INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

DESIGN REQUREMENT DATA AND THE OLDER ADULT

Bruce Carse[1], Avril Thomson[2] and Ben Stansfield[3]
(1&2) University of Strathclyde,UK, (3) Glasgow Caledonian University, UK

ABSTRACT

It is well recognised that many products do not meet the requirements of the rapidly growing older adult population. The research described in this paper aims is to provide designers with relevant and useable older adult requirement data. Data relating to older adults capabilities is being produced largely by the biomechanics community however, there is little evidence of its adoption. This project focussed specifically on the design of everyday consumer packaging. Poorly designed packaging can present a significant barrier to achieving one of the most important basic activities of daily living - being able to feed oneself. Initially a study of practising designers was conducted to establish how they currently design for older adults. An Observational Video Study followed which examined 60-90 year old adults opening packaging, from which typical opening strategies were identified. Relevant "new" design data was extracted from the observational video study and presented to packaging designers in a series of interviews together with typical biomechanical data. These interviews established exactly what data designers want and the best formats for integration in the design process.

Keywords: design data, design requirements, older adults, packaging, biomechanics, Inclusive Design

1 INTRODUCTION AND BACKGROUND

Biomechanical research is producing valuable data relating to the strength and mobility of the older generation and how they interact with products. However, the existence of this data is not frequently apparent in the design of everyday products. There are thought to be a number of reasons for this including:

- designers are not aware that such data exists
- the data is presented in a format that designers find difficult to understand and use
- data produced from biomechanical testing does not directly match the requirements of product designers

There are a number of researchers currently addressing elements of the issues raised. One recent study involved a survey of twenty-nine design professionals [1] which showed there was no evidence of them using bioemechanical data. The same study found that designers were aware of Inclusive Design however a lack of time, resources and client backing were found to be the main reasons for them not routinely practicing this. Another study found that not only did designers view the main barrier to Inclusive Design as 'lack of client requirements', but they also specified that they required support through new 'data and tools' [2]. Packaging openability research to date has tended to be highly specific, concentrating mainly on measuring people's strength [3, 4, 5 & 6]. One study found that in addition to age, hand anthropometry and mid arm circumference were important predictors of pinch and power grip strengths, both of which are vital for package opening activities [7] and therefore accounts for a large variation in the strengths of older adults. Although some of the more recent work has examined grip types involved with package opening [8], none of it has sought to investigate the combination of biomechanics, grip type, posturing and dexterity required. Further investigations into which types of packaging cause people most "difficulty" have been carried out using a consumer survey, this work however, did not truly explore the nature of the physical difficulties experienced [9]. Previous work has also been carried out to gather together comprehensive data on older adults;

anthropometric, strength, and a description of how cognitive functioning and psychomotor functioning change with age [10]. A large scale study [11] also attempted to place 'design guidelines' alongside the raw data, to help the designers interpret and use it correctly, highlighting that others recognise this as an area requiring attention. While there is much research effort being put into gathering data, there are significant concerns over how it is disseminated to the practicing design community [12]. In summary, research to date has focussed on addressing individual elements of the overall problem area. The research described in this paper adopts a holistic approach allowing the loop to be closed between the data produced and its successful integration in to the design process. This work was carried out in three main stages:

Stage 1 Survey of practicing designers: Structured interviews with packaging designers across ten UK based companies were conducted to provide an insight into how designers' currently take older adults in to account, what data they currently use and their understanding of Inclusive Design.
Stage 2 Observational Video Study: an observational study was performed with 60-90 year old subjects opening different types of "difficult to open packaging" in a typical kitchen environment. Typical opening strategies were identified and classified. This phase provided examples of a range of data presentation formats which could be used to inform designers of older adults' abilities in comparison with a younger cohort.
Stage 3 Integration in the Design Process: The data obtained from the observational video study together with typical biomechanical force and motion data was presented in formats which met the criteria of the design community identified in Stage 1. A second round of structured interviews with packaging designers helped to identify which formats they were most likely to use together with further developments they would like.

