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DESIGNING ERGONOMIC DATA TOOLS FOR DESIGNERS

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ABSTRACT
Ergonomics provides important user data for design. However, when interviewing designers about their use of data in the design process, we found that experienced designers' use of ergonomics data were very limited. Being "out of date", "irrelevant" and "hard to understand and work with" were the main comments on existing ergonomics datasets, especially anthropometrics. The eleven designers interviewed all tend to adopt more experimental approaches to data capture, for example, through building ergonomics rigs and conducting user tests. They prefer designer-friendly user data tools, e.g. relevant, intuitive, highly visual tools which are fast and easy to learn and to work with; and prefer tools that are compatible with other design tools they typically use. Based on the designers' preferences and suggestion, we have prototyped a number of new tools for communicating user data to industrial designers. Two workshops were organized to evaluate the effectiveness of these tools with novice and professional designers. The feedback from the workshop participants was used for further development of these user data tools.

Keywords: Ergonomics data, anthropometrics, inclusive design, user data, prototype tools, evaluation workshop

1. USER DATA FOR INCLUSIVE DESIGN
Inclusive design aims to accommodate the capabilities and needs of the widest possible population. It requires a good understanding of the range of the user population in terms of their sizes and capabilities. Anthropometrics provides important user data (e.g. physical characteristics and abilities of people) for design of environment and products. However, there are a number of problems with existing anthropometric databases: they are often difficult to understand and interpret [1]. When discussing the importance of research in developing accessibility standards in India, Sharma listed the problems with existing anthropometric data in detail [2]:

- Very few databases include data of older people and people with disabilities
- Comprehensive anthropometrics studies have focused on non-disabled adults
- Data collected from western worlds, with much of the work performed on military personnel
- Lack of standards for the measurement techniques to produce anthropometric data
- Data typically used by designers is extremely outdated.

He concluded that:

- Data collected exclusively from able-bodied persons is useless when designing inclusive environments
- Data that is directed towards populations of users and wheelchairs in predominantly western countries and their environment has limited application in the region where people's sizes, characteristics of assistive devices used and the environment are all different.

In recent years, new user data tools have been developed in the UK for inclusive design, for example, the human modeling tool HADRIAN [3] developed in Loughborough University, the Sprout Web tool [4], the online Inclusive Design Toolkit [5] developed by the Cambridge Engineering Design Centre and its research partners, and the InclusiveCAD tool [6] visualizing biomechanical data of older adults developed by the Glasgow School of Art. HADRIAN and InclusiveCAD collected data from real users, 100 and 84 respectively, and the Sprout Web tool and the Inclusive Design Toolkit are based on the 1998 national disability survey data of the Great Britain [7]. However, none of these tools has

focused on the conventional anthropometric data which are problematic for designers. Making ergonomics data more designer-friendly is yet to be done. There are two aspects to consider when dealing with ergonomics data for inclusive design:

1. the 'inclusivity' of the data (e.g. whether they include data of older people and people with disabilities)
2. the 'ease of use' of the data (e.g. whether they are presented in a usable and designer-friendly format)

The study reported in this paper focuses on the second aspect: the 'ease of use' of ergonomics data. The designers' use of such data was explored through interviews.

2. INTERVIEWS: DESIGNERS' USE OF ANTHROPOMETRIC DATA

Eleven experienced designers with medium/high managing roles from ten design companies were interviewed. The samples were mainly drawn from those who have participated in the DBA Inclusive Design Challenge–an annual UK-based inclusive design competition targeting design consultancies [8]. In addition, two large companies with in-house design teams were also included. The design expertise of the companies ranges from industrial design, interior design, graphics design to transport and service design.

The interviews typically started with a brief introduction to the study and general warm-up questions (e.g. the company's core business, its design process etc). Following that, specific questions were asked regarding their usage of ergonomics, especially anthropometric, data. The interviewees' thoughts, feedback and preferences were explored in an open discussion and their suggestions for future data tools were collected. At the end of each interview, the interviewees' education background and professional experience were also recorded. The Interview sessions generally lasted between 60 and 90 minutes. According to the natural process of the interview and the flow of raised issues, the questions' order or content could change slightly and was kept flexible. The interviews were all tape recorded and were fully transcribed [9]; notes were also taken throughout the interview.

2.1 Designers' current use of data

The designers' current use of ergonomics data was investigated through a series of questions addressing various aspects of the data, including the sources and types of data. Table 1 summarizes the result.

