CHAPTER II

LITERATURE SURVEY

It has been nearly 30 years since the visual display units (VDUs) appeared on the computer workstations, and since then they have drastically transformed the nature and architecture of office-work and industrial environment. Recently, all over the world the concern has been voiced about the possible adverse effects of VDUs, in general, and of the computer keyboard-design in particular, on workers' health and well-being. The purpose of the present review is to put forth some major features of the previously conducted researches in ergonomics (human factors engineering) pertaining to VDU operation from human performance engineering standpoint with particular reference to the keying tasks. A systematic and well-focused review of the thematic matter follows.

2.1 **Studies On Human Performance Involving Electromyography**

Varieties of technique for measuring human fatigue have been developed over a span of about last three decades or so. Among these, one of the most celebrated techniques is the electromyography (EMG) which has been widely used for the last so many years in assessment of human muscular fatigue. It has been found to be highly sensitive to pathological changes that occur in muscles (Bilodeau et al, 1992).The electrical activity recorded from a muscle when the muscle is under contraction is commonly known as the myoelectric or muscle potential (Strasser et al, 1992). The relationship between muscle-fatigue and integrated EMG signals as reported in literature has been found to be linear (Lind and Petrofsky, 1979), exponential (Metral and Cassar, 1981) and quadratic (Zuniga and Simons, 1969). The frequency shift was studied for a variety of muscles (Komi and Tesch, 1979). The slope of the EMG/force relationship has been used as a measure of the efficiency of muscles in such tasks where muscles are in tension (De Vries, 1968; Hagberg, 1981). The shift in the mean (Kwanty et al 1970) and median (Boxtel et al 1983; Jorgensen et al, 1985) frequency of the EMG spectrum was used as an index of fatigue. In addition, sometimes the root mean square (RMS) value was also used for this purpose. It was reported that the mean frequency also provided information about localized muscle fatigue (Lindstrom et al, 1977). The center frequency of the EMG signal was found to be independent of muscle fatigue, and decreased linearly with "exercise-time" during the isometric contractions of the muscles (Petrofsky, 1980). However, some of the studies also reported of increase in center frequency with the level of muscle fatigue (Moritani and Muro, 1987). It was also found that the integrated EMG signals increased with the muscle-fatigue (Currier, 1969). The frequency spectrum of EMG signals has been found to shift towards lower frequencies during contractions (Edwards, 1981). The amount of shift in frequency was due to increase in the power of the lower frequency (Chaffin, 1969).

The set of techniques used to collect tne data through EMG varied considerably from one area of application to another. For example in studying the cost of work in medical nursing, data were obtained by continuously monitoring method. The electromyograms using a 4-channel, miniature, body-worn tape recorder was employed such that one channel was used to record the EMG while the other was used to record time. The recorder worn on a belt scarcely interfered with the nursing duties (Fordham et al, 1978). In another study pertaining to the physiological responses to load holding and load carrying, the EMG signals were recorded by telemetry on a multi channel recorder. It integrated the EMG signals and recorded an impulse whenever the integrated EMG reached a threshold value (Evans, 1983). In yet another study involving back load in assembly line work, the myoelectric activity of the posterior back muscles was recorded with the six bipolar surface electrodes. The signals were fed to pre-amplifiers placed in a box which was strapped to the chest of the subject and from there to main amplifier and, finally, to the tape recorder (Anderson, 1984). Similar technique was also used by Jorgensen (1985). In the assessment of fatigue in tasks involving repetitive arm elevations, the myoelectric activity was recorded by means of bipolar surface electrodes. EMG signals were amplified and recorded on a tape recorder and were analysed by computer (Hagberg, 1981). In studying the fatigue of upper extremity posture in a VDT data entry task, the EMG signals were amplified by Backman EMG couplers that converted the raw signals to contour following integrated EMG (IEMG) technique. The IEMG was sampled through analogue to digital conversion and averaged by means of a microcomputer (Rosa and Anderson,1985).

