STUDY OF EFFECT OF SELECTED UNDERLYING FACTORS OF SITTING COMFORT AND DISCOMFORT ON COMFORT AND DISCOMFORT PERCEPTION

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Abstract:

The present study was carried out under university class room settings to investigate the influence of selected underlying factors of sitting comfort and discomfort at their different levels on the perception of sitting comfort and discomfort while sitting. Questionnaires with 7-point rating scales were used to obtain feelings elicited with five different chairs while sitting. Questionnaires filled by 49 subjects were analyzed. In the factor analysis, comfort and discomfort factors were extracted validating the factor structure of comfort and discomfort obtained in previous studies. The results obtained indicated that comfort and discomfort factors can co-exist at the same time at different levels. The results further showed that back pain was the most important discomfort factor while relief feeling is the most important comfort factor in sitting comfort and discomfort perception. From the findings of the study it is suggested to study seat features that may influence relief feeling in comfort perception.

Key words: *physical factors; emotional factors; seat features; comfort*

Introduction

Comfort is one of the main concerns in office seat design. Scientific work in the past in the design of seat made a remarkable progress in providing comfortable seats. Researchers keep on investigating the factors related to comfort in sitting. Comfort is influenced by several factors, such as postural support provided to the body, contact pressure with the body, thermal and humidity characteristics of the seat and aesthetics.

Several studies indicate that comfort and discomfort are affected by distinctly different variables (Kleeman, 1981; Kajimo et al, 1982). Zhang et al, (1996) identified the multidimensional properties of comfort and discomfort. It is argued that the sitting comfort and discomfort are affected by different set of factors. Physical strain factors (e.g. muscle contraction, joint angles, pressure distribution – that produces feelings of pain, soreness) affect the discomfort. Comfort is affected by well being factors (e.g. relaxation, impression) (Zhang, 1992; Zhang et al., 1996; Helander and Zhang, 1997). A theoretical model presented by DeLooze et al (2003) recognizes discomfort and comfort as conceptually separate entities. The model identifies the underlying factors for comfort and discomfort at the human, seat and context level. Zhang et al, (1996) postulated a two-stage hypothetical model, based on which, comfort and discomfort need to be treated as different and complimentary entities in ergonomic investigations. They noted that transition is possible from discomfort perception to comfort perception while sitting. Hence, it is considered that different underlying factors at their different levels may affect different range of comfort/discomfort.

Several subjective and objective methods have been used to evaluate or predict seat comfort. Shackel et al. (1969) suggested that in sitting comfort assessment the user's subjective assessment be the ultimate criterion. Subjective sitting comfort evaluation is a widely accepted method in the field of ergonomic research. Though, the merits of subjective rating scale were questioned by Annett (2002), many practitioners and researchers assume that comfort and discomfort are two opposites on a same continuum. Comfort/discomfort ranges from extreme comfort through a neutral state to extreme discomfort (e.g. Shackel et al., 1969). On the other hand, Helander and Zhang (1997) argue that comfort and discomfort can be quantified / measured independently. Further they stated that multi-dimensional chair evaluation checklist developed by them produced consistent results in field studies. Having their findings they concluded that the checklist can be used for practical evaluation of sitting comfort and discomfort. Kyung et al. (2007) recommends to use discomfort ratings to measure basic qualities of seats with a prevention of pain objectives and to use comfort ratings to measure more subtle qualities of seats with hedonomic objectives.

The checklist used by Helander and Zhang (1997) assumes that different levels of feelings are produced for various individual underlying factors of sitting comfort and discomfort. Further, Helander and Zhang (1997) indicated that when physical strain factors are present (biomechanical factors), contribution of well-being factors to overall comfort feeling diminishes. Hancock and Pepe (2005) showed that discomfort and comfort are at different stages of needs, the latter being placed at a higher stage than the former. In summary, previous studies indicated that comfort and discomfort are two stages in human comfort perception. The one of the important outcomes of the two stage (comfort /discomfort) concept was the development of the multi-dimensional check list which recommends to evaluate comfort and discomfort using separate scales.

Preliminary evidence indicated the tendency that the two stages (comfort/discomfort) may overlap (Zhang, 1992). This may be due to the different degree of effect of various underlying factors at different levels. This ultimately may have an influence on the development of multi-dimensional check list. However, the understanding of how various individual underlying factors of sitting comfort and discomfort at their different levels affects comfort and discomfort perception while sitting is lacking in the literature. In this study therefore we intend to investigate further how underlying factors of sitting comfort/discomfort influence the perception of comfort/discomfort while sitting.

