DESIGN TECHNOLOGY

Peter Metcalfe
Roger Metcalfe

3rd Edition

FOR USE WITH THE I.B. DIPLOMA PROGRAMME

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THIRD EDITION

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AUTHORS' NOTE

This text has been developed primarily to meet the syllabus requirements of the International Baccalaureate Design and Technology Syllabus. However, it also goes beyond the syllabus to deliver background knowledge and support for the concepts and principles underpinning the program.

In a rapidly changing technological world, texts like this must reinforce the changing nature of design and the role of designers. Designers have both an opportunity and a responsibility to shape our future. Courses such as the International Baccalaureate's Design and Technology program continue to support and encourage the principles of sustainable design, creativity, problem solving and ethical decision-making. It is hoped this text goes some way to supporting these goals.

It is intended that the added depth will provide students of design with a better understanding of the complex relationships between technology, humankind and the environment. On occasions, historical notes have been provided to show the origins of current practice but, in general, the information is as contemporary as possible.

ABOUT THE AUTHORS

Peter has a Diploma of Teaching (Industrial Arts) and a Master of Educational Studies Degree (MEdStud) and over 40 years of teaching experience. He has worked as the Head of faculty in several locations around the world, including Australia, Asia, Europe, and the United States, teaching both the NSW High School Engineering Studies Curriculum and International Baccalaureate Design and Technology curriculum.

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PREFACE

Design is a deliberate, intentional approach to creating or arranging elements with purpose and intention through an iterative, non-linear process to solve an identified problem or brief. It is not limited to physical objects but encompasses systems, environments, and experiences.

Paul Rand (1914–1996) was an American graphic designer and art director, celebrated for his iconic corporate designs. He is famous for his enduring logo designs for companies such as IBM, ABC and UPS. The oft quoted statement, "Everything has to be designed. Anything else is an accident." is often attributed to Paul Rand.

His philosophy of design emphasised what he saw as the critical design elements of simplicity, functionality, and timelessness. His notion of 'the intentionality of design' extended to the smallest details, aesthetics and user experience.

The results of applying the design process also possess the ability to impact our emotions, actions, decision-making, and potentially even the direction of our future.

Steve Jobs, co-founder of Apple Inc., believed design was much more than aesthetics. It was also about functionality, how things worked, and a user interaction that would lead to a positive experience. This philosophy is reflected in the many successful products, systems, and services his companies have produced.

At its heart, the design process is about creating effective, innovative solutions to existing problems and manifesting these solutions in a functional, aesthetically pleasing and user-friendly way.

The history of engineering is one of seeking those solutions while using both traditional and newly emerging materials and processes, often in an iterative manner. In his book '*To Engineer Is Human: The Role of Failure in Successful Design*', the American Engineer and Academic Henry Petroski contended that "It is the process of design, in which diverse parts of the 'given-world' of the scientist and the 'made-world' of the engineer are reformed and assembled into something the likes of which Nature had not dreamed, that divorces engineering from science and marries it to art." He argued that the paradox of the engineering design process was that the cycle of success and failure drives innovation in future designs.

The field of Design is today undergoing a transformative shift, thanks to the increasing integration of advanced technology. Computer-Aided Design (CAD) software has made significant contributions to the design industry, allowing designers to create precise and intricate models with comparative ease. CAD's capabilities have expanded significantly over the years, enabling more complex simulations and analyses that streamline the design process and enhance productivity. This has paved the way for innovations such as generative design, which uses algorithms to explore a vast array of design possibilities based on specified parameters and constraints. Generative design mimics nature's evolutionary approach, proposing optimised solutions that might not be immediately apparent to human designers. This not only accelerates the design process but also often results in more efficient and sustainable outcomes. An example of this is the world's first production chair created by A.I. in collaboration with humans. The chair, unveiled in 2019, is the result of Philippe Starck's collaboration with Italian contemporary furniture maker Kartell and Autodesk Research.

Artificial Intelligence (A.I.) is poised to further revolutionise design by providing tools that enhance creativity and efficiency. A.I.-driven design software can analyse vast amounts of data, learn from past projects, and predict outcomes, thus assisting designers in making more informed decisions. A.I. can automate repetitive tasks, freeing designers to focus on more creative aspects of their work and can facilitate collaboration by offering insights and suggestions that might not be obvious to human collaborators.

Research shows that A.I. can significantly influence the design process by eliminating tedious processes, improving user-centricity, and stimulating creativity. AI may also support designers' decision-making, prototyping, and ideation processes, resulting in more creative and effective design solutions.

A guide to teaching the syllabus

Order of topics: The IBO recommends teaching the guide "topics by row, i.e. teach all topics organised as people, then process, then product, then production. This approach facilitates the sequential development of topics from theory to practice to context; it can be difficult to plan units of study that are interesting, engaging and meaningful—the approach is limited in providing opportunities for authentic links across the syllabus." Design technology guide First assessment 2027, p 22 ©IBO 2025.

Linking questions: At the end of each topic, linking questions have been provided, taken directly from the guide. Teachers may use the linking questions to connect the learning and teaching of each of the topics. This approach is designed to connect the learning holistically and allow transfer of knowledge between topics, thus deepening understanding. Examples of topic-linking questions are provided below.

To what extent does UCD rely on a strong foundation of ergonomics? (A1.1)

How important is a good understanding of user-centred research methods to ensure effective UCD? (A2.1)

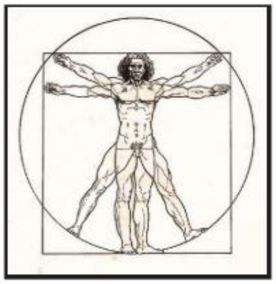
To what extent can the UCD process be influenced by the quality of modelling and prototyping of potential design solutions? (B2.2).

CONTENTS

The 'PEOPLE' row of the 2025 Syllabus

PEOPLE: DESIGN IN THEORY (SL)

Contents



A1.1

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TOPIC A1.1 ERGONOMICS

Guiding question

How do ergonomic considerations influence the design of a product?

Ergonomics, or human factors engineering, studies the relationship between people and systems, artifacts and environments. Ergonomics has its roots in ancient societies.

Prioritising ergonomics in design significantly enhances the likelihood of producing functional products, improves user comfort and makes them safe and efficient to use. Products that excel in ergonomic attributes often gain popularity in the marketplace and can command a premium price due to their superior design features.

Content

A 1.1.1 Ergonomics is the relationship and interaction between people (aspects of the human body) and the products, systems and environments they use.

Some examples of the application of the principles of ergonomic design include:

Office Chairs:

Key features such as adjustable height, lumbar support and armrests are integral to this design philosophy. Adjustable height allows users to ensure their feet rest flat on the floor, with thighs parallel to the ground. This feature helps maintain a neutral spine position, reducing strain on the lower back.

Ergonomically designed chairs often include adjustable lumbar support to provide targeted support to the lower back and maintain the natural curve of the spine, thus preventing slouching and alleviating pressure on the spinal discs. Adjustable armrests support the arms and shoulders, reducing tension in the upper body. Properly positioned armrests help maintain a relaxed posture, preventing strain on the neck and shoulders.

The ergonomic design of office chairs plays a vital role in enhancing comfort, promoting good posture and reducing the risk of back pain for users who spend extended periods seated.

Keyboards and Mice:

Keyboard features such as wrist support, alternative keyboard arrangements and button placements on mice are all considerations that can not only reduce discomfort and strain on the wrists and hands but also improve workplace productivity.

SL

Figure A 1.1.1a Microsoft Natural Ergonomic Keyboard 4000

Medical Devices:

Products in this field are engineered with ergonomic considerations to reduce physical strain on healthcare providers, promoting sustained performance and reducing the risk of errors. Medical device design prioritises user safety through the incorporation of features that prevent accidental injuries and ensure reliable operation.

Automotive Design:

Significant advancements have been made to optimise comfort and safety for drivers. Key components such as car seats, steering wheels and control panels have been engineered to enhance the driving experience. A notable innovation in this field is the introduction of Head-Up Displays (HUDs). These systems project critical driving information onto the windshield, allowing drivers to access customizable and diverse data without diverting their gaze from the road. This dual approach addresses both safety and accessibility. The convenience of HUDs is enhanced through the integration of smartphone connectivity, enabling drivers to manage notifications and calls seamlessly without taking their hands off the wheel.

Consumer Electronics:

Smartphones, tablets and wearables are designed for ease of use and to minimise physical strain during extended use.

Household Items:

Kitchen knives are designed with several key factors in mind. Considerations such as muscle exertion, comfort, efficiency and slicing performance are integral to the design process. Chefs' knives should be designed to feel like extensions of their hands.. The use of lightweight, non-slip materials and shaped or textured surfaces is often employed to enhance grip and safety. The balance of a knife (through precise weight distribution) is critical for creating a tool that offers superior safety and accuracy by improving user control and maneuverability.

Content

A 1.1.2 Anthropometrics involves the measurement of human physical dimensions expressed in the percentile range. This method specifically focuses on determining and presenting the range of individuals' physical characteristics.

Anthropometry is the study of human body properties such as height, mass and volume and is used extensively in the design of consumer goods. In a report titled '*Physical status: the use and interpretation of anthropometry*', (1995). The World Health Organisation (WHO) views anthropometry as, "the singly most universally applicable, inexpensive and non-invasive method available to assess the size, proportions, and composition of the human body."

Structural or static anthropometry includes data from measurements such as those made between joints. Data is recorded using standardised equipment such as calipers. It is easy to collect because the subject is not moving. Height, weight and data related to various body structures are included in this data set.

Functional or dynamic anthropometry includes data obtained while the subject is moving, and while quantitative data is more difficult to obtain, is often of greater use because it demonstrates the range and ease with which movements can be made. Reaction times, reach arcs, grip strengths, etc, are all examples of dynamic data.

A range of instruments is used to obtain anthropometric data. The main criteria for such instruments are that they are calibrated and are of sturdy design to ensure they provide reliable results.

The quality of anthropometric data is important when determining the reliability of any inferences or relationships from data sets. Determinations of height and weight can be amongst the most reliable and easily gathered data sets. However, body fat data gathered using skinfold calipers can often be unreliable over a population sampling.

Anthropometric data is intended to represent the measurements of the nude body. Cultural restrictions, however, may also prevent the gathering of data from unclothed subjects. To adjust for this situation, investigators make allowances for the type and thickness of the clothes worn.

Factors such as age, gender, ethnicity and disability may affect the anthropometric data in the following ways.

Gender

- **Height and Weight:** men on average tend to be taller and heavier than women. The differential is attributed to hormonal influences. Male bones are generally larger and denser than those of females. The maximum bone mass of men is around 50% greater than women's, and women lose bone more quickly as they age, adding to the discrepancy over time.
- **Body Composition:** women generally have a higher percentage of body fat. This difference is important for understanding and interpreting variations in health-related metrics such as Body Mass Index (BMI).

Ethnicity

- **Body proportions** differ between ethnic groups, eg Individuals of African descent tend to have higher bone density and fewer fractures than Caucasians.
- **Health Indicators:** Ethnicity can influence the prevalence of certain health conditions. For instance, waist circumference and waist-to-hip ratio, which are important indicators of metabolic health, can vary significantly among ethnic groups.

Disability

- People with disabilities may have unique anthropometric profiles that differ from the general population.
- Some disabilities that affect mobility, such as cerebral palsy or muscular dystrophy, may lead to differences in body measurements that are critical to the design of environments and assistive devices. Wheelchair users might have different upper body strength and proportions compared to non-users, which impact the biomechanical design

A 1.1.3 Percentiles aid in the selection of appropriate anthropometric data to satisfy the majority of a user population.

While some products can be used by almost everyone, many designs acknowledge that some people within a population may not be able to use a product for one reason or another. Within any group, variation will exist. Because of this, statistical methods are used to collect data from a large number of people to describe the population.

Percentiles refer to 100 equal groups into which a sample population can be divided according to the distribution of values of a particular variable. As an example, an individual in the 70th percentile has scored as well, or better than, 70% of those in the total sample population.

Percentile ranges are used to measure dispersion within a sample population. A spread between the 95th and 5th percentiles would be expressed as: P95 — P5. Percentiles shown in anthropometry tables determine whether the measurement given relates to the 'average' person, or someone who is above or below average in a certain criterion. If the heights of a group of adults are sampled, many will have data recorded showing them to be around the same height. Some will be appreciably taller while others may be shorter. The 'same height' group will be near the average or 'mean' and will be displayed in anthropometric tables as the 50th percentile. The 50th percentile in this case, identifies the most likely height of an individual within the group. In a design context, determining which percentile value or range may be critical to success depends on what is being designed and for whom the design needs to cater. Age, gender and even cultural background can affect ergonomic design.