In multiple-muscle studies, EMG signal of fatigue has been encountered in some muscles, while other muscles which would be expected to bear equal or greater effort showed no significant indication of fatigue (Kedefors et al, 1976; Hagberg, 1981; Bobet and Norman, 1984). Large differences have also been encountered in EMG signals of subjects who worked even under equivalent working conditions (Asfour et al,1985). In studies on fatigue developed in hands, neck and shoulder Hulter (1980) reported that in work posture demanding elevated arms, the local load on the shoulder-muscles is basically responsible for giving rise to fatigue. By means of EMG analysis, shoulder-fatigue has been found to be dependent on the working posture. Strain on the shoulder and neck muscles during the letter sorting operation was studied by EMG and result indicated that muscle fatigue was present in the trapezius and in spinets muscle (Jorgensen et al, 1985). It was also found that unsuitable arm positions, led to localized muscle fatigue and frequently employed unsuitable arm position often led to even shoulder pains. In many studies strain on shoulders and neck muscles of welders, painters, carpenters and industrial workers was studied through EMG analysis revealing that in all these cases muscle fatigue was present (Jonsson et al, 1981; Ekholm et al, 1982). On the basis of the EMG technique, the laterality effect was studied. It was reported that in very few cases differences between contralateral sides of normal subjects were observed. In most of the cases no differences have been found for both upper and lower limb muscles (Bilodeau et al, 1992), between right and left sides with regard to both the time and frequency of EMG signals (Blaschack and Keesey, 1990). Investigation on fatigue of the first dorsal interosseous found that during sustained contractions of the muscular fibers the EMG signal decreased faster in the dominant hand of right-handed individuals, whereas no such observation was recorded for left-handed subjects (De Luca et al, 1986).

2.2 Studies on Keyboard Design

Since the first traditional typewriter was produced about 135 years ago by Sholes and Glidden, "there has been innumerable efforts to improve the typing performance by changing the keyboard layout" (Kroemer, 1992, p.83). The original QWERTY keyboard considered mainly the efficiency of the machine, while human factors were not of great interest (Gopher and Raij, 1988). The first version of the typewriter which was produced in 1866 comprised of keys arranged alphabetically in two straight rows, whereas in 1873 the QWERTY version of the keyboard layout was introduced for the first time as an international standard and since then it has been in use. Today it is now being used in the keyboard of computers also (Kroemer, 1993). In the past, only few studies have been conducted on various facets of the keyboard layout. These have focused mainly upon such parameters as the layout of the keys on the keyboard (Dovorak et al, 1936; Ferguson and Duncan, 1974; Alden et al, 1972; Martin, 1972), keyboard angle, key characteristics, and colour and thickness of the keyboard (Claridge, 1980). So far as the shape of the keyboard is concerned there has been perhaps only one major study in the field resulting in the evolution of a three dimensional keyboard called MALTRON keyboard (Hobday 1985).

As the science of man-machine systems has been improving day by day and electronics based systems have been emerging at a very fast rate, there has been a tendency to go deeper into the mechanical components associated with the keyboard design. This situation has already led to the conditions of separating the keys from the VDU (Hobday, 1985). However, the introduction of electronic keyboard and visual display units (VDUs) has not reduced the static load imposed on clerical workers (Hunting et al, 1981). Basically it was for long term typing task that the split-keyboard design was recommended (Zipp et al, 1983).

