974; Maddox, Burnette and Gutman, 1977; Beldie, Pastoor and Schwarz 1983). The latter also showed that proportional, as against fixed-width, character sets, gave faster reading times with less errors.

The relationship between resolution and character size is dependant on character brightness. As turning up the brightness has the secondary effect of enlarging the apparent pixel size. In dot matrix characters this can compensate for the sparseness of pixels in low resolution matrices. The perceived size of characters will vary with viewing distance from the VDU. Each user will have a preference with screens, however, a preferred distance of between 40 and 80cm was shown by subjects observed by Hüting et al. (1981). A viewing distance of 66cm required a minimum character height of about 2mm (Grandjean et al., 1982) which is half that suggested by Giddings (1972) for words, while Schmidtke (1980) recommends 4mm at 50cm.

Viewing distance to the screen and its angle of inclination should be individually adjustable with due regard being paid to the factors
mentioned in section 1.2. Users who wear spectacles must ensure that they are adapted to the VDU viewing distance as normal lenses may cause bad posture to be assumed.

1.1.6 Refresh Rate and Flicker

These factors have a great influence on the users ability to read information from the screen. The refresh rate is the number of times per second (cps) the electron beam passes over the phosphor on the screen. The phosphor glows after being excited by the beam, but soon decays unless the beam regenerates that same part of the screen on the next pass. The more passes the beam makes (higher cycle frequency) the less the screen appears to flicker. A point is reached, called the Critical Fusion Frequency (CFF), where the image appears constant. This frequency is not however constant, and varies with factors such as screen luminance.

Refresh rates are based on the mains electricity supply frequency (50Hz in Europe and 60Hz in the USA), any fluctuation in its supply to the screen is a further cause of image instability - as well as causing possible data loss from the computer memory. However, this frequency is usually adequate to eliminate flicker, (Gould, 1968) although it can still be possible to detect it in peripheral vision. As screen technology improves this problem is less noticeable.

Flicker (oscillating character luminance), is one of the most disturbing features of VDU use, affecting the way the eye moves, causing eye strain (Läubli et al, 1980) and epileptic fits in a small proportion of the population. So the conventional practice has been to keep luminance down - hence the common use of positive contrast screens. However, as technological advances are made with regard phosphors, this may become less of a problem. Wilkins, Darby and Binnie (1979) suggested that reducing the contrast between the screen and its surroundings should reduce the probability of epileptic fits.

There is a linear relationship between flicker and luminance (Ferry-Porter Law), which demonstrates that a VDU with a 50Hz refresh rate that is just at the threshold of flicker perception at 10cd/m² will flicker violently at 100cd/m². Therefore, to reduce flicker the tendency is to reduce luminance but the contrast must be maintained for legibility reasons.
The use of high persistence phosphors can reduce perceptible flicker but the image is more likely to smear when scrolled up and down. The Apple Mac computers use the most up-to-date screen technology of all the computers I found in schools, using a white phosphor thus aiming to replicate white paper.

1.1.7 Colour

Sometimes VDUs used for text editing are multi-colour graphics displays - although the opportunity of using colour is not always used by the software. Bouma (1980) points out that as coloured letters/digits can only be read very close to fixation (Engel, 1971, 1977 & 1980), colour is a good aid for visual search ie. good for quickly locating text, if different subjects are displayed in different colours - thus used to good effect, for example, on Viewdata displays like Ceefax and Oracle. A preferred maximum of 4 or 5 colours per screen is the norm. Colour used in software should only be used to enhance information, as excessive or inappropriate use can reduce performance and cause confusion (Durrets, Trezona, 1982).

Turning to look at monochrome displays eg. Apple Mac's used in schools, specifically there is little to choose between the actual colour chosen for the display, other than personal choice and financial restrictions. Many people have expressed a preference for yellow/green which is in the middle of the visible spectrum. Coloured characters can make it a little easier to see past reflections on the screen (Grandjean, 1980).

Radl (1980) discovered that users preferred and performed better (letter transcribing task) with yellow phosphors. He also studied the effect of colour (background/foreground) combinations - best results occurred when coloured characters were displayed on a grey background. Most errors occurred where there was low contrast between background and foreground colours, eg. violet on blue etc. Thus, luminance contrast affects the actual reading of information more than colour itself.

