Human Variability and Accommodation

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- Ergonomics
- Human variability
- User/population accommodation
- Design principles for accommodating target population
  - Design for the extremes
  - Providing adjustability
  - Horizontal segmentation
- Design tools for supporting population accommodation

Ergonomics?

International Ergonomics Association Definition

The discipline of ergonomics

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.

Ergonomics?

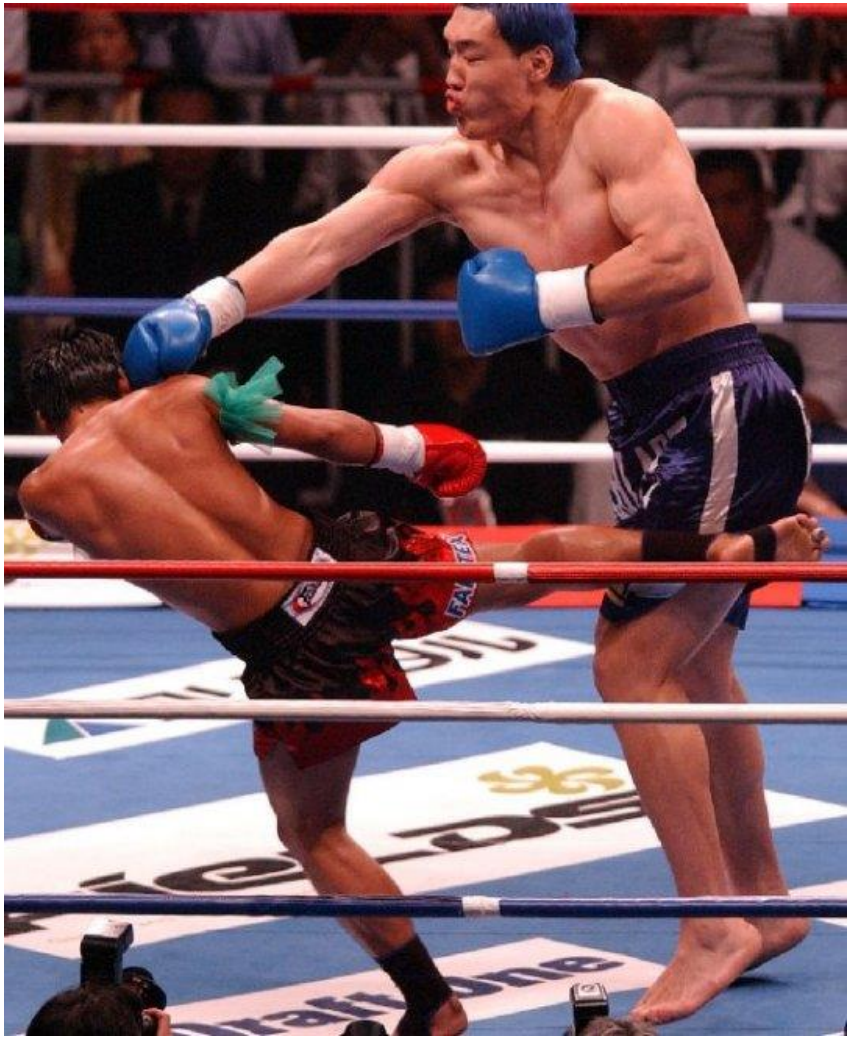
- Design of products, jobs, services and other systems to enhance human lives
- Understanding the human variability is the key to achieving the goal

Human variability (1)

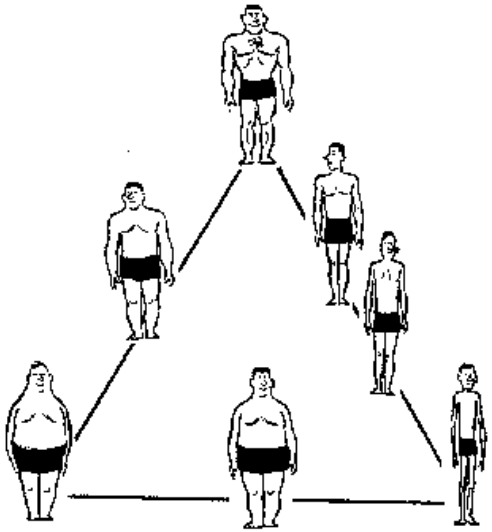
People vary significantly in:

- Body size and shape,
- Muscular strength,
- Body flexibility,
- Perception/cognition ability,
- Mentality or world view,
- Taste/preference,
- Behaviors, etc.

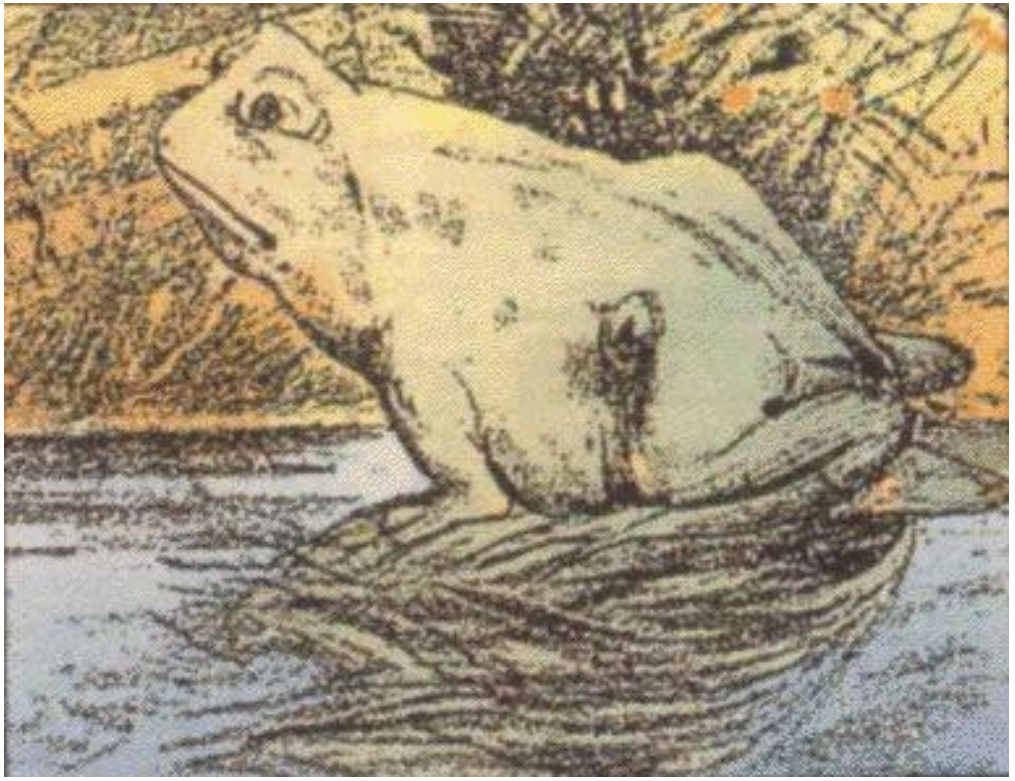
Human variability (2)



Human variability (3)



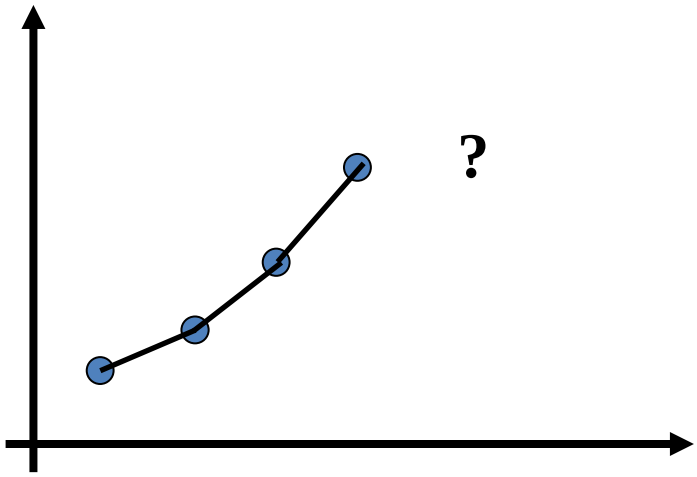
Human variability (4): visual perception



Human variability (5)

*** Cultural differences in world view ***

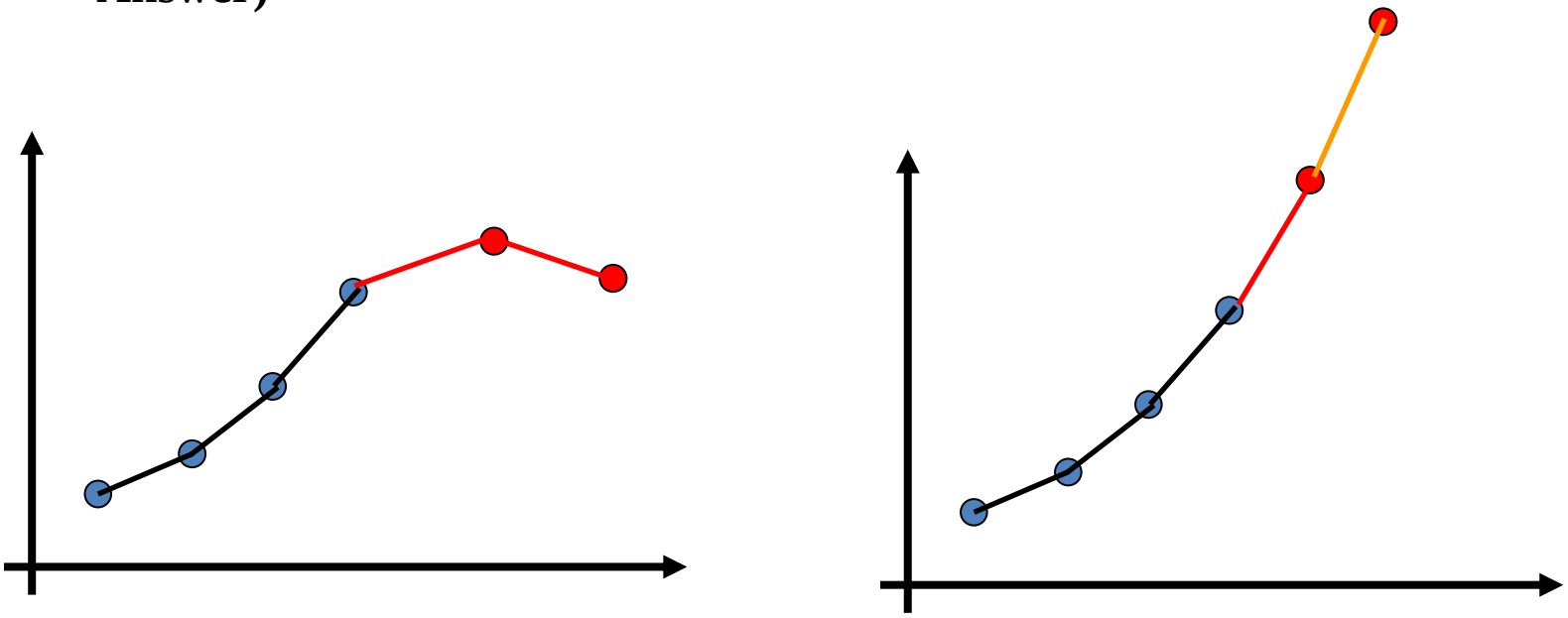
Question)



Predict how this curve will change.

