CHAPTER III

PROBLEM AND RESEARCH METHODOLOGY

The literature reviewed presented in the preceding chapter (Chapter II) suggested that the effects of several organismic factors like sex, laterality and age on human performance in the context of HCI in general and in working with VDTs through the keyboards, in particular, are yet not fully understood. It thus offered a scope to investigate the effect of such most important organismic variables on human performance , in the context of HCI environment. Accordingly the research problem was formulated, the general methodology pertaining to such details as experimental design, subjects' selection, stimuli, the experimental task, experimental set-up was laid down, and the general procedure employed to carry out the research was evolved as given below:

3.1 **Problem Statement**

In recent years there has been a rapid growth in the use of computers as one of the most critical tools of information system. However, the pace of research in the field of Human-Computer Interaction (HCI) has been rather slow in comparison to the growth rate of wide-spread use of computers not only in developed nations but also in developing countries. Human problems today constitute one of the major issues determining the rate of success or failure so far as the effective and fruitful use of modern days' information systems are concerned. There remains a dire need of catering to the demands of designers, manufacturers, purchasers and users regarding how information and communication systems could be made more useful, easier and faster from learning as well as fatigue view points. The literature surveyed indicated that previous researchers have been mainly emphasising the need to design and develop systems irrespective of the age, sex and

laterality characteristics of the users' population (Brown and Schaum, 1980).

So far as the computer operation is concerned, since the keyboard is the only means of communication between humans and computers, it was concluded that the ergonomic design of the keyboard perhaps is one of the most important facet of todays' research in HCI. This fact is amply illustrated by such observations as "standard keyboards which are available in the market are ill designed" (Technorama, 1992; p.31) and "conventional flat keyboards have a major ergonomical problems: you have to angle your hands to the side in order to type. This posture is unnatural and may lead to serious health problems like Repetitive Strain Injury (RSI)" (AliMed, 1994; p. 7). Keeping in view that the evolution of an ergonomically shaped keyboard would reduce the incidence of repetitive strain injury (RSI) (Hobday, 1988), various studies presented in this work were designed to provide answers to some of the basic issues related to the problem. In all, six experiments were conducted. Three experiments were undertaken to investigate human performance on "Conventional" and "Unishaped" keyboards, whereas in the remaining three experiments, human performance was examined under "Conventional" and "Split-shaped" designs of computer keyboards. In the three studies of the first set, the first one (study-1) investigated the effect of sex on keying performance. In second study (study-2) the effect of age on keying performance was examined. In the third study (study-3) investigations on the effect of motor-sidedness or laterality on keying performance was carried out. For the other set of experiments stated earlier, again three studies were undertaken. These studies investigated the effects of sex (study-4), age (study-5) and laterality (study-6) on keying performance in an HCI environment. In all the six studies, the muscular fatigue, expressed in integrated EMG units constituted the basic measure of human performance. Through the set of studies, stated as above, an attempt was made to evolve an optimum configuration of the computer keyboard that could provide a higher level of human-computer compatibility. Further, in all the investigations, performance

was studied under different levels of inclination (either tilt or base angles as explained in Appendix-D) of both the conventional "QWERTY" and the experimental "Shaped" keyboards.

3.2 **Experimental Design**

In all the studies undertaken in the present work, human performance were measured in terms of muscular fatigue expressed in integrated EMG-units which was treated as the dependent variable. EMG was selected in light of the recommendations of previous researchers (e.g. Zipp et al., 1983; Marek et al., 1992). Two independent variables viz the keyboard design at two levels: "Conventional" and "Experimental" (which was either "Unishaped" or "Split-shaped"), and inclination (tilt/base) of the keyboards at four levels: 4, 10, 16, 22 degrees for tilt and 15, 20, 25, 30 degrees for base, were present in all the six studies undertaken in the present work. The third variable which was varied from study to study was Sex at two levels: males and females (study-1 and -2), Age at four levels: 13-15y, 18-23y, 25-35y and 40-50y (study-3 and -4) and Motor-Sidedness at two levels: Right-motor sidedness and Left-motor sidedness (study-5 and -6). A 2 (the varying factor) x 2 (keyboard design) x 4 (inclination level of the keyboards) factorial design with repeated measures on the last two factors was used in all the investigations except the one involving age which had four levels as stated earlier. For the repeated measures kind of factorial design adopted for the present research, there was no software package available in and around Aligarh so that, to perform the analysis of the data a computer program was specifically developed for this purpose.

3.3 **Subjects**

A pool of 198 potential subjects was consciously selected for the present work.

