The impact of manikin family configuration on accommodation

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The impact of manikin family configuration on accommodation

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The complexity in considering human anthropometric diversity in multivariate problems commonly leads to a situation where more people are excluded by the design than was the objective. Ergonomists and product designers would benefit from tools and methods that make it less demanding to assess and achieve the expected accommodation level of the product in multivariate design problems. One approach is to employ computer manikin families in human simulation tools. This paper discusses how different configurations of two manikin families affect the way they represent targeted users.

Keywords: Anthropometric diversity, Human simulation, Product design.

1. Introduction

Daniels (1952) showed that the tendency to think in terms of the 'average man', "is a pitfall into which many persons blunder when attempting to apply human body size data to design problems." Daniels showed that, even with a generous definition of average, no one in his study proved to be average when 10 dimensions were considered. A similar reduction of accommodation, but declining less quickly, would be achieved if the 'average' range was enlarged from 30%, as in Daniels' study, up to 90%, representing the common design objective of accommodating from the 5th percentile to the 95th percentile. This would exclude 10% of the population, which may be relevant or required due to economic or practical reasons. However, when several dimensions affect the design, i.e. being a multivariate problem, the aim of accommodating 90% is often reduced considerably due to human anthropometric variability. Roebuck et al. (1975) showed that, when attempting to accommodate 90%, approximately 53% were accommodated after 15 dimensions were considered. This is a major issue since the design will accommodate a smaller proportion of the population than was the objective. More people are excluded by the design than intended, basically due to the complexity for the designer in considering human anthropometric diversity in multivariate problems when designing the product.

Since many anthropometric databases present data for male and female as 5th percentile, 50th percentile and 95th percentile values, it is reasonable for a non-specialist to assume that such 'constant percentile people' exist, and that by designing from the 5th percentile female to 95th percentile male, the product would accommodate 95% of the population, due to the overlap of the two distributions (Haslegrave, 1986). This may be true for design based on one dimension, e.g. defining proper headroom in a doorway, but will not be true for multivariate problems, such as vehicle occupant accommodation or workstation design (Roebuck et al., 1975; Porter et al., 2004). Besides, the assumption that the dimension of the 95th percentile male always will be larger than the 95th percentile female will in some circumstances not be true, e.g. hip breath and chest depth.

If one or two body dimensions affect the design, or in the case of a bespoke design, it is relatively easy for the designer to assess and achieve the expected accommodation level of the product. However, when the product should fit a population of users and several body dimensions affect the design, the design task becomes complicated due to human anthropometric diversity.
Ergonomists and product designers would benefit from tools and methods that would make such considerations less demanding. One approach is to employ computer manikin families in human simulation tools.

1.1 Use of manikin families in human simulation
Starting from a statistical treatment of anthropometric data, Bittner and his colleagues developed the CADRE manikin family, and subsequently developed it into A-CADRE (Bittner, 2000). This resulted in anthropometric descriptions for 17 manikins which we may consider as being members of a manikin family representing anthropometrical diversity in a proficient way. By using these manikins as user representatives in design, a high level of accommodation can be achieved. The manikin family in the human simulation tool RAMSIS consists of 45 members in each gender. RAMSIS Typology is based on the knowledge that the definition of the characterising property of length, proportion (ratio of sitting height over body height) and corpulence of an individual is sufficient to predict all other body dimensions for this person (Speyer, 1996). Depending on the design problem the human simulation tool user determines if all manikins in a manikin family are useful to include in the simulation or if a subset is sufficient. However, for some design problems it is complicated to determine which manikins are limiting the design problem and which manikins could be left out of the analysis. This leaves it to the tool user to carry out the frequently complex selection of appropriate manikins for the design problem at hand. For an expert tool user this might be straightforward, but for a 'normal' tool user this is a difficulty and a source of error, especially in multivariate design problems. One approach to this problem is to perform simulations including all members of the manikin family. This approach would be supported by a predetermined set of manikins, e.g. as a company or project standard family of manikins that is established to correctly represent the targeted product users. This would be similar to, and indeed a complement to, having a group of real test persons within a company that would always be recruited to assess products being developed. One difference between virtual and real test persons is that the virtual test group will always be available, even concurrently at different places. A concern is that the virtual test group will only do what they are told to do, putting pressure on the tool user to set up the study properly (Ziolek and Kruithof, 2000).