Human variability (5)

Answer)



‘The Geography of Thought : How Asians and Westerners Think Differently...and Why

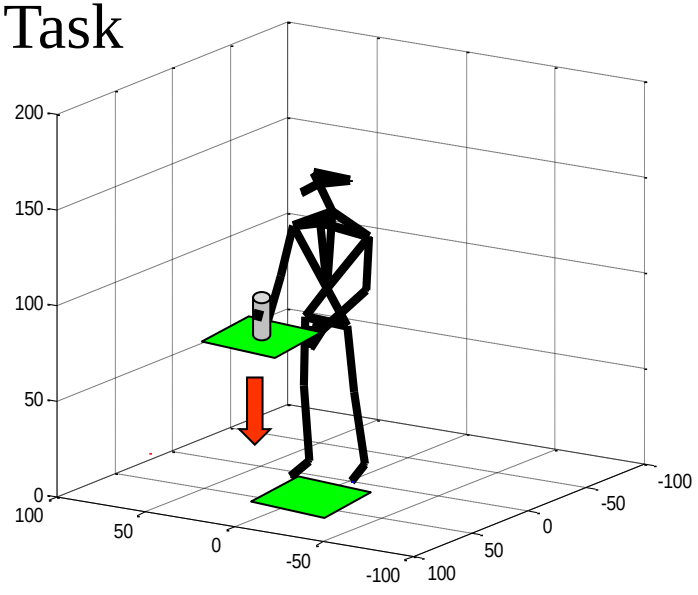
By Richard Nisbett

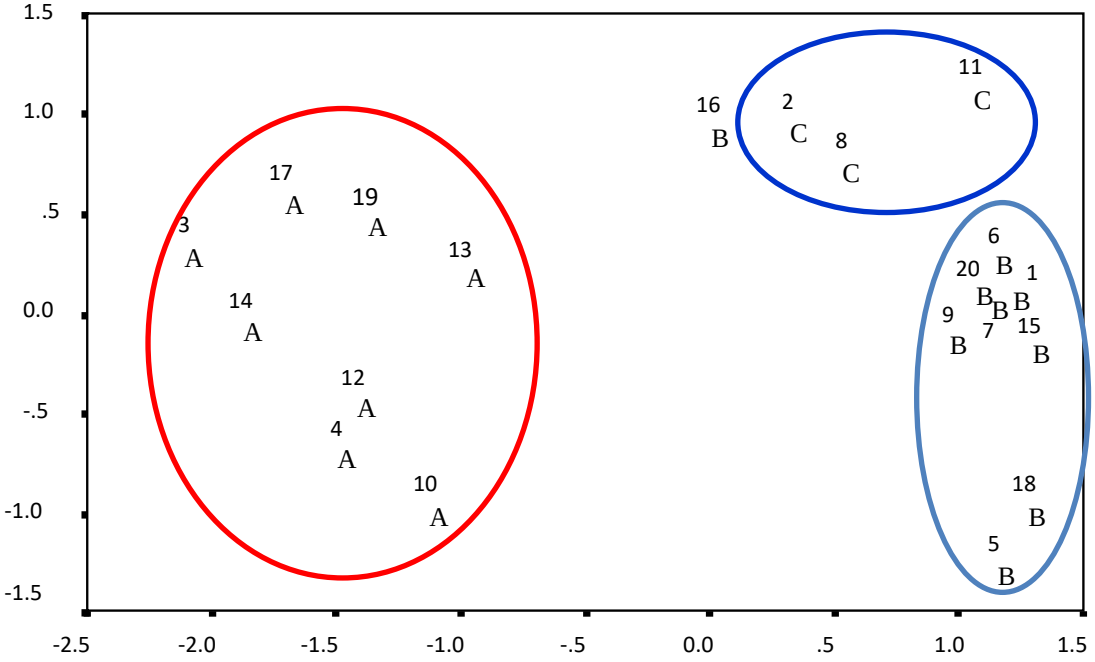
Human variability (6)

Human variability (7)

Example: 20 One-handed Load Transfer Motions

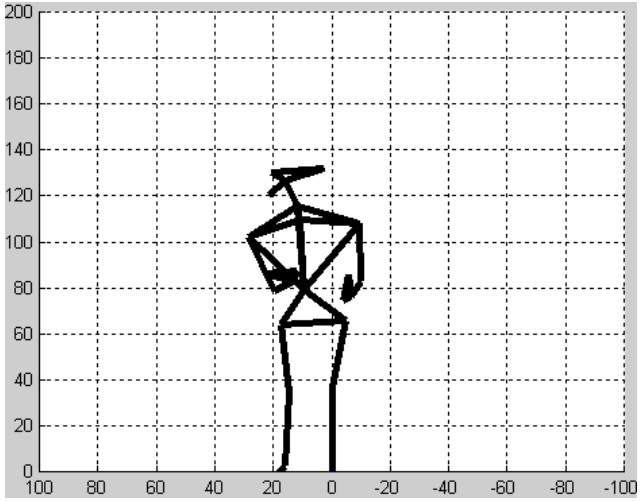
Task



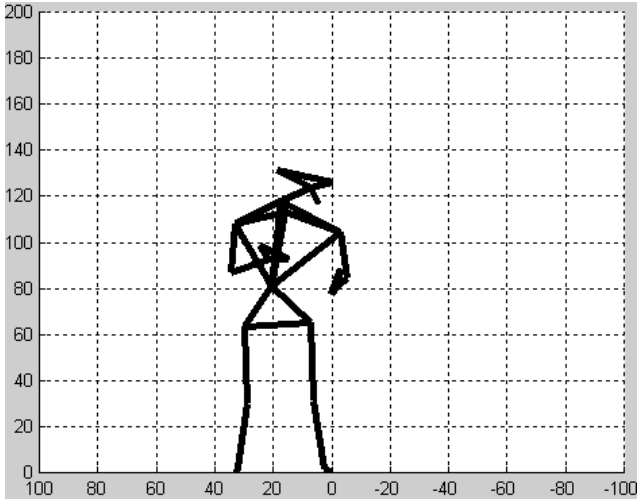


3 clusters revealed by K-means clustering

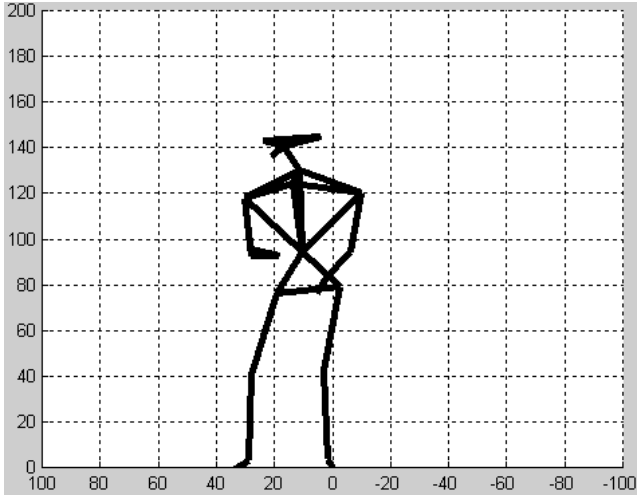
Example: 20 Load Transfer Motions (Cont'd)



Cluster A: 8 motions



Cluster B: 9 motions



Cluster C: 3 motions

The “accommodation” concept

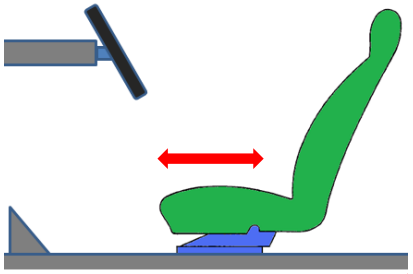
- If an artifact is designed to allow a person to use it or interact with it without difficulties, we say that person is accommodated by the design.

Accommodation level?

- The percentage of the target population that an artifact accommodates
- "What percentage of the target population can be accommodated by this product?"
- Factors that affect a product's accommodation level include:
  - Product size and shape
  - Product component arrangement
  - Adjustment ranges (size, shape and location)
  - Materials
  - Image
  - …
- Many ergonomic design problems are concerned with satisfying a given "target accommodation level."

Accommodation level (cont'd)

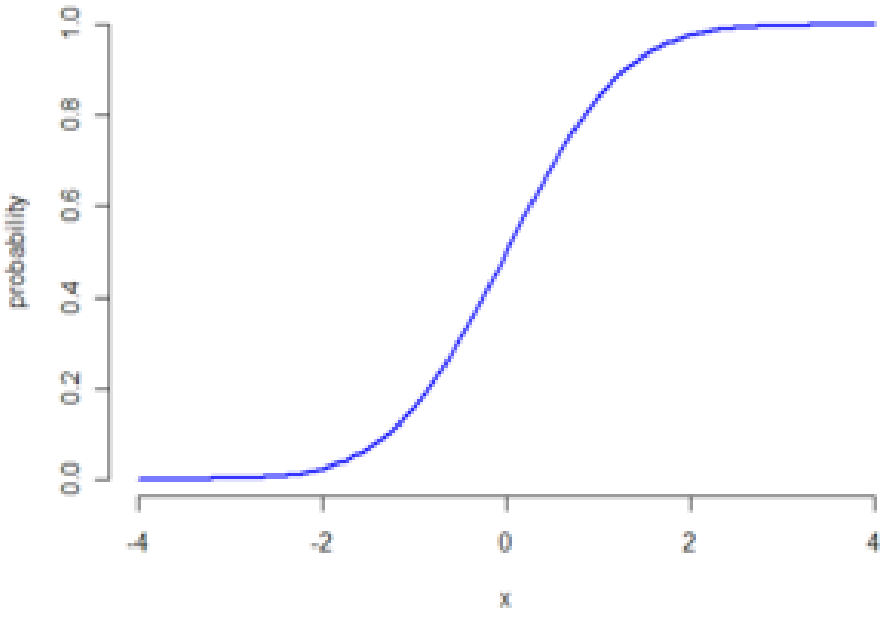
- An example design problem:
  - "Determine the seat travel length so as to ensure that 95% of the driver population can obtain sufficient visibility, reach and manipulate pedals and controls, and operate the steering wheel "



  - One way to solve this problem is empirically collecting "preferred seat position data" from a large sample of drivers.
  - In many cases, such population/large sample data follow the normal distributions.

Selection of target accommodation level

- Seat position versus percentile accommodated
  - Mid 90% is linear
  - Points of diminishing return exist near both ends.
  - Accommodation level directly affects vehicle manufacturing cost.