This pool included both males and females and right-motor sided as well as left-motor sided persons in the age ranging from 13 y to 50 y. Most of the subjects were either students of engineering or employed in this university, This ensured that their availability did not pose any problem at the time they were needed for experimentation. To determine motor-sidedness characteristic i.e. laterality of the subjects, Annet's inventory system (Annet, 1970) was administrated to the sample population. This was a standard, self-administrated questionnaire (Appendix A) related to the handedness and footedness, and provided same information on motor-sidedness as that provided by behavioural tests of individuals (Porac and Coren, 1981; Raczkowski et al., 1974). Out of 375 questionnaires circulated among the AMU Aligarh community members, 267 persons responded and out of these, 198 persons expressed their willingness to participate in the present study, the sample response status being presented in Table 3.1.

Motor sidedness of the subjects was measured through the Preference Index (P.I.) (Annet, 1970) for each of the 198 cases who agreed to participate in the study. Information related to the sample characteristics were processed through a computer

Table 3.1: Sample Response Status

Number of Persons				
Contacted	Responded	Agreed to participate		
		Total	Males	Females
375	267	198	145	53

program (written in BASIC) that was specifically developed for this purpose. Subjects having P.I. greater than 0.90 were considered to be right-motor sided, whereas an ideal value for PI is +1.0, a value that represents a perfectly right-motor sided laterality. Those having negative P.I. were considered to be left-handed people, whereas an ideal value for

PI is -1.00, a value that corresponds to represent a perfectly left motor-sided feature of laterality. Any negative score in the latter category was taken to be an index of left-motor sidedness due to shortage of left motor sided people in Indian society. Results of the computer output pertaining to this analysis are summarized in Table 3.2 below.

Table 3.2: Result of Sample Data Analysis Pertaining to Laterality characteristic of the Subjects

No. of cases			Males	Females	Right Motor-Sided	Left Motor-Sided
Processed	Rejected	Accepted				
198	31	167	141	26	155	12

From this pool of subjects, sample sets with appropriate subject characteristics were selected for different experiments with the condition that none of the subjects participated in more than one experiment except for that which investigated the effect of laterality (study-5 and -6). In these two experiments the left-handed subjects participated in both the experiments as there was a shortage of the left handed persons.

3.4 Stimuli and the Experimental Task

Stimuli material was presented to the subject in the form of a printed sheet held on the document holder that remained fixed throughout the experimental sessions. Document holder was adopted in the light of recommendation of the previous researchers (e.g. Hunting et al.,1980). The sheet contained words having no literal meaning (Appendix-B). This feature of words was adopted to minimize the difference between the subjects whose level of proficiency at English language was difficult to be controlled. So far as the task is concerned the matter-content was printed (double spacing) on electronic typewriter and presented on a white sheet of paper such that the quality of printout was

of a very high order. The sheet was fixed on a document holder designed locally and specially for this purpose. The position of the document holder was maintained throughout the experimental session. As a part of the present work, a survey was undertaken to have an assessment of the level of tilt angle of the conventional keyboard which computer operators/users were usually used to, while working on computers in the University and other computer centers. It was found that the tilt angle varied from 4 (minimum as provided by the manufacturer) to 22 (maximum adjusted by user) degrees in different environments of HCI. In light of the result of the survey the levels of the tilt angle of the conventional keyboard (Appendix D; Figure D-1) in the present research were set at four levels :4, 10, 16 and 22 degrees . So far as the inclination levels (Base angle) of the shaped ("Unishaped" and "Split-shaped") keyboards was concerned obviously there was no data available as this new configuration was being experimented for the first time and was to be put to test from ergonomics standpoint. Based on the logical observations and the limited height and length of the keyboard incorporated into the design with respect to the height and width of the computer terminals, four inclination levels of base angle (15, 20, 25, 30 degrees) were selected (Appendix D; Figure D-2).

During experimentation, subjects sat on the chair (without back rest) with the two hands on the keyboard as was the observed usual practice of the users while working on the Video Display Terminals (VDTs). They were required to respond to the voice START by starting the data entry task as per instructions of both speed and accuracy. Each subject participated in two different experimental sessions involving either "Conventional" or "shaped" version of the computer keyboards. So far as the shaped keyboard was concerned, there were two keyboards "Unishaped" and "Split-shaped" types, designed, fabricated and developed locally in the Ergonomics Laboratory of Department of Mechanical Engineering AMU Aligarh, for being put to trial as a part of the present work. The design did not involve any change in the existing layout of the keyboard. It however,

provided a condition of re-shaping the QWERTY keyboard into two specific configurations as elaborated through the Figures C-1 and C-2 (Appendix C). While working on "Split-shaped" type of keyboard, subjects were instructed to use right hand for the right side of the keyboard and left hand for its left side. Half of the subjects participated under "Conventional QWERTY keyboard" environment while for the other half, the order of presentation of "shaped" (unishaped and split-shaped) keyboard was reversed.