Analysis of the relationship between operating posture while working on the keyboard and symptoms of fatigue was carried out by many investigators (e.g. Duncan and Ferguson, 1974; Ferguson, 1971; Zipp et al.,1983; Nakaseko et al 1975). The static tension produced while maintaining the sedentary posture in typewriting endured over some time may lead to strain and, hence to fatigue (Rohmert and Luczak, 1978). Physical impairments in hands, shoulders and neck were reported by some workers working on the computer keyboards. Such operators were found to be often belonging to the working groups at data entry terminals (Hunting et al, 1980). In order to reduce this physical impairments or what is called fatigue researchers recommended that neck should not be bent more than 20 degrees, shoulders must be relaxed, elbows should be hanging down with an angle ranging from 80 to 100 degrees, forearms and hands should be in horizontal position and finally, forearm and hand supports should be provided (Grandjean, 1980). Medical findings indicated the incidence of painful pressure on tendons, joints and muscles of the shoulders. These clinical symptoms in the shoulder were observed in data-entry tasks as well as in typing work, while it was rarely observed in control group of traditional office workers (Hunting et al, 1980). In the last decade or so , design of the keyboards focused heavily upon the keyboard thickness. The aim was to design a thin keyboard, which did not require a hand rest (Claridge, 1980). However, the complaints about wrist-fatigue and other pains continued to be reported (Hobday, 1985). The work-related disorders of the neck, shoulders, and arms cause concern in occupational health all over the world. This state of disorder has been given many names. In Japan and the Scandinavian countries the term OCD (Occupational Cervicobrachial Diseases) is used (Maeda, 1977), in USA and Canada Carpel Tunnel Syndrome (CTS) and RSI (Repetitive Strain Injury) are used. In India, the equivalent term is occupational injury, while in Anglo-Saxon countries the terms Cumulative Trauma Disorder (CTD) and Repetitive Strain Injury (RSI) are generally used (Kilbom et al, 1986). RSI emphasizes the continuous repetitive kind of work-related injury, and concentrates more on forearm and wrist disorders (Browne et al, 1984). Repetitive Strain Injury is usually associated with the tasks characterized by raised arms, visual control, repetitiveness of work and a high demand of accuracy (Maeda, 1977; Bjelle et al, 1979; Hunting et al, 1980; Kvarnstrom, 1983). Further it was reported that RSI developed in operators where work was often performed in the seated posture under the environment of time stress (Kvarnstrom, 1983; Hunting et al, 1980). Similar symptoms were reported to have been often observed in writer's cramp, tennis elbow,cotton picker's arm, painters and in production and assembly line kind of work-settings (Hobday, 1988). It was also reported that RSI symptoms appeared in the hands and wrist of operators also when they worked on computers specially in the data entry kind of tasks. These symptoms were in the form of aches, pains and tingling in fingers, wrists, arms and shoulders (Hobday, 1986). Such injuries were reported to have influenced as many as about 185,000 US workers in 1990 (Computers Today, 1992). Stress from the keyboard operation was recorded to be the main cause of illness in telex operators in the Australian Department of Postal Services (Ferguson and Duncan, 1974). Similar findings were also reported in Germany (Zipp et al, 1983). A data entry female operator in California is reported to have developed carpal tunnel syndrome (CTS). The nerves serving her hand have been compressed as a result of typing on an IBM PC (Computers Today, 1992). When end users work on the keyboard with bent wrists, a very stressed and strained position, they get tired as a result of the fatigue induced in wrists. This kind of injury is referred to Carpal Tunnel Syndrome. The carpal tunnel is a small channel formed by the carpal bones of the wrist. The median nerve runs through it and provides sensation and feeling to the users' hand. Tendons connecting the fingers also run through it. When wrist is extended the nerve and tendons get stretched and press the top of the tunnel. When repeated, long-term stress induced irritates the tendons resulting in its swelling which in turn exerts pressure on nerves. This irritation feeds upon itself cycle after cycle and thus CTS starts and users' fingertips have feeling tingling and pains (AliMed, 1994). To sum up, the keyboard is a very important component of human computer interaction (HCI) system and a concerted effort is required to be made in order to evolve a fully compatible and ergonomically designed keyboard, which at present is perhaps just not existing in the market. An ergonomically designed keyboard should take into consideration the tolerable angles of the joints of the shoulders,arms and hands (Zipp et al, 1983). QWERTY keyboard is presently being used all over the world , there being no other alternative to this keyboard (Owen and Bishop, 1985), as it can be used by any one without much of training needed for its operation .

