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Design and Medicine Collaborate Using Digital Anthropometry

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RESEARCH

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Abstract

Background

Five projects, conducted collaboratively between design and health/medicine researchers, are described including: study of the osteoporotic figure to develop apparel designs that encourage active life styles, evaluation of weight loss induced body changes, evaluation of breast cancer treatment related effects on body asymmetry, improved fit and design of a liquid cooling garment to maintain healthy body temperature of astronauts, and development of a body satisfaction intervention for young women. Steps of a design process were used to facilitate project work and to communicate progress to participating researchers.

Methods

All projects were conducted using facilities in the Human Dimensioning© Lab at the University of Minnesota. "Digital anthropometry", a method of measuring and analyzing the body using a topical laser body scanner, was used to measure and describe the human body for applications in the five projects.

Results

Results vary from providing detailed information concerning body shape and size, to incorporating the body measurement data into improved designs of wearable products, to using the body data to educate young women about healthy bodies.

Conclusions

The fields of design and medicine share common interests in improving the human condition. More specifically apparel designers and physicians have in-depth, but varying, knowledge of the structure and workings of the human body and use that knowledge to address human needs. By using the design process as a means of communication, the two fields can develop solutions to human problems.

What do apparel design and medicine have in common? Medical researchers are acutely aware of the inner workings of the human body, while apparel design researchers understand how anthropometry, measuring and describing the body surface and contours, is used to design apparel to fit a range of shapes and sizes. A team of researchers in the Human Dimensioning© Lab uses their unique skills and interests to address health and medicine issues that combine both perspectives. To facilitate work, communicate progress, and promote understanding the team uses the design process with steps of defining the problem and conducting research, exploring possible solutions, and implementing best solutions to the problem. The Human Dimensioning© Lab is equipped with the latest apparel design technologies including full laser body scanner, motion capture equipment, apparel design and CAD engineering software and soft goods prototyping equipment. The digital anthropometry technologies are used to assess the surface of the human body and to design products that fit and function with the body.

This paper presents five projects conducted in the Human Dimensioning© Lab (HDL) demonstrating effective collaborations between medicine and design. The projects include: 1. In-depth study of the osteoporotic figure with applications to apparel design to encourage active life-styles, 2. Evaluation of body change through a controlled weight loss program with implications for improved fit of apparel, 3. Evaluation of breast cancer treatment related effects on body form asymmetry and shoulder restricted motion, 4. Improved fit and design of a liquid cooling garment to maintain healthy body temperature, and 5. A body satisfaction intervention for 18 and 19 year olds using 3-dimensional body scans of young women with healthy BMI's. The design process was used to conduct the projects and to communicate progress and results to partners within the research teams. Descriptions of the projects will highlight how various stages of the design process facilitated each project.

The Human Dimensioning© Lab

The Human Dimensioning© Lab in the College of Design at the University of Minnesota was established with funding from a National Science Foundation grant. The grant team consisted of researchers in apparel, kinesiology, and engineering, with an apparel design researcher as the principal investigator. Since the inception of the lab, make-up of research and implementation teams has varied according to the problem that is being addressed. Researchers and collaborators from many fields have been involved including: computer science, architecture, graphic design, interior design, museum studies, medicine and health, and engineering.

The HDL houses state of the art equipment used to gather and assess anthropometric measurements and to develop and test wearable prototypes. Digital anthropometric equipment includes a Human Solutions VITUS/Smart three-dimensional laser body scanner and a BTS Bioengineering passive marker motion capture system. Projects described in this article used the VITUS/Smart scanner to collect anthropometric data that was then used in various ways from providing understanding of scanner processes for medical/health applications, to providing detailed information on body shapes and sizes, to providing data used to design wearable products. Figure 1 demonstrates one out-put type from the scanner; the visual representation of the form of the body. When viewed on the computer screen the three-dimensional form can be rotated to examine all perspectives. A rotating scan can be viewed on the HDL web site (web site available at http://dha.design.umn.edu/research/Human_Dimensioning_Lab.html). Other data available from the scan process are linear measurements (either automatically extracted with scanner software or specified), cross section and profile visuals, and segment volumes calculated with engineering software.

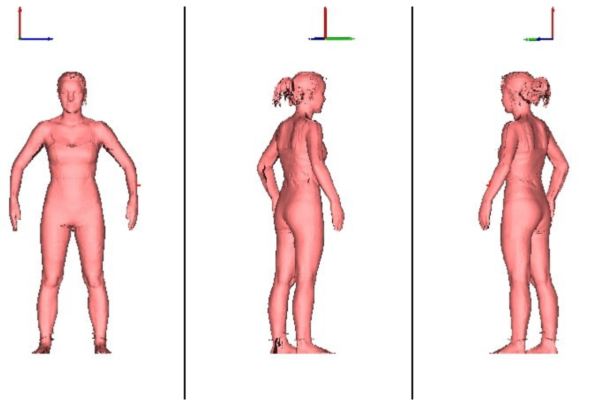

Figure 1. Body scan of participant from three views
Figure 1. The three-dimensional body scan can be viewed as an .avi file on the computer screen, allowing rotation and inspection from all perspectives

The HDL staff is comprised of apparel faculty and graduate students with research interests ranging from aesthetics, to social-psychological aspects of apparel, to production methods, to fit and sizing of wearable products. A medical doctor, co-author of this article, holds a research associate position with the HDL and works as a team member on projects related to health and medicine.

