5. METHODS AND MATERIALS

Selection of the site and subjects: This cross-sectional study was conducted on about 5228 healthy adults (18-60 years) and 500 children (6-9 years) from different districts of West Bengal state, India on the basis of random sampling. As we know that at the above mentioned age children were not much aware about control-display compatibility during their operation. It was hypothesized that that there may be some differences in motion stereotype among adult and children subjects. So to test whether motion stereotype is habituated (learnt) or inborn the children were also included in the present study. Among all the subjects, 2600 were male and 2628 were female. Prior to the experimental trial, the protocol was explained verbally in local language (Bengali) and informed consent was obtained from the participants. Ethical consent and prior permission were taken from the institutional Ethical Committee prior to the commencement of this study and the experiments were performed according to the ethical standards of this committee and the Helsinki Declaration. The numbers of participants selected for the study for different subgroups are mentioned in respective chapters and tables.

Inclusion criteria: The eligibility criteria for recruitment of the participants for the study were as follows

- Age groups between 6 to 9 years and 18 to 60 years
- Apparently healthy, without any acute physical or mental illness history
- Not having any physical deformity.
- Not having any history of colour blindness or visual problem history

Exclusion criteria: Participants with background of neuromotor disease, psychological disorder, orthopedic disability or having any vision problem were excluded from the

study. The subjects beyond the above mentioned age ranges were also excluded from the study.

5.1 General demographic study: some general information regarding the subjects was recorded which were as follows:

Weight: The body weight of the participant was measured by a portable weighing machine (Libra made) with an accuracy of 0.1 kg.

Height: The vertical distance from floor to the vertex was taken as the body height of the subjects. Subjects were asked to stand erect. The head was oriented in the eye-ear plane. Measured by an anthropometric rod (Hindusthan Minerals made)

Body mass index (B.M.I): BMI was calculated using the following formula given below:

BMI = **Weight (Kg) / Height (meter)** ^{2}(Poskit, 2000)

To identify the overweight and obesity, the cut off values of BMI set by the International Obesity Task Force (IOTF) were used (Cole et al., 2000).

5.2 Determination of Control-response stereotype:

The motion stereotype of the subjects was tested with different combination of control and display units. The subjects were instructed to operate controls for a given change in the display. The direction of motion of controls was noted while the subjects were executing the instruction. The photograph of the execution of task was taken during movement of the controls. Thus the direction of motion of the control was recorded for each of the control display combinations. The tests were also repeated by asking the subjects to operate the controls for changing the display in reverse direction. For example, if the subjects were asked to operate a rotary control (say) for rightward movement of

pointer in the analog display in the first set of experiment, the subjects were asked to operate the same control to move the pointer in leftward direction in the second set of experiment.

Simulation of control–display combination: Different combinations of control and displays were simulated for performing the experiments. Some digital and analog displays (vertical, horizontal and semi circular) with different controls (rotary switches, rocker, horizontally and vertically sliding switches) were set on wooden / bakelite box separately for each combination of control and display. The following combinations were made:

Rotary motion switch and display combinations: The motion stereotype of the subject was studied by using a rotary switch and an analog display. Five combinations of control and display units were made for this purpose:

(A) **A rotary control knob with a horizontal analog display system** in which an indicator in the display can be moved in horizontal direction - either rightward direction or leftward direction. The simulated testing kit is shown in Fig. 5.2.1

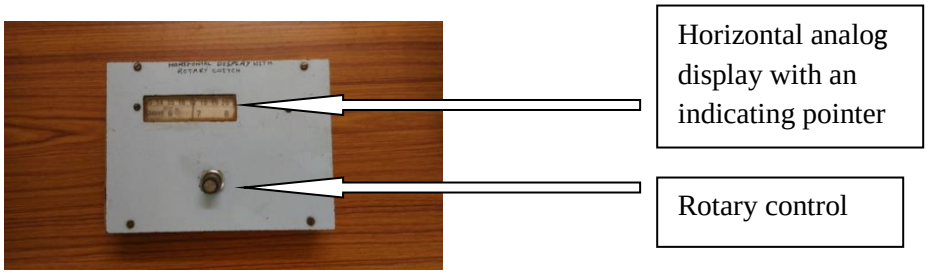

Fig.5.2. 1: horizontal display- rotary

(B) **A rotary control knob with a vertical analog display system** in which an indicator in the display moved in vertical direction either up or down (Fig.5.2.2).