2.3 **Effects of Age on Human Performance**

All individuals in the world follow the course of aging which after 40 years or so decreases their adaptability to the working environment. Also as the people advance in age, their individual differences increase (Yokomizo, 1985). In general "older workers" refer to the persons between 40 and 60 years of age (Smith, 1986). There is a general agreement that humans decline in their ability to do a work after the age of 40 (Kumashiro, 1985). The selection of age 40 as a dividing point between the younger and the older workers is an arbitrary demarcation, because the age at which actual employment difficulties are faced depends upon the operators' skill, union policies, the industry in which one works, and such other factors (Davis and Mebarki, 1983). Despite the fact that anthropologically persons in the high age group differ from those in the low-age group in terms of such factors as sitting height, arm-reach and arm-span (Stoudt, 1981), "there are almost no data at all available on the aged and infirm" (Chapanise, 1974; p.8). Existing data on psychological aging are not of much value to human factors engineers (Fozard, 1981). Few studies have appeared in the literature where effects of age on industrial tasks have been investigated (Murrell and Humphries, 1978; Salthouse, 1982; Marquie, 1985; Rabbitt, 1990). In the context of aging, studies on the hand movement ability indicated that the age of operator has a significant role to play (Davis and Mebarki, 1983). Older workers were slower in movement than the younger ones and they differed in physical and mental abilities (Yokomizo, 1985). Also younger people were reported to have committed more lapses than the older ones (Rabbitt, 1990). So far as the upper limbs' motion are concerned it was found that degradation was largest in the shoulders and smallest in the fingers (Yokomizo, 1985). Many studies have shown changes with age. It was found that the age as a variable had a significant effect on humans. Older subjects were found to have a higher level of exploratory activity than the younger people (Marquie, 1985). Sensory cardio-pulmonary functions and perceptuo-motor performance were also found to get effected by age (Kumashiro, 1985).

Studies on the effect of age on such factors as visual performance with special reference to the visual display units (VDUs) indicated that visual performance went on decreasing with the increasing age (Mc Cormic, 1986). It was also suggested that the magnitude of the age-related differences for a process was directly proportional to the time it took the subjects to complete the process (Cerella et al, 1980). The ability of operators to perform work on VDUs was studied by Yamamoto et al (1982). They found a relation between aging-characteristics and the operators' performance in terms of character size of display and visual accommodation. Also the age of operators, the print quality, and illumination level significantly influenced the performance of the VDU operators (Smith and Rea, 1978). In divided attention kind of tasks, it was found that the age differences significantly affected the task involved (Kausler, 1982; Craik, 1973; Salthouse, 1982). Older subjects showed poorer performance than the younger one's (Burke et al, 1980), and the older subjects were found to have been penalized more than the younger subjects under the work-environment of dual-task conditions (Sombereg and Salthouse, 1982). Although the allocation of attention across trials was similar for young and older adults, there was an age related increase in the time required to allocate attention within the individual (Madden, 1992). It was also found that in a dual task situation reaction time (RT) for the older subjects was greater than that observed in case of the younger ones (Mc Dowd and Craik, 1988), while some reported that there was no significant age differences in situations where divided attention kind of task was involved (Somberg and Salthouse, 1982).

There is a reason to believe that the demand of technological innovations would be disproportionately settled in older workers over the age of 40 years (Hendricks,1984). Due to micro-electronics revolution a large number of people have been replaced by the new technology workshops (Yokomizo and Kmatsubara, 1986). It was reported that all over the world the life expectancy rate is increasing, and the average birth rate is decreasing from year to year (Nagamachi, 1985). The future population is expected to have its average age higher than that of todays' population (Mc Farland, 1986). In Japan the number of people older than 65 years will reach about 22% of the total population (Nagamachi, 1985). It is expected that "human factors engineering in the years 2000 to 2025 will be dealing with many design problems different from those of todays" (Fozard, 1981;p.8). Hence there is a need to take up more studies in order to dig deeply into the insight of the phenomena of human aging.

