ERGONOMICS ANALYSIS METHODS USED IN THE DEVELOPMENT OF A NEW BED

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ABSTRACT

New Zealand manufacturer Design Mobel NZ Ltd received Technology New Zealand funding for the design and manufacture of a new sleep system (bed mattress and base). Ergonomists from SPE Ltd were involved as members of the project team, which was managed by in-house Designers and included materials manufacturers, sleep research physicians, and management. The main aim of involving ergonomists was to provide user data to the design team of an innovative product for which there was limited market knowledge.

A literature review was conducted to inform the choice of the ergonomics methodologies to be used, and narrow the search for a suitable system to measure pressure distribution on a bed.

Pressure distribution profiles were collected from an opportunity sample of 100 adults (50 female, 50 male) in four lying positions. The data from this study was further analysed by the design team in the development of a selection matrix for mattress and bed support base configurations. Usability trials were conducted with a selected sample of 36 people, with the primary aim being to test whether the selection matrix was an accurate predictor of reported subjective comfort. Participants were asked to rate the overall comfort of three mattress / base configurations.

Findings from the trials were passed back to the design team and used in the ongoing development of a prototype sleep system and selection matrix for use in sleep trials and structural testing. These findings were viewed as usefully pragmatic by the design team, enabling them to reach a workable range of modular variations.

INTRODUCTION

In 1998 South Pacific Ergonomics (SPE) Ltd were invited by a manufacturer to assist in the development of a new sleep system. A Technology for Business Growth (TBG) application was successful and the project commenced in 1999. An Industrial Designer led the project, whose team members included component manufacturers, other designers, ergonomists, and sleep researchers. This paper concerns the role of the ergonomists in the initial assessment and design phases.

An integral part of the development of a new sleep system was to attempt to accommodate body type variations in the design to enable customers to specify a sleep system that they found most comfortable. Our brief was to provide the project team, and specifically the designers, with the following information:

- System options for the accurate and repeated measurement of weight distribution in lying positions.
- Weight distribution and anthropometric data from a sample of 18-65 year olds.
- Results from usability trials testing the bed selection matrix and prototypes.

Subsequent design phases included further analysis of prototypes through sleep trials and polysomnography.

Load Profile Measurement

Measurement of pressure between a body surface and a piece of equipment has long been of interest to designers of such equipment as: seats, beds, footwear, gloves, handles, and tools. The two areas where most research on pressure measurement has occurred are clinical environments and vehicle seats.

Within a clinical setting, information on interface pressure measurements are used to evaluate and design support surfaces that minimise complications such as the risks of pressure ulcers caused through mechanical load and shear forces on body tissues.

More recently this technology has been used within the automotive industry, where the emphasis is on achieving higher levels of user comfort due to the importance placed by potential purchasers on seat design and comfort. The objective measurement of seat interface pressures enables prototype designs to be evaluated and modified earlier in the design process (Gyi & Porter, 1999).

Efforts to quantify interface pressure measurements have progressed from such methods as sitting on absorbent paper placed over inked corduroy cloth (Treaster, D., Marras, W.S. (1987), to the electronic and pneumatic sensors used in much of today's research. The desire to accurately measure pressure distribution on a compressive surface (rather than a hard, non-deforming surface) has been a significant factor in the development of alternative methods. A review of pressure measurement technologies can be found in Gyi, Porter, Robertson, (1998). Fergusson-Pell (1980) also provides a thorough list of design criteria for the measurement of pressure at body interfaces.

Bed Evaluation

Parsons (1972) in his review of 'the bedroom' notes that there are many factors which are likely to have an affect on perceptions of comfort and therefore individual preferences on sleep system design, including; physiological differences, variations in individual size, weight and somatotype, personal preferences, bed width, and support firmness.

The comfort rating of beds can be complex given the range of factors that can affect person's subjective feelings on comfort, which include both thermal comfort and mechanical comfort issues. Hanel et al (1997) assert a correlation between objective measurement of firmness and subjective assessment of comfort. A comprehensive methodology for assessing contact pressure and comfort based on standard ergonomics assessment methods is provided in Buckle (1998). Park & Whang (1995) compared objective (pressure distribution) and subjective (comfort ratings) findings from a study using five beds and found a positive correlation in their study.

LOAD PROFILE STUDY

Aims

1. Establish pressure distribution profiles for a physically representative sample of potential bed users in supine, prone and side lying.
2. Collect anthropometric data and compare with NZ Anthropometric Data Estimates.