2. Method
This study compares results obtained when using two different approaches for user representation: the RAMSIS Typology family and the A-CADRE family. The RAMSIS Typology approach renders a manikin family consisting of 45 members in each gender. The A-CADRE family consists of 17 members in each gender. Since not all of the 19 body variables in the A-CADRE definition are possible to enter in RAMSIS, the decision was made to just use the three key variables stature, sitting height and waist circumference. Waist circumference is not present in the A-CADRE definition, so values for weight were used instead. This assumption is believed to be adequate due to the relatively high correlation between the two dimensions (Kroemer et al., 2001). The anthropometric database incorporated in RAMSIS was used in the study, with German females as the selected nationality and gender and age group selected as 18-70 years. Table 1 show the minimum and maximum percentile value of each key variable for each family approach. The accommodation level that these value ranges answer to was calculated using the multidimensional analysis functionality in two separate anthropometric software packages: PeopleSize 2000 Professional (PeopleSize, 2004) and BodyBuilder (Human-Solutions, 2003).

3. Results
Table 1 shows that A-CADRE has greater percentile coverage than RAMSIS Typology in stature, but smaller in sitting height and very similar for waist circumference. Even though different percentile ranges are covered, the two approaches result in approximately the same
accommodation level, i.e. approximately 86%. Further reduction in accommodation will happen if more body dimensions limit the design problem. However, this reduction is likely to be moderate due to relatively high correlation of the added dimension with either *stature*, *sitting height* or *waist circumference* (which between themselves have low correlation), i.e. the major reduction has already been made.

*Table 1. Characteristic data of RAMSIS Typology and A-CADRE families.*

<table>
<thead>
<tr>
<th></th>
<th>RAMSIS Typology</th>
<th>A-CADRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>4.6%-ile</td>
<td>1%-ile</td>
</tr>
<tr>
<td>max</td>
<td>97.5%-ile</td>
<td>99%-ile</td>
</tr>
<tr>
<td>coverage</td>
<td>92.9%</td>
<td>98%</td>
</tr>
<tr>
<td>Sitting height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>1%-ile</td>
<td>3.4%-ile</td>
</tr>
<tr>
<td>max</td>
<td>99.1%-ile</td>
<td>96.6%-ile</td>
</tr>
<tr>
<td>coverage</td>
<td>98.1%</td>
<td>93.2%</td>
</tr>
<tr>
<td>Waist circumference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>5.3%-ile</td>
<td>3.1%-ile</td>
</tr>
<tr>
<td>max</td>
<td>99.4%-ile</td>
<td>96.9%-ile</td>
</tr>
<tr>
<td>coverage</td>
<td>94.1%</td>
<td>93.8%</td>
</tr>
<tr>
<td>Accommodation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PeopleSize</td>
<td>86.8%</td>
<td>86.7%</td>
</tr>
<tr>
<td>BodyBuilder</td>
<td>86%</td>
<td>86%</td>
</tr>
</tbody>
</table>

Figure 1 show skin compositions of all members in the RAMSIS Typology (black) and the A-CADRE (grey) merged into one CAD geometry to illustrate differences in the volume that the two manikin families embody, in standing and car driving postures.
Figure 1. Skin compositions of RAMSIS Typology (black) and A-CADRE (grey) female manikin families in standing and car driving posture.

4. Discussion
Not surprisingly, considering the larger coverage of stature of A-CADRE (Table 1), the A-CADRE family represents smaller and taller manikins (grey geometry in Figure 1). More interesting is that the RAMSIS Typology seems to represent corpulence differently than A-CADRE. Table 1 shows similar coverage of corpulence but Figure 1 indicates that the RAMSIS Typology represents corpulence to a higher degree (hence the black abdomen), particularly for shorter persons. This may be an effect of sources of anthropometric data when creating the manikin families, and particularly of correlations between body measurements. The RAMSIS Typology is largely based on large anthropometric surveys done in Germany by measuring civilians (Human-Solutions, 2004), whereas the A-CADRE is mainly based on US Army personnel data (Bittner, 2000). It is likely that people represented in the US study are on average more fit than people in the German study, and hence that the RAMSIS Typology manikin family more accurately represents corpulence of common people.

By enabling the human simulation tool user to see and operate the product user as well as the product modelled in the same virtual environment, human-product interaction issues are more easily considered concurrently with other design issues, thereby supporting the synthesis work
that is characteristic of design. The implementation of pre-defined manikin families in human simulation tool aids the tool user to consider anthropometric diversity rather straightforwardly even though not being required to know the problems in detail or the theory behind the manikin family, but rather putting his or her efforts into making sure that all manikins are accommodated by the design. Both manikin family approaches embody human diversity in a credible way. Even though it is hard to draw major conclusions from this study, it is worth emphasising that A-CADRE gave these results by 62% fewer simulations required (17 compared to 45).

References