Methodology

The methodology adopted for this study is described below.

Subjects

Fifty university students (26 males and 24 females) from the University of Moratuwa, Sri Lanka participated in this study. All of the students who were willing to participate from the freshmen of Faculty of Architecture were selected as experimental subjects. Their consent to participate in the study was obtained. Their stature and weight were obtained. The characteristics of experimental subjects were given in table 1.

Table 1: height and weight of the experimental subjects

Characteristics of subjects	Minimum	Maximum	Mean	Standard deviation
Height (mm)	1474	1763	1624.3	83.5
Weight (kg)	34	83	50.1	10.4

Chairs

Five different types of student chairs currently used by the university students were selected for the study. Though the chairs were student chairs, efforts were made to keep the chairs different in design i.e. dimensions and appearance to represent the different feelings produced by the chairs (Vergara and Page, 2002). The chairs used by Vergara and Page (2002) were office chairs and ergonomically designed compared to the student chairs. Figure 1 shows the chair types used in the study. The chairs were mounted with the desktops in the right side to the position where armrests are fitted. The mounted desktops are mainly used for writing purpose. Hence no tables were used in the experiment. The chairs were marked as F, G, H, K and M in the back side of the backrest. The mounted desktop of chair H was foldable. Except this, all the other chair features were non adjustable for each chair. Five chairs were taken from each different chair type to facilitate the participation of 25 subjects at a time.

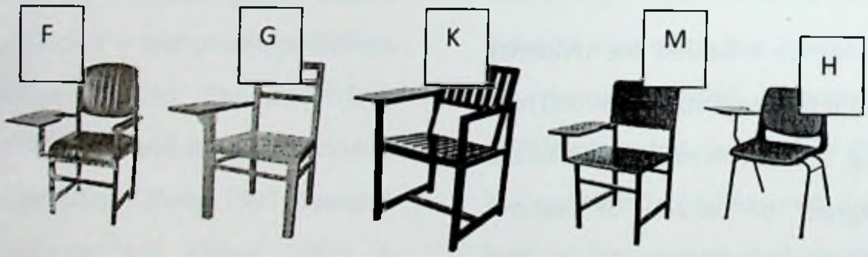

Figure 1: Student chairs used in the experiment

Questionnaires

Two types of questionnaires were used.

Rating questionnaire

The principles adopted by Helander and Zhang (1997) were utilized with modifications to construct this rating questionnaire. For this study, discomfort descriptors such as pain and fatigue were selected. The discomfort descriptors in the cluster analysis by Zhang et al, (1996) were the main basis to select pain and fatigue for the study. Further, the factors such as pain and fatigue are normally used in chair evaluation studies (Wilder et al, 1994 and Vink et al, 1994). The questions to rate pain feelings from different body regions were included in this questionnaire. The results of the cluster analysis of Zhang et al. (1996) were the basis to select three comfort descriptors i.e. impression, relaxation and relief.

The questionnaire was structured in order to obtain various feelings of subjects while sitting in different types of chairs. Those feelings such as impression, relax, relief, neck pain, upper back pain, mid back pain, low back pain, upper leg pain, lower leg pain and fatigue were included in this questionnaire to be rated at a 7 - point numerical rating scale (i.e. 1- not at all, 4-moderate and 7-extreme). Rating scales to measure both comfort and discomfort independently at 7 – point scale also were included in the questionnaires. With the addition of the separate rating scales for comfort and discomfort, two different sets of questionnaires were used. The first set of questionnaire was marked as "A" and the second set of questionnaire was marked as "B". The only difference between the questionnaire A and B was that Questionnaire A contains rating scale for comfort and the Questionnaire B contains the rating scale for discomfort. Inclusion of both comfort and discomfort scales in the same questionnaire may confuse the subjects (Helander and Zhang, 1997). It is assumed that the questionnaire will measure the different levels of feelings that are elicited with different chairs in the students learning environment.

General questionnaire

It was used to obtain the general information such name, age, sex etc. Stature and weight were included in this questionnaire. The questionnaires constructed in English language were translated by professional translators into Sinhalese and Tamil languages which are native to the subjects in Sri Lanka.

Procedure

The subjects were divided into two groups with 25 participants in each group. They were given a brief introduction about the study prior to the experiment. All of the participants were requested to test each chair by sitting for 3 hours in the lecture room during their lessons. They were given instructions on how and when to fill out the rating questionnaires. Chairs were randomized and assigned to the participants before starting the testing. The subjects were given explanation on how to use the adjustability features in the case of foldable mounted desktop.