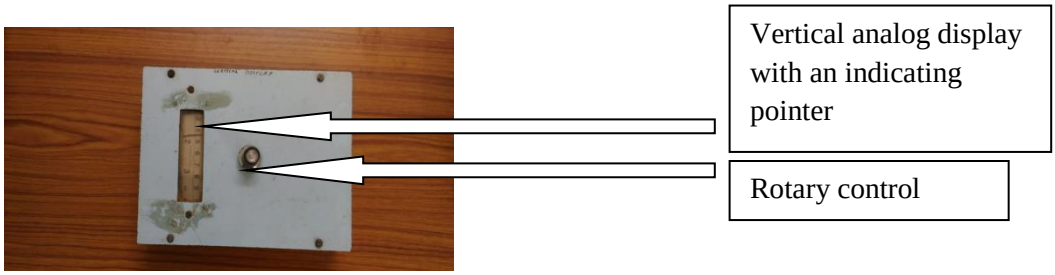

Fig 5.2.2: vertical display- rotary

(C) **A rotary control knob with a semicircular analog display system** in which an indicator moved in circular pattern either clockwise or anticlockwise (Fig. 5.2.3).

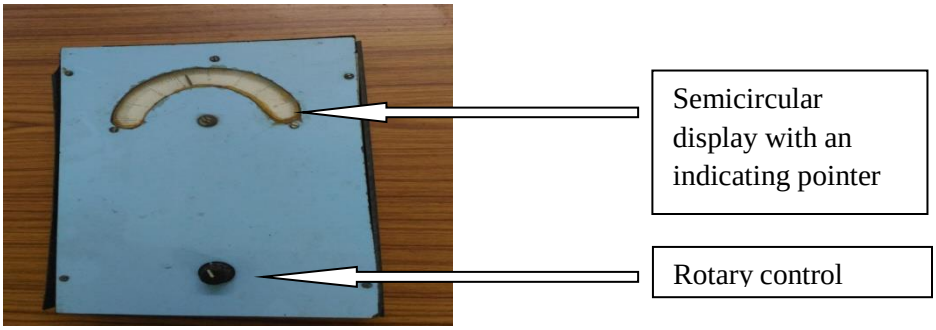

Fig 5.2.3: Semicircular display- rotary switch

(D) **Rotary control knobs and an intensity testing display system** in which the light intensity was changed from dim to bright with the movement of rotary switch (Fig. 5.2.4).

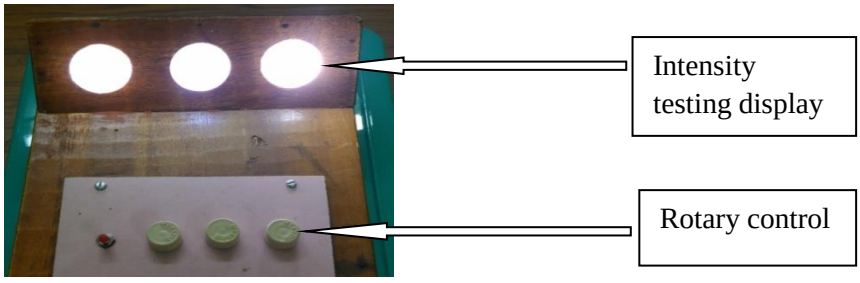

Fig 5.2.4: Intensity testing display-rotary switch unit

(E**) An analogue semicircular display with spatially aligned rotary switches** in which there were four rotary switches positioned spatially (3 dimensionally) in the unit, as presented in Fig. 5.2.5.