2. SURVEY OF PRACTICING DESIGNERS

2.1 Description of Study

Structured interviews were conducted with ten design companies involved in packaging design. Participating companies ranged from small consultancies through to large multinationals. The structured interview investigated key issues including:

- the companies' current design process and practices i.e. common tools and techniques.
- their awareness, understanding, and use of ergonomic, anthropometric and biomechanical data.
- how older adults are currently considered when designing new packaging.
- what design criteria were more important to them and where 'openability' ranks in importance amongst their design criteria.
- their understanding, and use of Inclusive Design.
- what types of design data they currently use and why?

The structured interview was conducted with an experienced designer within each company, to ensure a thorough understanding of company processes and practice. Each interview was recorded using a dictaphone and subsequently transcribed. Transcriptions were analysed to identify similarities, differences and patterns in the response from the companies.

2.2 Finding from the Study of Practicing Designers

Findings from the structured interviews can be summarised as:

- 'openability' is not a major concern amongst the packaging designers interviewed. When asked to rank a number of design criteria in order of importance 'openability' was not amongst the top 3. Following discussion it became apparent that it is not a requirement of the companies or their clients to make the packaging 'easy-to-open' . Ultimately, openability would be the decision of the individual designer. Designers interviewed felt that if they designed difficult to open packaging this would be identified early in the process through user groups.
- packaging "appearance" consistently ranked top. Designers generally believed that addressing openability issues would have an adverse effect on other 'important' design criteria.

- packaging designers knew what inclusive design was, with 90% confidently offering an accurate definition. However, they had little or no knowledge of how to put it in to practice with very few having any experience of actually designing products inclusively. Some of the designers interviewed felt they intuitively designed products to be inclusive. However, there was little tangible evidence of this occurring. One company commented that they would start adopting inclusive design techniques if their clients demanded it.
- most of the designers interviewed felt they included older adults in their design process through consumer testing or informal discussion.
- there was very little evidence of ergonomic data being used by packaging designers with only one of the ten companies regularly using it. Most felt this data was too generic and would rarely be suitable for their specific requirements. The preferred approach was to design then test products using end users through the adoption of user trials, focus groups, observation and ethnography. None of the designers interviewed were encouraged by their management or clients to use ergonomic data.
- all designers interviewed had an awareness of biomechanics but only one out of ten could offer an accurate definition. Very few knew where they could access biomechanical data.
- companies interviewed adopt user trials and focus groups, However, these did not always include older adults. Examples of practice included a small design consultancy who regularly used a small, informal group comprising mainly of relatives and their friends through to a large international manufacturer on one occasion employing a focus group of older adults (this was considered to be a one off as they did not consider older adults to be in their target market).

This initial study of practicing designers provided a broad overview of how packaging designers currently take older adults into account including an understanding of what data they use. It was apparent that designers were not using biomechanical data in their day to day work

3 OBSERVATIONAL VIDEO STUDY

3.1 Description of Observational Video Study

During this study a total of 40 adult subjects were studied opening six different types of “difficult to open” packaging, specifically:

- Jars (tesco value pasta sauce, 440g)
- Soft drinks bottle (irn-bru, 500ml)
- Soft drinks can (irn-bru, 330ml)
- Tin with ring pull (Heinz vegetable soup, 400g)
- Child Resistant Medicine Bottle
- Bleach bottle (original Domestos, 750ml)

Subjects were grouped into four age groups equally balanced in gender, these being a control group aged between 20-35 years old and three groups of older adults aged 60-70, 70-80 and 80+ years old. A dimensional replica of a standard kitchen worktop was created. Subjects were studied and video recorded opening each of the different types of packaging using the method they would normally use in their home environment. All packaging was placed on the worktop. A number of everyday kitchen tools and items i.e. knives, scissors, tea towel etc were made available to all subjects and could be used freely to replicate everyday practice. Subjects were also given the option of using an Assistive Device should they regularly employ one in their home. Figure 1 shows the laboratory set up for the video study showing the standard kitchen worktop with typical kitchen implements provided and camera positions.