2.4 Effect of Sex on Human Performance

The recent human rights all over the world has sought to guarantee the equality of employment opportunity irrespective of the sex. However, from literature reviewed it appears that fewer studies have been conducted in the past to study the effect of sex on human performance. Many studies have investigated the sex-difference in terms of only the muscular strength. It has been reported that the muscular strength of the women is of order of 40% to 70% of that of the men (Nordgren, 1972; Wilmore et al., 1978; Miyashita and Kanehisa, 1979). Such a large variation in the magnitude of sex differences in muscular strength may be traced in terms of the specific segments of the body tested (Bishop et al., 1987). It was found that female subjects were 43% to 63% weaker than men from upper body strength viewpoint and 27% weaker from the lower body parts standpoint (Wilmore, 1974). It has also been reported that there is a large body difference in the two set of populations, when viewed in terms of their upper body parts and lower ones (Hosler and Morrow, 1982; Nordgren, 1972; Hoffman et al., 1979). It was observed that women have a smaller upper body muscle mass (Hettinger, 1961), and have lower strength values for upper body muscle-groups (Laubach, 1976), and lower maximal oxygen uptake (Bergh et al., 1976). Such differences in the muscular strength and body parts may result from genetic differences in the muscle-mass, neuromuscular function or from culturally linked behaviour- differences by way of the amount of participation in strength developing activities (Bishop et al., 1987). Sex-related differences have also been observed in terms of arm and leg strengths (Hoster and Marrow, 1982), walking speed, energy expenditure and maximum aerobic power (Evans, 1980), and the process of acclimatization to hot-dry environment (Shapiro et al., 1980). There is doubt that the average female is at a disadvantage physically in terms of strength and endurance performance when compared with that of an average male (Cureton and Sparling, 1980). One factor which contributes to the gender difference is the greater body fatness of the females when compared to the males (Martin and Nelson, 1986).

The sex-differences when viewed in the context of responding to stimuli, it was reported that in terms of decision time (DT) and movement time (MT) components of reaction time (RT), females were respectively, found to be faster and slower than males. However, DT and MT on addition, nullified the effect of each other, resulting in sex-independent mean reaction time (Landauer et al., 1980). It may be argued that the females are as much superior to males in their cognitive competence as they are inferior in muscular power (Rizvi, 1984). Studies conducted by Sherman (1967), and Thompson et al. (1981) indicated that males and females differ in their performance on spatial and cognitive tasks. In an extensive review of the sex differences in the context of human performance, Maccoby and Jacklin (1974) cited two studies that involved risk taking and concluded that sex differences in risk taking was not demonstrated. Hudgens and Fatkin (1980) and Fatkin and Hudgens (1982) located 27 original investigations that involved subjects who stated preferences regarding risk taking behaviour of humans. In 20 of these studies, the sex differences indicated greater risk taking for males, three indicated greater risk taking for females, three indicated greater risk taking in males under certain conditions and in females under other conditions, and one indicated no sex differences.

The literature reviewed as above, however, indicated that the sex as a variable in the context of HCI is yet to find a place for being investigated. In light of the fact that the number of females performing work in an HCI environment is on the increase these days at a tremendous rate, this is getting very important and crucial to investigate the effect of sex, an important organismic factor in the HCI, in general, and in operation of the keyboard in particular.

2.5 Effect of Laterality on Human Performance

Studies on the capabilities and limitations of human performance through split brain research have revealed that there are asymmetrical behaviours in human beings leading to an efficient use of either of the right or left sided parts (called preferred part) of the body. On the basis of preferences, humans are either right-handed or left-handed. Similarly they are also either right- or left-footed, right- or left-eyed and right- or left-eared. This characteristic of humans is referred to as human laterality. Reasons for this laterality have been suggested in term of biological (Porac et al., 1980), genetic and asymmetrical embryo developmental processes, all of these being based on the assumption of the presence of primary sidedness that dictates all the motor and sensory functions in human beings (Porac et al., 1980).