Design principle for target population accommodation

Principle 1:

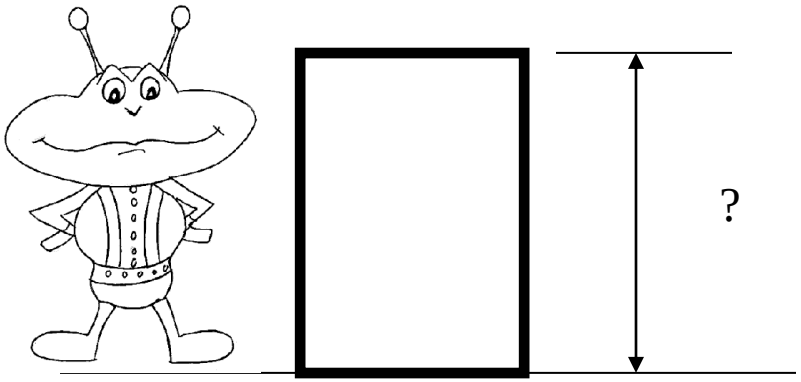
Design for the extremes

Design for the extremes

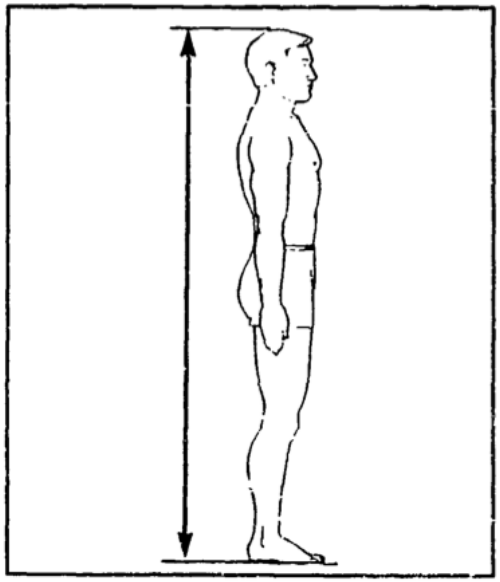
- “Design a product such that it accommodates the extreme individuals within the target population.”
- For simple problems, this results in population accommodation.

Example) Door Opening Design

- Stature of an alien population follows a normal distribution with a mean (μ) of 100 meters and a standard deviation (σ) of 10 meters. Determine the minimum height for doorways which allows 99% of the population to avoid unintentional head injuries.



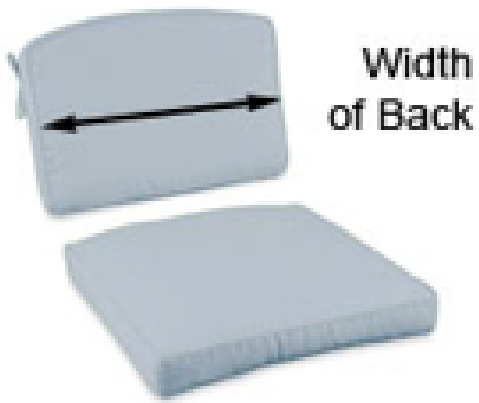
STATURE



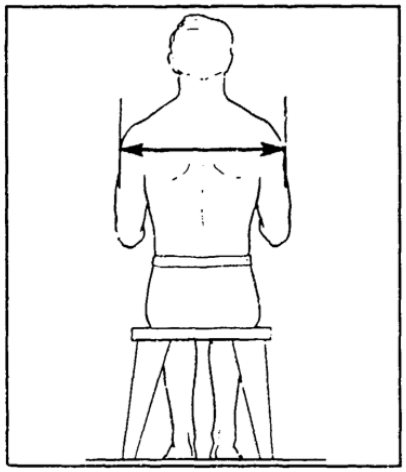
THE PERCENTILES

FEMALES			MALES	
CM	INCHES		CM	INCHES
148.32	58.39	1ST	160.27	63.10
150.18	59.13	2ND	162.05	63.80
151.31	59.57	3RD	163.17	64.24
152.78	60.15	5TH	164.69	64.84
154.97	61.01	10TH	167.03	65.76
156.43	61.59	15TH	168.62	66.39
157.58	62.04	20TH	169.89	66.88
158.58	62.43	25TH	170.99	67.32
159.48	62.79	30TH	171.98	67.71
160.32	63.12	35TH	172.90	68.07
161.14	63.44	40TH	173.78	68.42
161.93	63.75	45TH	174.64	68.76
162.72	64.06	50TH	175.49	69.09
163.53	64.38	55TH	176.34	69.43
164.35	64.70	60TH	177.21	69.77
165.21	65.04	65TH	178.11	70.12
166.13	65.40	70TH	179.06	70.50
167.13	65.80	75TH	180.09	70.90
168.27	66.25	80TH	181.24	71.35
169.59	66.77	85TH	182.57	71.88
171.27	67.43	90TH	184.23	72.53
173.73	68.40	95TH	186.65	73.48
175.28	69.01	97TH	188.16	74.08
176.39	69.44	98TH	189.24	74.50
178.04	70.09	99TH	190.87	75.14

Example) Vehicle Seat Design



BIDELTOID BREADTH

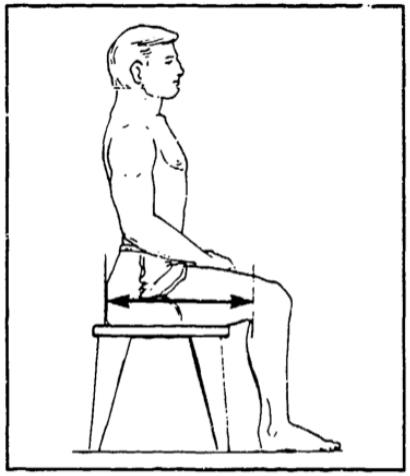


THE PERCENTILES

FEMALES			MALES	
CM	INCHES		CM	INCHES
38.03	14.97	1ST	43.40	17.09
38.73	15.25	2ND	44.02	17.33
39.16	15.42	3RD	44.43	17.49
39.70	15.63	5TH	44.99	17.71
40.49	15.94	10TH	45.87	18.06
41.00	16.14	15TH	46.48	18.30
41.40	16.30	20TH	46.96	18.49
41.75	16.44	25TH	47.39	18.56
42.05	16.56	30TH	47.77	18.81
42.34	16.67	35TH	48.13	18.95
42.61	16.78	40TH	48.47	19.08
42.88	16.88	45TH	48.81	19.22
43.14	16.99	50TH	49.14	19.35
43.41	17.09	55TH	49.47	19.48
43.69	17.20	60TH	49.81	19.61
43.99	17.32	65TH	50.16	19.75
44.30	17.44	70TH	50.53	19.89
44.65	17.58	75TH	50.92	20.05
45.06	17.74	80TH	51.37	20.23
45.54	17.93	85TH	51.89	20.43
46.17	18.18	90TH	52.53	20.68
47.17	18.57	95TH	53.48	21.05
47.85	18.84	97TH	54.07	21.29
48.36	19.04	98TH	54.50	21.46
49.21	19.37	99TH	6	21.71