Figure 1 Laboratory set up for the Observational Video Study (camera's circled)

The subjects were presented with each of the 6 different types of packaging in a random order. Initially, they were asked about how they would normally open each type of packaging i.e. sitting or standing, with their bare hands, using a typical kitchen tool or assistive device. The subject was then asked to open the packaging adopting their normal approach. Each type of packaging was placed directly in front of the subject so as not to influence which hand the subject used. The number of attempts taken before successful opening occurred was recorded. Once the subject successfully opened each type of packaging they were asked to rate the difficulty. If they experienced any pain and discomfort during the process they were asked to rate this together with a description, i.e. sharp, dull, aching, lingering and its location. Capturing video together with other data, including difficulty ratings, pain and discomfort etc., allowed the most difficult types of packaging to be identified and the characterisation of typical opening strategies and motion patterns.

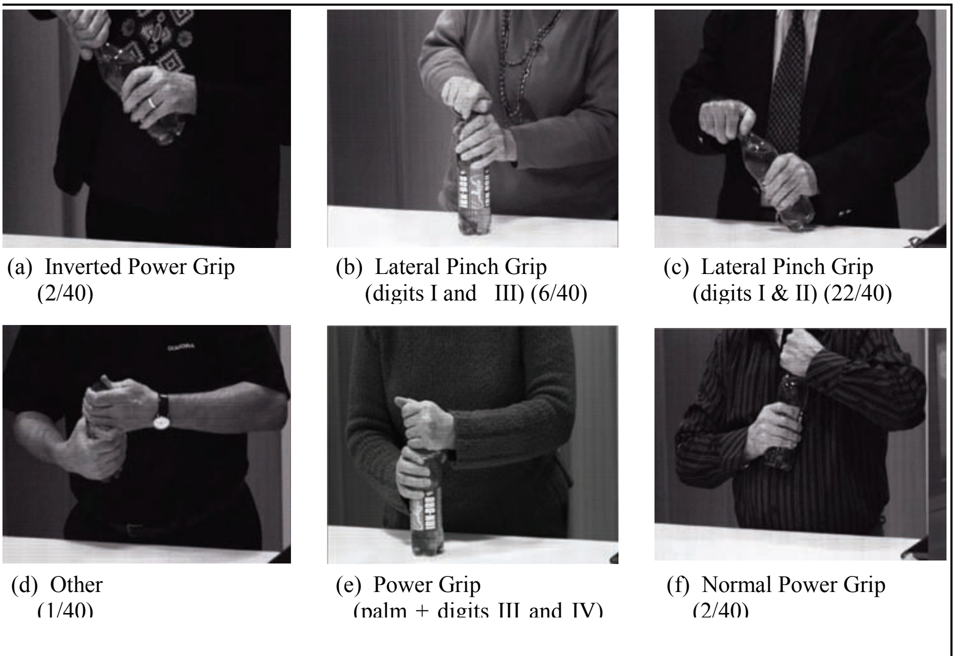
3.2 Observational Video Study Findings

The video study results were analysed to identify typical Opening Strategies. A series of photographs showing each of the grip types adopted throughout the study were produced from the video recordings to facilitate analysis. "Opening Strategy" is defined here as consisting of three key interrelated components these being hand grip type, starting posture and opening motion:

- **Hand Grip Type** refers to the way in which the subject grasped the lid of the packaging such that they could apply a torque by rotating their wrist/elbow/shoulder.
- **Starting Posture** refers to a description of the static position of the wrist, elbow and shoulder joints immediately prior to the application of the force or torque to the packaging.
- **Opening Motion** refers to a description of the dynamics of each joint as the main opening force or torque was applied to the packaging.

Opening strategy findings focus on two types of packaging found to be the most challenging for older adults specifically, jars and bottles.

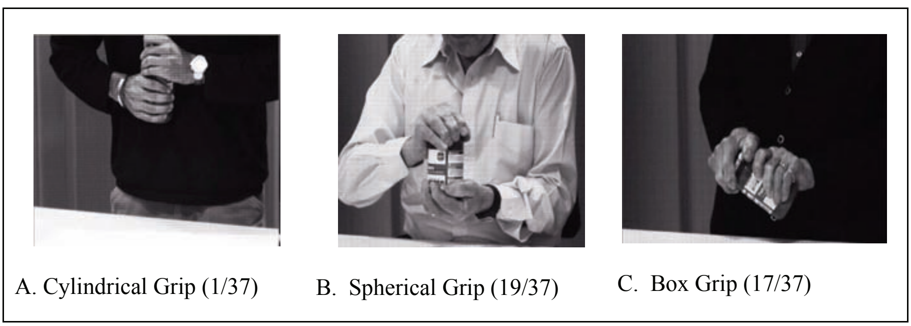
Hand Grip Types: Six common grip types were identified for the bottle, as illustrated in Figure 2, frequency of occurrence is also indicated.