Adding to what was said earlier concerning flicker, this is also determined by the decay times (when luminance drops to 10% of peak level) of the phosphor used. This can range from fractions of milliseconds (white -P4 & yellow - P20) to several hundred milliseconds.
(green - P1 & P39). Review of much of the research on colour uses on VDUs has been provided by Davidoff (1987).

One possible trouble with using colour displays, however, is that 8% of the male population is colour blind (as compared to 1% females). Most common is red/green blindness and a large proportion of those effected don't realise it until they have to use a colour display eg. green screen, or have an eye test.

1.2 Workstation Environment
1.2.1 Physical set-up

Bad posture is common amongst VDU users and is caused by badly designed, ill-fitting, workstations. Figure 1.5 shows some of the problems and their causes.

![Figure 1.5](Image)

An example of common but harmful posture
(From Cakir, Hart & Stewart, 1979)

Badly designed, ill-thought out arrangements of the component parts required for work at VDUs cause the user to adopt strange and
uncomfortable positions, which after even short time periods lead to headaches, neck, back and eye strains, as well as stress. These factors all lead to reduced productivity, increased errors and days lost through illness.

Therefore, there has been much research into improving the ergonomic standard of the VDU environment. The Health and Safety Executive recommendations cover all aspects of workplace design, for example:

| Knee Clearance         | 120-170mm for easy access moderate, to avoid excessive trunk movement |
| Arm Reach              | eyes 44° down cast from horizontal, and head inclination of approximately 20°  |
| Eye height and position of head | 45cm - 55cm, causing minimum frequency of focus changes |
| Viewing Distance       | |

Average adult standing height 5' 6''
Optimal viewing range 0 - 45°
Optimal keyboard/arm arc 70°
Desk depth 30°
Average desk height 25''
Average chair-to-desk height 8''
Average chair height 17''

Figure 1.6  Recommended set-up for a comfortable posture
(From Apple Mac Owner’s Guide)
The Apple Macintosh SE Owner's Guide comes complete with the following table which helps you to set-up your computer workstation environment correctly.

<table>
<thead>
<tr>
<th>If you are:</th>
<th>Your work surface should be:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 feet 11 inches (150cm)</td>
<td>23 inches high (58cm)</td>
</tr>
<tr>
<td>5 feet 4 inches (163cm)</td>
<td>24 inches high (61cm)</td>
</tr>
<tr>
<td>5 feet 6 inches (168cm)</td>
<td>25 inches high (64cm)</td>
</tr>
<tr>
<td>5 feet 9 inches (175cm)</td>
<td>26 inches high (66cm)</td>
</tr>
<tr>
<td>6 feet 2 inches (188cm)</td>
<td>28 inches high (71cm)</td>
</tr>
</tbody>
</table>

British standards have been developed for keyboard design and layout (eg. BS4822, BS5231). These concern such factors as distances between key centres (19 ± 1mm), their heights and spacing (Rupp & Hirsch, Hart 1976).

Furniture should be designed to fit work with VDUs ie. lower tables, more space for reference papers, copy holder and high backed chairs. To summarise:

(i) Raised reading stand is advantageous - bring 'copy' to same level as VDU (reduce eye movement)

(ii) Keyboard should be separate from the screen - gives user more opportunity to adjust and optimise the terminal environment to suit himself

(iii) Screen should have adjustable titling mechanism - again for user adjustment (not always standard on VDUs)

(iv) Relatively high-backed chair (backrest approx. 50cm) - beneficial for all office workers, particularly operators.
Problems with reading from VDUs are more extreme than normal reading of print as characters are usually blurred, poorly defined and the screen may flicker (as mentioned before). A study by Hultgren & Knave (1974) where people had complained about the VDUs found that much of the trouble was due to an excessive difference between the positive contrast display and the brightness of the rest of the room, since this produced discomfort, glare and screen reflections. In addition to reducing the contrast of the material to be read, such reflections can mislead the eyes into focusing at the wrong distance.

Problems with displays concern poor definition, instability of the image and interaction between the lighting of the room (especially bad with fluorescent lights) and the display.

The most important factor about workstation design is variability. This is true not only in the workplace but also in the classroom. The user should be able to set-up the VDU and surrounding environment to best suit his personal needs and preferences. Thus helping to reduce detrimental effects on work (errors and health problems). Training in the set-up and use of the workstation should be the initial step.