The Design Process

The design process is a structured method of defining, investigating, and providing solutions to human needs. Many fields such as education, psychology, and philosophy have used design processes to aid in developing creative thinking. The processes that evolved from these fields have contributed to the use of similar processes in all applied design fields. Today, practitioners in the fields of architecture and environmental design, engineering design, industrial product design, and apparel design routinely use some variation of the design process to work through a problem typically to produce a physical product. However, design processes are also used to develop new approaches for service industries and in developing more efficient, cost effective and user-friendly systems in many fields.

LaBat and Sokolowski (1999) reviewed design processes used in the fields of environmental design, engineering design, industrial/product design, and clothing design and proposed a simple 3-step process to use when working with industry partners to design improved medical softgoods products [1]. This process is used in the Human Dimensioning© Lab. One step or all steps in the process may be used, depending on project requirements. The three steps are: 1. Problem definition and research, 2. Creative exploration, and 3. Implementation. A brief description of each step is presented here.

Problem definition and research is the expansive segment of the process and can be quite time-consuming. Collaborators on the project, designers and medical/health practitioners in cases presented in this article, agree on an initial problem definition. They discuss their perspectives, come to agreement on a problem definition, and typically agree on the need to find a solution to the problem. Research involves collecting the primary data for the project, but may also involve extensive background reading as collaborators expand their knowledge of less familiar areas. The designers typically need to read extensively from medical literature related to the problem. The medical/health collaborators provide guidance in selecting the most relevant and current literature. Because the projects are focused on human needs, observations of and interviews with the identified user group(s) are essential. As research progresses dialogue between collaborators continues and the initial problem definition is revised to develop a working problem definition. Regular meetings between collaborators are essential in coming to a mutually beneficial solution to the problem.

The creative exploration stage is the least well-defined and is often thought of as the realm of the designer. Archer (1965, 1984), one of the first people to research and write about design processes, describes the “creative leap” from research to feasible solution [2, 3]. Jones (1963) speaks of this stage as “inspired guesswork” [4]. While a “creative leap” and “inspired guesswork” may not seem very scientific or applicable in the medical field; this type of inspiration and creativity has lead to innovative scientific discoveries. Ideation, which can take many forms, is a tool designers often use at this stage to express any possible solution to the problem without editing or criticizing. Ideas generated through ideation are subjected to review based on the criteria developed from the research. Viable ideas are developed into working hypotheses. Designers use this stage to propose or make prototypes that are tested as part of the exploration. Prototypes give designers and researchers the opportunity to test their inspired guesswork. Successes and failures are defined and further testing continues or final products are developed.

Implementation narrows focus to reality of what can be presented on a short or long-term basis as a real solution to the problem. Products may go to commercial production stage and be disseminated to user groups or flaws in the "final" prototype may result in spiraling back to the beginning of the design process to redefine the problem and take on a new research direction.

The projects described in this article demonstrate how various stages of the design process were used to work through an identified medicine/health-related human need. All projects described in this article received University of Minnesota Institutional Review Board approval for protection of human subjects before projects were initiated.

Osteoporosis Study

The project, "In-depth study of the osteoporotic figure with applications to apparel design to encourage active life-styles", exemplifies application of all stages of the design process to develop a designed product for people facing health challenges. The initial problem was defined by a physician. She observed that women with osteoporosis, who had suffered multiple spinal compression fractures resulting in height loss and posture changes, experience frustration with finding clothing that is aesthetically pleasing and fits comfortably. She realized that this problem with clothing fit results in less social interaction and further limits physical activity which only exacerbates physical problems. She completed a master's degree in the College of Design addressing this problem using apparel design tools and methods. After determining the initial problem definition and conducting preliminary research, she could further define the problem with the realization that the apparel industry plays a part in maintaining the problem by focusing on an ideal, youthful, balanced body form in developing mass-produced garments. The focused research for the project involved using body scanning to assess the osteoporotic figure, developing apparel patterns for the figure and comparing those pattern shapes to the industry standard pattern shape (Figure 2). The results dramatically demonstrate pattern changes that are necessary to properly fit garments to the osteoporotic figure. In-depth interviews with users and a structured ideation process resulted in garment design ideas that were made into prototypes and tested with users. She used the test results to develop a series of custom designed garments for representative users. The final prototypes were quite successful with participants in the study evaluating the designs positively. Further resolution of this problem will require a method of designing and producing for, and marketing to, this rather small market segment.