Within a gender, the 5th through 95th percentile range will cover 90% of people, only the uppermost and lowest 5% are outside the range. In a mixed population, samples where half of the group is male and the other half female, the 5th through 95th percentile range covers 95% of people. This occurs because only the top 5% of men and bottom 5% of women are excluded. If only half of the sample are men and half are women, then: 2.5% + 2.5% = 5% of the total sample to be excluded.

A survey of a large population typically results in a **Gaussian Distribution**, also known as a **Normal Distribution** of measurements, in which the highest numbers correspond with the mean or average value and the other members of the population are distributed evenly about the mean in an ever decreasing amount. The distinctive shape of the distribution results in its common description as a **bell curve**. The distribution is defined by two basic measures, the Mean, described above, and the Standard Deviation. The standard deviation is a measure of the dispersion of values about the mean and is represented by the Greek letter sigma (σ). The Normal distribution presented in Figure A 1.1.3a is shown with the standard deviation divisions on the *x*-axis. As indicated, the area bounded by ±1 standard deviations represents approximately 68% of the population, while approximately 95% of the population is bounded by ±2 standard deviations.

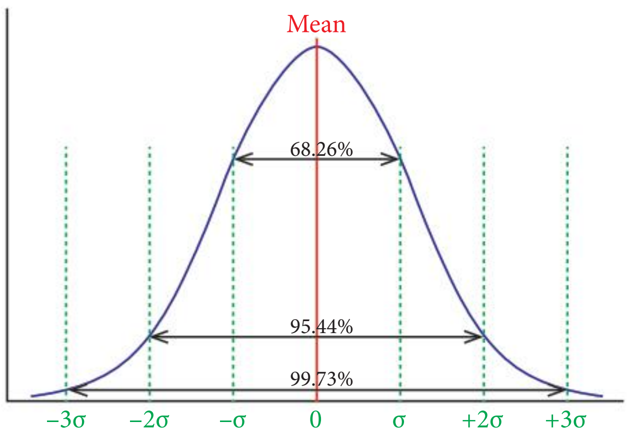

Figure A 1.1.3a *Normal population distribution*

Designers cannot accommodate every user, extremes of any population sample will always require special consideration.

An example of a product using only the 95th percentile would be the standard architectural doorway. The tallest people should then be able to negotiate the opening. The 5th or 50th percentile people being smaller in stature would naturally be catered for in this design as well.

Conversely, 5th percentile data only may be used in such instances as vehicle controls where ease of reach would be the determining constraint. Here, data as low as the 5th percentile may be required to gather in a sample population, including those with the shortest of reaches.

Even though designing for the mean seems to make sense, the majority of people are excluded, i.e. outside the range of this group. Designing for the average user can also be difficult if the range of users crosses age and/or gender boundaries.

A design context where 50th percentile data has been used relates to the development of crash test dummies. In 1971 General Motors created Hybrid I, a crash test dummy modelled on the 50th percentile male, i.e. it was developed from data recording average male height, mass, and proportion. Hybrid I was a redesign of 'Sierra Sam', a 95th percentile male dummy (heavier and taller than 95% of human males) used by the aviation industry to test emergencies involving: ejection seats, aviation helmets and pilot restraints.

The lack of vehicle data available for occupants other than a male driver left women and children outside of design considerations. This historical focus on exclusively male crash test dummies resulted in a significant gap in safety data for women and children, who were largely excluded from vehicle safety design considerations. It was not until the 1980s that a female crash test dummy was introduced. This initial model was essentially a scaled-down version of the male dummy, representing a smaller female body but failed to account for the anatomical differences between males and females.

In 2022, Swedish researchers made a significant advancement by developing a crash test dummy that accurately reflected the female anatomy. This new dummy is specifically designed to capture more precise crash test data, particularly regarding injuries that women are more likely to sustain.

The THOR 5th ATD shown in Figure A 1.1.3b represents a 5th percentile female, and is an advanced, biofidelic anthropomorphic test device (ATD) that is designed around women's unique physiology. This development aims to enhance the accuracy of safety data and improve vehicle safety standards for all occupants.

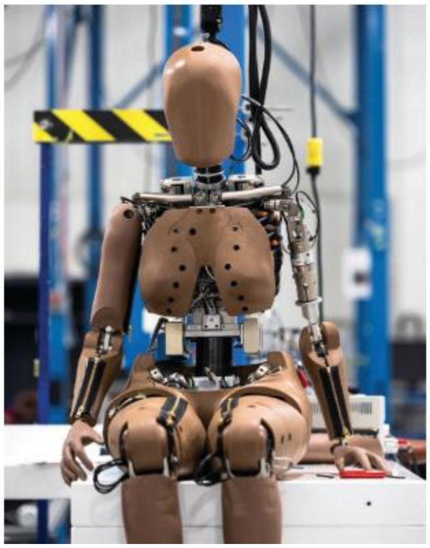

Figure A 1.1.3b Female Crash Test Dummy - THOR 5th

The crash test dummy family, Hybrid III, shown in Figure A 1.1.3c, now consists of a male, a smaller female and three children based on data replicating a 6-year-old, a 3-year-old and a 12-month-old infant. The use of these models generates very different data than that gathered from the earlier testing of male models. The development of crash test dummies to now incorporate percentile range models across strategically selected age groups is a good example of where particular user groups are identified within a very specific design context.

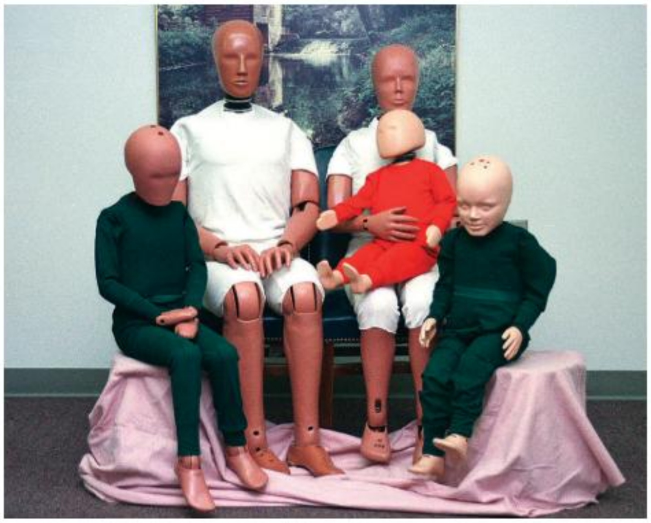

Figure A 1.1.3c Hybrid III, Crash test dummy family

Many products developed for children will also require careful consideration of anthropometric data and ergonomic design. Specifically, the designing of computer furniture for primary school age students is a complex issue requiring consideration of a large percentile range, 5th–95th, across genders and encompassing significant age variation. Appropriate design would encourage correct posture, reduce fatigue, facilitate ease of use and avert long-term health problems.

A 1.1.4 To ensure products are appropriate to a range of percentiles, designers can choose to design products to be adjustable and/or to be produced in a range of sizes.

Designing for adjustability means that provision is made within the design for adjustments to accommodate the anthropometric variability between members of the user group. In other words, adjustability avoids anthropometric mismatch. These adjustments can be performed using mechanical, electrical, pneumatic or hydraulic means.

Most cars, for example, incorporate systems to adjust seat height and steering wheel position. Similarly, many office chair designs allow height and back rest tilt adjustment. Domestic equipment such as an ironing board is also manufactured with several height adjustment positions to increase the population that can use it in an ergonomically appropriate position.

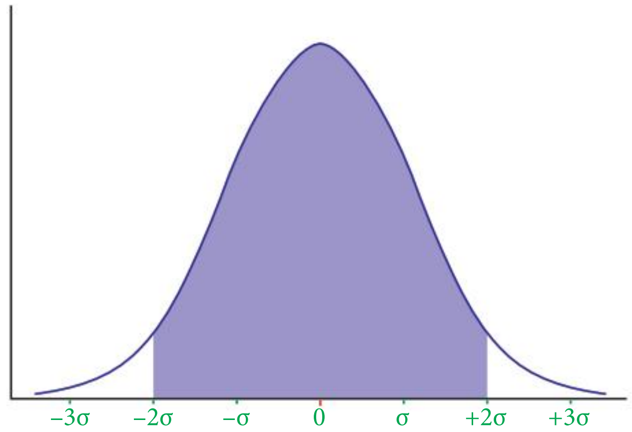

Figure A 1.1.4a represents a population distribution curve in which the broad population range is accommodated due to the inclusion of device adjustability in the design.

The commonly chosen design range of 5th—95th percentile of a population is a trade-off that allows for the inclusion of almost everyone in a design context and only excluding the extremes. The practice of catering for a larger percentile range is often called 'design for more types'. Traditionally, using a range from the 5th to the 95th percentile, it is deemed to provide the best coverage without being skewed by extremes, i.e. the greatest 5% and the least 5% in the data range. Products designed to meet these requirements would include furniture, household appliances, 'one size fits all' free-size clothing, etc. Consumers outside this range often have to seek customised solutions to meet their needs.

The fashion industry may employ both adjustability and a range of sizes to garments designed with adjustable features, such as drawstrings, elastic bands, belts and adjustable straps. These features may be applied to allow consumers to customise the fit of their clothing, making it more comfortable and a better fit to their body shapes.

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A 1.1.5 In design, consideration must be given to work envelopes, reach, clearance, adjustability and range of sizes.

When considering adjustability, the percentile range generally considered appropriate is the 5th percentile of females and the 95th percentile of males. Because of the overlap in dimensions of the male and female population, this regime would account for 95% of the user population as calculated previously. This would be the case if human dimensions were always in the same proportion.

Unfortunately, human dimensions are not always in the same proportion, and a tall person can have short arms, and a short person may have proportionally longer arms.

Multivariate analysis is used to account for all variations and means that more than 5% of the population may be excluded on one or more dimensions if using the 5th to 95th percentile range.

However, the cost of accommodating all possible combinations increases dramatically past this range and in most situations is not justified. Figure A 1.1.5a shows an operator sitting on an adjustable chair in front of a computer screen that is also adjustable. While the desk may be of a standard design and height, the other elements in the arrangement together should accommodate most of the user population.

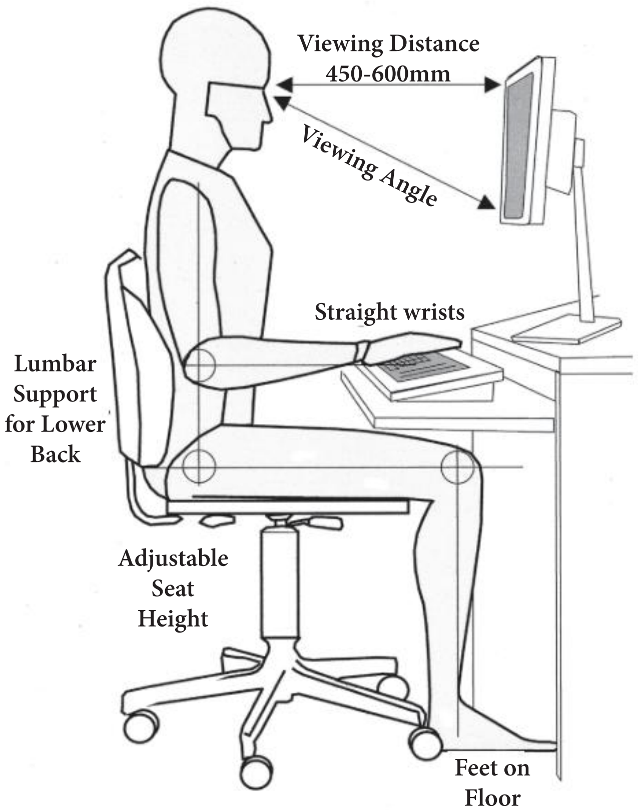

Figure A 1.1.5a Simulation of seated figure at workstation after adjusting equipment appropriately

In this situation, the most important limiting factors relate to the reach of the individual's arm. The reach envelope for a range of users is defined as a three-dimensional space.

Reliable data is required to develop an appropriate response to reach envelopes when considering a broad population sample. Data may be gathered from anthropometric tables, dynamic measurement or through the use of software simulations. These data can be affected by such restrictions as clothing.