1.2.2 Health concerns regarding VDUs

Various researchers have looked into the effects VDU operation may have on health. There findings have been of importance to Trades Unions and employers in the field of job design and working conditions. Furthermore, these concerns are obviously of importance to parents and children especially if duration of use is long. Prolonged working periods with VDUs have been found to increase the incidence of eyestrain, (Cakir, 1978; Gunnarsson & Soderberg, 1983; Sauter et al, 1983) visual fatigue, (Bedwell, 1978 & Dainoff, 1980) neck, back and head aches. Radiation emissions have been found to be no higher than natural background levels (Terrana et al , 1980). Stress was studied by Sauter et al , (1983) by comparing the tasks of office workers with and without VDUs - the latter was found to be more stressful.

However, because pupils at school rarely spend more than an hour or 2 at the screen per week (although more if studying Higher Computing
etc), health risks are assumed to be insignificant. The only acknowledged possible problem might be focusing difficulties.

Focusing problems have been identified among VDU users in their 20s and 30s. The patients of the VDU Clinic at Berkeley School of Optometry, University of California, were requiring reading glasses long before the normal age for such visual assistance. Of the 153 patients, 27% found focusing took 56% longer than normal. The cause of this has been put at the door of inadequate ergonomic standards. Fine-tuning flicker rates and character resolution, as well as controls for screen colour, glare and luminance, were requested. However, the Business Equipment Manufacturers Association blames the problems on illuminance controls (room lighting) rather than the VDUs.

The government has finally recognised that there may be health problems associated with the use of VDUs, and in response a new piece of safety legislation is going to be introduced soon. Commercial organisations as well as academic institutions (including schools) will be covered by the new Act. Therefore, it is important to assess both the usage of, and the environment in which people are using VDUs. An example of this being done in practice is Heriot-Watt University. They are currently surveying the "present working conditions in respect of both staff and students who use VDUs on a regular basis ", as a direct response of the forthcoming introduction of legislation. The questionnaire being used is contained in the Appendix.

1.3 Summary

This project therefore, looks at the physical environment computers are being used in in schools. To appreciate how the workstation environment should be set-up, in order to improve interaction between computer and user (HCI) and to reduce any detrimental effects eg. health problems, initially you have to identify the factors concerned. This chapter investigated research into those ergonomic factors which affect human-computer interaction. Indeed, the most important point to come out of this research is that the user should have the ability to set the attributes and features eg. screen brightness and contrast, thus enabling him to have the environment best suited to his needs.

The following chapter looks at the practical situation in schools and briefly its consequences for learning.
Learning Considerations

This chapter is concerned with the implications the factors investigated in the last chapter have on the set-up of the workstation environment and on learning. Firstly, it briefly looks at the particular problem users have with reading from VDUs and some of the processes involved. Secondly, how can software design cope with the problems mentioned in chapter 1, and finally, how are these ergonomic factors taken into account as regards computers in secondary schools.

2.1 Reading Techniques

A lot of work using computers involves reading from screens. Many researchers have investigated what effect VDUs have on reading (Muter, Latremouille, Treurniet & Beam, 1982; Kolers, Dachnicky & Ferguson, 1981). It is therefore relevant to look at the sort of processes involved in reading and what effect VDUs have on this.

Reading can be regarded as extracting information from text. The factors in section 1.2 affect the ability of the user/reader to do this from VDUs. In reading and visual search, the eyes move in quick jumps called saccades. In between these jumps the eye fixates - eye fixations last for milliseconds but this is when the images of the words are obtained. These images then have to be interpreted, given meanings and related to the other words in the sentence with regard to grammar etc. Internal speech may be used to aid understanding of the sentence (Kleiman, 1975; Baddeley et al, 1982). The sentences have to be related to the whole passage. This is obviously related to previous knowledge gained by the reader about life.
The shape of a word has been identified as being important to the way we perceive it, especially with familiar (frequently read) words (Bruder, 1978). Previously we have looked at research into character size and shape. Couple these with studies which have found reading in general slower on VDUs than on paper (Muter, Latremouille, Treurniet & Beam, 1982; Tinker, 1965) and it becomes apparent that there can be significant problems for the user. The latter study concerned legibility and also found reading continuous capitals 14% slower. Capitals do not give a word an identifiable shape, like lowercase or mixed text does.