Example) Vehicle Seat Design

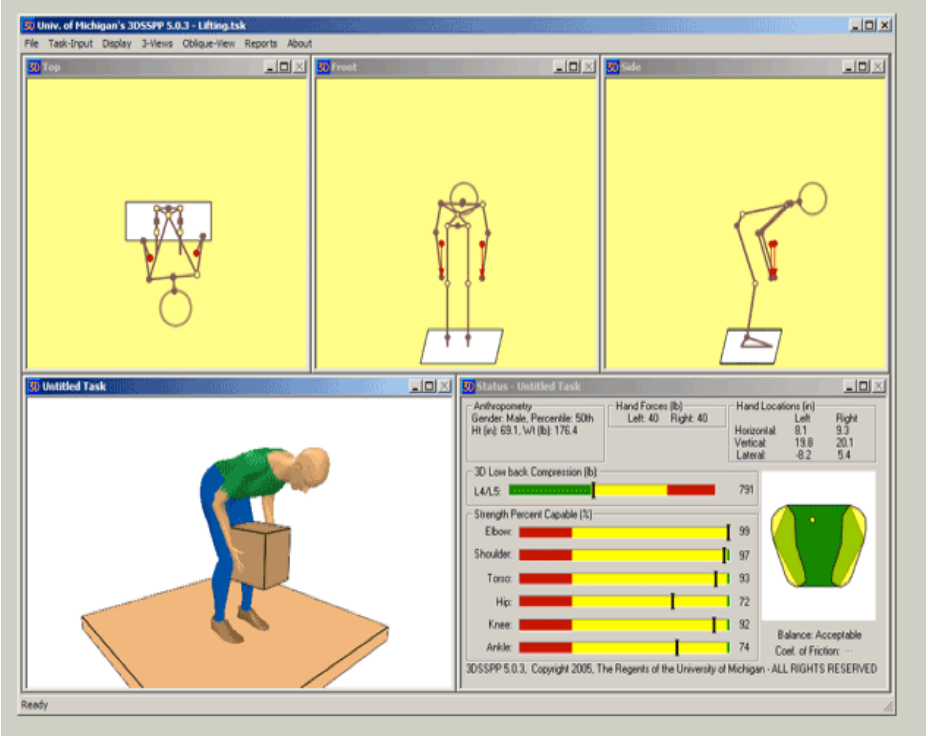
BUTTOCK-POPLITEAL LENGTH



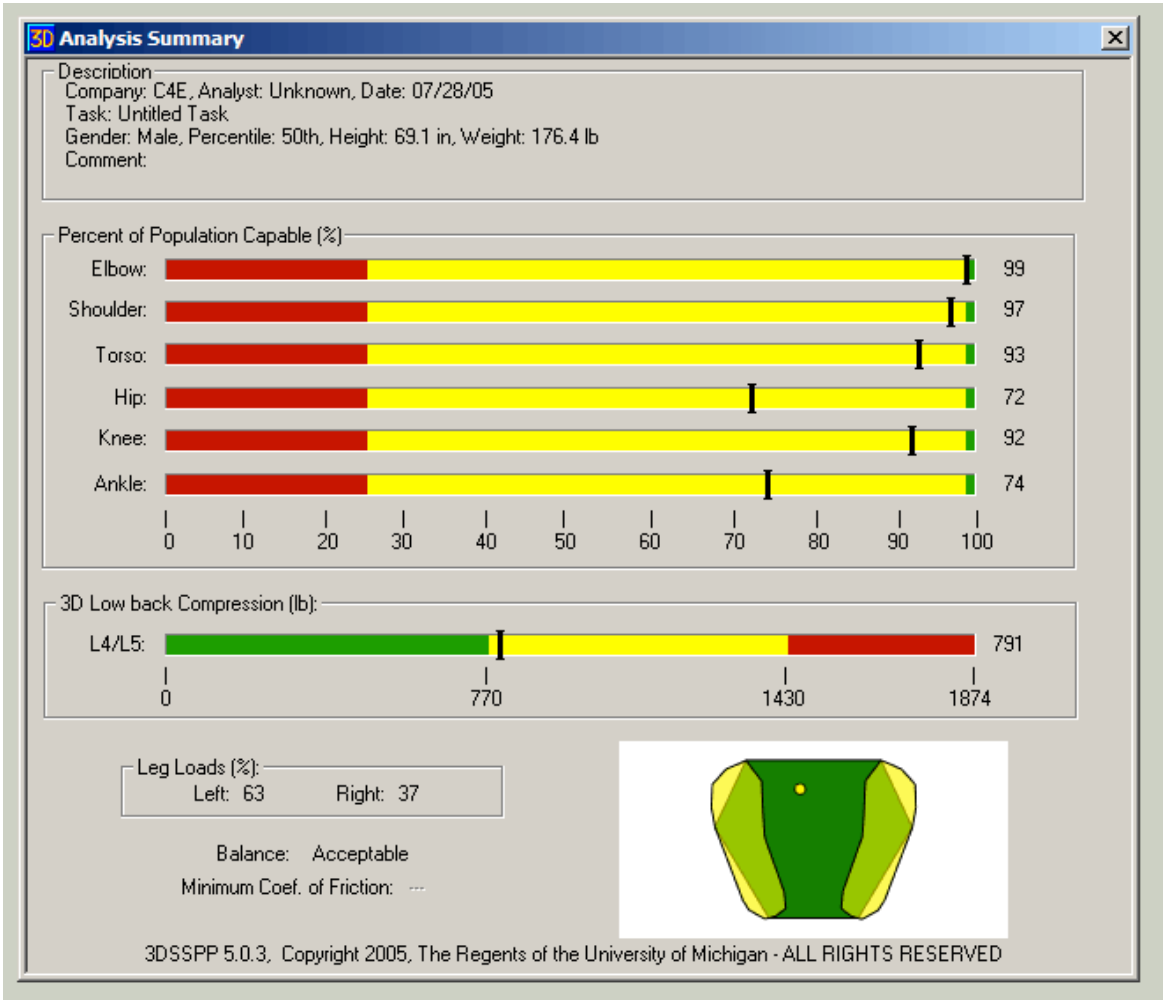
THE PERCENTILES

FEMALES			MALES	
CM	INCHES		CM	INCHES
42.10	16.57	1ST	44.13	17.37
42.91	16.89	2ND	44.81	17.64
43.39	17.08	3RD	45.24	17.81
44.00	17.32	5TH	45.81	18.04
44.89	17.67	10TH	46.70	18.39
45.47	17.90	15TH	47.30	18.62
45.93	18.08	20TH	47.79	18.81
46.34	18.24	25TH	48.21	18.98
46.71	18.39	30TH	48.59	19.13
47.05	18.52	35TH	48.95	19.27
47.39	18.66	40TH	49.29	19.41
47.72	18.79	45TH	49.63	19.54
48.05	18.92	50TH	49.96	19.67
48.39	19.05	55TH	50.30	19.80
48.73	19.19	60TH	50.65	19.94
49.10	19.33	65TH	51.01	20.08
49.49	19.49	70TH	51.39	20.23
49.93	19.66	75TH	51.81	20.40
50.42	19.85	80TH	52.28	20.58
50.99	20.07	85TH	52.83	20.80
51.72	20.36	90TH	53.53	21.07
52.77	20.78	95TH	54.55	21.48
53.43	21.03	97TH	55.21	21.74
53.88	21.21	98TH	55.68	21.92
54.54	21.47	99TH	56.40	22.21

3DSSPP for work task design (occupational biomechanics tool)



3DSSPP for work task design (occupational biomechanics tool)

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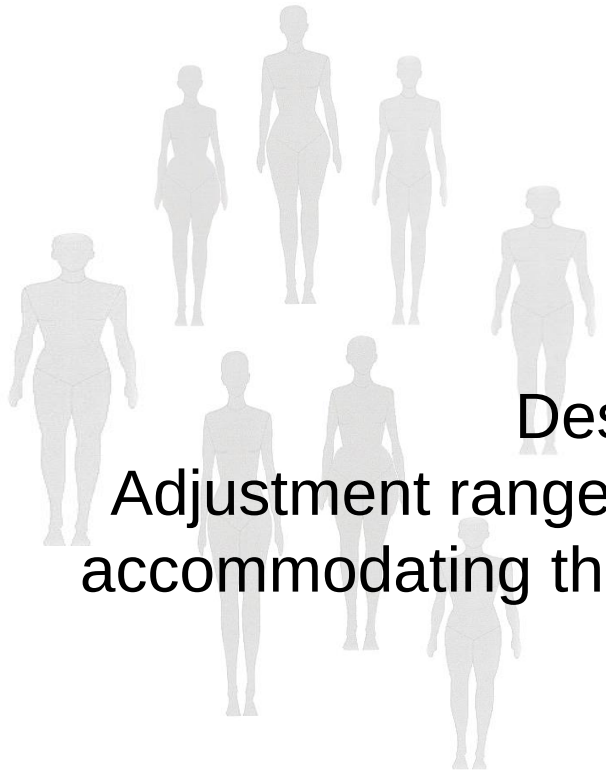
OPTICOM

Design principle for target population accommodation
Principle 2:
Providing adjustability

Providing adjustability

- “Determine the optimal adjustment range for accommodating the majority of the target population.”
- Optimal adjustment range?



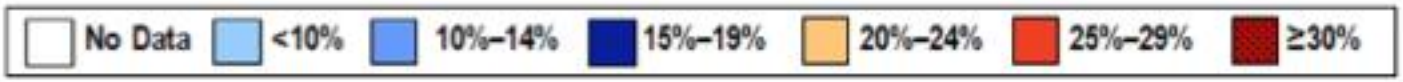
Design project example:
Adjustment ranges of vehicle interior components for accommodating the obese population in North America

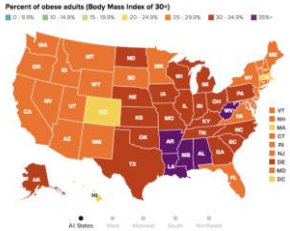
Background: Prevalence of Obesity

Significant increase during the last 20 years time period

Less than 10% (1988)

26% (2008)





2018

Background: Prevalence of Obesity

Obesity is expected to continue to increase

Cup of Coffee

Twenty years ago
Coffee with milk and sugar
8 ounces
45 calories

Today
Grande café mocha with whip, 2% milk
16 ounces
330 calories

Size Neutral Design (SND)?

Ergonomics for large individuals

SND aims to:

- Understand physical capacities, limitations and preferences of large individuals,
- Develop design tools and methods that guide creating size-neutral products, systems and services, and
- Create innovative size-neutral products, systems and services

Why SND?

- Very little ergonomics research on obese individuals (Williams and Forde, 2009)
- Consequently, bad designs that design out obese individuals are common.
- Ergonomic design can help obese individuals lead more active and