3.5 **Experimental Set-Up**

As stated earlier, electromyography for the assessment of human fatigue was employed for the present research. The electro-myograph (model: EM6452; make: ECIL, INDIA) available in the Ergonomics Laboratory did not have the facility of converting its analogue output of muscle potential into the digital form. To incorporate this facility in the equipment an interfacing system with analogue to digital (A/D) converter was developed locally (Appendix E). The muscular fatigue induced in the subjects' muscles was recorded from the extensor carpi radialis muscles of the operators. This specific muscle was chosen in light of the recommendation of the previous researchers (Baidya and Stevenson, 1988) who reported that the extensor carpi radialis was found to fatigue faster with an increase in wrist extension in the situations where workers carry out repetitive light work with ulnar deviation and/or hyperextention of the wrist for long duration. The two EMG electrodes were fixed on the right and left arms of the subject. Great care was taken to ensure that the electrodes' pairs were placed on the similar sites of the right and left arms, while the third one i.e. the earth electrode was placed over the lateral epicondyle of the right elbow joint. To ensure good conductivity from the muscles, the skin of the corresponding muscles was cleaned with alcohol and a small quantity of conductive jelly (Electro Gel) applied over the concerned muscles before fixing the electrodes on the surface of the muscle. The bioelectric signals were

amplified and processed by interfaced Electromyograph that converted the raw signal into integrated EMG (IEMG). The IEMG was then processed through analogue to digital converter so as to be averaged through a microcomputer. Following the methodology used by Rosa and Anderson (1985), two 4-s samples were taken from each subject every 5th minute during the experimental task of 10 minute duration when the subject worked on a specific design of the keyboard at the given level of inclination (tilt/base angle). The mean of the two 4 s samples constituted the score used for statistical analysis.

All the experiments were performed in an environmental chamber of 3 m x 2.5 m x 2.5 m size. The temperature was maintained approximately at 25 ± 4 degree celsius. Reflection of the light from windows and doors was eliminated because when the chamber was closed, the cubicle got acoustically sealed from the outside environment. The illumination level throughout the experimental session was maintained at 340 Lux, a satisfactory value as per recommendations of ILO (1989). The level of illuminance was monitored through lux meter (Model 101, make: Lutron, Taiwan, range 1 lux to 5000 lux). The contrast ratio of the screen was 4:1 and was kept constant throughout the experimentation, in follow up of the ILO recommendations, referred earlier. The screen luminance was 310 cd/m^2, a satisfactory value according to Kalsbeek and Mbach (1980). The position of the keyboard, monitor and other documents was maintained in a prespecified position as portrayed in the schematic diagram (Figure 3.1). The distance from the screen to the eyes of the subject was kept at 500 mm which is the recommended value according to Buhmann (1980). The height of screen center from the ground was 910 mm, and has been taken according to Grieco et al. (1980). Finally, the digital computer that was employed in all the six studies was IBM made, (model: 5151002, Taiwan) the display system of which was of green colour.

A schematic diagram showing complete arrangement of experimental set-up and relative positions of the subject's seat, screen, electromyograph, and other accessories is presented in Figure 3.1 while Figure 3.2. represent a phographic view for the same. Photographic views of the unishaped, split-shaped and conventional keyboards are represented in Figures 3.3, 3.4 and 3.5 respectively.

3.6 **General Experimental Procedure**

Before the actual experimentation was started, a pilot study was undertaken. This helped in preplanning the details of experimental sessions and in checking the suitability of the observation sheet designed for collecting the experimental data. For each study a sample of 20 subjects (28 in study-3 and -4) with each subject fulfilling the prespecified characteristics was selected from the pool of potential subjects, described elsewhere (section 3.3) earlier. None of the subjects participated in more than one experiment except in study-5 and -6) for the reasons stated earlier. The following preparatory steps were undertaken before the actual conduct of the experiment.

(a) Each subject selected for any of the experiment was briefed about the objective of the experiment. Instructions to be followed by the subjects (Appendix F) while performing the experimental task were imparted to the subjects in writing.

(b) The subject related characteristics like age, visual acuity and the experience in the trade of computer operation were recorded.

(c) A training session was organised for each subject in order to familiarize her/him with the new keyboard designs tested in the present study. At least one complete run for the experiment was undertaken for this purpose.