\[\text{Shape} \quad \text{SHAPE} \quad \text{shape}\]

**Figure 2.1** Recognition of word shape - difficult when continuous capitals are used

As can be seen in Figure 2.1, underlining a word also changes its shape or outline, its contrast luminance, its general legibility and makes it a lot harder to recognise. Therefore, all these factors can combine to make recognition slower, resulting in overall increases in reading time. It is therefore important for software designers to appreciate the difficulties users can have when trying to read text from a computer screen.

### 2.1.1 Software and Interface Design

The design of software and the use of enhancement codes (reverse video, **bold**, *italics*, flash and edit trails) have a significant affect on the users ability to obtain information from the VDU. They are used to give emphasis to text and are predominantly used by word processors.

Software designers have made these highlighting techniques available as they reflect traditional or conventional paper techniques, e.g. highlighter pens. The user can apply these techniques to enable him to locate particular parts of the text.
The style of interface a computer has is very important because it is through this that the user interacts with the computer software. The WIMP interface (as used by Apple Mac computers) is graphical and very easy to use, requiring little learning time. Other features include windows to display documents or run programs in. These windows are an easy way to manipulate the working area or document. This type of interface is becoming more common as it has been adopted as a standard. However, older styles of interface are still in use in schools on computers such as Amstrads and BBCs.

2.2 Computers in the classroom

The 2 schools I visited had very different computer resource allocation. I wanted to look at where in the school they had placed their computers and how they were set-up. For example, were computers equally distributed throughout the departments or were there a few rooms full of computers that could only be used by that department? How were these computers placed in the room? Were they on desks in rows all facing the front of the classroom? Were they on desks around the edge of the room facing the walls or windows? How was the room lighting controlled and what form did it take? Was there room for expansion and had this been planned for? If expansion was likely would it require a major redesign of the room and its provision of services?

Turning to look at the individual ergonomic set-up of the computers I was interested to investigate: How high were the desks that the computers rested on? Were there reflections on the screen which made reading it very difficult or impossible? Was the available seating the correct height or adjustable? Was the keyboard separate from the computer so that its position could be adjusted by the user?

2.2.1 St. Columba's High School, Dunfermline

Both schools have received TVEI funding, part of which has been used to provide computer equipment. However, this school are also part of the Flexible Learning programme and computers are being used for this purpose. Figure 2.2 shows a range of computer equipment in a science lab which is currently being used for flexible learning.
This room is not designed for the use of computers and machines regularly fall down the old sink holes in the benches. The room will obviously be refurbished to cater for its new requirement when more funding becomes available.

Figure 2.2  Flexible learning room - "converted" science lab

There is poor wire management and little space for the computers on each bench. Seating is fixed position but is of a suitable height to bring the user up to approximately the correct level. However, computer use in this room is far from idea.

In the Technology department computers are used for computer aided design (using an Arcamedies) and for controlling robots, lathes and other equipment. Figure 2.3 shows a BBC master with printer set-up on a trolley and used for controlling a small robot. Mobility in this case enables the computer to control various pieces of equipment around the room.

In the Business Studies department there are 20 Amstrad PCs with one printer between 4 machines. Figure 2.4 shows a typical set-up with VDU mounted on a swivel mechanism allowing the screen to be set at
Figure 2.3  BBC Master used to control equipment eg. robots

Figure 2.4  Amstrad with printer in the Business Studies department
the angle required by the user. The monochrome VDU is placed on top of the CPU thus raising the screen which means that users don't have to lower their heads so much, thus less neck strain. The keyboard is separate from the CPU, again allowing the user to position it individually.

The main word processing room (figure 2.5 below) in the department suffers from direct sunlight through the windows and therefore the blinds have to be down most of the time. This means that the fluorescent lights are switched on which may cause problems for some people. Their is also one Apple Mac on the teachers table.