Table 1 Summary of current data use

Design company	Sources and types of data
A: Product design	Measuring people, prototyping, clients' data, benchmarking, web search, getting people's feedback, guidelines, standards.
B: Interior design	Standard diagram of average person, templates supplied by manufacturers, disability regulations, first-hand user data (through measurement).
C: Product design	Meeting real users through the clients, model making, manufacturers' & clients' data, web search, standards, safety regulations, experimental data.
D: Product & service innovation	Model making, measuring & testing with people in the studio, books, ergonomist, guidelines, standards.
E: Healthcare innovation & design	Working with users & collecting data, prototyping, clients' data, measuring and testing, standards.
F: Industrial design	Measuring and testing with the users, prototyping, videos from focus groups, web search, ergonomist, one book, standards & guidelines.

G: Product design & strategy	Model making & testing with people in the studio & outside, asking experts, clients' data, manikins in Auto CAD, standards & legislation, guidelines.
H: Industrial design	Prototyping & testing with users, books, web search, British Standards and legislation, clients' data.
I: Product design	Clients' data and expertise, model making & testing, web search, professionals' network, legislation & standards.
J: Industrial design	Prototyping and testing with people, web search, client's data, standards.

When asked about their sources of ergonomics data, the designers hardly mentioned any existing data tool they actually use or would use in the design process. Many reported that they had not used anthropometric data for a considerably long time.

"I don't think I have actually used an ergonomics chart for ten years or so!"

Instead, the main methods for data collection, as shown in Table 1, were practical and pragmatic, for example prototyping (model making, rig building, mock-ups) and working with people (taking measurement and asking users for feedback).

Another important source of data is clients (e.g. manufacturers) and experts (e.g. ergonomists). For example, designers often obtain important design data and useful references such as guidelines, standards and legislation from manufacturers.

The majority of the designers interviewed also reported on relying on their common sense, intuition and experiences as their inherent source of data, therefore the major type of data implemented into the design process was experimental. The other major type of data was the ever-increasing rules and regulations introduced by various bodies.

Anthropometric data was considered as just a "start point". Most designers had an overall negative and passive perception on the existing data. Being "out of date", "irrelevant" and "hard to understand and work with" were the main comments made repeatedly by almost all the designers interviewed. Compared with designers' own practical methods of collecting data, referring to data tools was considered as neither effective nor efficient.

2.2 Suggestion on data tools for inclusive design

The designers were asked about their suggestion on user data for inclusive design. They proposed a number of ideas, including (the numbers are used for ease of reference, not indicating the order):

1. A 2D tool with an easily adjustable person to be dragged and dropped in various designed environments
2. Software enabling effective documentation of companies' own product and user data
3. 3D software simulating a person determined by age, gender and physical and mental capabilities
4. 3D software simulating a flexible human body, capable of producing new measurements of unmeasured body parts
5. A virtual person to be put into Auto CAD showing how the human and environment relate to the CAD modeling of the products
6. A tool enabling data share and management within the company
7. A PlayStation version of a tool to simulate a person with specific age, gender and physical abilities in a specific position
8. Software presenting examples of best and worst products versus each other enabling comparison and seeing the percentile each fitted
9. Ergonomic 'facebook' with confidential immediate access to millions of people
10. A fully equipped up-to-date lab with adjustable products and services for test

3D data tools were preferred by many designers because they use 3D software packages a lot. For example, several designers expressed their interest in a tool which can be plugged into SolidWorks and give them a good simulation of a person with real time interaction with the product under design.

Rather than an 'average person', the mannequin should change with different variables (e.g. age, gender and physical and mental capabilities). However, some designers challenged their own proposed ideas by questioning the feasibility of such complicated 3D human simulations and the level of complexity of such software. Most designers said they would prefer a simple, intuitive, highly visual tool which is fast and easy to learn and to work with.

Many of the industrial design companies interviewed were specialized in small-scale consumer products (e.g. telecommunication products or portable medical devices), and the designers found the predominant full-body anthropometric data irrelevant to their design.