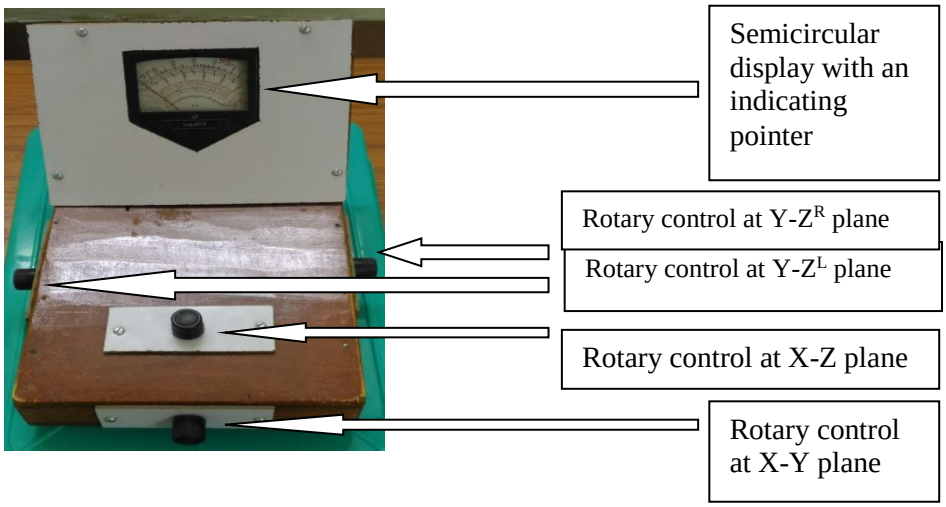

Fig5.2.5: Semicircular display with spatially aligned rotary switches unit

The subjects were asked to operate the control knob to cause a movement of the indicator in a particular direction (left or right, up or down and increase or decrease). The subject's effort to rotate the control knob (either clockwise or counterclockwise) for desired movement of display indicator was recorded. In case of semi circular display, the subjects were asked to move the display pointer for increasing (or decreasing) the scale.

Operation of rocker switch for on-off response: Rocker switches are connected to the electric lights (Fig. 5.2.6). The switches will be aligned in two directions: (1) vertical (2) horizontal.

The subjects were asked to operate the switch to make the light on or off. They were asked to press the switch to make the lower end depressed or upper end

depressed (while the other end was remain raised) in first case and in second case it was required to press the switch to make the right end depressed or left end depressed (while the other end was remain raised). The mode of operation of the subjects was recorded.

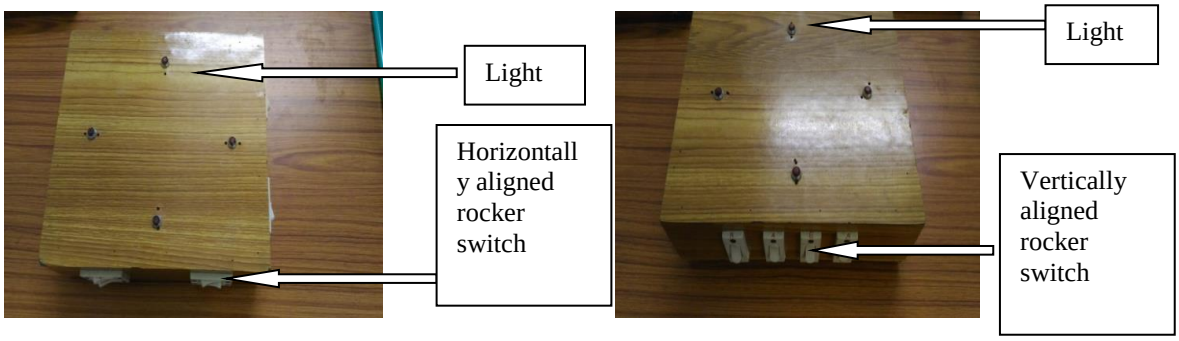

Fig.5.2. 6: horizontally and vertically aligned rocker switch-electric light units

Operation of the digital displays: three type of digital display-control units were made for this purpose

i. **Digital display with rotary switch:** A rotary control knob and a digital display unit, where two types of control were present, one switch allowed clockwise motion for increasing the digits and vice-versa and the other switch allowed functioning in opposite direction (Fig. 5.2.7).

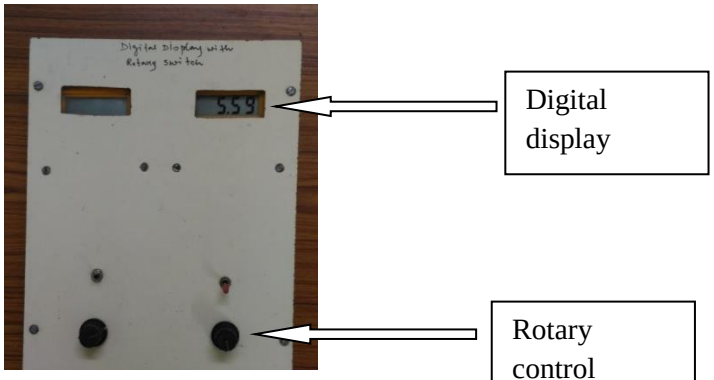

Fig 5.2.7: digital display-rotary switch unit

ii. **Digital display with horizontally sliding switch:** A digital display with two horizontally aligned sliding switches, one of which was slid to rightward direction for increasing digits and vice versa, as shown in Fig. 5.2.8.