From the aesthetics viewpoint, symmetry has its opponents and proponents. Thus Weyl (1952) defined the concept of symmetry as a harmony of properties. Humans have a right and left hand, small differences in the size may exist between them and in absence of any defect, the two hands are similar (Fritsch, 1968). Relating hand-preference to the age, it was found that the age- related right-ward trend in hand-use continued into adulthood (Porac et al, 1980). But the concept of preference and proficiency are not interchangeable (Coren et al, 1982; Porac and Coren, 1978). On the basis of lateral preference Coren et al (1982) found a relationship between stressful births and shift towards left sidedness. In a review of the laterality and human performance Rizvi et al (1990) reported that Porace and Coren (1981) did a good work to find the relationship between laterality and sex, age, medical history, cognitive abilities, motor skill, social and cultural factors with reference to physiological and cerebral asymmetries. Such increasing pysiological asymmetry was not only a function of age, but the laterality preferences also varied with the variation in the sex taken as variable of human performance (Wada et al, 1975). In a review of the work of Porac and Coren,Jones (1985), observed that a small difference in right- and left-handers might have confounded with sex, particularly in the light of the study of Bryden (1977). So far as the laterality versus human fatigue is concerned, effect of hand preference asymmetry on fatigue has been studied by many researchers (Annet, 1976; Barnsley and Rabinovitch, 1970; Peters and Durding, 1979). These findings implied different brain organizations for the manual control among right- and left-sided people (Annet, 1972; Peters and Durding, 1979). Sex of an individual has also an effect on between-hand-differences in motor performance (Mc Keever and Van Deventer, 1977) and so is the case with the characteristic of input information required to be processed by the two hemispheres (Erikson and Schultz,1978;Sergent, 1983). In a task of tapping and dotting it was found that 35% of the left-handers did better on tapping with the right hand, while 6% showed no difference. On the other hand, 12% showed better tapping with there nonpreferred left-hand and 1% showed no difference (Satz et al, 1967). In another similar task it was found that 10% of the right-handers performed better at this task with their left-hand, while 40% of the left-handers did better with their nonpreferred right-hand (Provins and Cunliffe, 1972). On studying the reading-ability it was observed that increased incidence of left-handedness or left- eyedness, and/or crossed hand-eye preference patterns were shown by poor readers (Ortan, 1925,1929). It was also found that there was no relationship between congruency of lateral preference and reading preference, but it can be said that lateral preference and specially handedness is an indicator of a variety of intellectual abilities (Satz and Friel, 1974). Preference and proficiency showed very small correlation for difficult tasks (Todor and Doane, 1977). The increase of movement precision requirements increases with the right-hand superiority, regardless of preference (Sheridan, 1973). Superiority may be effected by such factors as fatigue (Hellebrandt and Houtz, 1950), practice (Provins, 1967), stimulus and response compatibility (Annet and Sheridan, 1973) and directional or timing properties of the specific movement involved (Browne et al., 1984; Flowers, 1975; Red and Smith, 1961).

One can administer preference measures through behavioral tasks where an individual actually performs simple actions involving the choice of a limb or sense organ. In general, preference measures show higher concordance with each other than do the proficiency tests. Buxton (1973) used simple unimanual task of throwing an object, reaching for an object, picking up a small object, and brushing with one hand and reported an average intercorrelation of 0.63, which is 94% classification concordance (Winggins, 1973). Thus all the patterns of these results indicated that lateral preferences are less sensitive to specific task-components than the lateral proficiency measures. Hand preference does not seem to be a multifactorial behaviour, as in the manual proficiency. Many studies looked at the factorial structure of the hand preference items and showed that the hand preference was described by a single factor (Richardson , 1978). It was reported that all the hand preference responses loaded upon a single factor (White and Ashton, 1976; Bryden, 1977). Many studies dealt with relationship between cognitive abilities and lateral preferences, particularly, handedness. Left hemisphere was responsible for verbal functions and abstracting abilities while right hemisphere pertained to motoric tasks (Hecaen and Albert, 1978). About half of the studies relating handedness and cognitive abilities found significant relationship between them, and the majority of significant findings favored better preference in right-handers.

The literature reviewed as above revealed that laterality was yet not being considered as an important parameter in the field of human factors engineering, and more so in the context of HCI. It appears that almost none of the investigations could be found in the literature regarding lateral preference and VDU operation. As the previous researches available in literature indicated important role of laterality in work environments other than that of HCI, it would be worthwhile to explore the relationship between laterality and performance of the VDU operators in an HCI environment.

The researches carried out in the recent past on the themes of the keyboard design, age-effects, gender effects and laterality effects on human performance were surveyed in a systematised and lucid manner and presented as above. In the light of the previous findings the problem of research for the present work was structured and methodology for solving the same was designed as portrayed in the next chapter (Chapter III).