Traditionally, measurements were taken manually but in recent years video has also proved to be an effective tool for gathering data. Figure 1.1.5b shows operational areas of an individual from the axis of bilateral symmetry.

The sketch shows normal and maximum working areas in the horizontal plane, Data applications here include desk workspace, kitchen and bathroom design.

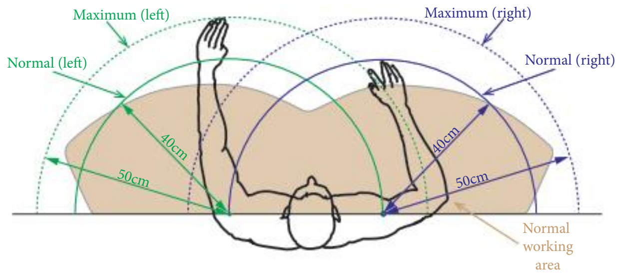

Figure A 1.1.5b A simple work space envelope

A 1.1.6 Physiology is the study of systems and biomechanics within the human body, their responses, limitations and capabilities.

Physiological data refers to information gathered focusing on the functioning of an individual's major organ systems. The systems they refer to, and some of the data gathering that takes place, are shown in the table below.

System	Data gathering
Heart	Heart Measuring heart activity, blood pressure, heart rates, etc.
Brain	Measuring responses concerning central and peripheral nervous systems
Sight	Eye movement, tracking etc.
Respiration	Lung capacity and oxygen exchange
Hearing	Audiology and balance information

Figure A 1.1.6a Physiological data collection

An example of the use of biomechanics appears in the area of sporting equipment design. The study and use of biomechanics can lead directly to better designed sporting equipment manufactured to enhance an individual's performance, reduce fatigue or prevent injury. These products are manufactured and customised for the needs of elite athletes but may be mass-produced for use by recreational sportsmen and women. Equipment examples include choice of more responsive materials for tennis racquets and golf clubs, swimsuits creating less drag and damping technologies built into javelins to reduce vibrations induced by forces applied transversely during their initial acceleration.

Biomechanics is the study of the mechanical laws relating to the movement of living organisms, particularly concerning animals and the human body. Within the design of any device or product, several assumptions are made by the designer regarding the biomechanical capacities of the user population. That is to say, that successful operation assumes that sufficient pressure will be able to be brought to bear to push and activate a button, or toggle a switch on a control panel, or that sufficient force can be applied to turn the handle of a can opener or corkscrew.

While assumptions are made in designs, these assumptions are based on anthropometric measurements establishing the population distributions for capabilities such as strength, dexterity and fine motor control.

Age-related muscle weakness and several medical conditions such as Arthritis, Parkinson's disease, Multiple Sclerosis, etc. can significantly impact assumed capabilities. To accommodate these groups of users, special adaptations or modifications may be required either to the original design or through the development of adaptive technologies that amplify biomechanical capabilities such as those shown in Figure A 1.1.6b.

Figure A 1.1.6b Biomechanical aids

Biomechanical engineers examine the application of engineering principles and practices to everyday situations. Through the careful study of how people physically interact with products, biomechanical engineers design or re-engineer products to feel comfortable, prevent or mitigate injury and enhance human performance.

Applied to the entire population range, young, elderly and those with a disability, biomedical design involves a process called **design for inclusion**.

Backpacks, child safety harnesses and tennis racquets are just some of the products that biomechanical engineers use their knowledge and creativity to design and test. Biomechanical analysis may be employed to examine the data field of events surrounding the use, misuse or difficulties associated with a product design. It may also produce results surrounding age appropriateness of equipment.

In many occupations and leisure activities, some form of protective helmet must be worn, which will add to the load that must be resisted by the muscles of the neck. This is of particular concern to sections of the armed services and search and rescue, where extra equipment such as night vision goggles or a heads-up display (HUD), units may be attached to the front of the helmet to improve and enhance visual acuity.

Product designers should also carefully consider biomechanical data when developing packaging. As a demographic, older consumers often have difficulties opening packages including lids on jars, soft drink bottle tops, ring pull openers and child-resistant screw caps. Reduced muscle strength, dexterity and complications associated with diseases such as Arthritis make it difficult for older individuals to open packages. Better designed packages or assistive devices that provide grip and a mechanical advantage would make simple tasks such as opening a container much easier.

Figure A 1.1.6c shows a plastic covered metal device designed to open a range of jar lids. The force required to open the jar has been lessened through the mechanical advantage produced by the length of the utensil lever arm. The frictional grip force required by the hand has also been enhanced through the introduction of a serrated metal contact strip.

Figure A 1.1.6c metal jar opener

The cone-shaped flexible rubber moulding shown in Figure A 1.1.6d fits a range of lid sizes and relies on the frictional resistance generated between the lid and the rubber utensil. The soft grip material improves the user's feel of the lid.

Figure A 1.1.6d Soft-grip jar opener

This four-in-one jar opener, pictured in Figure A 1.1.6e, uses a 2nd order lever to supply a mechanical advantage. The rubber-lined metal construction provides a strong body with a high coefficient of friction.

Figure A 1.1.6e Lever-based opener

Colour perception significantly impacts product design. Colours enhance the visual appeal of a product, making it more attractive and desirable. Bright and vibrant colours can make a product stand out, while neutral colours can create a sense of elegance and sophistication.

Colour contrast is crucial for readability. High contrast between text and background improves legibility, making it easier for users to read and understand information on everything from packaging to mobile phone screens.

As a feature of inclusive design, consideration of users with colour blindness and other visual impairments may be addressed by employing colour combinations that are easily distinguishable. Colour contrast checkers assist designers in this area.

Consistent use of brand colours helps reinforce brand identity and recognition. Colours become associated with a brand's values and personality. These colours, when adopted as a company logo, help differentiate products from those of competitors. The use of gold, silver, and black are often perceived by consumers to convey luxury and exclusivity.

Colour is also linked to contextual relevance, e.g. the use of camouflage colour schemes to allow products such as clothing to blend into the environment. Equally so, the use of bright colours may be employed as a safety feature to make products such as lifeboats stand out and be highly visible in the environment.

Visual data

For normally sighted individuals, visual information is often the most important. For this information to be useful, it needs to be unambiguous, conveying relevant information when and where it is needed in a manner that is meaningful and free from distracting clutter.

It is the designer's job to ensure that considerations of visibility are taken into account concerning how the operator is to use the information. For example, visual clues should be provided that indicate how equipment should be used. If a door opens in only one direction, push or pull should be displayed. Figure A 1.1.6f shows a commonly used L-shaped door handle on a door on which a sign indicates the action required to open the door.

Figure A 1.1.6f Door handle sign

Figure A 1.1.6g shows a highly visible ocean-going lifeboat. Orange is used because it is the most visible colour to the human eye, even in poor visibility or at night. Emergency rescue lifeboats are orange so they are easier to spot in emergencies, especially when they are far away, or if they are in the water. The bright colour is also meant to draw attention to the boat, making it easier to find in the event of an emergency. The orange colour provides a stark contrast against the blue of the sea, making it easier for rescue teams to spot them in dark, low light or foggy conditions.

Figure A 1.1.6g Highly visible lifeboat

Hearing thresholds

Designers incorporate the sense of hearing into their designs in various creative ways to enhance the overall experience and for a variety of purposes. Some examples are listed below.

- **Safety:** Volume limiters may be enacted as software or hardware components on devices such as headphones. Safe volume limits may be determined for children as well as adults to reduce the deterioration of hearing due to listening at high volumes for extended periods

- **Privacy:** Soundproofing or treatment of spaces where noise reduction/transmission may be an issue e.g. office spaces, bedrooms. Soundproofing may be conducted to prevent noise ingress, egress or both.

- **Alarms:** The acoustic properties and intensities of alarm signals are engineered to ensure effective transmission and penetration across various groups of individuals. This strategic design serves to deliver timely warnings and prompt corresponding actions, such as in the case of police or ambulance sirens, and fire or smoke alarms.

- **Environments:** Acoustic treatment of surfaces reduces echoes and reverberations, which make it difficult to understand speech or appreciate musical performances. It assists with ensuring sounds are clear and decipherable without distortion.

SL

A1.1.7 Psychology is concerned with the study of the human mind and involves the study of all the human senses that may be involved in sending information to the brain.

Psychological factors are those that impact operations, including the effects of environmental conditions such as stress, lighting, temperature, humidity, noise, vibration, etc. Psychological human factors data is used in the design and improvement of many products. The effectiveness of a product can be affected by an individual's reaction to a range of external sensory stimuli. Design should take into account these factors to improve the user experience. A range of influencing factors is included in the table below.

Stimulus	Factors affecting
Sight	Ease of visibility, readability of computer screens
Hearing	Pitch, frequency, volume, mobile phones
Sight	Eye movement, tracking etc.
Touch	Texture, grip, friction, temperature, keyboards, dentistry tools
Taste	Ingestion of toxins from children's toys
Smell	Aroma, perfume, odours in workspaces

Figure A 1.1.7a Psychological factors

An example of the incorporation of psychological data into product design is the development of a mobile phone. Mobile phone design is carefully considered when targeting specific markets. Design variations in colour, shape, materials, use of backlighting and surface finish are all carefully combined to be attractive to different consumer groups.

It is not just the functions and services available that sell mobile phones. Physical design variations that attempt to meet an individual's psychological needs are also of importance.

Figure A 1.1.7b Mobile phone design

Environmental psychology studies the relationship between an environment and how it affects its inhabitants. Typical psychological human factors to be considered when designing an indoor office environment, it would include:

- lighting
- acoustics
- air quality
- temperature
- worker densities.

Thermal comfort, particularly in office spaces, can be a critical factor in determining staff morale and productivity. Air temperature, such as radiant temperature, has the strongest influence on humans due to the absorptive nature of the human body. Higher temperatures can lead to worker heat stress and eventually heat exhaustion.

Thermal comfort for office spaces can be difficult to achieve, however, considering there would be a range of psychological responses to the environment.

It is generally considered that when 80% of a given population feels comfortable then a situation of 'reasonable comfort' is achieved. Air temperature alone, however, is not a valid indicator of reasonable comfort. Many other factors influence workspace comfort for employees and are essentially grouped into the following factors.

- Air quality is often dealt with in the form of air conditioning to assist with controlling ventilation, movement of air and humidity. It may also filter pollutants from the environment. Unfortunately, air conditioning may also generate problems such as air movement, less than optimal temperatures, noise, etc.

- Building acoustics in the form of quiet spaces encourage concentration by minimising noise that may cause distractions and disruptions.

- Lighting includes opportunities for the provision of natural lighting and views to the outside. Adjustable task lighting also allows individuals the ability to control lighting conditions to their liking and relative to the task being undertaken.

- Worker densities and the creation of adjustable and adaptable spaces supplying space that is flexible enough to be personalised to fit an individual's work style.

Open-plan offices are often developed to allow for greater worker density. They also allow for larger amounts of unrestricted space. This may be in the form of reducing the number of interior walls and replacing them with partitions or in some cases, reducing the size of partitions themselves.

The purpose of removing or lowering walls is to remove barriers to communication and provide people with the feeling or perception of space. Partitions of reduced size, also allow freer movement of air and distribution of light from windows. The disadvantages associated with this, however, include the reduction of barriers to general noise transfer, reduced personal privacy and the opportunity for greater visual distraction. Standard space allocations in offices are often based around the requirements of job-specific tasks, seniority or status within an organisation.

While open-plan offices free up communication and provide more public space, there also exists a need for individuals to have their own space. The amount of personal space an individual requires varies and may be influenced by culture or upbringing. This comfort zone or personal space is also known as, 'defensible space', a term coined by John Calhoun in the 1940s. Defensible space is incorporated into office design to overcome the sense of overcrowding and the negative behaviours or feelings this may create. Through the judicious use of barriers or partitions, personal spaces may be created while still maintaining an open plan.

The creation of areas such as this allows employees to customise their space within an office space and improves the individual's feeling of comfort, safety and control.

Office space designers may use the "Physical Work Environment Satisfaction Questionnaire," (PWESQ), to measure worker satisfaction and better inform their designs. This tool takes into account aforementioned environmental factors relative to a worker's occupational health and safety but also includes physical demands,work systems.