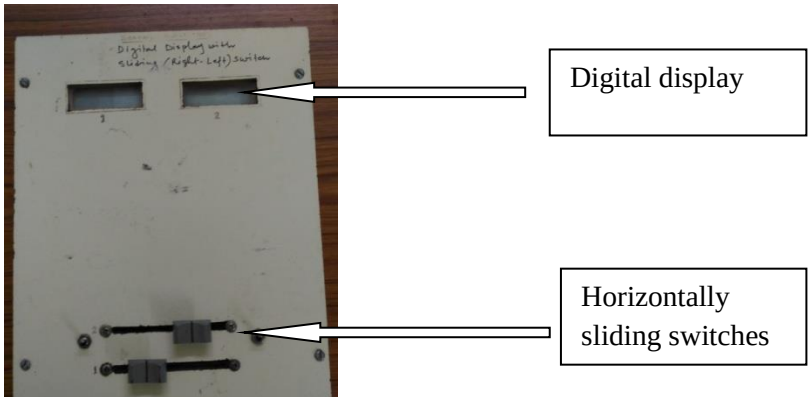

Fig 5.2.8: digital display-horizontally sliding switch

iii. **Digital display with vertically sliding switch:** A digital display with two vertically aligned sliding switches, as given in Fig.5.2. 9, one of which was slid upward direction for increasing digits and vice versa; the other control functioned in the opposite direction.

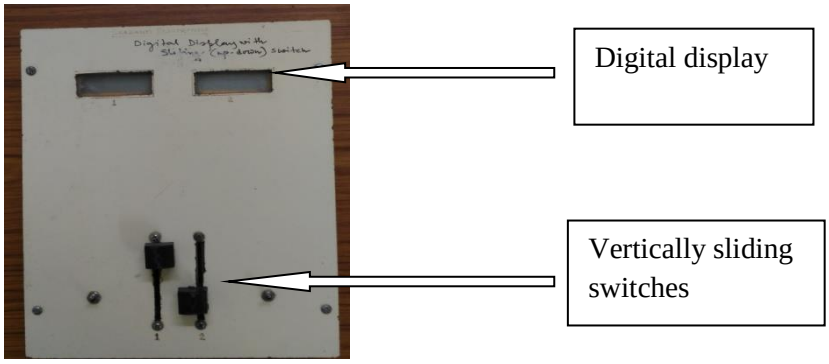

Fig 5.2.9: digital display-vertically sliding switch unit

iv. **Digital display with spatially aligned rotary switches:** A digital display with four rotary switches positioned in X and Y planes (as presented in Fig. 5.2. 10. Each set of

switches in each plane had facility for clockwise rotation to increase and anticlockwise rotation to decrease the digital values.