Airline Seatbelt Extender

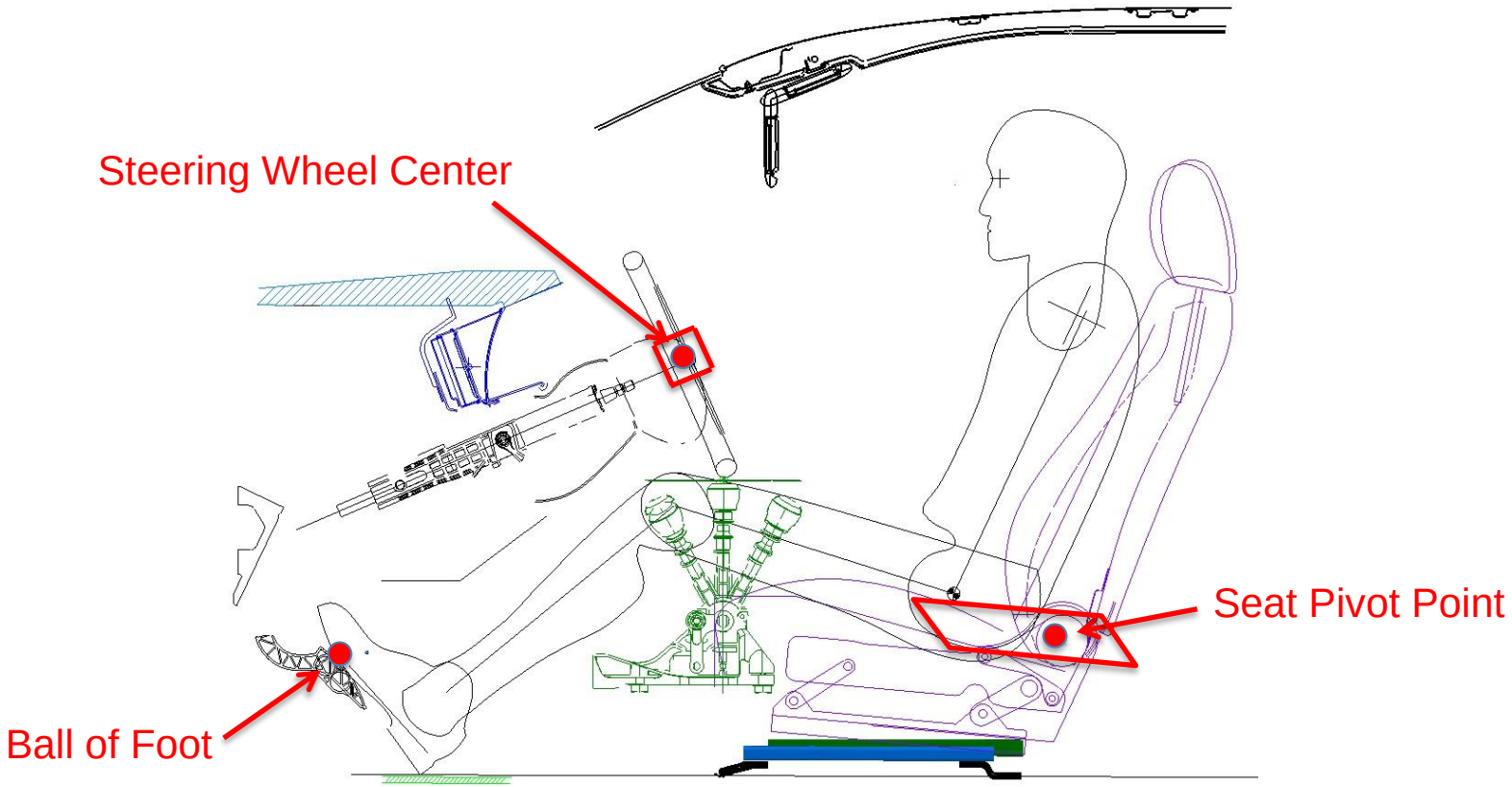

Bariatric Chair


Leg Lifting Aids


Personal Desk Fan


Reaching Aids

Background

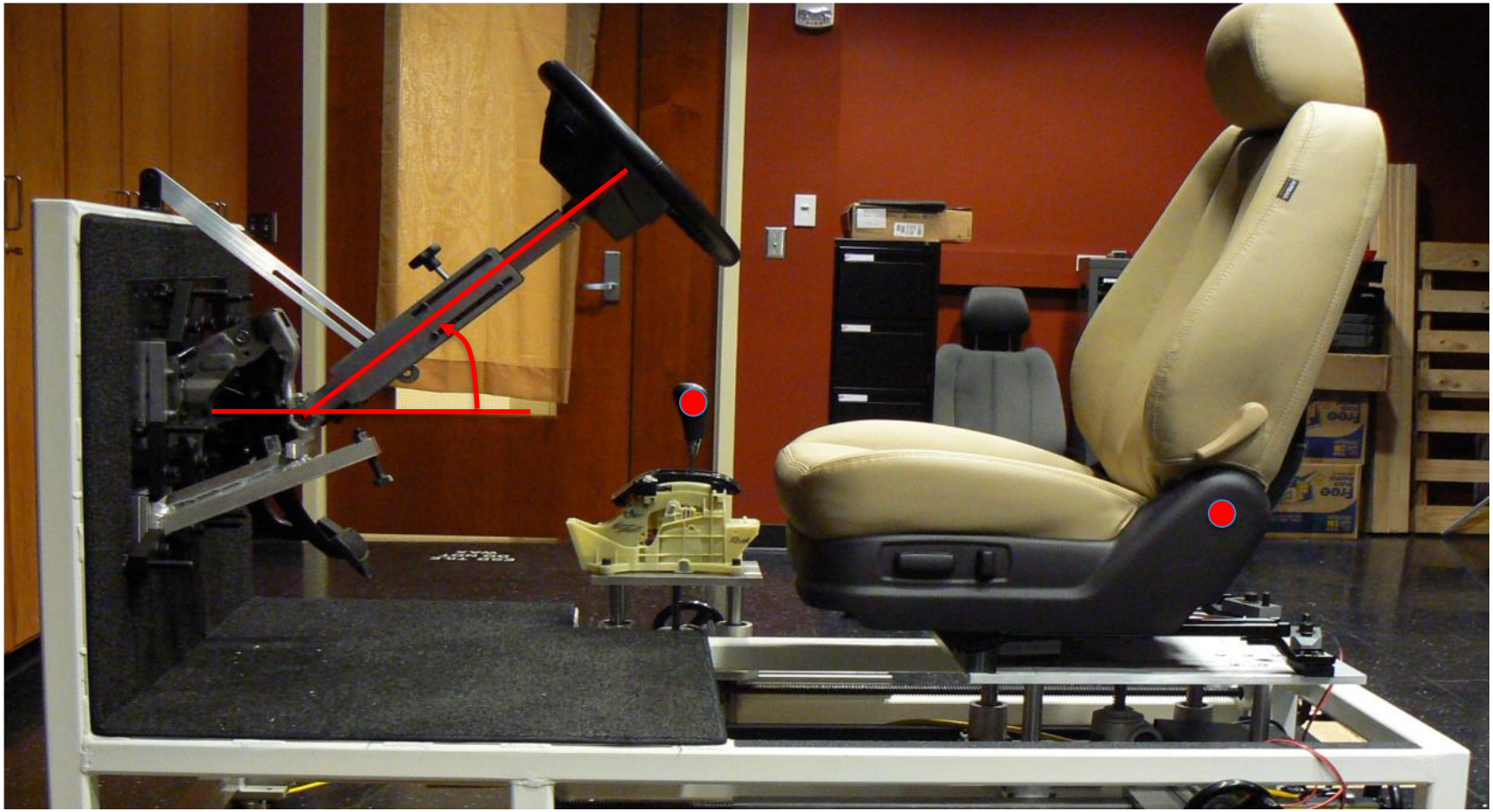


Background

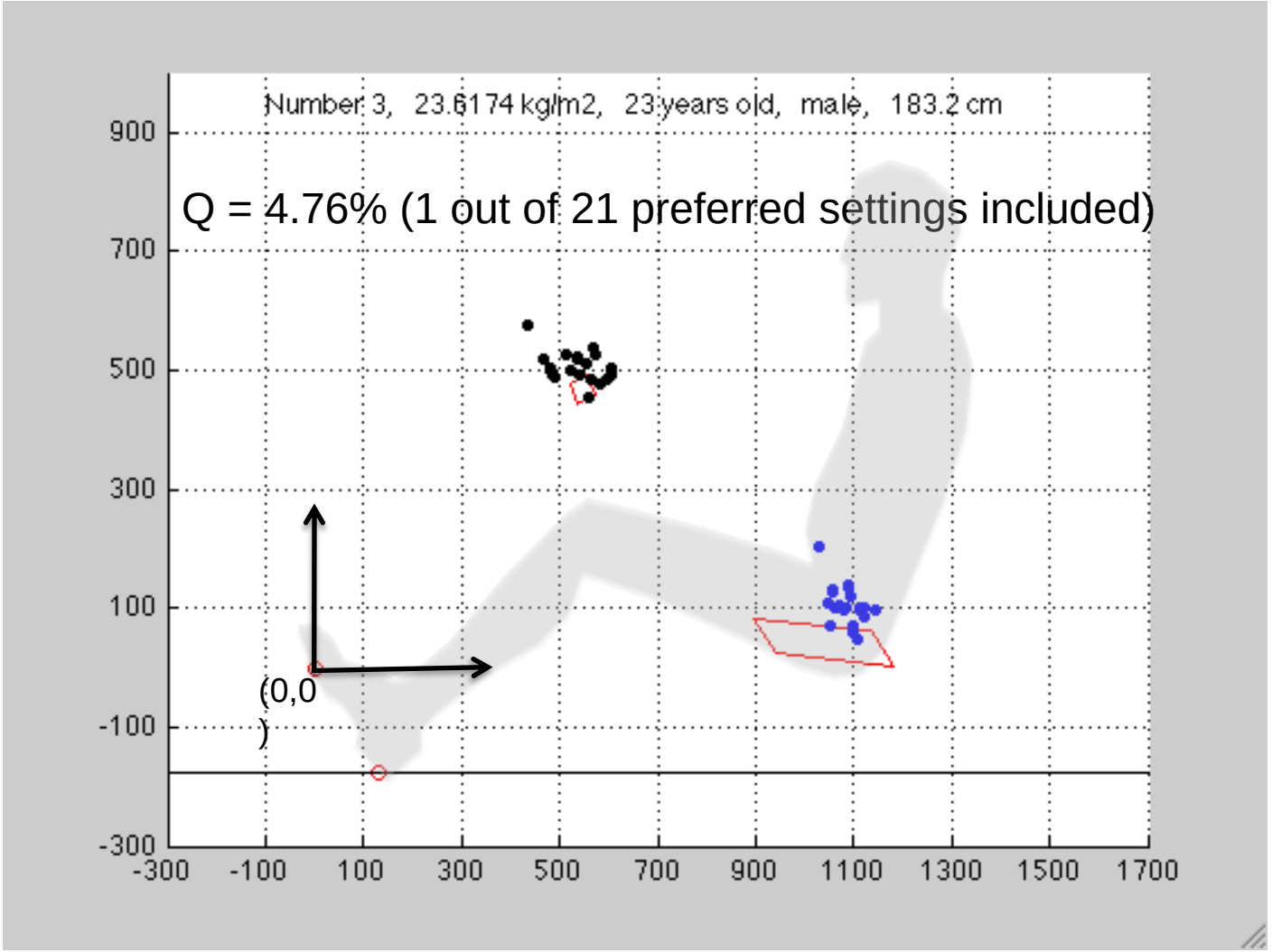
Some difficult questions that need answers:

- What % of the obese driver population are currently accommodated?
- How do we quantify the effects of design changes on the accommodation level?
- How do we maximize the accommodation level?

The Seating Buck



Novel q %-cloud accommodation concept (for an individual)

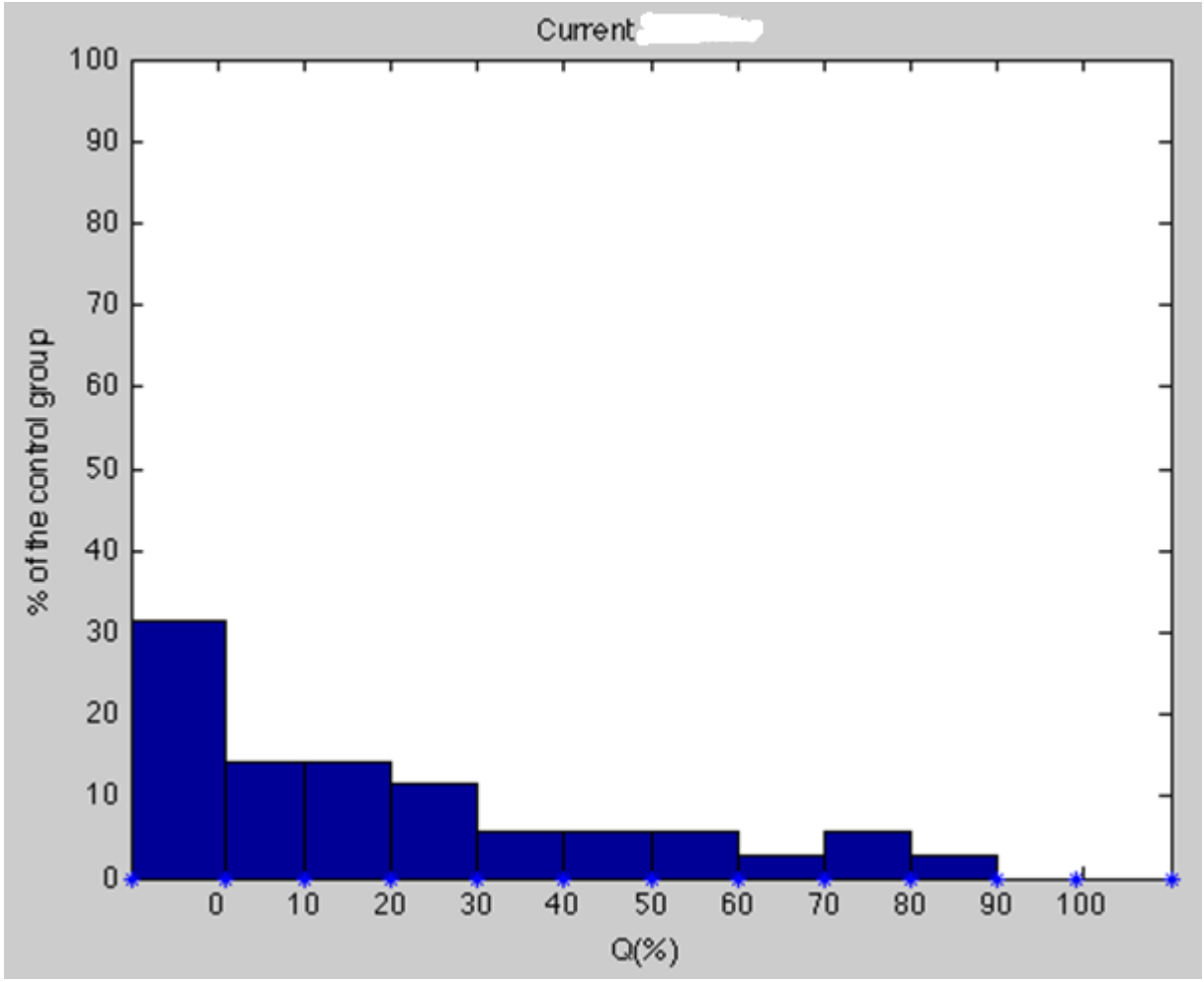


Vehicle analysis and redesign

Vehicle Evaluation and Redesign Recommendation (Cont'd)

Group Q-value Distribution (Current Vehicle)