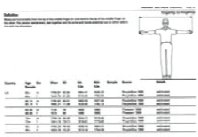
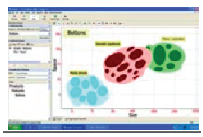
> "*The trouble with this (data) is that it is kind of big, most what we do is not this size. How do you translate it into something which is for small objects? This is all kind of reaching, lifting, how many products do we design where that is relevant?*"

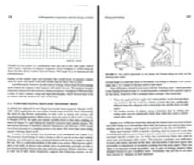
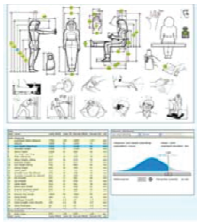
3. QUESTIONNAIRE: DESIGNERS' RANKING OF ANTHROPOMETRIC DATA TOOLS

In addition to the interviews, five anthropometric data tools were chosen and presented to the designers. The criteria for the selection of the tools were to cover a wide range of sources, presentation formats, data types and also issues such as familiarity and accessibility. This was in order to provide extensive information of the designers' 'preferences' of data. Among the data tools, four were existing tools, and one (Tool 3) was mocked-up by one of the authors.

The designers were asked to rank the tools. Each of them had a different ranking order, making it hard to derive conclusions about the tools based on simply adding up the weighted ranking scores. However, by looking at the most and least preferred tools, some conclusion could be drawn. In Table 2, the numbers in the 'highest' cell show how many designers ranked the tool the highest (i.e. most preferred); and the numbers in the 'lowest' cells shows how many designers ranked the tool the lowest (i.e. least preferred).

Table 2 Summary of the designers' preferences of anthropometric data tools

Anthropometric data tool		Highest	Lowest	Comments
	**Humanscale** [10] Interactive cards with rotating wheels to enable selection of age and gender, with an accompanying booklet	2	3	Holistic, interesting presentation of data, out-dated, irrelevant, too much information
	**Older Adultdata** [11] Handbook with many data tables and simple illustrations	2	1	Simple, easy to use, boring, unexplained, separated data
	**Ergo-CES** Software enabling 2D data visualization and comparison of data	5	0	Complex, good features, unprofessional graphics, too analytic

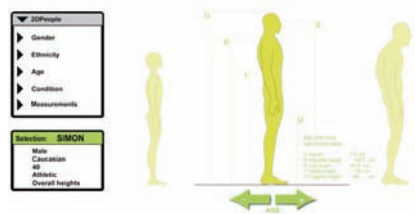
	**Bodyspace** [12] Textbook incorporating data and guidelines	0	6	Comprehensive, too much text, academic, student-oriented, lacking color, too scientific
	**Dined** [13] Web-based resource enabling selection of data and visualization of percentages	1	0	Interactive, accessible, visually unprofessional, irrelevant data, useful features

The mocked-up software tool Ergo-CES which enables 2D visualization and comparison of data received the highest score. It was ranked first by 50% of the designers. In contrast, Bodyspace, the book typically used in the UK colleges in teaching ergonomics to design students, received the lowest score; it was ranked last by 60% of the designers. The remaining three tools received a combination of contradictory rankings from the lowest to the highest. All tools received both negative and positive comments and in some cases a feature considered as highly positive by one designer was evaluated as distracting by another. However, features such as having too much text and lacking color and pictures were considered dissatisfying by all the designers. On the other hand, features such as being simple and interactive were liked by all the designers.

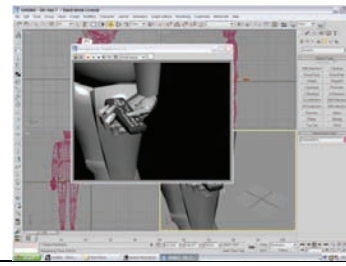
4. DEVELOPING USER DATA TOOLS FOR DESIGNERS

There are serious problems with existing ergonomics data in terms of supporting inclusive design. Lack of 'inclusivity' has been mentioned by [2], and our study suggests that the lack of usefulness, usability and desirability [14] are prohibiting designers from using existing ergonomics data effectively in the design process. There is a need to improve the existing tools. Based on the designers' suggestion and preferences, we have prototyped a number of new user data tools (Table 3)

Table 3 New user data tools

2DPeople (based on Suggestion 1, Section 2.2)	
Description: 2DPeople is a source of anthropometric data. Variables such as gender, age and ethnicity can be input in order to generate a 2-dimensional subject and data for use in design and visualization. The figures can be modified at its joints and relevant numeric data is displayed. Possible to browse through age brackets of figures being used.	
Main feature: Searchable database of 2D data. Searchable criteria includes age, ethnicity, physical conditions; age manipulation; drop-down menu; joint manipulation.	