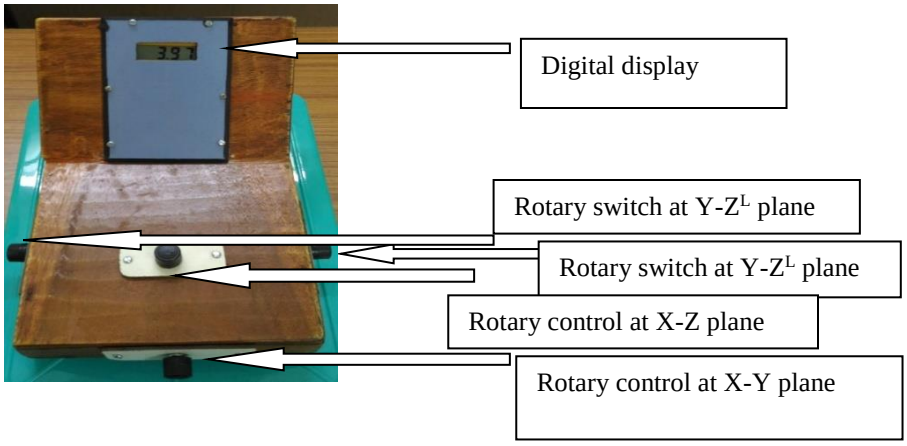

Fig 5.2.10: Digital display with spatially aligned rotary switch

5.3 Index of Reversibility:

The index value ranges from 0 (zero) which represents absolute non-reversibility to a value of 1(unity) for ideal reversibility, that happens when the response to 'increase' is opposite to the response to 'decrease' (Chan & Chan, 2007). The index indicates the perfectness of the direction of motion stereotype. It was computed mathematically considering motion of two opposite directions, say, clockwise and anticlockwise. The index of reversibility (IR) was derived based on the totaling of two products. One product was calculated from the proportion of clockwise-for-increase (CI) and anticlockwise-for-decrease (AD) responses, and the other came from the proportion of the opposite duo of anticlockwise-for-increase (AI) and clockwise-for-decrease (CD) responses (Chan and Chan, 2007). Mathematically, it can be expressed as follows:

$$\mathbf{IR = p\,(CI) \times p\,(AD) + p\,(CD) \times p\,(AI)}$$

Here 'p' is the proportion (A proportion is a name we give to a statement that two ratios are equal.)

p(CI) = sum of clockwise to increase (right) response ÷ total no. of subjects took part in the study

Likewise,

p(AD) = Sum of anticlockwise to decrease (left) response ÷ total no. of subjects took part in the study

p(CD) =Sum of clockwise to decrease (left) response ÷ total no. of subjects took part in the study

p(AI) = Sum of anti clockwise to increase (right) response ÷ total no. of subjects took part in the study.

5.4 Response initiation time:

A digital timer was used for recording response time (RT) of the subjects for operating the interfaces (switches and analog and digital displays etc).

5.5 Studies on stereotype in relation to handedness:

The impact of hand dominance on motion stereotype was evaluated. Prior to perform the experiment the handedness of the subjects was determined by the following criteria:

Determination of handedness: Handedness was determined by the methods followed by Bowman and Katz (1984) and Chau et. al., (1997) in which handedness of the subjects was evaluated by the greater strength of the hands. In this study hand grip dynamometer (lafetty made) was used to determine the hand strength for determination of handedness of the subjects. Depending on the dominance of grip strength of the hands the handedness of the subject was determined

5.6 Studies on motion stereotype in relation to socioeconomic status:

Socioeconomic status (SES) is strongly associated with cognition. Education (Barnett, 1998; Ramey & Ramey, 1998) is all correlated with both SES and cognitive achievement. Socioeconomic background has traditionally been associated with large outcome differences across a variety of broad-band measures of cognitive performance.

The Socio-economic status of the subjects in this study was determined by questionnaire method, Modified B.G. Prasad Scale (Singh et.al, 2017). BG Prasad's classification is used in both urban and rural areas and is based on per capita monthly income. It was launched in 1961 in view of the base of Consumer Price Index (CPI) for 1960 as 100. In the present study modified scale (**Table 5.6.A**) was used. From the scores of the socioeconomic studies the selected subjects were divided into different classes, i.e., upper class, upper middle class, middle class lower middle class and lower class. The pattern of stereotype of the subjects using different types of control-display units was determined in the subjects of different socio economic classes

Table 5.6.A: Modified BG Prasad scale (Singh et. al., 2017)

Socio economic class	**Per capita monthly income (based on January 2017 CPI)**
Upper class	≥6254
Upper middle class	3127-6353
Middle class	876-3126
Lowe middle class	938-1875
Lower class	<938

5.7 Studies on motion stereotype in relation to Stress:

Different kinds of stresses may influence the motion stereotype. In the present study the motion stereotype was studied in relation to cardiovascular stress, job related psychological stress, and heat stress.

5.7.1 Evaluation of work related stress: In this study we determined Cardiovascular stress index (CSI) as the work stress (physiological stress). The CSI was computed in terms of resting and working heart rate.

Measurement of heart rate: The resting and working heart rate of the subjects were measured with the help of a heart rate monitor (Polar S610i). The resting heart rate of the subjects was measured in sitting condition after a rest of 30 minutes before their scheduled work at factory and the working heart rate of the subjects was recorded throughout the work schedule. The data were analyzed by the Polar Precision Performance Software.

Determination of CSI: Cardiovascular stress index (CSI) is a good parameter for measuring the level of stress imposed on the human due to work. It was determined in this study by the following formula (Trites et.al., 1993).