(a) Inverted Power Grip (2/40)
(b) Lateral Pinch Grip (digits I and III) (6/40)
(c) Lateral Pinch Grip (digits I & II) (22/40)
(d) Other (1/40)
(e) Power Grip (palm + digits III and IV)
(f) Normal Power Grip (2/40)

Figure 2. Grip types used for bottle opening (frequency of occurrence indicated)

Three main grip types were identified for the jar. These grip types are illustrated in figure 3 with the frequency of the occurrence of each grip type indicated in brackets.



A. Cylindrical Grip (1/37) B. Spherical Grip (19/37) C. Box Grip (17/37)

Figure 3: Grip types for Jar Opening (frequency of occurrence indicated)

Unlike the bottle there was no clear favourite grip with the spherical and box grips being similarly popular.

Starting Posture and Opening Motion - Starting posture describes the static position of the wrist, elbow and shoulder joints immediately prior to the application of the force or torque to the packaging. The shoulder, elbow and wrist joints have three, one and three degrees of freedom respectively as shown in Figure 4.

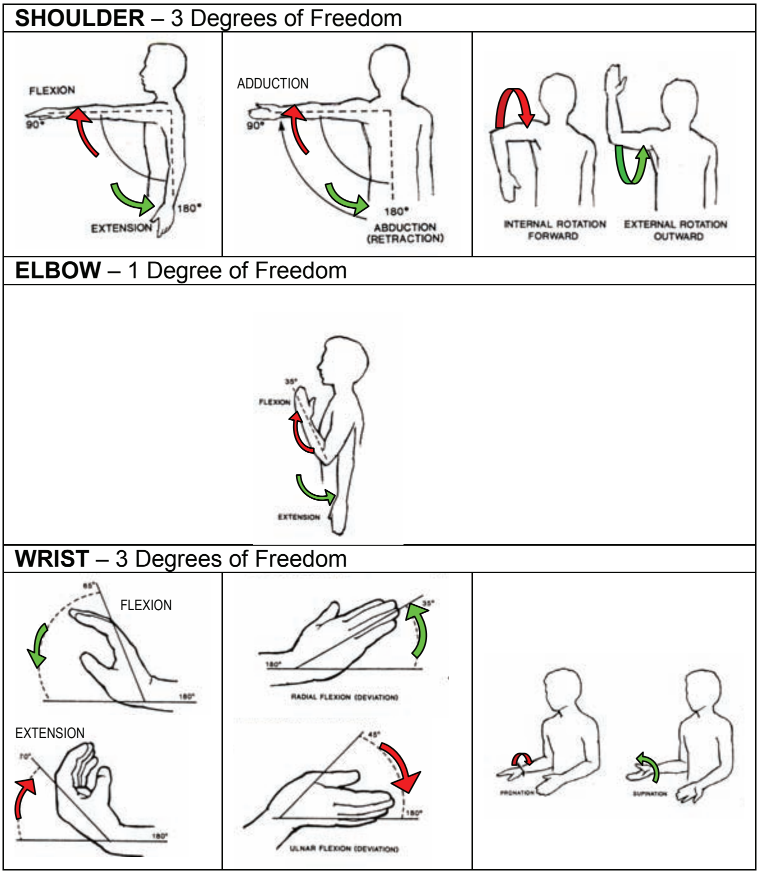


Figure 4: The degrees of freedom of the shoulder, elbow and wrist joints Illustrations adapted from Biomechanics of Human Movement 2nd Edition, Adrian, M and Cooper, J (1995)*

Both the starting posture and opening motions for each subject were described using a code made up of 14 variables, each one representing a different degree of freedom and each degree of freedom having 3 discrete alternatives as shown in figure 5.