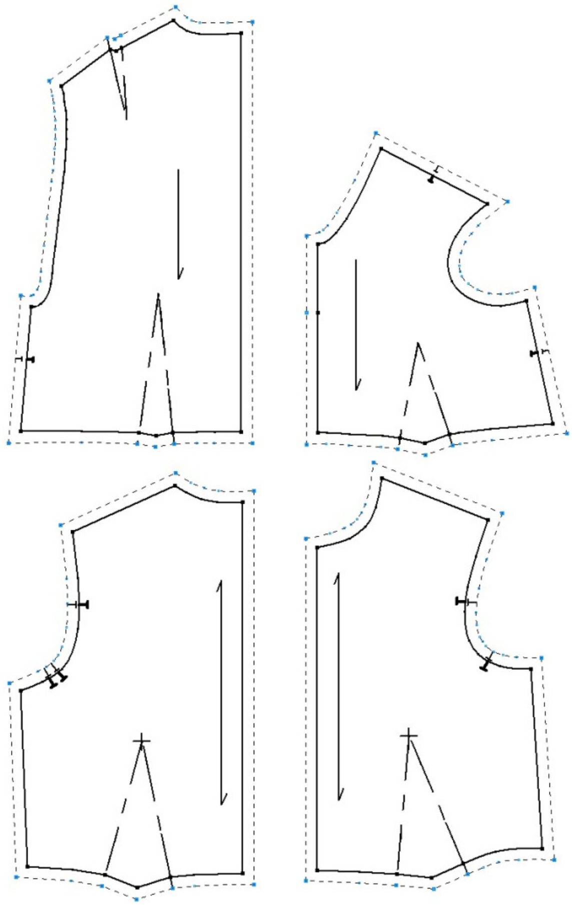

Figure 2. Bodice patterns for osteoporotic figure (top) and standard industry figure (bottom).

Figure 2. In comparison to the typical industry pattern used for apparel mass production, the pattern for the osteoporotic figure reflects a different body posture, with a shortened center front (neck to waist) and elongated center back (neck to waist). Patterns for osteoporotic figure: top left is bodice back, top right is bodice front. Patterns for standard figure: bottom left is bodice back, bottom right is bodice front.

Weight Loss Assessment for Health and Design

This study involves researchers in nutrition and design who are interested in measuring how weight loss affects body physical dimensions. More specifically researchers are interested in determining the usefulness of laser body scanning in assessing body composition changes that are the result of a controlled weight loss program. Nutrition researchers are interested in quickly and inexpensively measuring body changes, particularly changes in central adiposity because intra-abdominal (visceral) fat is associated with many health risks from heart disease to diabetes. Current assessment methods include simple tools like tape measures and calipers that may result in inaccurate and unreliable data or more expensive and time-consuming methods such as DEXA regional scanning and MRI. Body scanning that is currently used by apparel design researchers is fast (a person can be scanned in approximately 11 seconds), relatively inexpensive and non-invasive with no radiation exposure and no health risks. The issue is, if this simple fast procedure will meet the needs of nutrition researchers. Apparel design researchers are interested in how the changing body form affects fit and sizing of apparel. By understanding how the body changes through controlled weight loss, apparel could be better designed to accommodate size and form changes through weight gain or loss, aging, and pregnancy. Four subjects were followed through several months of a controlled weight loss protocol. DEXA, laser body scanning, and manual anthropometry methods were used to track body changes. Participants were also interviewed to determine their satisfaction with fit of apparel as they lost weight. Advantages of using the laser body scanning method are that traditional linear measurements, like waist circumference are quickly and easily obtained and qualitative data, like the rotating body form, can be used to dramatically demonstrate body change to study participants. Some measures have potential, for example calculation of body segment volumes using Polyworks® engineering software as a comparable technique for assessing body fat to the more costly DEXA scans. However, this technique needs further testing to refine the method. This project requires that researchers return to phase one of the design process.

Breast Cancer Asymmetries

This project is in the earliest stages of problem definition bringing together apparel researchers and oncology nurses and doctors to explore effects of breast cancer treatment-related body asymmetries on quality of life (QOL). The first step in this project was for collaborators to agree that quality of life is becoming a major focus of breast cancer survivorship as treatments improve and survivors are living longer. The next step is to determine if body asymmetries that result from treatment affect QOL. The asymmetries identified range from the obvious and dramatic, e.g. mastectomy and lymphedema, to subtle, e.g. shoulder asymmetry and restricted motion due to radiation treatment. The team is currently researching and refining the problem definition. Next steps will be to assess asymmetries of a sample of participants using laser body scanning (and possibly motion capture) and use interview methods to determine their perceptions of QOL. The team will use these results to determine possible actions, such as developing improved designs for breast cancer products such as prostheses, and lymphedema sleeves. Laser scanning could also be developed as a diagnostic tool or rehabilitation assessment tool for patients with lymphedema.