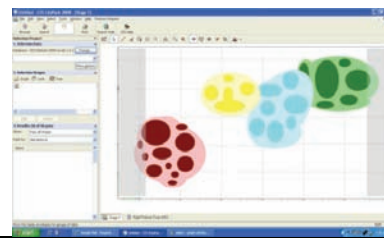
3DPeople
(based on Suggestions 3,4, 5, and 7, Section 2.2)



Description:
3DPeople is a source of anthropometric data. Variables such as gender, age and ethnicity can be input in order to generate a 3-dimensional subject for use within 3D CAD packages allowing CAD work to be assessed alongside realistic representations of potential users. The generated models can also be used for visualization and presentation.

Main feature:
Construct specific 'people'; manipulate mannequin; interrogation of products through use of mannequins; generation of renders and information replicating sensory conditions (e.g. visual impairments).

ErgoCES
(based on Suggestions 2, 6 and 8, Section 2.2)



Description:
ErgoCES incorporates large quantities of existing data sets. Parameters of these datasets can be compared in a highly visual manner. The category of each axis selected by the designer, enabling 2D data visualization and comparison.

Main feature:
Compare parameters of interest; select range according to specific criteria defined; display of both structured information (e.g. tables) and non-structured information (e.g. text descriptions). Main function includes "search", "browse" and "select".

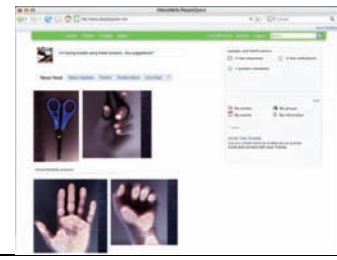
ErgoLab
(based on Suggestion 10, Section 2.2)

Description:
ErgoLab is a physical laboratory staffed by researchers, industry experts and extreme users, which brings together the cutting edge expertise, resources and tools of inclusive design. It can be used for general research or to interrogate and test product concepts and

prototypes. Among the resources available are simulation aids, books, user database, 3D scanners, products and accompanying case studies.

Main feature:
Advisors/professionals on-site; up-to-date books; database of users; simulation aids; body scanner; brainstorming/work area; examples of good products with case studies; 'domestic' test rooms.

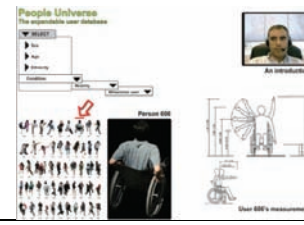
PeopleSpace
(based on Suggestions 8 and 9, Section 2.2)



Description:
Peoplespace is an online community, which brings together real people and real designers. It is a special interest group where people can express issues they have with current designs and query the experts. Designers can explore what end users really want from products of today.

Main feature:
Social network; real people and real designers; allow the rating of products; specific companies allowed to advertise in space: searchable conversational information capture

People Universe
(based on Suggestions 7 and 9, Section 2.2)

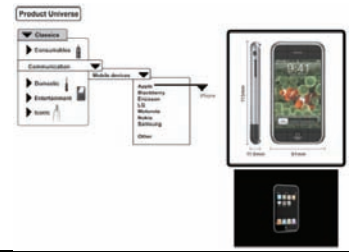


Description:
People Universe is a user database; it utilizes highly visual search capabilities as well as the more conventional keyword and drop-down menu searches. It is fully updatable, and provides a simple framework to input new user profiles and data.

Main feature:
Expandable database (30 users profiles included as standard); video profiles; anthropometric data; visual search facility (users depicted) as well as conventional word search

Posture Sourcebook
(inspired by designers' preference of source books)

Description:

Posture sourcebook is a pictorial resource of common everyday work and leisure activities. Through gathering representation of the full range of body movements typically used in everyday tasks it can inspire and give designers insights into how products are manipulated.
Main feature: Comprehensive pictorial documentation of common activities and realistic representations of postures typically used during these activities.
Product Universe (based on Suggestion 8, Section 2.2) 
Description: Product universe is a searchable database of 'good' design examples, which can be used for comparison when designing. It lists the critical dimensions of products, to give an insight into the sizes adopted. Each sample has images, video and full dimensions, amongst other useful data about the product characteristics.
Main feature: Collection of good design examples, with full measurements and commentary; video presentation.

5. EVALUATION WORKSHOPS

To evaluate the effectiveness of the new data tools, two workshops were organized, one focusing on novice designers (16 final year design students and 7 postgraduate design students); the other focusing on professionals (9 experienced designers and 7 design lecturers).