Linking questions

- How are user-centred research methods used to collect human factor data? (A2.1)

- Which aspects of ergonomics are appropriate for user-centred design (UCD) practice? (B1.1)

- How does ergonomics affect modelling and prototyping of potential design solutions? (B2.2)

- How important is ergonomics to inform effective inclusive design? (C1.2)

Sample questions

1. Human factors design is also known as:

   A. ergonomic design

   B. ergonome design

   C. workplace design

   D. anthropometric design.

2. Ergonomics involves:

   A. designing new products

   B. designing for aesthetic appeal

   C testing products in extreme environments

   D. designing for people and their interaction with products.

3. Designing for adjustability provides:

   A. del spacefor arthroscopic investigations

   B. caters for ergonomic adjustability

   C. designs that consider anthropomorphic variations

   D. del means for adjustments to accommodate anthropometric variability.

4. A Work envelope is a:

   A. container for business mail

   B. reach space determined by a specific individual

   C. measuring of the highest and lowest point an .individual can reach

   D. reach perimeter for a range of users, defined as a three-dimensional space.

5. Biomechanics is the study of:

   A. biological robots

   B. surgical implants

   C. mechanical laws relating to the movement of living organisms

   D. products are manufactured from materials of biological origin

6. Explain how the study and use of biomechanics can lead to the design of better products

7. Outline the key differences between physiological and psychological factors.

8. Explain what the following data reveals about a student who scored 70 on the test, with their score falling between the 30th and 70th percentiles relative to the rest of the class.

9. Outline the benefits of ergonomic design, citing specific examples.

10. Explain in terms of anthropometric data why there is no such thing as an 'average' human.

Bibliography

Figure A 1.1.1a Microsoft Natural Ergonomic Keyboard 4000. Modified from: Mliu92, CC BY-SA 3.0, via Wikimedia Commons https://commons.wikimedia.org/wiki/File:Microsoft_Natural_Ergonomic_Keyboard_4000.jpg

Figure A 1.1.3b Female Crash Test Dummy - THOR 5th Lin Pan, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Figure A 1.1.5a Simulation of an operator sitting at a workstation after adjusting equipment appropriately, and

Figure A 1.1.5b Work space envelope, Bolumena (own work) GFDL (www.gnu.org/copyleft/fdl.html), via Wikimedia Commons and https://ergo.human.cornell.edu/ErgoPROJECTS/PRI02/PRI%20final.html

Figure 1.1.7b Mobile phone design Thom Cochrane, CC BY 2.0, via Wikimedia Commons

Figure 1.1.6g Highly visible lifeboatModified from: Roberta F., CC BY-SA 3.0, via Wikimedia Commons https://upload.wikimedia.org/wikipedia/commons/3/34/Life_boat_ri_p_170909.jpg

USER-CENTRED DESIGN (SL)

Contents

B1.1

SL

Guiding question

How does understanding user needs directly impact the design of products and services?

> B1.1.1 User-centred design (UCD) requires a plan to structure an inquiry using user-centred research methods.
>
> © IBO 2025

User-centered design (UCD) focuses on understanding the needs, preferences and limitations of end-users throughout the product development process. It involves actively engaging users in an iterative process, gathering feedback and using that information to prioritise the user when creating products and services that are usable, accessible and enjoyable. Below are a series of questions. Depending on the context, these questions may be used in surveys, focus groups, interviews, etc.

Understanding User Needs

- Who is the target market?
- What are the critical functions users need to achieve with this product?
- What problems are an issue for users of current product solutions?
- What are the product expectations of users?

Context of Use

- What environmental or contextual considerations need to be accounted for when users interact with this product?
- What products are currently available that meet the needs of the design brief?
- What physical, social, or cultural factors need to be considered and taken into account?

User Experience

- What are users' expectations for this product?
- Is this a new problem?
- How do current products solve the issues in need of addressing?
- What do users consider product-critical features?

Usability and Accessibility

- What user accessibility issues need consideration?
- What usability issues are dealt with by currently existing products?
- How can the product be developed to be intuitive in its use and provide an ease of learnability?

When planning the user-centered design (UCD) process, designers must address several critical considerations, including:

- Determining optimal methods for gathering and incorporating user feedback.
- Selecting appropriate techniques for data collection, analysis and presentation.

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- Ensuring insights, decisions and iterations derived from user data are effectively integrated into the overall design process.

These elements are pivotal in developing a design that meets the needs of its intended users.

The traditional aeroplane cockpit:

...has become the modern 'glass cockpit'. There is extra information such as weather radar. However, the traditional information such as attitude, altitude, airspeed etc is mainly in the nearest panel.

B1.1.2 UCD uses specific research methods to target persona populations and it develops empathy and understanding of users' demographics.

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Field research

Field research involves observing people in their natural environment to obtain an understanding of their needs and normal behaviour and is typically carried out early in the design process. Techniques commonly employed include:

- field trials
- ethnographic[1] interviews
- observation of everyday activities.

Because field research is conducted in the natural environment

- data is obtained in the context of use
- previously unrecognised issues are discovered
- there are no artificial effects generated from evaluations such as those occurring in laboratory testing.

Method of extremes

As the name implies, the 'method of extremes' looks at the extremes of the user population distribution. These positions along with the mean are used to design equipment used for general use.

Doorways, ladders, step heights and escape hatches are based on the 95th percentile of males while the forces required to operate control panel buttons are based on the 5th percentile of females. By adopting these extremes the greatest number of users is accommodated. By its nature, this form of design will not include those members of the population that lie beyond the extremes chosen.

Designing for 'extremes' or 'extreme users' often includes, and even prioritises, considering the needs of people with disabilities, as they represent a group facing unique

1 the scientific description of peoples and cultures with their customs, habits and mutual differences.

challenges that, when addressed, can lead to better designs for everyone. Because people with disabilities can include people with particular needs outside of the able-bodied 95th percentile population, designs that include this population are often referred to as 'universal design'. In this sense, 'universal design' differs from 'designing for extremes' by aiming to create designs that are usable by all people to the greatest extent possible, without the need for adaptation or specialised design.

Observation, interviews and focus groups

Observation involves watching users as they use a product. Observations may be undertaken in the controlled environment of a laboratory or the field within the normal environment of the user. The purpose of observation is to gather information on the way a product is used and any problems of usability that are encountered.

For observation to be an effective usability technique, the effects that the presence of the observer may have on the actions of the user need to be recognised and steps taken to minimise such effects. Some advantages of observations are listed below.

- Potential to uncover previously unrecognised usability problems.
- Products are tested under actual conditions of use.

Disadvantages of observation

- Data can be complex to analyse.
- Noise represented by the environment may disguise small effects.
- Observation is usually only performed on finished products/systems.

Interviews involve the observer interacting directly with the user to ask questions regarding issues of usability and can take several forms, they can be structured, semi-structured or unstructured.

Unstructured interviews use predominantly open-ended questions. These are questions that require more than one or two words to answer and allow the interviewee to answer in their own words. Typically these questions take the same form as examples listed below.

- What did you find were the most useful features?
- Were there other features you would have liked?
- In what situations do you think this product would be most useful?

Because some ideas of the issues known to be of concern have already been discovered, questioning can be more specific but still seeks comprehensive answers from the subject being interviewed. While the questions asked may still be open-ended in nature, the interviewer will attempt to restrain answers to the topic and may prompt responses where necessary.

Advantages of unstructured interviews include:

- The interviewee has the opportunity to ask for clarification if the intent of the question is not clear.

Disadvantages of unstructured interviews include:

- interviews can be time-consuming
- relatively small groups may not represent all issues with usability
- respondents are not anonymous and therefore answers may be influenced by an attempt to please the interviewer.

Structured (standardised) interviews or researcher-administered interviews typically ask closed questions for which a set of fixed responses are provided or only a simple yes or no reply is required. The primary purpose of structured interviews is to ensure a fair, objective and consistent evaluation by using a standardised set of questions and evaluation criteria.

Structured interviews allow for a more focused assessment of the user requirements, as questions are designed to address specific needs such as the example below.

Did you like the positioning of the sound controls?

While structured interviews generally follow a fixed set of questions, they can allow for follow-up questions to clarify ambiguous answers, explore specific areas in more detail, or delve deeper into interesting points that arise during the interview.

In pursuing such a course, the interviewer may rate the usability similar to that of a Likert type scale questionnaire. Developed by the American social psychologist Rensis Likert in 1932, it is used to measure attitudes and opinions, by asking for an evaluation on a scale typically ranging from 1 to 5.

Although Likert surveys are not a form of structured interview, they can be used within a structured interview or as a standalone data collection method. Likert surveys are structured questionnaires that use a scale to measure opinions or attitudes. Structured interviews involve a standardised set of questions asked in a specific order, that may involve follow-up questions to further clarify answers regarding degrees of satisfaction.

Advantages of structured interviews include:

- Research suggests that structured interviews are better at predicting actual user experiences compared with unstructured interviews
- Standardised format and questions, ensure consistency across all user participants, leading to more reliable and valid assessments.
- The standardised format allows for easier data collection and analysis, making it easier to compare and assess the user experience.

Disadvantages of Structured interviews include:

- While offering consistency, the predetermined nature of questioning can result in limited flexibility that may restrict follow-up or more nuanced questioning.

Focus groups are an evaluation tool commonly used in market research and usability testing to gauge the opinions and experiences of the public in relation to a specific topic. Focus groups are generally small with no more than 8-12 participants, facilitated by a leader. The focus group leader/facilitator has many duties including:

- to introduce the topic
- maintain the discussion, should it begin to stall
- ensure all participants have an opportunity to express their opinion
- redirect the discussion on topic without stifling interaction between the participants.

Advantages of focus groups include that they can:

- uncover previously unrecognised usability problems
- be used throughout the design process, but are particularly useful in the early design stages.

Disadvantages of focus groups include:

- data is predominantly qualitative
- difficulties in group dynamics can arise, which may be disruptive
- relatively small groups are interviewed and may not represent all issues with usability.

Questionnaires

Self-administered questionnaires consist of a printed list of questions that are provided to a respondent to be read and completed by the respondent without any outside interference.

As was the case for an interview, the questions again generally fall into one of two groups:

- Fixed-response.
- Open-ended response.

Fixed-response questions are aimed at obtaining quantitative data and consist of questions with a selection of responses, from which the respondent is asked to choose, or a rating scale in which a level of agreement or disagreement is sought. A commonly used fixed response questionnaire of this type uses what is known as a Likert scale (see Figure B 1.2a), which is usually organised from ‘strongly dislike’ through to ‘strongly like’ or ‘strongly disapprove’ through to ‘strongly approve’ etc. Such a scale can have a numerical value assigned to each choice for later analysis.

Website User Survey

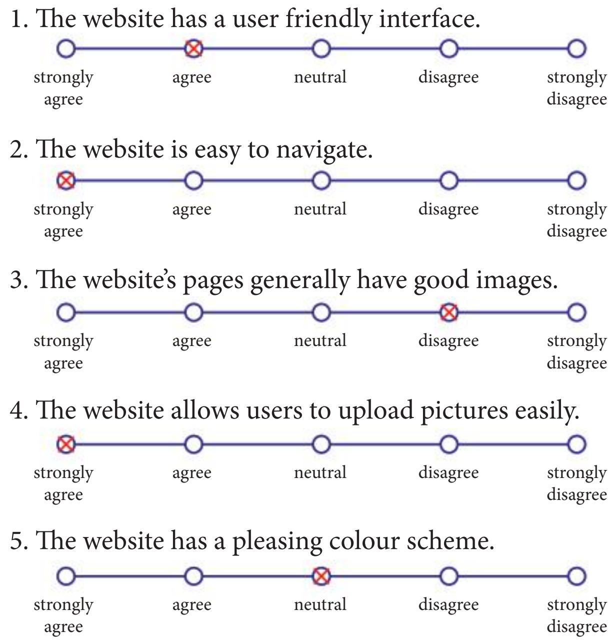


Figure B 1.1.2a Likert style questionnaire CC BY-SA 3.0

In these questionnaires, a final summation and averaging of the responses provides an overall determination of the participant's evaluation. The evaluation of this participant can then be analysed along with responses from other participants using statistical methods for factors such as age, gender, etc.

A primary requirement of fixed response questionnaires is that they have been evaluated for reliability and validity. Reliability relates to the repeatability of the response to the question, while validity is concerned with the degree to which the question measures what is intended. Such instruments can take considerable time to construct and validate, since the aim of being able to determine a final overall number requires that the questions be of equal value.

When measuring usability, there are some standard fixed response questionnaires available that have been evaluated for reliability and validity. One of these is the **System Usability Scale (SUS)** developed by John Brooke in 1986. The SUS represents a widely used example of a Likert Scale employed to evaluate product usability. An example is provided below in Figure B1.1.2b of the type of questions included in this questionnaire from the "Ten Question System Usability Scale" (SUS), ©Digital Equipment Corporation.