The questionnaire "A" was distributed to a group of subjects and the questionnaire "B" was distributed to another group of subjects. They were given body part diagram (Vink et al., 1994) which indicated the body parts to facilitate rating pain. They filled the questionnaires four times during three hours; i.e. 5 minutes after sitting, 1 hr, 2 hrs, and 3 hrs after sitting. The experiment was organized to suit the lecture time schedule of the students. A two-hour and a one-hour lectures one after the other were selected. This helped the students to sit for three hours. The subjects were allowed to leave their chairs between the two lectures only for essential need such going to toilet. The subjects took rest in their chairs between two lecture sessions. The subjects participated evaluated one chair each day, thus it took five days to complete five different types of chairs for each subject. The same lecture hall was used for the entire experiment. The subjects were compensated for participating in the experiment. One incomplete questionnaire was discarded, therefore, total of 49 subjects' questionnaires were used for the analysis.

General questionnaires were administered only once in each session. At the same time stature and weight were measured using anthropometer and weigh scale. Data collected were analyzed using the SPSS statistical software.

Results and discussions

Factor Separation

The factor analysis was conducted with Varimax rotation to separate main factors for data collected on feeling factors using questionnaires. All of the feeling factors rated in the questionnaires were separated into two main factors (Table 2). The factor 1 consists of all the discomfort feeling factors, and the factor 2 consists of all the feeling factors of comfort. The resulted factor scores were plotted against the comfort ratings and discomfort ratings (Figures 2, 3, 4 and 5).

Table 2: shows the results of factor analysis

Feeling factors	Factor 1 (Discomfort)	Factor 2 (Comfort)
Neck pain	0.869	-0.126
Upper back pain	0.910	-0.191
Mid back pain	0.890	-0.196
Low back pain	0.880	-0.211
Upper leg pain	0.819	-0.202
Lower leg pain	0.853	-0.134
Fatigue	0.813	-0.268
Impression	-0.017	0.727
Relax	-0.290	0.868
Relief	-0.313	0.851

Two main factors were separated in the factor analysis for the data colleted. The first factor consists of neck pain, upper back pain, mid back pain, low back pain, upper leg pain, lower leg pain and fatigue. Therefore, it is named as factor 1 or "discomfort factor" thereafter. The second factor consists of impression, relax and relief, and it is named as factor 2 or "comfort factor". The results obtained were similar to the results obtained by Zhang et al. (1996) and Helander and Zhang (1997) where the comfort is affected by different set of factors and discomfort is affected by different set of factors. Factor 1 and factor 2 for the data collected explain 77% of the total variance. The factor loadings for upper, mid and low back pain indicate that back pain was the most important discomfort feeling factor in sitting.

The factor scores of factor 2 (comfort) was plotted against the actual comfort ratings (Figure 2). The relationship indicates that comfort scores had strong linear correlation with actual comfort ratings. With the increase of comfort scores, comfort rating increased. This indicates that sitting comfort level can be predicted having variables such as impression, relax and relief. This result also provides evidence for the sensitivity of comfort scale used to measure comfort. The results also indicate that impression, relax and relief can be included in the multidimensional scale to measure comfort. These results were found to be consistent with the findings of Helander and Zhang (1997). The Figure 3 shows the plot of factor score of factor 1 (discomfort) against the actual discomfort ratings. Discomfort factor score was positively correlated with actual discomfort ratings; this was not strong as the correlation between comfort scores and comfort ratings. The correlation value between comfort score and comfort ratings was 0.76 where as it was 0.60 between discomfort score and discomfort ratings.

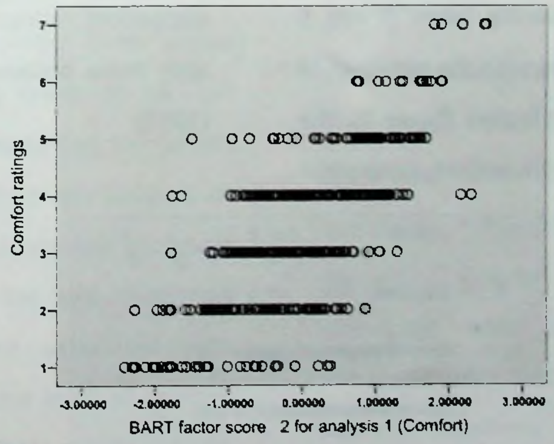

Figure 2: factor score of factor 2 (comfort) was plotted against actual comfort ratings