In the workshops, the prototype tools were introduced to the participants (as briefly described in Table 3), and the participants were asked to give individual comments on each tool using color-coded post-it-notes (Figure 1):

- Green: "Go! I Like it"
- Yellow: "Maybe! I could like it if…"
- Red: "Stop! I don't like it"

The tools were quick and early prototypes, and they did not provide interaction features to the targeted users. The feedback was purely based on the features and details provided by the 2D images (A1 poster mounted on walls) and a presentation of the concepts. To help the participants remember the features of each tools, A3 landscape paper with the images and descriptions of the eight tools were provided to each participant for reference. By giving rough rather than well defined prototypes to the targeted users, the authors expected to receive honest comments with open minds.

Figure 1 color-coded comments on individual tools

The participants were then asked to discuss in groups (4-6 persons per group) and vote for their favorite tools, with specific comments on the features they like. The final stage of the workshops was 'co-design': each group proposed their 'ideal' data tools. Feedback to the workshops was gathered through questionnaires (Figure 2).

Figure 2 Participants fill in feedback questionnaires

The feedback to the workshops was predominantly positive. A lot of data was gathered (individual feedback on each tool in a format of written comments, group discussion and ranking in a format of voice recording, 'co-design' ideas in a format of voice recording and group sketches). These data are being analyzed to help prioritize potential tools for further development.

6. DISCUSSION AND FURTHER WORK

The study presented in this paper has been focused on detailing the problems of existing ergonomics data tools and identifying preferences of user data tools from designers' perspective. Nine out of the eleven designers interviewed have more than twelve years of professional experiences; and nine out of the ten companies' core businesses fall in the field of industrial design, so the findings are likely to be generalizable to experienced industrial designers in the UK context.

From the interviews we found that experienced designers' use of ergonomics data, specifically anthropometrics data, are limited. They tend to reply on experimental methods such as making models and testing with people to get first-hand data.

We also found that designers with an ergonomics background tended to have different preferences of anthropometrics data compared with the designers who do not have a strong ergonomics background. The former seemed to prefer specific data (e.g. tables in ergonomics handbook) and the latter prefer general data presented in a context (e.g. images showing lots of dimensions). To investigate this further, we plan to interview more designers with ergonomics backgrounds.

As shown by the designers' varying ranking of the anthropometrics tools, individual designers' viewpoints often differ from one another; however, when they discuss in groups (as they were asked to do in the evaluation workshops), consensus emerge. In the workshops, several groups suggested that features of each individual prototype tools could be combined to form a more comprehensive data tool. Some of the tools suggested already have commercial products on the market, for example the 3D human modeling tool 'Jack' and the 3D software 'Poser'. However, none of such tools were used in any of the companies interviewed, either because they were not aware of the tools and/or because they did not see the value of investing on such tools. The future development of the proposed tools will therefore not focus on 3D software tools, but more on tools to help designers effectively obtain and manage their user data.

Initial analysis of the data gathered from the evaluation workshop suggested that novice designers' data behavior and preferences differ from those of the professional designers. So we plan to conduct investigation of the data behavior of novice designers in the future to explore whether it is necessary to develop different tools for novice designers.

We have adopted an inclusive design research methodology in this study. The users of our tools are designers, so their needs were investigated and they were involved in the early prototyping stage. They will be involved throughout the project.

7. CONCLUSIONS

Our interviews show that experienced designers' use of existing anthropometric data tools (i. e. text books, handbooks, software packages, online sources, etc) is very limited.

The study also highlights the dominant role of experimental methods in the design process: i.e. physical prototyping and engaging with people in providing designers with relevant user data and information.

Based on the designers' suggestion and preferences, a number of user data tools have been prototyped. Both novice and professional designers were invited to attend evaluation workshops and they were involved as users to co-design user data tools. This 'inclusive design methodology' proves effective and we have obtained useful information to further develop appropriate user data tools for designers. The directions are likely to focus on helping designers obtain and manage user data more effectively. Novice designers' needs will also be considered in the development of the tools.

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Chris McGinley is a Scottish-born designer and a PhD design researcher at Brunel University. His academic qualifications include a MEng from the University of Strathclyde and a MA from the Royal College of Art. He worked for five years at the Helen Hamlyn Centre where he produced inclusive design solutions for companies such as GlaxoSmithKline, Osaka Gas, and Thomas Pocklington Trust.