The questions alternate from good usability scoring highly on the odd numbered questions to low scoring on the even questions.

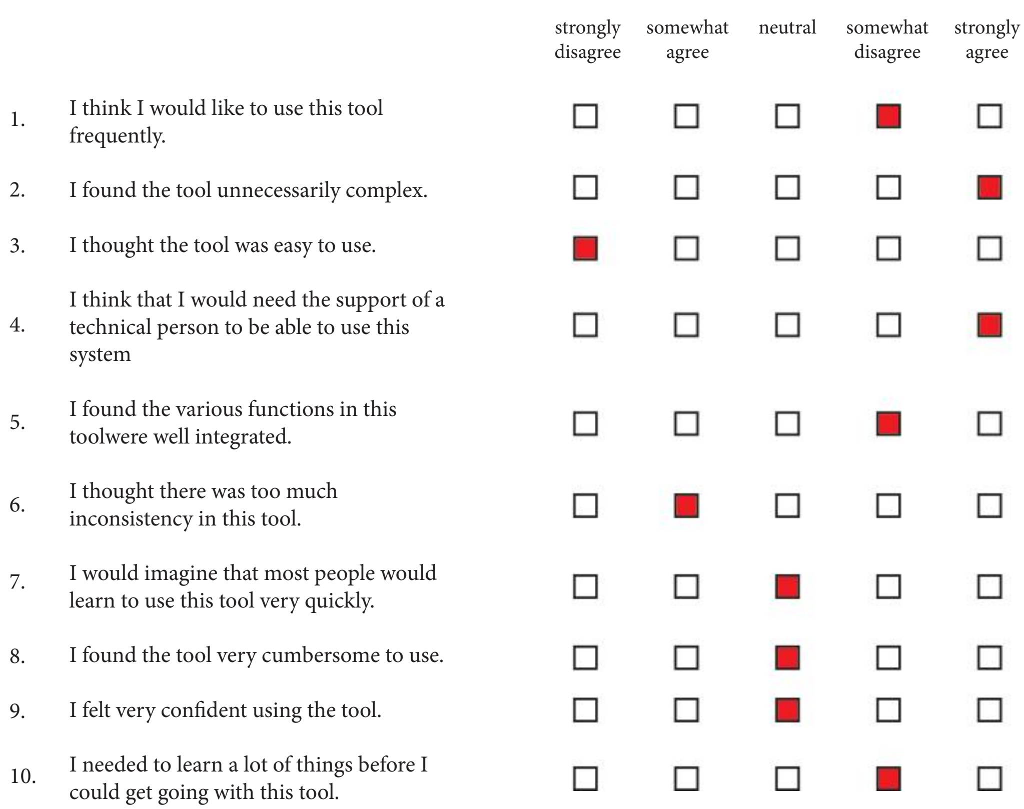


Figure B.1.1.2b System Usability Scale (SUS)

The formula for computing the final SUS score requires converting the raw scores, as indicated below, to obtain an SUS score between 0 and 100.

- For odd-numbered questions (1, 3, 5, 7, 9), subtract 1 from the user's response.
- For even-numbered questions (2, 4, 6, 8, 10), subtract the user's response from 5.
- Add up all the adjusted scores.
- Multiply the sum by 2.5.

This calculation is based on the response shown in Figure B1.1.2b would be:

SUS = 2.5 ((Q1–1)+(Q3–1)+(Q5–1)+(Q7–1)+(Q9–1) + (5–Q2)+(5–Q4)+(5–Q6)+(5–Q8)+(5–Q10))

= 2.5 ((4–1)+(1–1)+(4–1)+(3–1)+(3–1)+(5–5)+ (5–5)+(5–2)+(5–3)+(5–4))

= 2.5(3+0+3+3+2+0+0+3+2+1)

= 2.5 × 16

= 40

The average SUS score across various industries and products is around 68, with higher scores indicating increased usability while lower scores such as that above suggesting usability issues.

Open-ended questions: in contrast to the fixed-response type, questionnaires using open-ended questions allow the respondents to answer in their own words. While these questions have the advantage of potentially uncovering previously unexpected information, they also require considerably more time to analyse.

Questionnaires that use open-ended questions tend to gather qualitative data and are often useful when a designer is attempting to determine the important issues.

Open-ended response questionnaires are therefore particularly useful in the early stages of the design process, compared to fixed-response questionnaires which tend to be used in later evaluations of the design.

Advantages of questionnaires include:

- they can cover a wide geographic area
- interviewer observation bias is eliminated
- a large number of questionnaires can be sent, potentially surveying a large sample group.

Disadvantages of questionnaires include:

- unless respondents are guaranteed of anonymity accurate information may not be provided
- typically only a fraction of the questionnaires sent out are returned
- those questionnaires that are returned may represent a biased population in that only those interested may respond.

B1.1.3 Data collected from user-centred research is used to determine personae that represent attributes of user populations.

Large groups can be defined in terms of common characteristics such as age, gender, physical condition, handedness, ethnicity, etc. User research group classification tends to be defined in terms of common goals or needs. A group defined in this way is referred to as a user population. In usability research, a profile or persona is often created to describe the group. In developing a group persona, heavy reliance is placed on information obtained from field trials recording user experiences and requirements.

The persona developed represents a generalisation of a group and allows designers to test their designs against the requirements of a defined user group.

The use of personae, secondary personae and anti-personae in user research.

Personae are fictional constructs derived from ethnographic research and field trials that allow those involved in user research to focus on the behaviour of a user group with common goals and identify general issues and themes. As suggested above, while personae are fictional constructs, they are not hypothetical as they embody the results of extensive ethnographic research.

A persona therefore embodies the information obtained during observation of a group rather than what group members say they would do as might be recorded using focus groups and surveys.

\Constructing a persona from a group with common goals, designers can:

- Allow design activities to be prioritised.
- Focus development activities on user goals.
- Gain an understanding of customer motivations.
- Identify opportunities and shortcomings within a Market.
- Test and validate design concepts against user requirements.
- Evaluate designs without the need for numerous usability tests.
- Avoid costly and time-consuming research surveying the whole user community.
- Create a standardised reference available throughout a project to provide consistency and reduce disagreements.

In any survey of user needs it is common for several interrelated groups to be identified, with many common as well as differing requirements. In this instance, several personae can be created representing the primary user population and secondary user populations identified as the

Primary and Secondary personae respectively

The goal of the design process is then to satisfy the requirements of the primary persona while extending usability to incorporate the extended needs of the secondary persona where possible. In contrast to primary and secondary personae user research, also defines an Anti-personae for whom the design is not intended.

To make the personae seem real and build empathy for them within the design team, a physical and social context is typically produced, often including a photograph intended to put a 'face' to the personae. Information included in the profile of a persona might be:

- age
- health
- gender
- interests
- activities
- life goals
- education
- motivation
- employment
- expectations
- marital status
- organizations/affiliations.

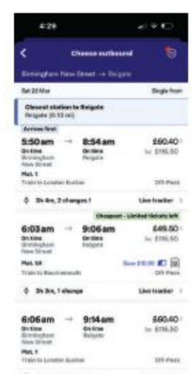
Anti-personae

The Nielsen Norman Group are a company who have worked in the field of UCD for more than 25 years. Their definition of an anti-persona is that it is "a representation of a user group that could misuse a product in ways that negatively impact target users and the business".

Anti-personae are developed to test for potential safety issues, security loopholes, risk of product damage, marketing, etc.

Companies such as McDonald's use anti-personae to establish marketing and communication practices to ensure they do not target or misinform vegans who would not want to purchase a hamburger.

Trainline, an online train journey booking site, uses an approach to their site that allows non-purchasers of tickets to plan a journey. This helps in ensuring a positive experience even when the user is not a paying client.



Anti-personae are also used in systems design situations to assist in developing defenses against hackers attempting data breaches, identity theft or malicious 'denial of service' attacks.

Use case

A use case is a written description of how a user will interact with a product/design as seen from the user's perspective. This analysis allows an insight into the usability of the product/design as experienced by the user. While personae have found extensive use in usability research and design, they are not without their critics who point out that:

- The size of the user group that a particular persona represents cannot be verified.
- The validity of the persona as an accurate representation of the user population cannot be independently assessed.
- The persona method still awaits peer review evaluation of its validity.
- Personae often contain ambiguities, allowing various interpretations that can lead to team conflict.
- Personae may represent stereotypical images of user populations which are damaging to the design process.

B1.1.4 Products can be analysed by using usability objectives to identify opportunities for improvement.

Often known as the '**five E's**,' these tools help to establish specific goals specific to usability

1. Effective (Functionality)
2. Efficient (Memorability)
3. Engaging (Satisfaction)
4. Error tolerant (Errors)
5. Easy to learn (Learnability)

Separating usability into specific features allows designers to focus on the individual components of the design independent of each other before bringing the design together in its entirety. This multidimensional approach both simplifies and extends the review process to produce a more holistic response meeting needs critical to the success of the product.

This process also uncovers key differences of the needs associated with various user groups, as some prioritise specific features over others.

The process should develop clear and concise statements about users' needs and generate clear areas of commonality and consensus between various user analysis groups.

The characteristics are usually examined via a set of precise objectives with measurable outcomes.

For example:

Effective (Functionality) Does the product meet the performance requirements of the majority of users?

Efficient (Memorability) 85% of registrations will be complete without any omissions.

Engaging (Satisfaction) Through a Likert test response, 90% of users indicate a high level of confidence in completing the task.

Error tolerant (Errors) All forms were completed satisfactorily through an error checking facility that required confirmation of correct information.

Easy to learn (Learnability) Intuitive design guides the user in a fashion that is predictable without the need for excessive help add-ons.

The five E's are designed to generate a set of data based on features that can be analysed to allow for future design iterations to then be retested.

The process enhances knowledge and the understanding of specific needs attached to each characteristic. It not only provides guidance for areas of future development but also indicates when the process is complete and specific benchmarks are achieved.

B1.1.5 A task analysis is a strategy used to develop empathy and gain understanding of how users perform a task to achieve their intended goal.

Task analysis, a cornerstone of user-centered design, provides a structured methodology for deconstructing complex user interactions into discrete, manageable units of analysis. This decomposition facilitates focused and detailed examination of user behaviors, cognitive processes and potential pain points within a specific task flow.

By systematically dissecting the task into its constituent sub-tasks, designers can gain insights into the intricacies of user-system interaction, identifying areas of cognitive overload, ambiguous instructions, or inefficient workflows. This unique perspective allows for the targeted development of iterative design improvements, addressing specific usability bottlenecks and optimizing the user experience.

In addition, task analysis serves as a valuable tool for bridging the gap between system functionality and user needs, ensuring that the design aligns with the actual cognitive and physical demands placed on the user.

There are two main approaches to task analysis: **Hierarchical Task Analysis (HTA)** and **Cognitive Task Analysis (CTA)**. These differing approaches to task deconstruction and analysis offer different pathways to the main objective that remains the same - a deep understanding of user behavior within the context of the task at hand. This rigorous approach to understanding user interactions ultimately contributes to the development of more effective, efficient and user-friendly systems.

HTA: Hierarchical Task Analysis (HTA) is a method for understanding and describing tasks by breaking them down into a hierarchy of goals, sub-goals, operations and plans, ultimately creating a structured, tree-like representation of the task. It's used in fields like Human Factors Engineering, UX design and software design to understand user tasks and improve system usability and design. HTA starts with a high-level goal and then systematically deconstructs it into smaller, more manageable subtasks, operations and plans.

CTA: is a method used to understand the cognitive processes, skills and knowledge required to perform a task effectively, which can then be used to improve training, design and user interfaces.

HTA and CTA can be used in conjunction to provide a comprehensive understanding of tasks, both in terms of their structure and the cognitive processes involved.

Task analysis is an iterative process, meaning it should be revisited and refined throughout the design lifecycle to ensure the product continues to meet user needs effectively. It is a process used by designers to understand how users understand and perform tasks and achieve their goals. It involves breaking down complex tasks into smaller, more manageable steps to identify potential usability issues and areas for improvement.