![Amstrad PCs staggered in 2 rows facing front of class](image)

**Figure 2.5**

The Computer department consists of one room with 11 BBC Masters and 3 Apple Mac's. The colour VDU for the BBCs are raised up slightly but they can not be positioned in any way by the user. The keyboards are also connected to the CPU. The height of the seating can not be adjusted. In this room again direct sunlight is a problem. The computers are arranged around the outside of the room with desks for traditional lessons in the middle. On one side of the room VDU are against the windows which is not very suitable if the blinds are up.
This school has more pupils and is better resourced. Again TVEI funding has been used to provide very good computer equipment. There is a central computer room (figure 2.6) with 22 Apple Mac's, a laser printer and an optical scanner. The decoration is modern with ample working shape and swivel chairs. Ergonomically the light coloured blinds and furniture make this a room which is easy to work in.

![Spacious Apple Mac room with swivel chairs](image)

**Figure 2.6** Spacious Apple Mac room with swivel chairs

The Business Studies department uses 20 Amstrad computers with individual printers. Locoscript word processor is most commonly used although spreadsheets and databases are available. There is not much space to work on each desk because of the printer. The computers are arranged facing the front in 5 rows of 4 with a central aisle. The room is small and this layout does not utilise the available space efficiently.

The seating is adjustable but no copy holder are available. Lighting is artificial and the blinds are usually down. However, the room is bright but not dazzling as the carpet is dark. Figure 2.7 shows the business studies word processor environment.
2.3 Summary

Schools are slowly improving their computer work areas and taking ergonomic factors into consideration. Funding is obviously the main restriction as IT policies tend to be well thought out when and where they exist.
Discussion and Conclusions

Software Interfaces and learning time

The interface used on BBC and Amstrads is called a command line interface and requires the user to learn a language in order to communicate with the machine. This obviously takes time and requires the user to remember control codes and keywords etc. Therefore, as far as time taken to learn a computer system and ease of use, the Apple Mac is much better than both Amstrad or BBC for most purposes.

However, as with most things it is money that is the restraint on school resources. Apple Mac's are coming down in price and the new Mac Classic is a very good around machine suitable for all current school requirements.

Specific problems observed in schools

Schools obviously cater for pupils who range in height quite considerably from first to sixth year. Because of this, seating provision etc should ideally be very adjustable. Unfortunately, schools usually have to make do with what they have already got. This can result in little first years sitting on chairs where their feet don't reach the ground, or using keyboards and VDUs which may be a little too high.

Furniture

The average height of desk being used for a computer workstation was within the range stated on the table on page 13 but there were no examples of desks with lowered keyboard facilities. As for
seating, the pictures show that there was quite a range. Boroughmuir was able to supply swivel chairs which enable the height and backrest position to be set by the user. The most common seating however, was height and position fixed plastic chairs.

Iluminance

A common problem was sunlight obscuring the screen (figure 3.1).

![Figure 3.1](image)

**Figure 3.1** Screen image obliterated by strong sunlight

Blinds had been fitted but some were damaged in places, thus some pupils had serious problems seeing the text on the screen. The layout of the computers in the room was such that usually sunlight and other strong light sources were not a problem. Indeed, no computers were placed so that the user was directly facing a window or had a window directly behind them. These are sound ergonomic considerations but unfortunately using the blinds reduced the ambient light level to the extent that artificial light had to be used most of the time. This could cause headaches etc for some
users if they could perceive interference flickering between the fluorescent lighting and the screen refresh rate.

Working space was restricted in all cases except Boroughmuir's computing room where each machine had plenty of work area for papers or books. Tables in the centre of the room, laid out in a horseshoe shape, allowed users to turn from the machine to read or interact with the teacher. It must be said that this room was very large and itself a very valuable resource!

Decoration Prolonged computer use can strain the eyes because they are repeatedly having to refocus and adjust to contrast changes. If room decoration and furniture colour are light this can help to reduce overall contrast differences in the room, thus reducing work for the eyes.

Further Research

If you wanted to continue and develop this subject area it could be useful to look at a wider range of schools in order to gain a better view of how computers are being used.

Conclusion

It would appear, through conversations with staff, that some schools are more aware of ergonomic factors relating to computer than others. Some schools have better resourcing basically because they have better overall funding or they have a direct policy of increasing the information technology resources. This may be because they have chosen to use TVEI funding centrally to produce a well equipped central computer room eg. Boroughmuir, which is available to everyone on an open access basis, ie. if there is a computer free anyone is able to use it as long as they don't disturb the rest of the class. This type of policy allows for flexible learning and utilises resources to the maximum.