Methodology

Draft methodologies were developed and reviewed by the project team designers and other ergonomists. All methods were then piloted and amended before the final study. An opportunity sample of 100 people (mostly staff, students, visitors to Massey University Albany Campus) were involved (50 female, 50 male).

Data collected from each participant included: age, weight, dimension relating to bed design (methodology as per Pheasant, 1984), and load profile data using Ergocheck (pneumatic sensor system). Participants were then asked to lie on a single bed surface covered with a pressure measurement system. Four pressure measurement readings were taken in each position. Supine, prone, and side lying postures were standardized (Buckle & Fernandes, 1998) using a goniometer), the fourth posture was their preferred sleep position. Total duration for each person was 15 minutes.

Results

<u>Load Profile Data</u>

Data was recorded in the Ergocheck software program. Data summaries were made by individual 'sensor' [i.e. 2x2 matrix of raw data readings], producing plan and 3d images in Excel and included male and female data summaries for each of the four lying positions.

Factors that were most useful for developing the rationale for zoning criteria included:

- Point pressure data. Point pressure occurred independently of body size and weight, with all body types, and were more related to the lying position.
- Distribution of pressure for each lying position.
- Overall total pressure.
- Body segment length.
- Age and weight factors.

Anthropometric Data

In all dimensions and weight, the data was comparable with the NZ data sets (Slappendel & Wilson 1992, Wilson & Wilson 1993). One notable exception was the sample of 45-65 year old males where 12 of the 17 participants were consistently larger than NZ data estimates across the percentile ranges for most dimensions.

Preferred Sleep Positions and Participants Comments

Of the 100 participants, 96 chose to demonstrate a preferred sleep position. It was noted that participants may also have simply obliged with a 'preferred' position. Almost equal numbers of females and males preferred side lying (58), 31 people preferred prone lying and 7 people preferred supine lying.

Limitations

Many limitations that may have a bearing on results were recognised at the outset, and these were added to throughout the study. The most significant of these were:

- Nature & size of the sample, length of time in each 'sleep' position, single bed only, constant order of measurement positions,
- Incentive effects, participant nervousness, relaxation levels, not asleep.
- Unknown effects on sleep positions due to injuries, physical changes.
- Reduced ability to mimic preferred sleep position due to: lack of darkness, privacy, duvet, partner, other triggers.

Conclusions

The data from this study, when combined with the manufacturing briefs, enabled the design team to set criteria for mattress and support surface specifications (these categories were a best guess by the client, based on Load Profile Study data, design criteria, stature percentile ranges for both this study and NZ Estimates, and weight ranges for this study and LINZ data.) After further interaction within the project team, a specification tool with which people could arrive more quickly at a mattress and base best suited to them was drafted by the designers for making prototypes and conducting usability trials.

USABILITY TRIALING

Aims

1. Test whether the client's specification tool (based on gender, height, weight) was an accurate predictor of subjective comfort reported by participants.
2. Collect information on the usability characteristics of the sleep systems trialed.

Methodology

Draft methodologies were developed and reviewed by the project team designers and other ergonomists, before being piloted and amended for the final study. 36 people were selected from the Massey University Albany Campus staff, students and visitors to the campus - with two people in each of the categories in an 18 cell-sampling frame that included three weight ranges and three height ranges for both males and females. Each participant trialed three beds; the one specified by the selection tool being assessed, the softest mattress & base combination, and the hardest mattress & base combination.

The data collected during the trial included:

1. Their weight, stature, shoulder height, hip height.
2. Ranking of three beds after lying on them for 20 seconds, plus comfort ratings.
3. Participants then spent 10 minutes lying on each of three beds in the position(s) they preferred to go to sleep in.
    - Static load profile data was collected after 1 minute (2 recordings).
    - Subjective comfort/discomfort ratings were collected after 3 minutes.
    - Static load profile data was collected after 10 minutes (2 recordings).
    - Subjective comfort/discomfort ratings were collected after 10 minutes.
    - Static load profile data was collected in right side lying (2 recordings).
4. Questions on the usability of design features common to all configurations.

Total duration was approximately 1 hour per participant. Participants were offered a $30 book voucher for their time.

Results

<u>Initial Sleep System Ranking</u>

- Most people either chose their specified configuration or the soft bed as the most comfortable (33 of 36).
- 12 of the 18 females chose the specified configuration as the most comfortable.
- 10 of the 18 males chose the soft bed as the most comfortable.
- 5 of the 6 heaviest males rated the soft bed most comfortable.