Steps in the task analysis process

1. Identify specific tasks users need to complete - achieved through observations, interviews and surveys.
2. Deconstruct each task into smaller, manageable chunks to help the understanding of sequence and complexity of actions required. It also reduces cognitive load.
3. Evaluate the individual tasks considering the user's actions, decisions, any potential problems, inefficiencies or pain points.
4. Document the results of task analysis using a range of tools including flowcharts, diagrams and notes. These notes serve as guidance for designs when reviewing the iterative development of the product around these specific tasks.
5. Retest the modified product with users to validate the efficacy of the design modifications to the product.

Advantages of task analysis

- Improves Usability: By understanding user tasks, designers can create more intuitive and user-friendly interfaces.
- Identifies Pain Points: Helps in identifying and addressing potential user frustrations and obstacles.
- Enhances Efficiency: Streamlines the design process by focusing on essential tasks and eliminating unnecessary steps.
- Informs Design Decisions: Provides valuable insights that guide the design of features and functionalities.
- Improved usability: Task analysis helps designers identify and address usability issues early in the design process, resulting in more user-friendly products.
- User-centered design: By focusing on how users perform tasks, task analysis promotes a user-centered design approach.
- Increased efficiency: Streamlining tasks and removing unnecessary steps can lead to increased efficiency for users.
- Reduced errors: designers can create systems that are more forgiving and prevent mistakes by anticipating potential user errors and making appropriate design modifications to deal with these issues.
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Disadvantages of task analysis

- Time-consuming: Conducting a thorough task analysis can be a time-consuming process, especially for complex tasks.

- Requires expertise: Effectively conducting task analysis requires knowledge of user behavior and design principles.

- Subjectivity: Some aspects of task analysis, such as identifying pain points, can be subjective and depend on the designer's interpretation.

- Limited scope: Task analysis typically focuses on individual tasks and may not capture the full user experience across multiple tasks or contexts.

Overall, task analysis is a valuable tool for designers to gain insights into user behavior and create more effective and user-friendly products. While it has some limitations, the advantages of task analysis often outweigh the disadvantages, making it an essential part of the design process.

Poka-Yoke

Poka-yoke translates from the Japanese to read mistake-proofing or error prevention. Developed by a Toyota engineer in the 1960s, this system focuses on the users and is designed to shape their behaviour in such a way as to prevent accidents, mistakes and errors. It complements the user-centred approach when designing systems, artifacts and environments.

Examples of Poka Yoke design applications:

- Battery placement: battery connections that only allow the battery to be installed in the correct orientation

- Child-proof medication caps: these caps require the joint operation of pushing and twisting to engage the thread and open the bottles, making them difficult for children to open.

- Colour coding and nozzle sizing: to distinguish diesel fuel pumps from gasoline.

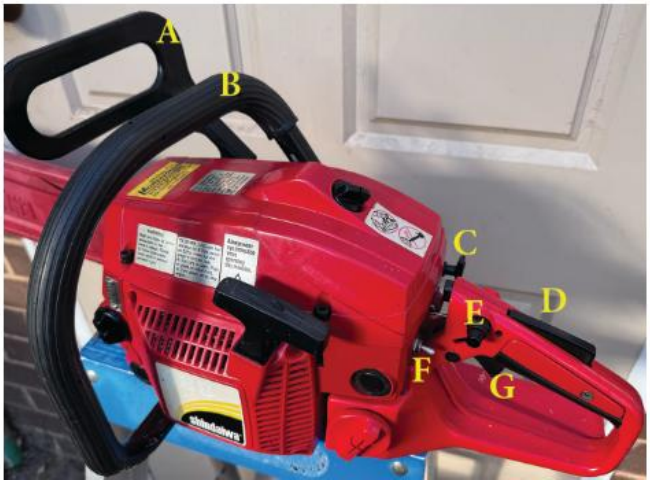
- Microwave oven: Operation of a microwave is only available if the door to the microwave is closed. Conversely, if the door to a microwave is opened, functionality immediately ceases.

- Medical checklists: to ensure all surgical sponges are accounted for after an operation and similarly with an instrument count.

- Limit switches: Often employed on machinery to prevent accidental travel of components beyond their intended limits, in the case of a lathe, preventing moving parts colliding.

Chain Saw

Chain saws are very dangerous machines. Even with all the 'designed-in' safety features, such machines should not be used by anyone who has not been trained by an expert.



This machine cannot be started at all without correctly setting the choke (C), the electrical switch (F) and the three triggers (E, G & D). It is unlikely that a child could start it accidentally.

The machine is heavy and cannot be lifted comfortably without one hand on B and the other on the trigger handle (G & D). This means that there is no free hand to accidentally get caught in the chain.

The chain can only be set in motion with D & G.

With the other hand on B, if the chain 'kicks' towards the user's head, the wrist of the hand holding bar B hits the automatic brake A, stopping the chain.

Even with all these features, users should still wear full protective gear (gloves, face mask etc,).

Sample Questions

1. UCD stands for

A. user-centred design

B. universal-centred design

C. user-centred development.

D. unconventional creative design

2. The "five Es" goals specific to usability are

A. Effective, Efficient, Engaging, Error tolerant, Eco-friendly

B. Effective, Educational, Engaging, Emotional, Easy to learn

C. Effective, Efficient, Engaging, Error tolerant, Easy to learn

D. Effective, Enterprising, Engaging, Experienced, Easy to learn

3. Intuitive design develops products that allow users to

A. play computer games easily

B. interact with the product in simple ways

C. interact with them replace with the product without extensive instructions

D. immediately see the consequences of their actions

4. During a product design interview, which of the following questions is most effective for understanding user needs?

A. "What is your favorite color?"

B. "How often do you use similar products?"

C. "What challenges do you face when using similar products?"

D. "Do you prefer online shopping or in-store shopping?"

Linking questions

- To what extent does UCD rely on a strong foundation of ergonomics? (A1.1)
- How important is a good understanding of user-centred research methods to ensure effective UCD? (A2.1)
- To what extent can the UCD process be influenced by the quality of modelling and prototyping of potential design solutions? (B2.2)
- To what extent should a UCD process focus on ensuring inclusive design? (C1.2)
- What influence can product analysis and evaluation have on the effectiveness of UCD? (C3.1).

5. Which of the following best describes a key principle of usability in product design?

   A. visual appeal:

   B. the product performs as expected, effectively.

   C. the product is based on current market trends

   D. users to feel in control and easily navigate the product.

6. Discuss the advantages and disadvantages of using interviews to gather user preferences.

7 Explain the benefits of task analysis for designers, manufacturers and consumers.

8. Detail an example of how anti-personae may be used by designers

9. Explain how a Likert scale questionnaire may be used to gather quantitative data

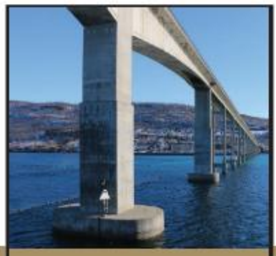
10. Explain the difference between qualitative and quantitative data and indicate which tools may be used to gather both.

11. Explain how designers use the 'method of extremes' spaceto be more inclusive.

12. Explain the disadvantages associated with the 'observer effect'

RESPONSIBILITY OF THE DESIGNER (SL)

Contents



C1.1

SL

Guiding question

What is the role of a designer in innovative and continuous product development?

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C 1.1.1 A designer has a responsibility to the needs of clients, their community and the environment when designing and creating products.

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Designers play a crucial role in innovative and continuous product development. They do this by translating user needs and business goals into tangible, usable and aesthetically pleasing products. This fosters innovation through research, prototyping and iteration, and ensures the product's success throughout its lifecycle.

Designers are responsible for rational utilisation of materials, manufacturing processes, energy usage, recyclability and reusability. They do this by maintaining a critical contemporary understanding of the science and technologies necessary to create designs. In performing this task, the designer must be mindful of the sometimes competing interests of the client, community and the environment when creating new designs, features and product updates. This process involves not just a one-off activity but a commitment to continued innovation and product development (Kaizen).

Kaizen

'**Kaizen**' is a Japanese term that means 'continuous improvement' or 'change for the better' and is based on the idea that small, gradual changes over time can lead to significant improvements. Kaizen emphasises the importance of understanding customer needs. It also involves testing improvements on a small scale before updating company-wide procedures. This process of continuous improvement was introduced in Japan in the 1950s as part of their post-war industrial reconstruction by the American business theorist W. Edward Deming. Deming championed the work of the American Engineer Walter A. Shewhart, who emphasised the use of statistics to study the effects of changes and is sometimes referred to as the **Shewhart Cycle**, PDSA (Plan, Do, Study, Act). Through Deming's work in Japan, this cycle (shown in Figure C 1.1.1a) became known as the famous PDCA (Plan, Do, Check, Act) philosophy of product and service improvement.

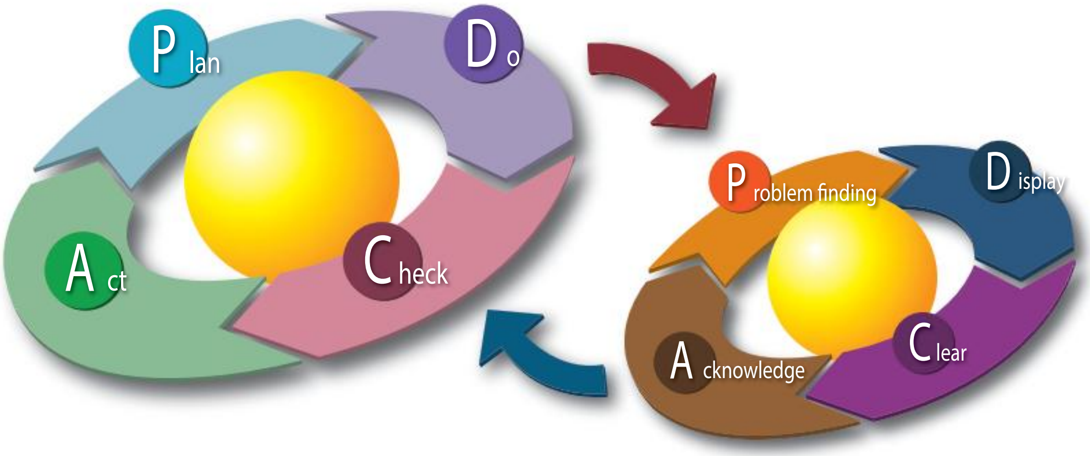

Figure C1.1.1a The Deming PDCA cycle of continuous improvement.

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A designer acts as a key catalyst, driving new ideas, iterating existing designs and ensuring products are user-centric by conducting research, prototyping, testing and incorporating feedback to create solutions that meet evolving user needs and market demands, all while staying aligned with business objectives and technological possibilities. Essentially designers act as a bridge between creativity and technical feasibility to constantly improve and evolve a product throughout its lifecycle.

Environmental sustainability

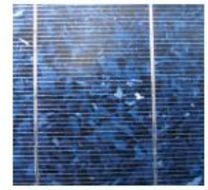
When developing a new product or refining an established design, designers have increasingly been required to consider the environmental impact of their work throughout its lifecycle. This means considering everthing from material sourcing to disposal while striving to minimise negative impacts and promote sustainability. This requirement gained significant traction in the late 20th century, particularly after the publication of the *Brundtland Report* (also known as 'Our Common Future'). This was published in 1987 by the United Nations World Commission on Environment and Development (WCED), chaired by Gro Harlem Brundtland. The Brundtland report addressed the growing concerns about environmental degradation and its relationship to development. It popularized the term 'sustainable development' and has had a significant impact on product design. The **sustainability movement** promotes the use of **eco-friendly materials** and **circular economy principles**. Eco-friendly materials reduce environmental impact, Circular economy principles, in which the entire product life cycle is considered, lead to more durable, repairable, and recyclable products, ultimately aiming for a positive impact on people, the planet and profits.

Sustainable products are made from renewable resources, use minimal energy, and are recyclable or reusable. They can be found in many categories, including food, home goods, and clothing. Such products are often referred to as **eco-friendly**.

Examples of eco-friendly products:

- Reusable bags: Made from organic cotton, these bags are a cost-effective alternative to plastic bags.

- Recycled Plastic Bottles: While products made from PET (Polyethylene Terephthalate) such as plastic bottles are initially manufactured from fossil fuels such as crude oil, the ability of PET to be repeatedly recycled into new products reduces the use of new, virgin plastic and reduces the likelihood of them ending up in landfills or polluting the environment.



- Solar energy devices: These devices use naturally renewable solar energy, which can reduce reliance on finite fossil fuels such as oil, coal and gas, and minimise environmental impacts during operation.