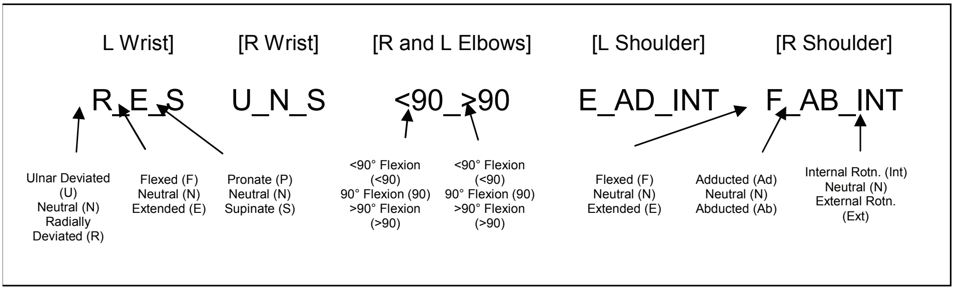


Figure 5: Example of a Subject's Unique 'Starting Posture' Code

A One-Way Chi-Square test for statistical significance was used to analyse the complete results for the common start postures and opening motions for both the jar and the bottle. Using the significantly common characteristics as identified in the statistical analysis these starting positions and motions for both the jar, Table 1, and bottle, Table 2, can be summarised as follows:

Jar Start Posture; Left wrist extended, right wrist extended and ulnar deviated, left shoulder internally rotated, right shoulder abducted and internally rotated.

Jar Opening Motion; Left wrist flexion, right wrist radial deviation, right shoulder abduction and internal rotation.

		LHS	RHS
Posture	Wrist	Extended	Extended + Ulnar deviated
	Elbow	-	-
	Shoulder	Internally Rotated	Abducted + Internally rotated
Motion	Wrist	Flexion	Radial deviation
	Elbow	-	-
	Shoulder	-	Abduction + Internal rotation

Table 1 Starting positions and motions for jar opening (for those who used right hand on lid)

Bottle Start Posture; Left wrist extended, right wrist ulnar deviated, left elbow flexed <90°, left shoulder internally rotated, right shoulder abducted and internally rotated.

Bottle Opening Motion; Left Wrist Flexion, right wrist radial deviation, left shoulder abduction.

		LHS	RHS
Posture	Wrist	Extended	Ulnar deviated
	Elbow	-	-
	Shoulder	Internally rotated	Abducted + Internally rotated
Motion	Wrist	Flexion	Radial deviation
	Elbow	-	-
	Shoulder	Abduction	-

Table 2 Starting positions and motions for bottle opening (for those who used right hand on lid)

In addition to identifying typical Opening Strategies a number of general findings were noted, these can be summarised as:

- very few subjects chose to use Assistive Devices. When they did, it didn't seem to make the task any less difficult, or speed it up much, but it did usually reduce the amount of pain or discomfort experienced. Those using Assistive Devices did not seem to do so with a particularly high level of control.
- the control group did report some high levels of difficulty, as well as pain and discomfort.
- difficulty ratings were generally consistent with previous studies [9&13] with jars having the highest difficulty ratings and requiring the highest number of alternative strategies.
- no obvious differences between age groups were identified.
- during gripping subjects were not using their fingers in isolation, they quite often used their palm as well.
- subjects and control group members quite often pressed the packaging down onto the work surface to provide them with extra grip.
- subjects and control group members often used a cup-shaped hand over the top of bottles and jars, grasping 2, 3 or 4 fingers together at once.
- when a subject was right handed they did not necessarily use their right hand to grasp the lid of the packaging and support the base with their left. This was the case for both the subject and control groups.

4. INTEGRATION IN THE DESIGN PROCESS

4.1 Description of Integration in the Design Process

The findings from the study of practicing designers and the observational video study were consolidated and developed to produce an annotated semi-structured standardised interview aimed at investigating and identifying the most useful way to present older adult requirement data to designers and other information they might need to complement this data. A semi-structured standardised interview approach was chosen to allow a free flowing, relaxed discussion that would allow the collection of rich qualitative data. The packaging design companies who participated in the study of practicing designers in stage one took part in the structured interviews with one experienced engineer in each company participating. Data produced from the observational video study was presented together with data typically produced from biomechanical testing i.e Vicon outputs as shown in Figure 6. Most importantly a number of various formats for presenting the data were explored, specifically:

- video recordings of most common opening strategies for bottles and jars.
- photos of "characterised" hand grip types whilst opening packaging.
- most common starting posture for bottles and jars.
- most common opening motion for bottles and jars.
- data relating to pain and discomfort experienced whilst opening packaging.