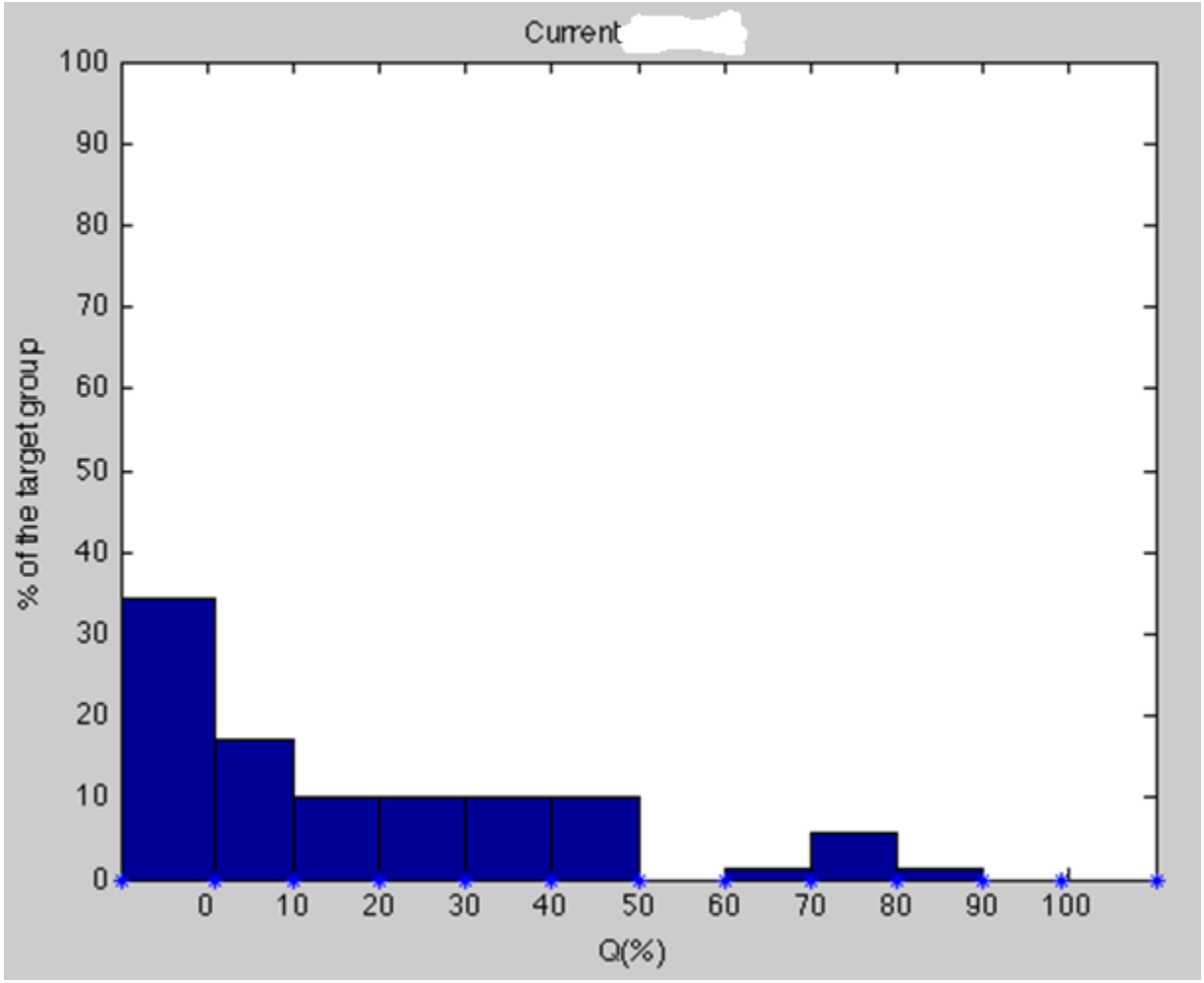
Control (BMI < 35 kg/m^2)



Vehicle Evaluation and Redesign Recommendation (Cont'd)

Group Q-value Distribution (Current Vehicle)

Target (BMI > 35 kg/m^2)



Vehicle Evaluation and Redesign Recommendation (Cont'd)

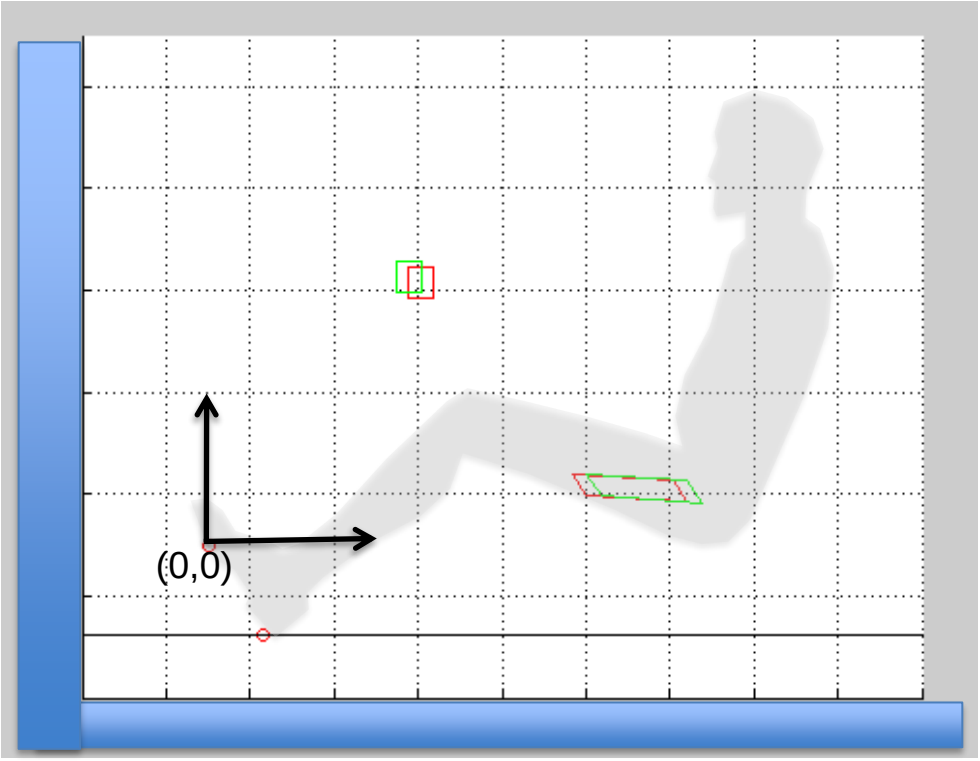
Optimization-based Redesign:

Maximize the overall drivers accommodation level (Q>0 = accommodated)

1*Accommodation Level for Control + 1*Accommodation Level for Target

Assumptions:

- **Both the SW and SPP travel windows can be translated w/o restrictions, and**
- **The travel windows cannot be changed from their current configurations.**



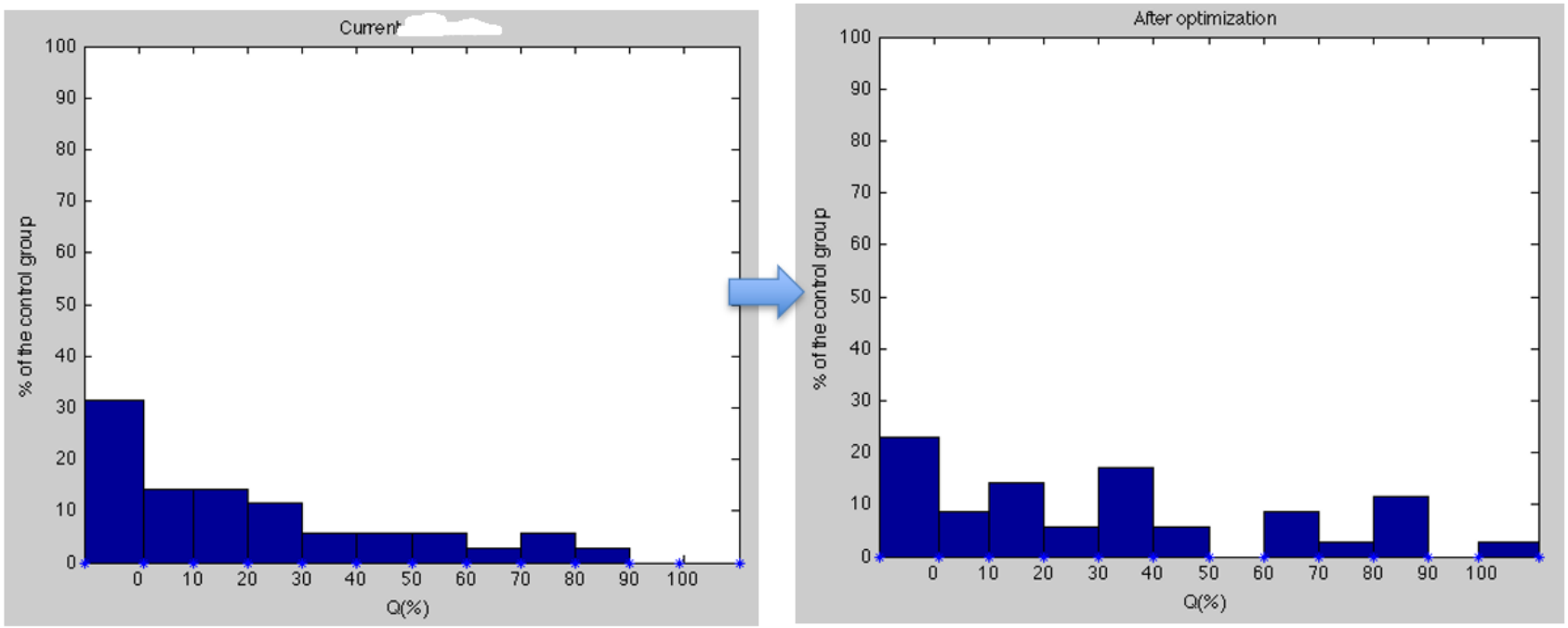
Vehicle Evaluation and Redesign Recommendation (Cont'd)

Optimization-based Redesign:

Maximize the overall participants accommodation level (Q>0 = accommodated)

1*Accommodation Level Control + 1*Accommodation Level Target

Before and after optimization comparison:



Control Group

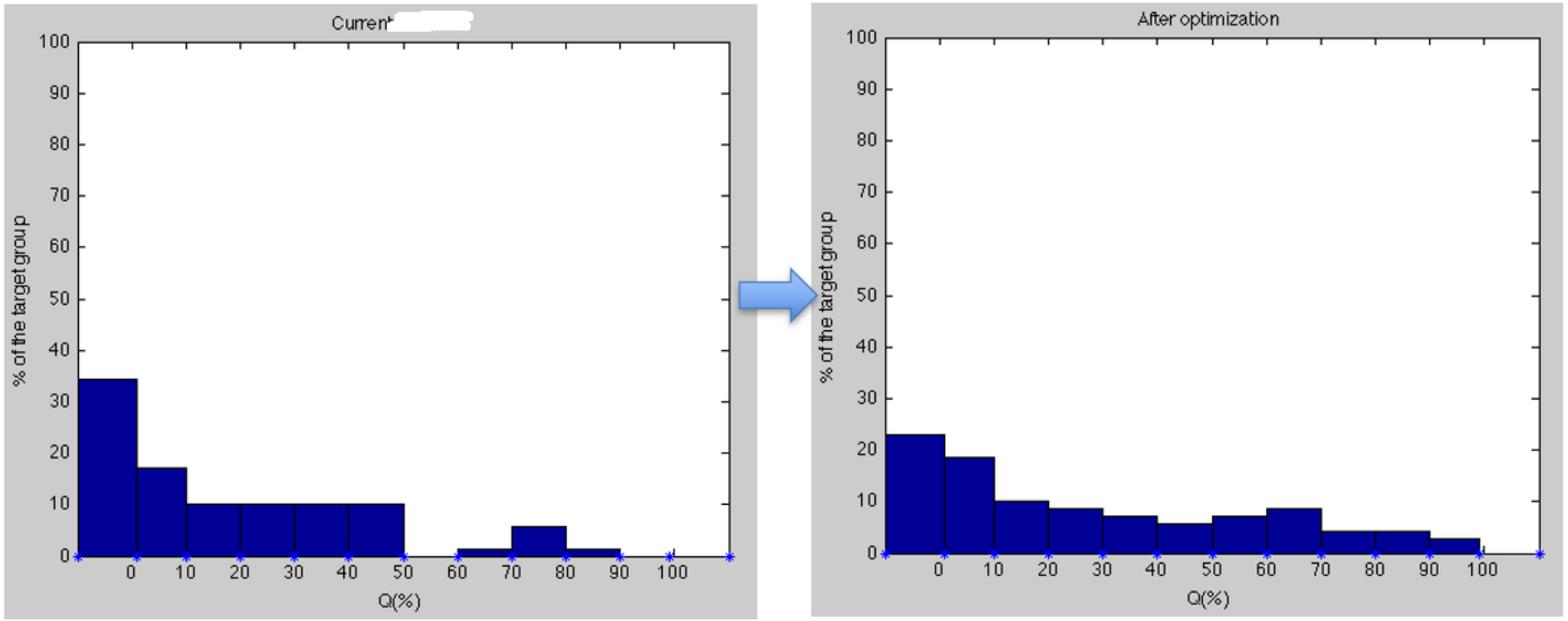
Vehicle Evaluation and Redesign Recommendation (Cont'd)

Optimization-based Redesign:

Maximize the overall participants accommodation level (Q>0 = accommodated)

1*Accommodation Level Control + 1*Accommodation Level Target

Before and after optimization comparison:



Target Group

Design principle for target population accommodation
Principle 3:
Horizontal segmentation

Horizontal segmentation

- “Segment the target population into distinct subgroups and design for each subgroup.”