- Biodegradable Products: Products and packaging that either break down in the environment naturally or are 'digested' by organisms in an ecosystem such as fungi and bacteria, or are compostable, can reduce plastic waste and promote a circular economy.

- Recycled clothing: Made from recycled materials like cotton, these products can reduce the carbon footprint of the supply chain. By promoting recycling, clothing is diverted from landfills.

Other ways to be more sustainable include:

- Using low-impact shipping materials and methods
- Choosing products with natural, organic, or plant-based ingredients
- Supporting brands that donate proceeds to charities
- Buying locally produced products to reduce the polluting effects of long-distance shipping.

Negative impacts on a community or on the environment's sustainability arise from the use of products that are not recyclable and/or are not recycled for a variety of reasons.

- Products containing microplastics
- Per- and Polyfluoroalkyl substances (PFAS), Polychlorinated biphenyls (PCBs) and dioxin: are often referred to as forever chemicals due to their resistance to degradation and their accumulation in the local groundwater, leading to health problems. PFAS has been widely used in firefighting foam and has increasingly been identified as having contaminated groundwater.

- Chemical Aerosols such as Chlorofluorocarbon (CFC) and Hydrochlorofluorocarbon (HCFC) emissions used in consumer products, enter the stratosphere, affecting the ozone layer

- Disposable Plastic containers and packaging, a significant proportion of which makes its way to the world's oceans, create hazards for marine life.

- Fast Fashion, involves the rapid production and sale of cheaply produced clothing, mimicking the latest fashion trends for sale at a low price and which is then discarded. Fast fashion has been criticised as contributing up to 8-10% of global CO_2 along with the creation of excessive waste and exacerbation of microfibre pollution, with approximately 87% of textile waste going to landfill each year (see Figure C1.1.1b).

- Mercury from Gold mining and chemical processes, if ingested, can cause kidney damage, impair hearing, vision, and balance and may result in coma, and death. Minamata disease arose in the 1960s and is named after the Japanese village of Minamata in which residents were subjected to mercury poisoning from the eating of fish contaminated by methylmercury discharged from a chemical factory into coastal water.

- Atmospheric Lead, sulphur, NO_x and particulate matter (PM2.5) from vehicle fuel, while aggravating respiratory conditions such as asthma, can cause cardiovascular issues, neurological damage and increased susceptibility to various diseases.

Not all mining operations are environmentally irresponsible. See: https://www.superpit.com.au and click on the Environment tab.

The 'super-pit' at Kalgoorlie in Western Australia is run by an operator that is mindful of its responsibilities. Find the car at bottom left for scale!

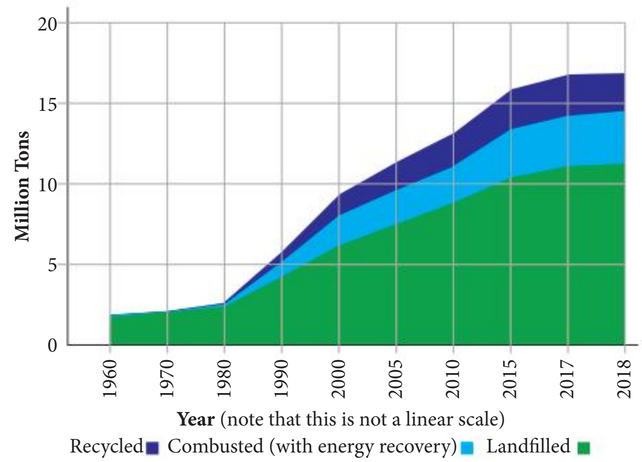


Figure C 1.1.1b Graph of Textiles Waste Management from the American Textile Recycling Service

C 1.1.2 It is a designer's responsibility to ensure their products are safe to use.

Standardisation involves the establishment of common practices, methods or formats to ensure consistency and can occur at a variety of levels, from international to country, state or company-specific. Our common systems of weights and measures are prime examples of standardisation, as they involve establishing and adopting uniform systems of measurement for quantities like length, weight and capacity. Using these helps ensure consistency and comparability across different contexts.

Before standardised systems were developed, different regions or even individuals might use different units for the same quantity (e.g., a 'foot' could be different lengths in different places). This led to confusion, difficulties in trade and inaccuracies in various fields. Through standardisation, a common language for quantifying things, facilitating trade, scientific research and many other activities has been created.

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Product standards are documented guidelines that specify technical requirements for a product, ensuring its safety, quality, consistency and suitability for its intended use. These standards provide consumers with confidence that a product meets certain criteria and is reliable across different manufacturers and markets; essentially acting as a benchmark for product quality and performance.

The role of state-based legislation is to guarantee quality assurance for the benefit of the consumer irrespective of the product source. Children's toys are an example of individual governments providing legislation to reduce potential risk to the end user of the product (see Figure C 1.1.2a). In the USA, ASTM F963 'Standard Consumer Safety Specification for Toy Safety' deals with the safety compliance of toys concerning material properties (such as toxicology, flammability, etc.) and the labelling of age range and functional hazards for children under 14. Similar standards have been enacted throughout the world, e.g. ISO 8124.1 'Safety of Toys-Part 1: Safety aspects related to mechanical and physical properties', with subsequent parts of the standard dealing separately with toy flammability and toxicology requirements.

Figure C 1.1.2a Children's toys require specific regulation, image by I, Daniel Schwen, CC BY-SA 3.0, via Wikimedia Commons

Government product standards for children's toys benefit designers by providing a clear framework for ensuring safety, reducing design risks and promoting consumer confidence, ultimately leading to more successful and ethical product development.

Product and test standards of course extend much further than those for childrens' toys. Standards set specific criteria for product design, materials, manufacturing, performance and testing. This provides designers with a framework to work within, ensuring products meet safety and quality benchmarks.

Standardisation is often a feature of mature markets and assists with quality assurance, component supply and the costs associated with expensive research and development, giving companies confidence to develop products for world markets. In a globalised world, design standards act as a common language, facilitating international collaboration, ensuring consistent quality, and enabling designers to navigate diverse markets and cultural contexts more effectively. Companies well placed in the standards development process may also be able to favourably influence the development of the standard protocol. Figure C 1.1.2b provides an orthogonal system of three axes within which standardisation may be visualised, in which the *X*-axis represents the Domains (subjects) of standardisation, with the *Y*-axis representing the important Aspects to which each Domain must comply. The Z-axis indicates the various Levels at which a standard may be applied. These range from company standards voluntarily adopted by manufacturers as indicators of good practice and reliability, to those mandated and regulated by governments to ensure consumer safety.

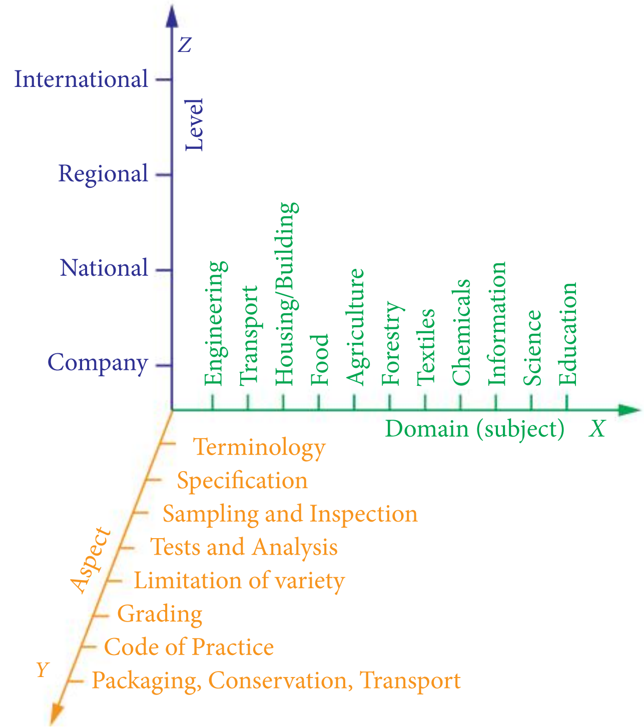

Figure C1.1.2b Diagrammatic Representation of Standardisation Space. Sanders, T.R.B. (Ed.). (1972). The aims and principles of standardisation. Published by The International Organization for Standardization. [https://www.iso.org/sites/edumaterials/trbsaunders.pdf]

The supply of products to National Standards, in particular, allows some confidence that products purchased from anywhere in the world will meet performance expectations. Products are often therefore affixed with a mark indicating compliance to an assessment standard such as those shown in Figure C 1.1.2c.

Figure C1.1.2c Selection of logos found on products to indicate compliance with a standard

Many countries maintain authorities charged with the responsibility of enforcing mandatory product safety and information standards, such as:

The Australian Competition & Consumer Commission (ACCC),

The United States Consumer Product Safety Commission (CPSC)

The Product Safety Enforcement Forum of Europe (PROSAFE)

Component standardisation by reducing variability also allows for the interchangeability of components across products and markets, while improved efficiency at a manufacturing level may be achieved through economy of scale and simplifying manufacturing processes.

The Flintlock Musket

The idea of mass-producing interchangeable parts was introduced in France in 1776 by a French artillery Officer Lieutenant General Jean-Baptiste Vaquett de Gribeauval in his role of inspector of artillery. This system of manufacture became known as the système Gribeauval and was originally applied to the production of large pieces of equipment such as cannons and cannonballs. This design innovation introduced the idea of standardisation while making the cannons lighter, and more mobile, and incorporating interchangeable parts, including carriages and ammunition, allowing for faster deployment and more accurate firing.

Another Frenchman Honorè Blanc later extended the système Gribeauval in 1778 to the manufacture and repair of the Flintlock Musket, the primary infantry soldier's weapon at the time (see Figure C1.1.2d). The system was introduced to solve the growing problem of the repair of weapons that up until that time required the work of a skilled armourer or gunsmith, as each contained numerous fragile and oddly shaped handmade components. The result was that damaged parts could not be swapped out in the field but required the weapons to return to the armoury for repair. This inevitably meant long delays for a service return. Under Blanc's system, the components were still made by hand, however, standardised jigs and gauges were introduced which meant that the components produced were of sufficient precision that they were interchangeable.

Figure C 1.1.2d Flintlock Musket late 18th Century showing the firing mechanism.

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It wasn't until the American Engineers John Hancock Hall (1816), Simon North (1818) and Thomas Blanchard (1817) independently introduced advances in machinery that allowed the mechanised mass production of the flintlock components and true interchangeability.

Today, standardisation and interchangeability of many products is commonplace. The standardization of bolt design, and reduction of variability, for example, has allowed high confidence in the interchangeability of nuts and bolts supplied by different manufacturers from different parts of the world, see Figure C1.1.2e.

Figure C1.1.2e Hexagonal head bolt with matching nut

Similarly, the standardisation of bolt grade classifications provides confidence in material properties such as strength, with the grade (or Property Class) information typically indicated on the bolt head.

C1.1.3 Products can become obsolete due to a number of factors and this can be planned.

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Planned obsolescence

Also known as 'built-in obsolescence', planned obsolescence is a deliberate tactic employed by manufacturers and designers to create products with a limited lifespan. It is designed to force consumers to purchase a product repeatedly, boosting sales while maintaining a competitive edge by constantly refreshing and improving products. Adopting a philosophy of planned obsolescence allows designers to create a desire for product replacement, or update, rather than repair. Planned obsolescence exists in such diverse product areas as computer software, mobile phones and automobiles.

The notion of planned obsolescence is not a new phenomenon and is documented as early as the 1930s when General Electric improved the efficiency of flashlight lamps through a corresponding decrease in their lifespan. Engineers at the time were encouraged to build items with a limited lifespan to increase sales and boost the economy. The proposition received mixed responses but proponents accepted this new ethical paradigm with almost patriotic vigour.

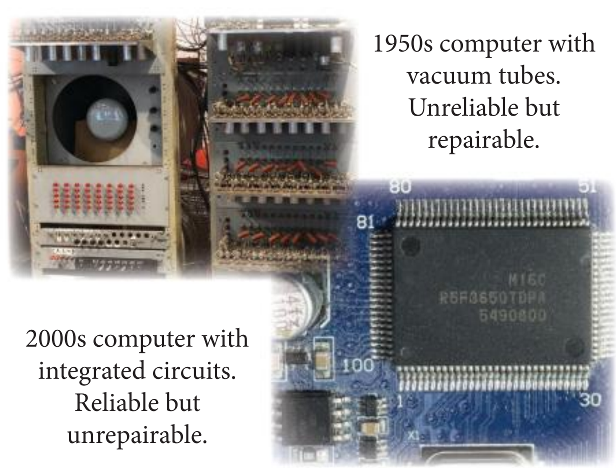
Design features of planned obsolescence may include:

- low durability
- style obsolescence
- not easily or cheaply repaired
- difficult to disassemble thus restricting maintenance
- regular introduction of newer technologies or 'improved' models.