As far as the individual set-up of computer workstations in schools is concerned, most schools are aware of the basics but are restricted in
their abilities to achieve some elements purely due to lack of funding. If there is a definite IT policy then as funding becomes available suitable resources will be added.

Being aware of ergonomic factors relating to computer use is important to users and teachers because it enables them to get the best out of the machine. Pupils are usually not required to use a computer in school for more than an hour simply because the school day is structured into periods. Therefore health and legal considerations are less of a restriction than in the commercial world.
In response to the forthcoming introduction of safety legislation on work with Visual Display Units (see March 1991 Safety Bulletin) this questionnaire has been drawn up on behalf of the University Safety Committee to identify present working conditions in respect of both staff and students who use VDU's on a regular basis.

Completed questionnaires should be returned to the Safety Office at Riccarton by 30 April 1991. Anonymity is assured as the identity of respondents is not required. Additional copies of the questionnaire are available from the Safety Office.

WHERE BOXES ARE PROVIDED TICK AS APPROPRIATE

A. WORK PATTERN
1. How many hours per day do you work at a VDU terminal?
   □ 1-2hrs  □ 2-4hrs  □ 4-6hrs  □ 6-8hrs  □ 8+hrs

2. What is the maximum amount of time which you spend at a VDU terminal without a break?*
   □ 1-2 hrs  □ 2-3hrs  □ 3-4hrs  □ 4+hrs

   *a break means time spent away from the workstation and may include doing other work. Just stopping for a cup of tea at the terminal does not count.

3. How long are the breaks spent away from the workstation?
   Lunch break (1) .................. minutes
   Other breaks (2) .................."
   (3) .................."

4. Nature of work
   Is your work mainly:
   □ Word Processing □ Data Processing □ Programming □
   □ Information Retrieval □ Other - please specify..........................

5. Briefly describe the work you do: ...........................................

.................................................. .........................................

B. THE EQUIPMENT
6. Do you have any of the following?
   (a) Adjustable screen:
       Viewing angle □ Brightness control □
   (b) Adjustable keyboard:
       Position □ Angle □
   (c) Adjustable chair:
       Height □ Backrest □ Swivel □ Castors □
   (d) Adjustable office lighting:
       Overhead □ Desk Lamp □
   (e) Copy holder □
   (f) Anti-static control □
   (g) Anti-glare screen □
   (h) State colours of display text and background.
       Text............ Background....
7. Type of printer used (if any)
   Laser ☐ Other ☐ Please specify...........................

8. If there is does it have a noise reducing cover?
   Yes ☐ No ☐

C. ENVIRONMENTAL CONDITIONS

9. How many people share the room with you?
   none ☐ 1-2 ☐ 3-5 ☐ 6-10 ☐ 11+ ☐

10. How would you rate the noise level?
    Quiet ☐ Average ☐ Noisy ☐

11. How good is the lighting?
    Too bright ☐ Just right ☐ Not bright enough ☐

12. Do you have any other comments about the conditions?
    ...........................................................................
    ...........................................................................

D. HEALTH PROBLEMS

13. Since starting to use VDU's have you suffered from any of the following?
    (tick appropriate column)
    Eye Strain ☐       Often ☐ Sometimes ☐ Never ☐
    Blurred Vision ☐
    Changes in colour perception ☐
    Skin rashes ☐
    Painful/stiff neck ☐
    Sore shoulders ☐
    Back pain ☐
    Stiff/sore arms ☐
    Stiff/sore wrists ☐
    Stiff/swollen fingers ☐
    Loss of feeling in fingers/wrists ☐
    Headaches ☐
    Irritability ☐
    Other symptoms - please specify...........................
    ...........................................................................

E. PERSONAL DETAILS

   Sex: Male ☐ Female ☐
   Age: 16-25 ☐ 26-35 ☐ 36-45 ☐ Over 45 ☐
   Occupation: Lecturer ☐ Research Assoc. ☐ Management ☐
   Secretarial/Clerical ☐ Postgraduate ☐
   Undergraduate ☐ Other Please specify...........