- Vicon video outputs showing forces of packaging being opened (Figure 6)
- Vicon video alongside standard video.
- joint angles at the point of greatest force exertion.
- resultant moments generated at joints whilst opening packaging.

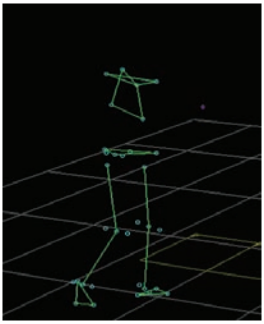


Figure 6. Vicon Output

The structured interview also provided an opportunity to obtain designers' opinions on the various 'novel' approaches of presenting and manipulating biomechanical information within the design process, specifically:

- Virtual biomechanical testing
- information on which muscle groups are being used at different points while interacting with packaging
- Vicon video footage with normal video footage synchronised on top
- the ability to assess the effects of changing various design variables
- a database of videos of users with various hand impairments interacting with packaging

These were shown to the designers at strategic points during the interview using a slide show on a laptop. The results were recorded using a digital voice recorder and were subsequently transcribed and analysed.

4.2 Integration in the Design Process Findings

The prevailing feedback from this series of interviews was that despite the high levels of precision offered by biomechanical testing, designers harbour a strong preference towards traditional video data. Designers feel that the "lifelike reality" of 3D motion and force data (i.e. Figure 6) is compromised by the fact that it is generated in a laboratory environment. They also highlight that the levels of precision and detail produced by biomechanical tests are not necessary in the case of packaging design. Another concern raised related to transferability of biomechanical data. Designers understanding is that biomechanical tests and data are very specific and therefore do not lend themselves well to transferability.

Designers found the 3D motion output screen (Figure 6) too clinical, whilst they commented that seeing a true 3D image useful, they also found it dehumanising. Finding out more than physical parameters and abilities was a recurring theme throughout the series of interviews. Simply considering how an individual physically interacts with a product in isolation was thought unrealistic. Designers wanted more information about the person; where they lived, their socio-economic status, what products they used and liked, their previous occupations, who they lived with, their aspirations, where they shopped, etc.

Biomechanical results were thought to be easier to interpret when they had some video complementing them, either overlaid or playing alongside. It seemed that capturing video data and presenting this with biomechanical data would make it clearer to designers. It was also discussed that some sort of introduction to biomechanics, what it means and its basic principles would be vital to allow any designer to interpret the data and most importantly to understand why it was important and how it could be used to improve design.

A number of designers mentioned that they would only want the conclusions from such testing, without having to understand what they meant or how they were derived. One mentioned that access to the raw data in tabular or graph format would be useful once their biomechanics knowledge grew and they were able to interpret the results themselves. They would also need to have a clear explanation of how the test was carried out, what variables were controlled and various other details.

It appeared established that biomechanical testing techniques would not be used as standard on a packaging design project. Many of the designers said they would only go into that level of detail if it had been requested specifically by their client, and obviously they would have to get some external help with this.

The test subject's natural environment, the people they'd be with, their state of mind could never be accurately reproduced in a lab. This was the main reason for the designers citing video footage as a richer source of information than pure biomechanical data. Ethnographic video footage was preferred over the observational video footage shown to them during the interview.

The results suggest that the best way to present biomechanical data is with an introduction to biomechanics, clear conclusions from the tests, a full explanation of the results and test procedures used, and preferably alongside some synchronised video data. This would all be done in conjunction with information about the end user of a product, giving the designer a more comprehensive view of the 'bigger picture'.

5. Summary and Conclusions

This paper describes a three stage study aimed providing designers with relevant and useable older adult requirement data. An initial survey of practicing designers highlighted that "appearance" rather than 'openability' is the top design priority. Whilst most designers knew what inclusive design was they had little or no knowledge of how to put it in to practice mainly because designing inclusive design is not a client requirement. Very few designers knew where to access biomechanical requirement data with older adults requirements currently being taken into account through consumer testing or informal discussion.

