Evaluation of Interactive Systems

Anthropometry & Anatomy

Caroline Appert - 2018/2019
References and Inspirations

[1] Halla Olafsdottir’s slides and discussions


Why should people in HCI know about the human body

“Biosignal” for input — make the medium/device as “thin” as possible

- Brain Computer Interfaces
- Mid-air gestures
- Health care monitoring...

Evaluation — does the interactive system take into account aspects related to:

- Anthropometrics
- Anatomy
- Physiology
Anthropometrics

Anthropometrics is the comparative study of human body measurements and properties

Ergonomics is the science of making the work environment safer and more comfortable for workers using design and anthropometric data
Anthropometry

Physical measurements of the human body to determine differences in individuals and groups

- Size (height, length of body segments)
- Mass (whole body, body parts) & volume
- Center of Mass (segments & whole body)
- Inertial properties, moment of inertia (resistance to angular acceleration)

Differ greatly for different sex, race, age & body type: no such thing as an average person
Anthropometric data
Collection

Measure large groups of people

Directly (height, segment length etc.)

Indirectly (Immersion in water to get segment weight)

Often relies on cadavers

Center of Mass of segments

Moment of Inertia of segments
Anthropometric data
Datasets

Most datasets focus on particular populations
children, populations sharing a particular medical
condition or profession, etc.

Merging datasets should be done carefully
same units of measurements, same physical
condition, same age, etc.

Chronology and geography is important
Migration, changes in diet, etc.
Anthropometric data
Units of measurements

Clear definition for the unit of measurement of reported data

Body planes  Body segments
Anthropometric data

Presentation

Table with descriptive statistics

<table>
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<th>Sample and Reference</th>
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<th>No. of Subjects</th>
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<td>165.3</td>
<td>5.8</td>
<td>155.8</td>
</tr>
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</table>

*Statue is defined as the vertical distance from the standing surface to the top of the head. The subject stands erect and looks straight ahead.

Data given in centimeters.
Anthropometrics & Evaluation

Check that a design fit the targeted population

Example: designing an interactive touch screen kiosk

Relevant anthropometric dimensions

- eye height
- length of shoulder-hand segment
Design strategies

- No attempt to accommodate the user
- The designer is the reference
- The mean is not the majority of users...
- Design for small users

- Design for the mean
- Design for adjustability
- Design for more types
- Design for all

- Design for the tall
- Design for tall users
- E.g., height adjustable screen
- Target a population and then fit for it
  E.g., multiple interactive kiosks
- Exclude as less as possible
  (inclusive design)
  E.g., make the interactive device accessible to people
Integrating Multiple Dimensions

Take caution when deriving measures

body measurements are not predictably proportional or strongly correlated

e.g., The 95th percentile arm length, for instance, is not the addition of the 95th percentile shoulder-to-elbow length plus the 95th percentile elbow-to-hand length.

Chairs theoretically designed to fit the size from the 5-th percentile female to the 95-th percentile male actually fit far fewer people

778 people tested

seat height
seat depth
armrest height
lumbar height
population included/ excluded

people not accommodated
people accommodated
Strategy for Evaluation

User-centered Design!

Define relevant populations (e.g. age range, nationality, sex)

Define key dimensions or variable for fit consideration (e.g. height, reach, weight, etc)

Determine boundary measures for each anthropometric dimension from reference data, from lower 5th to upper 95th percentile

Compare referenced dimensions with existing real-world products for reality check

Apply dimensions to create mock-ups for initial, informal ergonomic feedback with users

Refine design(s) to create similar low-fidelity mock-ups for fit evaluation

Continue to refine as needed/budgeted
Musculoskeletal System

The human body cannot be captured with a set of static dimensions

Human physiology consists in several systems that act together

Nervous system (brain, spine, nerves etc.)
Musculoskeletal system (i.e bones & muscles)
Cardiovascular system (i.e heart, arteries, veins)
Respiratory system (lungs etc.)
Gastrointestinal system (stomach, gut etc.)
Integumentary system (skin)
Urinary system (kidneys etc.)
Reproductive system (gonads etc.)
Immune system (lymph nodes etc.)
Musculoskeletal System

206 Bones

Approx. 640 muscles (Min. 51 in each arm)
The musculoskeletal system includes bones, joints, skeletal muscles, tendons, and ligaments.

Muscles generate force; tendons transfer it to bones; and the bones move if enough force is transmitted.

The force must be enough to overcome the weight of the moving body part, gravity, and other external resistance.

Motion occurs at joints associated with one or both ends of the bone.
MUSCULOSKELETAL SYSTEM

Why we should care

Avoid Repetitive Strain Injury (RSI)

Minimize fatigue
Risk Factors

Repetition
- Texting, trackpad use

Awkward Positions
- Mouse, Keyboard, tablet

Contact Stress
- Edge of desk

High Force
- Foot pedals, pressure sensors

Range Of Motion
- multi-touch gestures (e.g., pinch or rotate)
Mobile devices

Require a muscular activity to maintain the lever effect
Mid-air gestures

Mid-air gestures can cause fatigue
Providing guidance can help
Smartphones

One-handed usage

Some positions may be awkward

Some locations may be unreachable

To support access to all interaction targets within the confines of the ThumbSpace, the user-defined region behaves as a type of a Radar View for the display.

