CHAPTER V

SUMMARY, CONCLUSION AND SCOPE FOR FURTHER RESEARCH

In the late 20th century, there has been an unimaginable and explosive growth in the use of VDUs (Visual display units) in varieties of workplaces all over the world in almost every walk of life. However, there has been little effort from the researchers side to have an assessment of the effects of this new man-machine interface on human performance and also on the associated hazards pertaining to the safety aspects of its end-users. A review of literature related to the human performance in an HCI environment (Chapter II) indicated several organismic factors to be of critical importance in the optimal design of man-VDU interaction. It was found that there remained a wide gap between what has been achieved and what is yet to be achieved. In light of the nature of this "gap" some experimental investigations were undertaken in order to narrow down if not bridge this gap (Chapter IV). The general methodology for these studies is presented in Chapter III. Now through this chapter an attempt is made to present an overview of the findings of the studies conducted, some possible implications of these findings and finally, suggestions for future research.

The six studies presented in Chapter IV investigated the effects of sex (Study-1 and -2), age (Study-3 and -4) and motor- sidedness (Study-5 and -6) on human performance in the HCI environment when operators performed the data entry task on different types of keyboard. Following major conclusions were drawn on the basis of these studies. First, from the view point of the ergonomic design of the keyboards, the variables, sex and age of the end-users do not constitute significant factors. However, at

low levels (4 to 10 degrees) of inclination (tilt angle) of the conventional keyboard muscular fatigue for elders was found to be significantly higher than that recorded for the younger ones. Second, human-motor-sidedness, an important emerging variable in human performance engineering, emerged to have a significant effect on human performance in the HCI work environment. This important finding opens up new avenues for human factors engineering and system designers to evolve special keyboard designs specifically for right-motor-sided and left-motor-sided users of computers. In other words, the keyboards available presently in the market need to be redesigned ergonomically as of today these do not represent optimal keyboards from laterality point of view. Third, the modified shaped (either "unishaped" or "split-shaped") keyboards emerged to be less fatiguing as compared to the conventional keyboards. In all the six studies undertaken in the present work the keyboard design as a variable was found to have statistically a significant effect on human performance. The proposed modified "shaped" keyboard designs demonstrated an alleviated level of the stress induced in operators resulting in reduced level of the repetitive strain injury (RSI) that affected the users' hands, neck and shoulder. Fourth, a higher keyboard inclination (tilt/base angles) level within the range investigated revealed better human performance at the data entry kind of task accomplished by the users in an HCI environment. In all the experimental investigations keyboard inclination (tilt/base angles) level appeared to be a significant factor in the ergonomic design of the keyboard of a computer. However, in most of the studies undertaken, results of the analysis of simple main effects indicated that in the context of the "shaped" keyboards design.the level of the base angle of the keyboard within the range investigated was not a significant factor so that it could be ignored from ergonomics point of view.

In the light of the above findings following observations are made:

1. Re-evaluation of the existing computer keyboard (i.e. Conventional keyboard)

is needed. It appears that "shaped" (either "unishaped" or "split-shaped") keyboards offer a more efficient version of the keyboard design when compared with existing design of "Conventional" keyboard. It was found that a modification in the current keyboard design would result in a better quality of interaction between man and computers and would also resolve the problems of repetitive strain injury and carpal tunnel syndrome caused to the end-users of the computer keyboards.

2. Since the movement time appears to be an important factor in keyboards design (Drury and Hoffmann, 1992), it is felt that there is a need for further exploration for searching for a more compatible form of the computers' keyboard with more emphasis on experimental control. Due to lack of facilities and other limitations of the present work, this factor (movement time) could not be taken into consideration in the present research.

3. It appears that not many studies have been undertaken in the past on human motor-sidedness as a variable specially in the area of human computer interaction. Present study indicated that laterality has a role to play in designing computers keyboard. Present body of literature available on laterality indicated that either right motor-sided operators are superior to left motor sided persons or they are equally efficient (Porace and Coren, 1981). Present study indicated that in the context of the HCI, users with left-motor-sidedness are superior to those possessing right-motor -sidedness.