An observational video study allowed the identification and classification of typical opening strategies, consisting of most common hand grip types, starting postures and opening motion. Interestingly, there were no clear differences in opening strategy between the older adult age groups. Subjects and control group members often used a cup-shaped hand over the top of bottles and jars, grasping 2, 3 or 4 fingers together at once. Handedness did not necessarily determine the way in which the subjects gripped the packaging.

The final stage revealed that despite the high levels of precision offered by biomechanical testing, designers prefer traditional video data. In general, designers felt that data produced in labs has been compromised in some way. They wanted to know more than the physical parameters of peoples abilities including their socio-economic status, what products they used and liked, their current and previous occupations etc.

In conclusion, the best way to present biomechanical data is with an introduction to biomechanics, clear conclusions from the tests, a full explanation of the results and test procedures used, and preferably alongside some synchronised video data.

Whilst this study focused on packaging design it is thought that many of the findings of the initial survey and integration in the design process stages are common across design sectors. Further work will focus on diversification across design sectors and further closing the loop between the production of biomechanical data and its integration into the design process.

REFERENCES

[1] Sims, R., 2003. 'design for all': Methods and data to support designers. University of Loughborough.

[2] Dong, H. & Clarkson, J., Year. Barriers and drivers for inclusive design: Designers' perspectives. *Include 2007: Designing with People, 4th International Conference on Inclusive Design*, Royal College of Art, London.

[3] Berns, T., 1981. The handling of consumer packaging. *Applied Ergonomics,* 12 (3), 153-161

[4] Crawford, J.O., Wanibe, E. & Nayak, L., 2002. The interaction between lid diameter, height and shape on wrist torque exertion in younger and older adults. *Ergonomics,* 45 (13), 922-933.

[5] Voorbij, A.I.M. & Steenbekkers, L.P.A., 2002. The twisting force of aged consumers when opening a jar. *Applied Ergonomics,* 33 (1), 105-10

[6] Langley, J., Janson, R., Wearn, J. & Yoxall, A., 2005. 'inclusive' design for containers: Improving openability. *Packaging Technology and Science,* 18 (6), 285-293.

[7] Nayak, L.U.S. & Queiroga, J.M., 2004. Pinch grip, power grip and wrist twisting strengths of healthy older adults. Gerontechnology, 3 (2), 77-88.

[8] Yoxall, A., Luxmoore, J., Austin, M., Canty, L., Margrave, K.J., Richardson, C.J., Wearn, J., Howard, I.C. & Lewis, R., 2007. Getting to grips with packaging: Using ethnography and computer simulation to understand hand-pack interaction. *Packaging Technology And Science,* 20 (3), 217-229.

[9] Winder, B., Ridgway, K., Nelson, A. & Baldwin, J., 2002. Food and drink packaging: Who is complaining and who should be complaining. Applied Ergonomics, 33 (5), 433-438.

[10] Spirduso, W.W., 1995. *Physical dimensions of aging.* Champaign, IL: Human Kinetics.

[11] Steenbekkers, L.P.A. & Beijsterveldt, C.E.M.V., 1998. Design-relevant characteristics of ageing users: Backgrounds and guidelines for product innovation: Delft University of Technology

[12] Wilcox, S., Year. Effective communication of user needs to product designers. Include 2007: Designing with People, 4th International Conference on Inclusive Design, Royal College of Art, London

[13] Carse, B., Thomson, A. & Stansfield, B., 2007. Packaging and the older adult. Include 2007: Designing with People, 4th International Conference on Inclusive Design, Royal College of Art, London.

Contact: Avril Thomson
University of Strathclyde
Department of Design, Manufacture and Engineering Management
Glasgow, G1 1XJ
UK
Tel: Int +44 141 548 2354
Fax: Int +44 141 552 7986
Email: avril.thomson@strath.ac.uk
URL: http://www.strath.ac.uk/dmem/dmempeople/thomsondravril/

Avril is a lecturer in Engineering Design in the Department of Design, Manufacture and Engineering Management at the University of Strathclyde in Glasgow. She teaches Computer Aided Design and Design Engineering to undergraduate students. Her main research interests are in understanding and improving older adult product interaction and managing collaborative design.