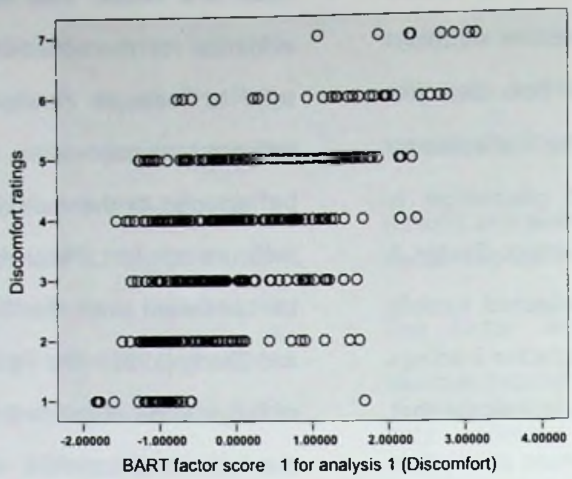

Figure 3: factor score of factor 1 (discomfort) was plotted against actual discomfort ratings

In Figure 3, Lower discomfort factor scores associated with lower levels discomfort rating as well as higher levels (levels 5 and 6) of discomfort rating. The result may indicate that to perceive mid and higher levels of discomfort (level 5 and 6), presence of higher level of discomfort factors are not necessary. Discomfort above moderate levels (levels 5 and 6) may be perceived with the presence of low levels of discomfort factors (figure 3). The association of higher discomfort perception with low value of discomfort score may indicate that there are other important factors affecting subjective responses (Kyung et al., 2007) that were not included in the study. However, the trend in Figure 3 shows that higher levels of discomfort factor scores reasonably associated with higher levels of discomfort ratings. This result is consistent with those obtained by Helander and Zhang (1997).

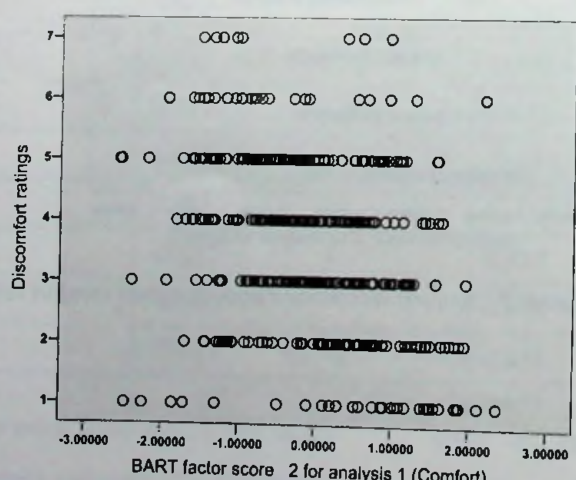

Figure 4: factor score of factor 2 (comfort) was plotted against actual discomfort ratings

Discomfort ratings has an inverse relationship with comfort factor scores (R=-0.46), see Table 5. As shown in Figure 4, there is no clear trend between comfort factor score and discomfort ratings, indicating overall discomfort perception is weakly affected by comfort factor score.

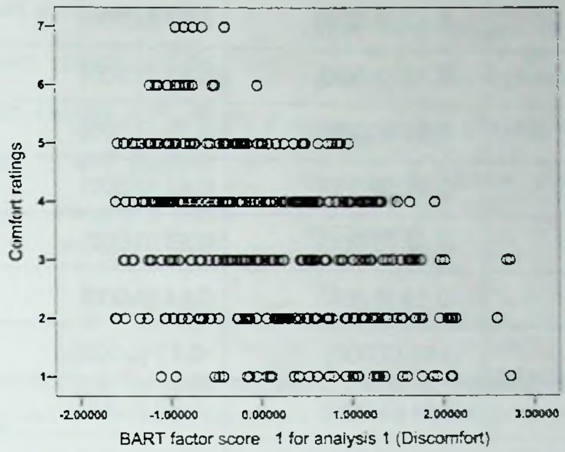

Figure 5: factor score of factor 1 (discomfort) was plotted against actual comfort ratings

Low values of discomfort factor scores associated with full range of comfort ratings from 1 to 7 (Figure 5). There was a general trend for decrease of comfort ratings with increase of discomfort scores. However, the moderate values of discomfort factor scores associated with various levels of comfort ratings (Figure 5). This shows that the factors that cause different effects on comfort or discomfort perception may co-exist at certain conditions. In Figure 5, the high discomfort factor scores were not associated with extreme and near extreme level of comfort ratings (levels 6 and 7). These results indicate that when discomfort factors scores are high, perception of comfort would not exist, because the balance of the harmony is broken. Or, high levels of comfort can only be achieved when all discomfort factors are low.