Traditionally, a Radar View is a miniaturized representation of a large display that serves as a within-reach proxy for out-of-reach objects; interactions upon objects within the Radar View are propagated to the associated objects in the original display, hereafter referred to as the “DisplaySpace”. This approach has proven successful for accessing distant windows and icons on large displays [19], but hasn’t been applied to small screen interaction, which presents no vel challenges. Consider, for example, that a straightforward implementation of a Radar View for the Windows Mobile Contacts application is shown in Fig. 1b. This approach has several problems: 1) the Radar View representation occludes a large number of DisplaySpace objects; 2) the Radar View proxies are unreadable; 3) the detailed Radar View representation contributes to unacceptable visual clutter; and 4) the Radar View proxies are far too small to access reliably with the thumb.

To address problems (1-3), we avoid using a miniature representation. Instead, we offer only a whitewashed region to suggest where the user should focus her attention. Fig. 2a shows this representation of ThumbSpace, which overlays the application at all times. Even without the miniature displayed, ThumbSpace retains the spirit of the Radar View by honoring an input mapping between the ThumbSpace and the DisplaySpace. ThumbSpace is partitioned so that each object in the DisplaySpace is associated with a sub-region (proxy) in the ThumbSpace; tapping a proxy in ThumbSpace selects the assigned object in the DisplaySpace. If ThumbSpace were to represent a linearly scaled DisplaySpace (as in Fig. 1b), the partition of ThumbSpace into DisplaySpace proxies would be that shown in Fig. 2b. Yet the ThumbSpace partition is not required to be a scaled representation of the DisplaySpace; in section 3.4 we discuss how different partitioning strategies may improve user performance.
Multi-touch gestures (effort)

Multitouch interaction can induce significant stress that may lead to musculoskeletal disorders [Lozano et al., CHI '11]

We obtained two maximum voluntary contractions (MVCs) for each muscle at the beginning and at the end of the experiment session. These measures were used for both normalizing the EMG data and measuring possible fatigue of the individual muscles after producing all the tested gestures.

Data analysis

We evaluated muscle activation as the percentage of MVC, since each muscle had different EMG amplification. We first calculated the root mean square of the EMG signal for the 10 to 20 seconds of the 25-second trial to assure we didn't include the transitions within the trial (e.g., beginning and end of doing the correspondent gesture). We then normalized it with the maximum EMG obtained from the MVCs. The maximum EMG values from both MVCs were extracted after smoothing the signal with a 1-second moving average window.

The kinematic data from the three joints of the index finger yielded angular changes in gestures presented in degrees. We obtained statistical comparisons using the average of the 3 replications of each condition for each participant (i.e., 8 values per condition). We used the ANOVA output of Design Expert for a general factorial design of the 3 factors with 8, 2 and 2 levels corresponding to gestures, device position and contextual conditions. This analysis allowed the removal of any variation attributed to blocks of data (each participant data assigned to one block). Significance was set at 5% (i.e., $\alpha = 0.05$ or $p$-value < 0.05).

Results

Gesture type had a statistical effect on the dominant arm doing the gesture. The average dominant wrist extensor muscle activity was generally greater for the gestures where both fingers (thumb and index) were involved than when only the index finger was used for the gesture (factor's $p$-value < 0.0001; see Figure 1a). In average rotating to the right produced the highest (16.1% of MVC) and panning down the lowest muscle activation (8.5% of MVC). It should be noted that the average muscle activation is higher to reported maximum activation of computer mouse use [4].

For the dominant deltoid, rotating to the right and panning up produced the highest muscle activation (9.2 and 8.7% of MVC, respectively), while panning sideways produced the least activation (5.1% and 5.4% of MVC; factor's $p$-value < 0.0001; see Figure 1b).

Figure 1. Muscle activation as percentage of maximum voluntary contraction (% of MVC) for each of the four muscles and all the conditions with error bars representing least significant differences. Axis labels of (a & b) same as (c & d).
Multi-touch gestures (range of motion & anatomy)

Taking into account fingers’ enslavement for individual gestures and chains of gestures

The set of gestures that can be considered is much more limited than we can think at first

<table>
<thead>
<tr>
<th>Constraint</th>
<th>FREE</th>
<th>ANCHORED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>EXTERNAL</td>
<td>INTERNAL</td>
</tr>
<tr>
<td>Shape</td>
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<tr>
<td>2 CP</td>
<td><img src="image9.png" alt="Image" /></td>
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<td>3 CP</td>
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<td><img src="image18.png" alt="Image" /></td>
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<tr>
<td>4 CP</td>
<td><img src="image25.png" alt="Image" /></td>
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<tr>
<td>5 CP</td>
<td><img src="image33.png" alt="Image" /></td>
<td><img src="image34.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Moving objects/devices on surfaces

It is more difficult to initiate dragging an object across a surface than to keep on dragging

friction mouse/desk < friction finger/touchscreen

tangible interfaces

The Device’s Human Resolution is the quantity of information that the user can transmit by unit of physical motion to the system, with a given input device [Berard et al., 2011]

thousands of dpi
tens of dpi
hundreds of dpi