After the subject had taken his/her seat in the experimental chamber and the two electrodes of EMG fixed on his/her arms and all the instructions imparted, the following

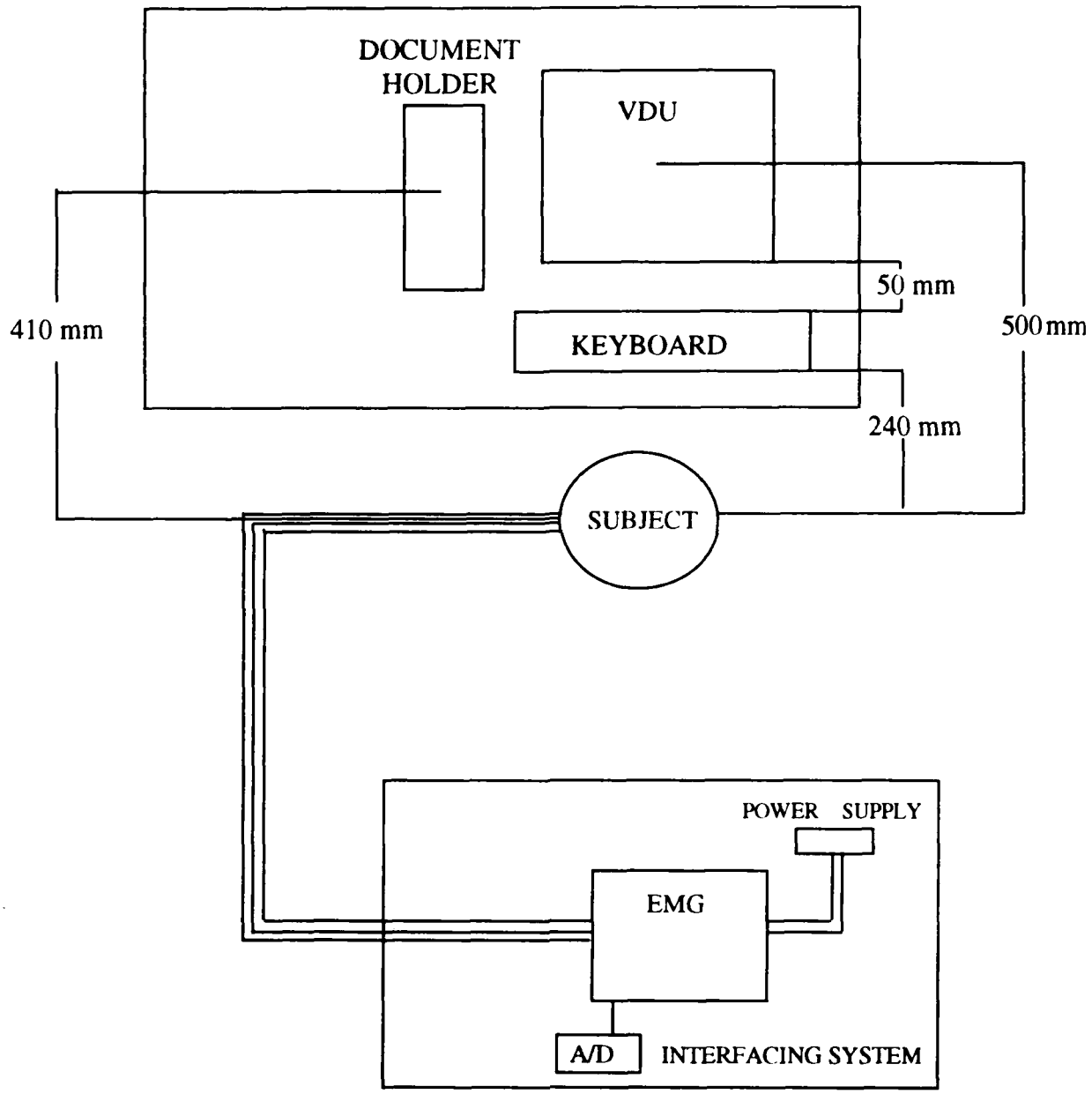

Figure 3.1. Schematic Diagram of Experimental Set-Up.

Figure 3.2. **Photographic View of the experimental set-up showing the subjects seat, the VDU, the document holder, EMG System alongwith the interfacing arrangement.**

. Figure 3.3. Photograph exhibiting the UNISHAPED keyboard

Figure 3.4. Photograph exhibiting the SPLIT-SHAPED keyboard

Figure 3.5. Photograph exhibiting the CONVENTIONAL keyboard

steps were taken, in that order, for both training as well as experimental sessions:

1. A prerecorded signal START was given.
2. A printed sheet of paper that contained the task fixed on a document holder was presented.
3. The subject responded by starting the data entry task.

This cycle was repeated for every level of inclination (tilt/base angles) of both the "Conventional" and experimental ("Unishaped" and "Split-shaped") types of keyboards. In every cycle of operation a rest period of 10 minutes was given and the subject was instructed verbally to relax his/her hand in the way he/she desired. Average time for each experimental session was of the order of 40 minutes in length. Human performance in terms of integrated EMG-units was recorded at approximately same time of the day on each day of the experiment. This has been kept in view in order to eliminate any temporal effect in experimentation that might have had its impact on the subjects performance.

The above described research methodology was employed in carrying out all the sets of experimental investigations presented in the next chapter (Chapter IV).