CSI= 100*(Heart rate during work - Resting heart rate) / Max. Heart rate - Resting heart rate

(Where, Max. Heart Rate = 220 - Age in years)

The subjects were further divided into three categories, according to their level of cardiovascular stress, viz., light stress, moderate stress and high stress. The percentile values of CSI were used to categorize the subjects as shown in **Table 5.7.1.A.**

Table 5.7.1.A: classification of stress according to CSI values

CSI values Up to 35th percentile	Up to 23.70	Light stress
CSI values from 36th to 70th percentile	24.00 – 26.00	Moderate stress
CSI values above 70th percentile	26.87 and above	High stress

The motion stereotype of the subjects, who were exposed to different stress conditions, was determined**.**

5.7.2 Evaluation of job related psychological stress: For this study subjects were selected, who were working in the IT sector. A standard questionnaire (Srivastava and Singh, 1984) consisted of forty six questions was used to assess the Occupational Stress Index (OSI) of the workers of IT sector. Each question denoted some scores. The scores of all questions were added to get the final score.

According to the total score of the subject, based on their answer of 46 questions, the subjects were classified by using the reference OSI classification scores (**Table 4.7.2.A**). The subjects were divided into three subgroups which were low, moderate and high level of job related psychological stress.

Table 5.7.2.A: Classification of stress (Psychological) according to occupational stress index (Srivastava and Singh, 1984)

Level of job related psychological stress	OSI Score
Low	46-122
Moderate	123-155
High	156-230

The pattern of stereotype of the subjects was determined in different levels of job related psychological stress

5.7.3 Evaluation of heat stress:

The effect of heat stress on motion stereotype was studied on Bell metal workers, who were exposed to heat stress during their scheduled work. The study was conducted two types of tasks performed under different working environment**s –** (i) melting of bell metal, which was done in hot environmental condition and (ii) processing tasks of bell metal, which was done under normal environmental condition. To evaluate the thermal condition different parameters were recorded by 3M QUIEST-36 (Périard et al., 2014), a

highly sensitive digital Thermal Environmental Monitor (Barcelona, France) (Fig. 5.7.3.1). The thermal parameters recorded were Dry Bulb temperature, Wet Bulb Temperature, WBGTi (indoor), relative humidity, heat stress index, and air flow.

A lot of heat stress indices were developed and most of them could be used to recognize environment when workers cannot cope up with them (Crowe et. al., 2009; Lee, 1980; Parsons, 2003). Among them WBGT is most likely the well known and used universally (Parsons, 2003) and accepted as an international standard (ISO, 1994; Parsons, 2006).

In the present study on the basis of computed WBGT and the environmental heat stress (**Table 5.7.3.A**) imposed on the subjects they were categorized into two heat stress levels, viz., high heat stress when the subjects were doing the bell metal melting job and normal / low heat stress when the same subjects were doing the other processing job of bell metal. Then pattern of the motion stereotype of the subjects were recorded at these two different WBGT levels and compared with each other.

$$\text{WBGT (Indoor)} = 0.7T_W + 0.3T_g$$

$$\text{WBGT (Outdoor)} = 0.7T_W + 0.2T_g + 0.1T_d$$

Where,

T_w = Natural wet-bulb temperature

T_g = Globe thermometer temperature

T_d = Dry-bulb temperature

Table 5.7.3.A: Heat stress situation prediction based on WBGT index, workload and work/rest regime (Source: OSHA, 2017)

% of work	Work load			
	Light	**Moderate**	**Heavy***	**Very Heavy***
75-100	31.0 ℃	28.0 ℃	N.A	N.A
50-75	31. 0 ℃	29. 0 ℃	27.5	N.A
25-50	32. 0 ℃	30. 0 ℃	29.0 ℃	28.0 ℃
0-25	32.5 ℃	31. 0 ℃	30.5 ℃	30.0 ℃

*Criteria values are not given for Heavy/Very Heavy work for continuous and 25% rest because of the severe physical strain