Spaghetti sauce design

- Dr. Howard Moskowitz
  - Psychophysicist
  - Reinventing the spaghetti sauce

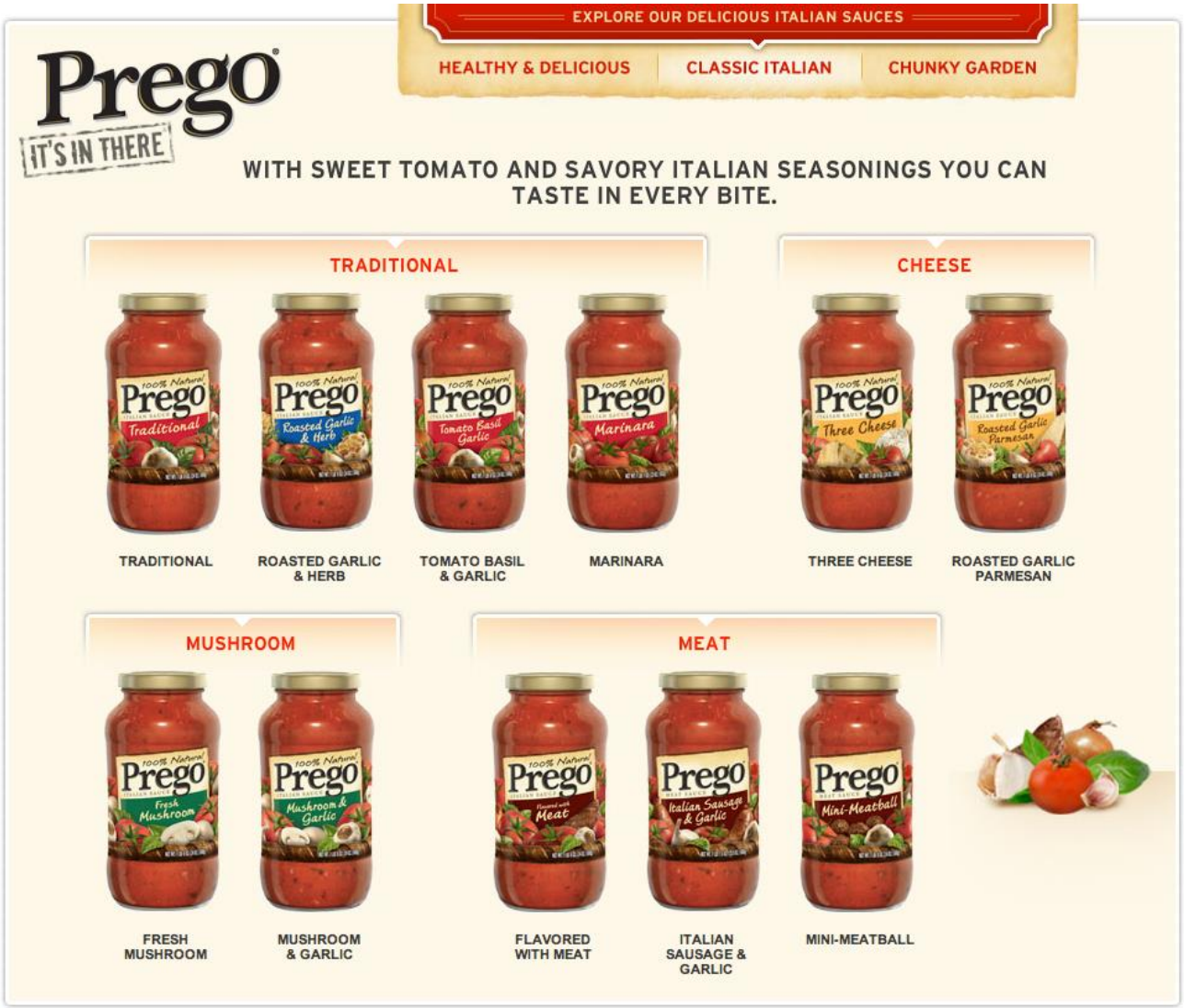
Spaghetti sauce design

- Diet Pepsi:
  - Tell us what the optimal aspartame % should be?
  - What is the perfect Pepsi?

Spaghetti sauce design

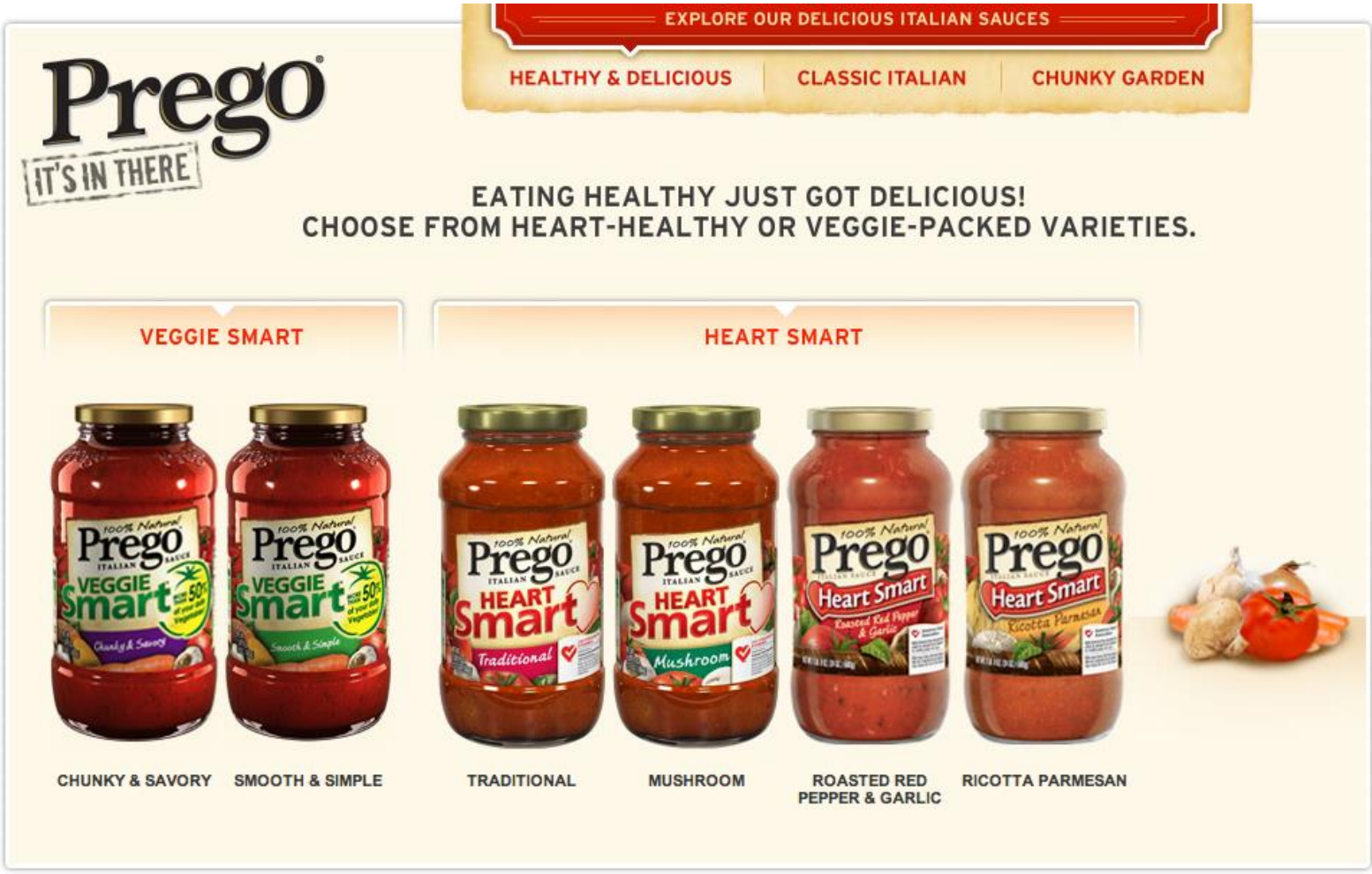
- Pepsi, pickle, spaghetti sauce
  - Perfect Pepsi vs. Perfect Pepsis?
  - Perfect pickle vs. Perfect pickles
    - Zesty pickles
  - Prego spaghetti sauce
    - Plain -> plain, spicy, extra chunky

Prego sauces 1



Prego sauces 2

Prego sauces 3



Some lessons

- The idea of “single optimal/ideal design” is often a fixation and hinders good design.
- Reflecting the human variability into design is important for enhancing human life through design