<u>10-Minute Trial Findings</u>

- 26 people found the specified configuration either comfortable or very comfortable after 10 minutes.
- Only 2 people found the specified configuration uncomfortable (1 at 3 minutes and another 1 at 10 minutes), and no one found it very uncomfortable.

- A total of 12 people changed their comfort rating for the specified configuration between 3 and 10 minutes. 7 of these people gave an improved rating.
- 30 people rated the soft bed as very comfortable or comfortable (31 people at 3 minutes), 20 of these ratings were for Very comfortable.
- These 30 people were spread throughout the configurations from A - L.
- 15 people changed their comfort rating for the soft configuration between 3 & 10 minutes. 8 of these people gave an improved rating, 7 gave a worse rating.
- 11 of the 36 people rated the hard bed as uncomfortable or very uncomfortable (12 at 3 minutes).

Usability Comments

Participants were invited to make comments and ask questions throughout the trial process. Occasions where this occurred formally were: in conjunction with the questions regarding comfort at 3 and 10 minutes for each of the configurations, and through specific usability questions at the end of the trials.

Limitations

Those that are in addition to the list for the load profile study include:

- Some of the participants were close in height &/or to the criteria for a different specified configuration.
- Assumption that height, weight and gender are the best indicators for specifying configuration type.
- 'Hawthorne' effects of study - potential bias in participants ratings and comments based on willingness to participate, provide helpful feedback, not 'be negative'.

Conclusions

The benefits of the integral ergonomic involvement in the design process were two fold. Firstly the Load profile data provided the foundations for the design and its specification, and then the Method of limits validated the design and its specification against both objective and subjective criteria.

This enabled the further refinement and resolution of the design and simplification of the system of options being used to create the specification. The other aspect of interest is the ergonomic involvement in the definition of a 'process' of selecting a persons most suitable sleep system without the use of a third party pressure measurement device such as the Ergocheck machine.

DISCUSSION

The professional designers deemed the exercise to be targeted and effective for those involved. As ergonomists it underlined the strength of operating within the Analysis – Design – Evaluation (AED) model utilising performance specifications and our method of measured and precise input. This approach fitted the professional demarcation of the project.

This AED model also works well within the context of iterative design, but gives a tighter framework for revision, helping to establish targets and clear factors for concern. This helps alleviate the subjective opinion issues that occur without objective data to rely on when making conclusions.
There was a huge amount of data produced in both phases that needed to be summarised. The load profile study generated 4800 txt files that each contained 80x40 rows of digits recording pressure. A script summarised these choosing the highest values in each row then the highest value every 13 (which constituted a 6^{th} of the bed length). This data could be graphed according to the subject's height, body weight, gender, or BMI or other more detailed anthropometric category.

(refer to PDF's attached to the email)

So the data generated at both levels was useful long after the study completion date for evaluating the system and criteria.

The Design Development continued through a regime of more in depth over night Studies using clinical sleep methods (EEG/Polysomnography), which help measure the objective sleep quality. This helped evaluate other longer-term comfort issues. It was the opinion of the design team that the continued involvement of the ergonomist through this phase would have been very beneficial to the overall project.

The Sleep system is now technically complete with a resolved 'method' for specifying the sleep system and then tailoring it to allow for the subjective comfort level of the user (within the bounds of criteria on their weight and height).

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Biographies

David Tappin (CNZErg) worked as a physiotherapist for four years before completing an MSc Ergonomics at Loughborough University in1989. He has worked as an ergonomist in a wide range of New Zealand industry, and has consultancy, research and teaching experience. Current research projects include: investigation of musculoskeletal disorders in sawmills, prevention of STF injuries in dairy farming and residential house construction, and optimisation of sawmill control cab work systems.

Timothy Allan graduated in Industrial Design from Wellington Polytechnic in 1996. After this he worked for the Te Papa Design Studio before taking a design position with Design Mobel NZ Ltd where he worked for 5 years. He was the Senior designer there for several years prior to starting his own development company on 2002, Locus Research Ltd. Current research projects include the development of a new natural wood fibre composite, Rehabilitation equipment design, Children's furniture for use in primary level schooling, and the development of a sustainable design method/tools for use in industry.

Dave Moore is a Certified New Zealand Ergonomist working with David Tappin at the Centre for Human Factors and Ergonomics in Albany. Prior to this he was a Director of the ergonomics consulting practice SPE Ltd. His first degree was in Architecture, and he worked in design related practices for 10 years before qualifying in ergonomics in 1993.