The presence of discomfort factors will disturb the harmonic state of physical and psychological feelings (Slater, 1985), causing the feeling to deviate from its neutral state (Zhang, 1992).

Correlation analysis

Impression, relax and relief are positively correlated with comfort perception and negatively correlated with discomfort perception. Comfort factor score is positively correlated with comfort and negatively correlated with discomfort. Discomfort factor score is negatively correlated with comfort and positively correlated with discomfort (Table 3). All correlation values were significant at p<0.05. The correlation of comfort factors with comfort ratings indicates that relief feeling is the most important comfort factor in sitting comfort evaluation.

Table 3: Correlation values of feeling factors and factor scores with comfort and discomfort, $p<0.05$ are significant and given within brackets

Feeling factors	**Comfort**	**Discomfort**
Neck pain	-0.53 (0.000)	0.58 (0.000)
Upper back pain	-0.57 (0.000)	0.64 (0.000)
Mid back pain	-0.57 (0.000)	0.62 (0.000)
Low back pain	-0.57 (0.000)	0.59 (0.000)
Upper leg pain	-0.47 (0.000)	0.62 (0.000)
Lower leg pain	-0.48 (0.000)	0.53 (0.000)
Fatigue	-0.59 (0.000)	0.64 (0.000)
Impression	0.48 (0.000)	-0.33 (0.000)
Relax	0.84 (0.000)	-0.52 (0.000)
Relief	0.91 (0.000)	-0.53 (0.000)
Factor scores		
Comfort factor score	0.76 (0.000)	-0.39 (0.000)
Discomfort factor score	-0.46 (0.000)	0.58 (0.000)

Chair and time effect

MANOVA was conducted to identify the chair, time, and chair*time interaction effects on comfort and discomfort factors, as well as comfort and discomfort perception. The results showed that there were significant chair main effect on discomfort factors, and discomfort perception. These results may indicate that the student chairs can be discriminated in the learning environment using discomfort factors such as pain and fatigue. Despite, Helander and Zhang (1997) argued based on their study and some previous studies that it is rarely possible to discriminate office chairs with discomfort factors. School chairs are generally considered to be uncomfortable or less comfort because of hard seats and non-adjustability features found with them. This may be why the student chairs were discriminated with discomfort factors. Similarly time main effect on discomfort factors and discomfort perception was significant. Chair * time interaction effect was not significant. The results indicate that discomfort factors increased as a function of time of day, and chair design is not a matter in the increase of discomfort factors. This result was consistent with result obtained by Helander and Zhang (1997). Helander and Zhang (1997) believed that the time dependency is a fatigue effect.

The chair main effect was significant on relax, relief and impression and comfort perception as well. Chair * Time

interaction effect was not significant for comfort factors and comfort perception. The results indicate that student chairs can be discriminated using comfort factors such as impression, relax and relief in the student learning environment. Time main effect was significant on relax, relief and comfort perception and not significant on impression. Significant effect of time on relax and relief may indicate that relax and relief were not purely emotional factors like impression. And these two factors seem to be somewhat related to biomechanical aspects of sitting. With passage of time, relax and relief feelings decreased. Hence comfort perception too decreased.

Table 4: Chair and time effect on comfort, discomfort and underlying factors of comfort and discomfort (p values were given in the table; values $p < 0.05$ are significant).

Items	Chair type (p values)	Time (p values)	Chair type * time (p values)
Discomfort factors			
Neck pain	0.000	0.000	0.803
Upper back pain	0.000	0.000	0.704
Mid back pain	0.000	0.000	0.555
Low back pain	0.000	0.000	0.875
Upper leg pain	0.000	0.000	0.493
Lower leg pain	0.000	0.000	0.887
Fatigue	0.000	0.000	0.976
Comfort factors			
Impression	0.000	0.781	0.984
Relax	0.000	0.000	0.976
Relief	0.000	0.000	0.973
Comfort	0.000	0.000	0.996
Discomfort	0.000	0.000	0.856

Conclusion and recommendation

The study under the university learning environment validated the factor structure of sitting comfort and discomfort established by Zhang et al. (1996) under office settings. Discomfort factors i.e. pain and fatigue can be used to evaluate student chairs for discomfort. Back pain is the most important discomfort factor. Relief feeling is the most important comfort factor in sitting comfort and discomfort perception and evaluation. The result indicates that comfort and discomfort factors can co-exist at the same time at different levels at certain conditions. From the findings of the study it is suggested to study seat features that may influence relief feeling in comfort perception.

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