Design tools for supporting population accommodation

Manikin Family

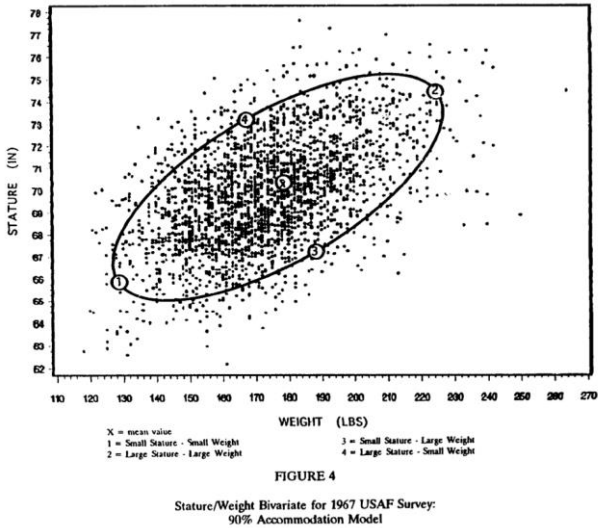


FIGURE 4

Stature/Weight Bivariate for 1967 USAF Survey:
90% Accommodation Model

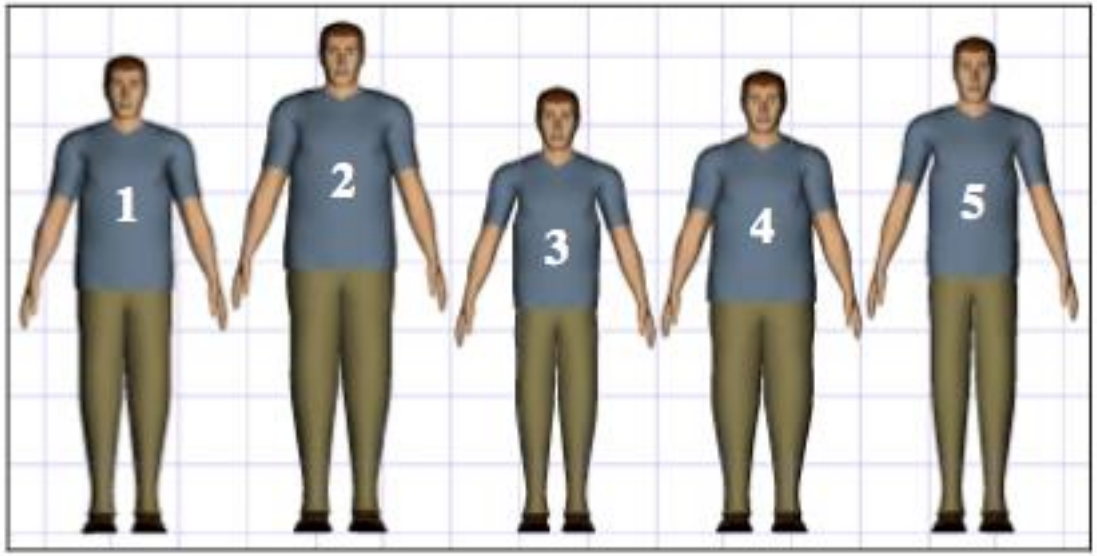
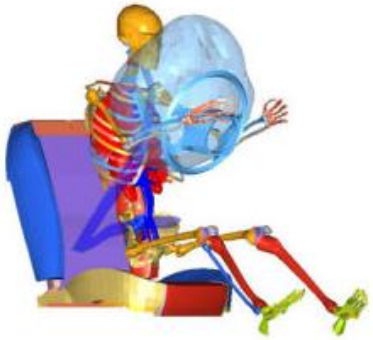


Figure 4: The five cases modelled in Jack.



Manikin Family

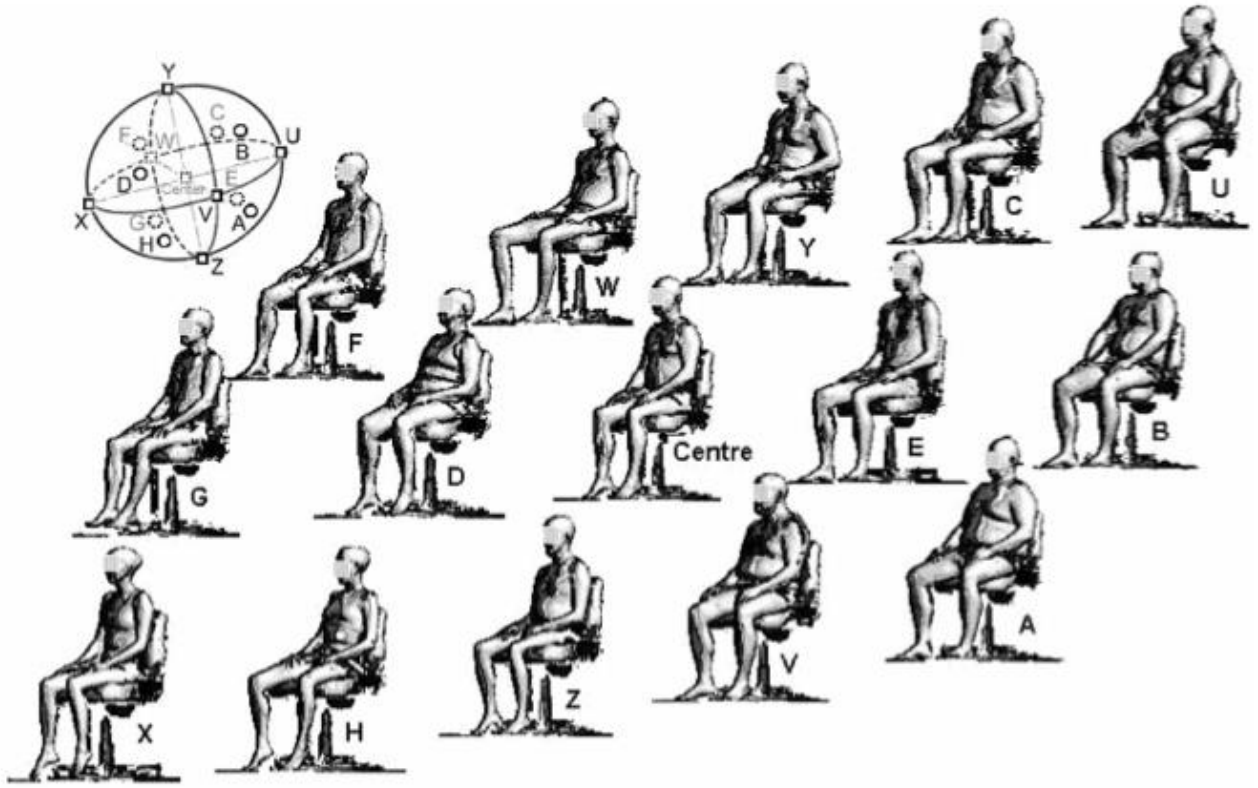
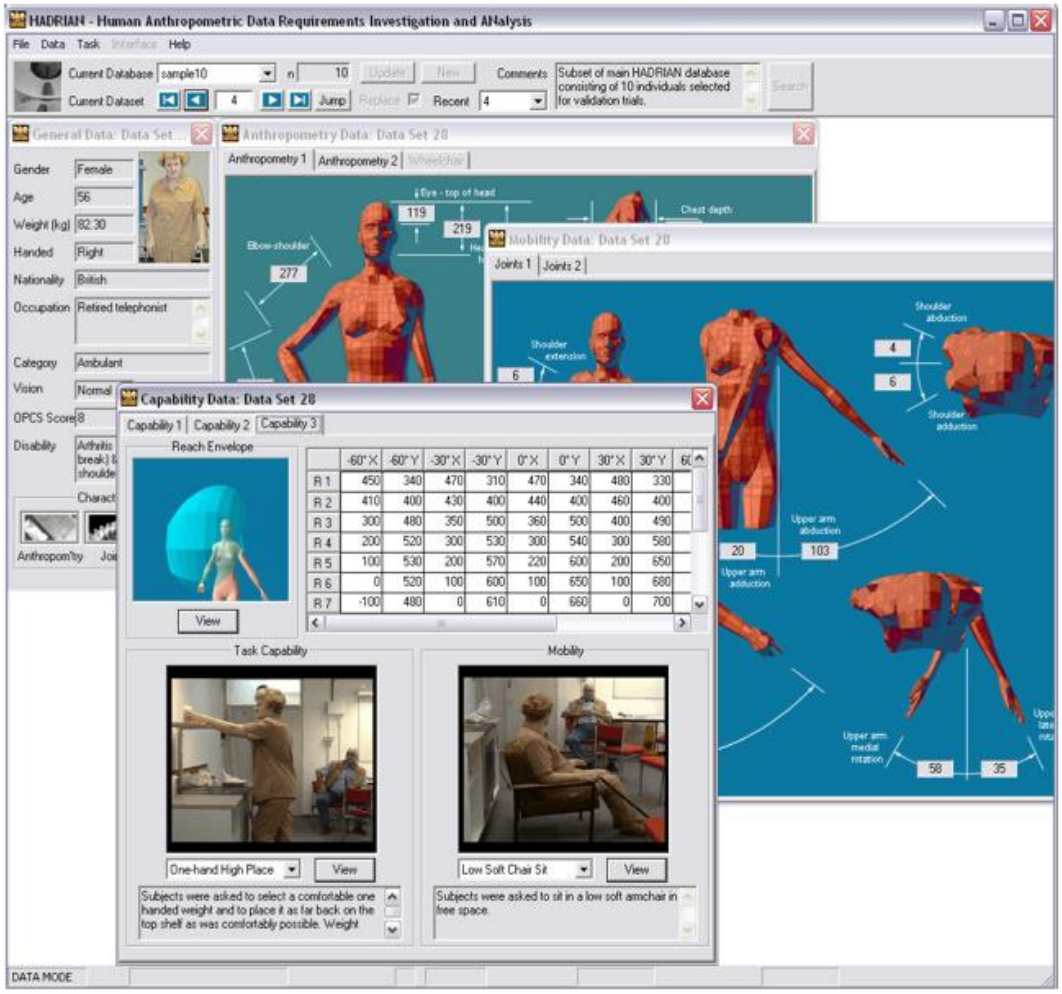


Figure 6. The 15 representative body models derived from the principal component analysis for tractor accommodation test.

HADRIAN Database



HADRIAN Database

Fig. 5. Members of the HADRIAN database

Ford's 3rd age suit

diques, eux, ont déjà commencé à s'adapter», observe Mme Schmitt.

Toyota a créé une voiture offrant aux personnes âgées cent options spécifiques: assise adaptée, fauteuil pivotant pour faciliter la sortie, pare-soleil automatiques... Aux Etats-Unis, Floride en tête, la grande distribution effectue sa mue, offrant des chariots électriques sur lesquels il est possible de s'asseoir, des rayonnages inférieurs à 1,70 mètre, un éclairage qui ne fait pas briller les emballages. On repense les téléphones portables, les télécommandes, les maisons tout entières.

Un Français sur quatre a 55 ans ou plus. Un Français sur trois sera concerné en 2020. *«On trouve des produits horribles pour le quatrième âge, dépendant, mais rien pour les sexagénaires qui sont en bonne santé mais n'ont simplement pas la force et la résistance de leurs 30 ans,* résument les créatrices de Seniosphère. *Ils ne veulent pas d'une salle de bains d'hospice! Ils détestent que la société leur rappelle en permanence qu'ils vieillissent.»*

Pourquoi les magasins de bricolage s'acharnent-ils à construire de hautes pyramides avec les pots de peinture de 15 litres? La SNCF est-elle contrainte d'imprimer en tout petit, sur ses billets, le numéro du wagon qu'on ne pourra pas lire, sur le quai, sans lunettes, valise à la main? Qui s'adaptera, qui lancera de nouveaux produits et services susceptibles de gommer les effets du vieillissement verra s'ouvrir un énorme marché, plaident les deux femmes.

A tout cela, une condition. Intégrer dans les produits les attentes spécifiques à cet âge (sécurité, confort, simplicité). Et surtout, surtout, ne rien étiqueter «Senior». La génération qui a vécu Mai 68 n'a aucune intention de s'identifier à ces « vieux » jadis honnis.

Experiential design with VR

Conclusions

- Many ergonomics design problems require considering the human variability
- Understanding the human variability and reflecting it into design is extremely important
- Focusing on the human variability may lead to the creation of better products and services