Fig 5.7.3.1: Measurement of thermal parameters

5.8 Study of colour stereotype:

A color chart was prepared with four sets of criteria with nine different colors (Fig: 5.8.1). The criteria were adopted from daily life uses of control and display, road traffic signals and thermal sensation of colour. In the chart (Fig. 12) the criterions were presented with their meanings. The criterions represents “safe area”, “danger zone”, “stop”, “caution”, “go”, “on” “off”, “hot”, and “cold”. The nine colours, which were used in the test, were green, white, yellow, black, red, orange, blue, pink, and violet. The subjects were asked to choose one colors to represent each criterion and their color preferences were recorded as the result. For example, for “criterion I”, which represented thermal sensation of the subjects, the subjects were asked to choose any one colour for ‘hot sensation’ among nine

colours (i.e., green, white, yellow, black, red, orange, blue, pink and violet) of the chart. And the chosen colour was recorded as his/her colour preference for hot sensation. Similarly, subjects were asked to choose colour for other criteria

Criteria	Meaning	Colour								
		Green	White	Yellow	Black	Red	Orange	Blue	Pink	Violet
Criterion I	Hot									
	Cold									
Criterion II	On									
	Off									
Criterion III	Safe area									
	Danger zone									
Criterion IV	Go									
	Caution									
	Stop									

Fig. 5.8.1: Colour Chart

5.9 Application of population stereotype for man- machine interface design

Efforts were made to apply the population stereotype on the common control display unit which is used in day to day life. In this experiment the control display unit of a gas oven burner, which is commonly used in the kitchen, was taken for this experiment. The knob of the burner was taken as control and the gas burner flame of the oven was treated as the display.

Gas oven knob and burner: The control knob of gas oven is somewhat different from the other control display units. In the existing system the control knob rotates in both clockwise and anticlockwise directions. The pointer of the knob remains in the right side in the horizontal position under ‘off’ condition. To ‘on’ the gas flow the knob is required to rotate in anticlockwise manner and to ignite the gas simultaneously. To increase the flame the knob is required to move in anticlockwise and to maximize it the pointer of the

knob is to be positioned in vertical direction. To reduce the flame the knob should be rotated in the same direction (anticlockwise) and to minimize the flame it should be positioned in the left side in the horizontal direction. To 'off' the gas flow, we have to move the knob in horizontal position towards opposite side (right side). From the vertical position the gas flow decreases when the control knob is rotated in both ways that is clockwise and anticlockwise direction. Thus this knob operation is somewhat confusing and may lead to errors.

In the present study interface design for gas oven burner has been don following the principle of motion stereotype.

Modified gas oven system: In the modified gas oven the knob function was modified on the basis of four selected criteria (based on response of the subjects), population stereotype, Response Initiation Time and error test. In this interface from the "off" position, the knob can be moved anticlockwise to get the desired flow of gas gradually from minimum to maximum flow. At the maximum flow the knob is locked at that position internally. "Anticlockwise to increase the flow" and "clockwise to decrease the flow" principle of motion stereotype were used in this interface. In the suggested interface design the "anticlockwise to decrease" function of the knob was eliminated. This modification might solve the problem of the confusion regarding the gas oven operation. The interface design has been illustrated in the results section of the thesis.

Efforts were made to evaluate two burner gas oven on the basis of following experiment:

Motion stereotype and Response initiation time evaluation: Some small tasks related to the gas oven (conventional and modified) operation like 'on the oven', 'maximize the flame' and 'minimize the flame' and 'off the gas flame' were assigned to the subjects and

the direction of motion stereotype of the subjects were recorded for each task. The response initiation time (RIT) was recorded in terms of the time (ms) taken to initiate each task.

The Error Test: Percentage of error was calculated on the basis of the number of wrong movements done by the subjects for each given task (Fig. 5.9.1) in case of conventional and modified gas oven operation. For example, for the instruction "off the gas flame" in case of conventional gas oven if a subject moved the gas knob anticlockwise, the response was recorded as an error movement. The error was expressed in terms of % of errors.

Evaluation of modified gas oven: The modified gas oven was evaluated to test its efficacy and compatibility over the conventional gas oven. Strength of motion stereotype, response initiation time and percentage of error were compared between modified and conventional gas oven to find out whether the modified gas oven was better than that of the conventional one.

Fig 5.9.1: error testing with the existing gas oven

Statistical analysis: Data were presented as means ± standard deviation and percentage. A classification of CSI was done by calculating 35th and 70th percentile values from the calculated experimental CSI values of the subjects. To find out the statistical significant

difference the Chi-square test and One-way analysis of Variance (ANOVA) were employed where applicable. Linear regression analysis was performed between response initiation time and preferred response percentage. Percent difference was also calculated between two IR values. These statistical analyses were performed using the MS Excel, GraphPad InStat (3.1) and OriginPro software.