4. The finding that age does not have an effect on human performance in the context of HCI, on one hand, and the available literature, on other hand, indicating that age does have an effect on human performance in varieties of situations, demanded a more concerted effort on the part of human factors engineers to resolve this issue, in general, and in the context of human computer interaction in particular.

In the form of scope for future research following suggestions are made:

1. In all the experimental investigations undertaken in the present work, muscular fatigue measured in IEMG-units, was employed as a measure of human performance, of late some other physiological measures like body impedance have been suggested (Rigaud et al, 1993) to be employed for having an assessment of human fatigue. Such measures of human performance if adopted as a dependent variable in future research on the topic might give more insight into the motor performance behaviour of humans.
2. The finding that "Shaped" (either "unishaped" or "split-shaped") keyboards design appears to be a better proposition as compared to the design of the presently available "conventional" keyboard was consistently demonstrated in all studies undertaken. Further investigation in this context would have to undertaken in future so as to determine which "Shape" of the keyboard design be more compatible and optimum from ergonomics point of view.
3. Inclination (tilt/base angles) level of the keyboards was found to have a significant effect on human performance. In the present work the inclination (tilt angle) level of "Conventional" keyboard at its highest value was 22 degrees. At this inclination level minimum muscular fatigue was recorded. Further investigations in future might address a widened range of inclination (tilt angle) level so as to determine the optimum inclination (tilt angle) level of the keyboards presently available in the market.
4. Human factors engineering data related to motor-sidedness (handedness) available in literature indicated either no effect of handedness or a better performance of right handers. Present set of studies indicated that so far as the work on computer is concerned persons with left motor-sidedness are superior to those having right motor-sidedness. However, the literature indicated that either no or very few studies have been conducted in the past so far as human laterality in the HCI

environment is concerned. Therefor, it is suggested that more extensive studies on human motor-sidedness in human computer interaction environment should be under taken in future experiments in order to let the system designers know whether two separate versions of keyboard would be needed to be evolved for laterality-wise two different populations of end-users, the left motor-sided and right motor-sided individuals.

5. Present research indicated significant effect of laterality on end-user's performance on computers. Since HCI system involves triggering of motoric as well as visual processes on the part of the users population, future researches might address the problem of isolating the role of the two processes in giving rise to laterality effects. This becomes all the more important when it is observed that, as per recent findings right and left hemispheres in humans specialise in motoric and verbal processes respectively.

6. Not many studies has been conducted in the past to determine the optimum layout of the keys on the keyboard. "Standard layout has been developed with little consideration of geometrical factors affecting performance" (Drury and Hoffmann, 1992; p. 192). Therefore, it is suggested that more effort should be directed in order to evolve a better layout of the keys on the given kind of computer-keyboard.

7. In the proposed "shaped" designs of the keyboard, the wrists were provided a resting pad through the frame structure of the keyboard itself. However, looking at the varieties of WRIST REST being evolved (e.g. AliMed, 1994) in order to alleviate the carpal tunnel syndrome problems, a more concerted efforts would have to be made to evolve an ergonomically designed wrist-rest that may be compatible to the users in elevating the wrists and provide an optimal place to rest. Major contribution of such a "rest" would appear in the form of a reduction in the level of tendon stresses by way of circumventing trouble by reducing the amount of bend in the users' wrists.

Besides research issues related to computers keyboard design, there are many problems associated with the man VDU interaction which have yet to be resolved from ergonomics point of view. For example, of late, new man-keyboard input devices like mouse, light-pen, joy-stick, trackerball, etc. have entered the HCI environment. However, the hazards, if any, associated with these devices have yet to be ascertained from the end-users point of view (Karlqvist et al, 1994). Similarly effects of display formats on human performance remains still unexplored in the HCI environment (Goh and Coury, 1994). Postural studies and studies on work place design (Saldana, 1994), "colour pollution" of the screen and work place, the man-computer dialogue design, impact of cognitive demands and workstress of computer users (Yang, 1994), menu structure for displays (Kwahk and Han, 1994) are some of the problems that would draw the attention of the future researchers working in the field of HCI.