   Do you have to wear spectacles specifically for working with VDU's?
   Yes ☐ No ☐

COMPLETED QUESTIONNAIRES SHOULD BE RETURNED TO THE SAFETY OFFICE BY 30 APRIL 1991.
1. **EUROPEAN SAFETY DIRECTIVES**

Under Article 118A of The Single European Act the Council of Ministers of the European Community are empowered to adopt Directives on minimum health and safety standards for Member States. Seven such Directives have recently been adopted for implementation by 31 December 1992 covering the use of Display Screen Equipment (VDU's); Manual Handling of Loads; Personal Protective Equipment; Work with Carcinogens; Work with Biological Agents; the Workplace and Workshop Equipment. The VDU and Manual Handling Directives when incorporated in UK safety legislation will have considerable implications throughout the University and the following is a brief resume of the requirements:

**The Display Screen (VDU) Directive**

Requires employers to analyse VDU workstations to evaluate safety and health conditions, taking appropriate measures to ensure that the standards specified for screens, keyboards, furniture, lighting and working environment are met. Workstations already in use before 31 December 1992 are required to meet the specified standards within four years of that date. Other requirements are for employers to plan activities so that daily work on VDU's is periodically interrupted by breaks or changes in activity. In addition, workers will be entitled to an eyesight test before starting work with VDUs; at regular intervals thereafter and if they experience visual difficulties. Workers will also be entitled to an ophthalmological examination if the eye test shows this is necessary, and they must be provided with special spectacles if these are needed for their work and normal ones cannot be used.
### Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodation</td>
<td>Adjustment of the eyes to accommodate changes in focal distance.</td>
</tr>
<tr>
<td>Ambient illumination</td>
<td>The general level of illumination in a room.</td>
</tr>
<tr>
<td>Brightness</td>
<td>Refers to character luminance on a VDU, rather than the usual perception of how bright something is, which takes into account the surroundings - a subjective response.</td>
</tr>
<tr>
<td>Contrast</td>
<td>The perceived difference in colour or brightness or both of the object.</td>
</tr>
<tr>
<td>CPU</td>
<td>Central processing unit.</td>
</tr>
<tr>
<td>Critical Fusion Frequency (CFF)</td>
<td>The point at which flicker appears to cease and the picture seems to be a steady continuous image.</td>
</tr>
<tr>
<td>Luminance</td>
<td>A measurable photometric quantity of light emitted from a source.</td>
</tr>
<tr>
<td>Luminance Contrast</td>
<td>The ratio between the difference in luminance of an object and its surroundings, to the background luminance.</td>
</tr>
<tr>
<td>Michelson Contrast</td>
<td>$\frac{(L_{\text{max}} - L_{\text{min}})}{(L_{\text{max}} + L_{\text{min}})}$ where: $L_{\text{max}} = \text{maximum luminance}$ and $L_{\text{min}} = \text{minimum luminance}$</td>
</tr>
<tr>
<td>Negative Contrast</td>
<td>Dark characters on a lighter background.</td>
</tr>
<tr>
<td>Positive Contrast</td>
<td>Light characters on a darker background.</td>
</tr>
<tr>
<td>Spatial Cues</td>
<td>Layout (of text/space) cues.</td>
</tr>
<tr>
<td>Visual Acuity</td>
<td>A measure of the ability of the eye to discriminate between or resolve fine detail, eg. characters or parts of a character image. Used in evaluating display legibility.</td>
</tr>
<tr>
<td>Wimp Interface</td>
<td>Software interface containing - Windows, Icons, Menus and pointers. For example, Apple Macintosh.</td>
</tr>
</tbody>
</table>
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43 Morar Rd, Crossford, DUNFERMLINE, Fife, KY12 8XY. Tel:(0383) 729813
Lorna BANKS

Once again a lesson in presentation. Excellent! Even if you get a bit carried away with the use of different typeface and font varieties (although I excuse the addition on page 26)

A nice sense of humour comes over in your Acknowledgements, at first I thought you had made a mistake... "Sandy Beany you have a lot to answer for." Is he the course leader?

I have to accept and indeed trust your para 1.1 page 3, as I wandered among the 'roster scan VDU's' and 'oscillating character luminance.' It sounds a bit like Caribbean folk music.

The photographs are very good and add to your reference points.

I feel this has been a worthwhile study into important matters of concern to schools. I learned a lot in reading this project.