Liquid Cooling Garment

A liquid cooling garment (LCG) protects astronauts by providing cooling effects and preventing overheating. It is the clothing layer closest to the body and must be closely fitted to function properly. The garment holds a network of tubing next to the skin. Water circulates through the tubing to extract excess heat from the body via conduction. The initial problem definition was presented to the HDL researchers by physiologists and psychologists at the University of Minnesota who have designed several LCGs for the National Aeronautics and Space Administration (NASA). The focus of the project was to redesign one segment of a LCG, the hood. The objectives of this project were to improve fit and comfort of the hood of the MACS-Delphi garment (US patent #7,089,995) and develop a new prototype. The physiologists and psychologists defined the design problem from the perspective of body functions in heat equilibrium and exchange and perceptions of thermal comfort while apparel researchers defined the problem as the need to accurately measure and describe the body to develop a method of shaping the hood to hold the tubing in close contact with the surface of the head. The researchers worked collaboratively on ideation sketches with physiologists determining tubing placement requirements and apparel researchers defining hood material, shape, and construction requirements. A male model representing a characteristic body shape of an astronaut was scanned, body measurements extracted and shape and conformation of the head evaluated. The apparel designers developed and tested appropriate materials for the hood and various shaping methods to provide best fit and comfort. The physiologists worked with designers to determine best placement of the tubing within the hood and the psychologist determined acceptability of the prototype hood from the astronauts' perspective. The prototype hood was tested in an environmental chamber and demonstrated effective cooling. The final prototype is pictured in Figure 3.

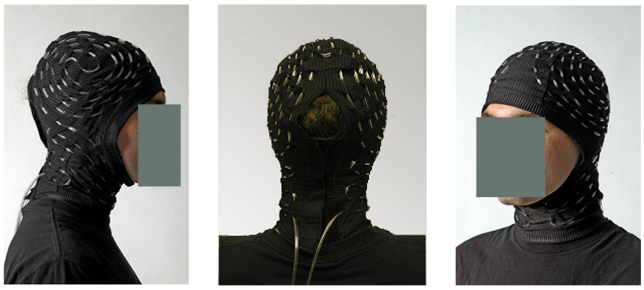

Figure 3. Liquid cooling garment (LCG) final hood prototype

Figure 3. The final hood prototype is made of a stretch mesh fabric with tubing threaded through the mesh. Tubing is placed to most efficiently extract excess heat from the head. The hood is one part of a whole body system designed to maintain body temperature equilibrium.

Body Satisfaction Intervention

This project brings together apparel researchers who have expertise in measuring and assessing the body and have researched ideal and often unrealistic body images conveyed by the apparel industry, with researchers in psychiatry and psychology who have experience in understanding and assessing body image and working with young women with eating disorders. In addition the team includes computer science and education researchers. The ultimate goal is to develop a body image intervention for young women using 3-dimensional body scans of like-age women with healthy BMI's. The initial problem was identified by middle school teachers who viewed a presentation given by HDL staff. The teachers stated that they thought if young women could view a series of body scans showing "real" people of their age range, their perceptions of what others look like in comparison to themselves would be more realistic with ultimate results that body satisfaction would increase. The HDL researchers used this working problem definition to secure funding to develop an educational intervention. The team of researchers was assembled to bring together pertinent areas of expertise. Initial meetings focused on agreeing on the problem, aligning definitions, and developing mutually beneficial working methods. Creative exploration included experimenting with the intervention presentation format and content and determining best methods of collecting data. The intervention in two formats and a control presentation are in final stages of preparation and will be pilot tested Fall 2009. This pilot test or "prototype" of the intervention will then be evaluated, revised, and retested in 2010.

Conclusions

The fields of design and medicine share common interests in improving the human condition. More specifically apparel designers and physicians have in-depth, but varying, knowledge of the structure and workings of the human body and use that knowledge to address human needs. By using the design process as a means of communication, the two fields can develop solutions to human problems. Successful outcomes result when all participants take time to share information, delve into research from the other fields, and meet often to revise and agree on project goals.

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PEER REVIEW

Not commissioned; externally peer reviewed

CONFLICT OF INTEREST

None of the authors, participants, or contributors to these studies has any competing interests

AUTHORS' CONTRIBUTIONS

KL coordinated projects conducted in the Human Dimensioning© Lab, was involved in study designs, IRB submissions, subject support, data acquisition and analyses, and drafted the manuscript.

KR was involved in study designs, IRB submissions, subject support, data acquisition and analyses, initiating contact with medical experts, and edited the manuscript.