The features listed allow manufacturers to cut costs and boost sales. This approach by manufacturers is also known as 'value engineering', however, as markets develop and competition increases, pressure is brought about to increase product life spans as consumers migrate to companies producing more reliable, more durable products.

Advantages for the consumers, when companies introduce new versions and generations of a product, include opportunities to upgrade products as new technologies become available and access to the latest in fashion trends. Strength in the consumer market through volume sales also has a knock-on effect on national economies and potential job prospects for the local population.

Disadvantages of planned obsolescence are around the constant need for replacement and associated inconvenience. Lack of repairability may mean consumers have to purchase a product before they are ready or replace a model whose features they are entirely happy with. New models and new technologies often bring new ways of operating and this can also be disconcerting for some consumers.



1950s computer with vacuum tubes. Unreliable but repairable.

2000s computer with integrated circuits. Reliable but unrepairable.

Increased consumerism through less durable goods can also have significant environmental impacts. These are largely through the generation of more waste, pollution, energy consumption and consumption of resources as consumers continuously replace, rather than repair products.

Style (fashion) obsolescence

Fashion is a general term for a currently popular style or practice and can therefore be subject to trends. These may include design features such as shape, form, colour, style, materials, finish etc., and appear in a diverse range of fields including but not limited to: vehicles, architecture, food, clothing, jewellery, footwear.

Perceived value and cost are vastly different and measured using entirely different criteria. **Value for money** is associated with cost and performance, while perceived value, also incorporating cost, may also include prestige, rarity and other social implications within a consumer's assessment.

While planned obsolescence often uses lesser quality materials and production values to cut costs, the prestige of owning a similar item branded differently but priced at a premium may still draw customers. Labelled the '**Veblen effect**' after Thorstein Bunde Veblen, (1857—1929) this theory describes counter-intuitive consumer behaviour. Reasons for this behaviour include the thought that pricing is an indication of quality and conspicuous consumption of expensive items provides a form of social prestige for the consumer.

The longevity of such trends can be unpredictable. Some styles may last years before being abandoned, while others last merely months and are often referred to as a 'fads'.

Fashion fads arise primarily due to a combination of:

- social influence
- the desire to fit in
- novelty seeking,
- the power of celebrities and influencers on social media platforms such as TikTok, YouTube and Instagram
- the rapid dissemination of trends through marketing and popular culture.

Fads often lead people into adopting a style quickly and then just as quickly abandoning it once it's no longer considered 'trendy'.

Examples of Style (fashion) obsolescence:

Zoot Suits (1930s - 1940s): A style of men's clothing that included high-waisted baggy trousers with a long watch chain, and a long coat with wide lapels. Often accompanied by a pork pie hat. They were popular in the 1940s among African American, Mexican American, Filipino American, Italian American, and Japanese American men.

The famous American Jazz bandleader of the 1940s Cab Calloway frequently wore zoot suits on stage calling them "totally and truly American", although they were criticised as unpatriotic by some for wasteful use of material during WWII.

Paisley Print (1960s): Although the repeating tear-drop style textile pattern is centuries old (see Figure C 1.1.3a), the paisley pattern was a key part of hippie culture in the mid-late 1960s It represented rebellion and non-conformity and was associated with the psychedelic style and free love movement. This saw the pattern used extensively in the youth fashion industry.

Figure C1.1.3a Persian Silk Brocade Paisley design (Sialkgraph CC BY-SA 3.0)

Bell-bottom jeans (1960s-1970s): Also known as flared jeans in which the pant legs characteristically flared out at the knee. Popular in both men's and women's clothing in the 1960s they fell out of fashion in the late 1970s as the 1950s fashion of straight jeans became more popular. Flared jeans periodically returned to favour in the mid-1990s to 2000s under the name 'Boot-cut'.

Shoulder pads (1930s-1940s, 1980s-early 1990s): Shoulder pads have been a popular part of women's fashion in several eras including the early-1930s to late-1940s reflecting the military styling of the time (see Figure C1.1.3b). They returned again in the 1980s, with their sharp silhouettes creating a symbol of power and authority, allowing women to visually project a more assertive presence in traditionally male-dominated workplaces. They essentially represented 'power dressing' by creating a broader, more commanding silhouette. The style was popularised by prominent female figures in the media, including characters from American television shows like *Dynasty* and *Dallas* and celebrities such as Princess Diana, Margaret Thatcher and Michelle Pfeiffer.

Figure C1.1.3b American Actress Joan Crawford (1946) wearing shoulder pads which became her signature look and helped to popularise them.

Examples of short-lived Fads:

- Troll Dolls (1960s, 1990s)
- Pet Rocks (1975)
- Beanie Babies (mid-1990s)
- Tamagotchi (mid-1990s to early-2000s)

Functional obsolescence

Functional obsolescence is when something becomes less useful or desirable due to an outdated design or functionality even if the technology itself is still functional. This can apply to real estate, technology and other assets. Functional obsolescence can lead to a loss of value or depreciation.

This form of obsolescence can be difficult to correct because the outdated design is not easily updated. However, sometimes it is possible to make a comeback from functional obsolescence. For example, a company may redesign their furniture to conform to the latest trends.

Examples of Functional obsolescence:

- A property with an outdated design may be less desirable to buyers and therefore have a lower appraisal value, due to features such as needing to walk through one bedroom to get to another, or bedrooms and bathrooms on separate floors
- Dwellings with inadequate electrical systems for modern appliances
- The absence of modern conveniences such as indoor plumbing
- New smartphone models make older models less desirable
- Manufacturers no longer support updates or repairs of their older products
- Changes in electronics resulting in incompatibility of older designs.

Technological obsolescence

Technological obsolescence has many features similar to functional obsolescence and happens when a technology is no longer useful or efficient compared to newer alternatives such that technological obsolescence can occur well before functional obsolescence may arise. This can happen to hardware and software.

Examples of Technological obsolescence:

- **Time Keeping**: The Hourglass and Sundial were both replaced by more accurate time keeping systems such as clocks and electronic timers, although still found in more ornamental situations
- **Refrigeration**: Ice chests were replaced in the early 20th century by the refrigerator
- **Displays:** Cathode Ray Tubes (CRTs) were replaced by Plasma flat screen displays which themselves have largely been replaced by Liquid Crystal Displays

(LQD) and Organic Light Emitting Diode Displays (OLED).

- **Sound recording**: Edison's cylinders were introduced in 1877. These were superseded by Shellac records, known as 78s (1898). In their turn these were superseded by Polyvinyl plastic discs which introduced the 45 rpm and 33 rpm formats (1948). More recently these were largely replaced by Magnetic tape (1960s) and by the Compact Disc (1980). At the time of writing it looks likely that these will be replaced by electronically stored digital files and streaming services.

- **Vacuum tubes** were replaced by transistors introducing miniaturisation.

- **Steel making**: The first widely used steel making method was the Bessemer Converter Steelmaking Process (1856). It was replaced by Open Hearth Furnace (OHF) (1860s). This began to be replaced in 1948 by Basic Oxygen Furnace (BOF) and the Electric Arc Furnace (EAF). The EAF was first introduced commercially in 1901 and became widely used from the 1960s due to growing availability of steel scrap.

- **Computer data storage devices** such as the 8", 5" and 3 ½ " 'floppy' discs, commonly used from the 1970s to 1990s were replaced by the CD-ROMs, DVDs and USB flash drives shown in Figure C1.1.3c.

Figure C1.1.3c 8", 5" and 3½ " 'floppy' disc computer storage

Bibliography

Figure C1.1.1a The Deming PDCA cycle of continuous improvement. Karn-b - Karn Bulsuk (http://www.bulsuk.com).Originally published at http://www.bulsuk.com/2009/02/taking-first-step-with-pdca.html, CC BY 4.0 <https:// creativecommons.org/licenses/by/4.0>, via Wikimedia Commons

Linking questions

- How does the classification and properties of the materials affect the designer's ability to meet their responsibilities to minimize negative impacts on the communities they design for? (A3.1)

- What are the key considerations of ensuring products can be used safely when designing them to include mechanical and electronic systems? (A3.3, A3.4, B3.3, B3.4)

- To what extent are there differences between the responsibility of the designer and the responsibility of the design student as they engage with the design process? (B2.1) • How does the designer mitigate the impact of social, style, functional and technological obsolescence when using a design for sustainability strategy? (C2.1)

- How do designers ensure they design out obsolescence when working with a design for a circular economy strategy? (C2.2)

- To what extent is it the responsibility of the designer to ensure that the outcome of the life-cycle analysis for their product is relatively positive? (C3.2)

SL

INCLUSIVE DESIGN (SL)

Contents

C1.2

SL

Guiding question

How do designers design mainstream products and environments that are accessible and attractive to the largest possible number of people?

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C 1.2.1 Inclusive design ensures products that address the needs of the widest possible audience, regardless of their age or ability and focuses on designing universally acceptable products for all users.

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Inclusive design seeks to break down barriers and ensure that experiences are accessible and usable by everyone, regardless of physical or cognitive differences. Inclusive design represents an extension of User-Centred Design (UCD) in that it aims to include those members of the community who might otherwise be forgotten during the product design process, such as those who are pregnant, elderly, disabled, or injured and through design attempts to improve the life of all people.

Inclusive design principles (sometimes called 'Universal Design', 'Universal Usability Design' 'Accessible Design' and 'Design for All') are increasingly being incorporated into building codes. The term **Universal Design** was originally used by Ron Mace, (1998) and was coined to meet the needs of people of all ages and abilities.

The **Centre for Universal Design** defines the term as, '... the design of products and environment to be usable by all people, to the greatest extent possible, without the need for adaptation or specialised design. The intent of universal design is to simplify life for everyone by making products, communications and the built environment more usable by as many people as possible at little or no cost.'

Centre for Universal Design, 2005

Universal design takes into consideration people of all ages, genders and abilities and through design attempts to improve the lives of all people. In the past, it has been misconstrued as 'one size fits all'. This is less than its full intention. Through legislation and public education campaigns, designers have come to realise their social responsibilities. They have recognised that good design reflects the needs of a variety of users and makes accommodations for this range.

The main features of Universal Design may be interpreted as:

- equity in use
- flexibility in service
- allowing tolerance for error
- simple and intuitive operation
- communicate unambiguous information
- need low physical effort to function
- provide space for operators and use

In many industrialised nations, legislation exists covering and enforcing consideration of people with a disability. Human factors research drives and informs designs based on these legislative requirements.

Just some of the countries with legislation requiring consideration of individuals with a disability include:

- Australia, the Disability Discrimination Act 1992
- Canada, the Ontarians with Disabilities Act of 2001
- US, under the Americans with Disabilities Act of 1990
- South Africa, the Promotion of Equality and Prevention of Unfair Discrimination Act 2000
- India, Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995.

In developing countries, formal legislation may not be enacted, but through a series of informal guidelines and international standards promoted by NGOs and government agencies, disability issues may be addressed to some degree.

Instances of everyday items where inclusive design can be found are in the design of currency, where coins of varying size, thickness and edge detail allow those with poor sight to avoid confusion. Similarly, many countries have adopted notes with differing sizes, colours and textural details that assist the vision impaired.

Raised dots warn the visually impaired that they are close to the edge of the platform.

C1.2.2 Inclusive design is not always possible.

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As indicated previously in section A 1.1.3, in statistics, the 50th percentile (or median) is the point below which 50% of the population falls and represents the 'average' adult or child in terms of a specific body dimension. Designing solely for this average is, however, often inappropriate because body dimensions aren't linearly correlated, meaning someone with short arms doesn't necessarily have short legs and vice versa. There is therefore no such thing as a truly 'average' person. Focusing solely on the 50th percentile can therefore exclude a significant portion of the population, especially at the extremes and when considering multiple dimensions, potentially creating accessibility issues for them. This is as true today as it was in the past.

Historic anthropometric data still available to researchers today, of the range in height of Union soldiers aged between 21 and 49 in 1850 and shown in Figure C1.2.2a, indicates that an average height was 5 foot 8 inches (~1.73m). While no soldier may have been of this exact height, all of the information contained in the graph may have been useful for producing a suitable range of sizes in clothing or weaponry.

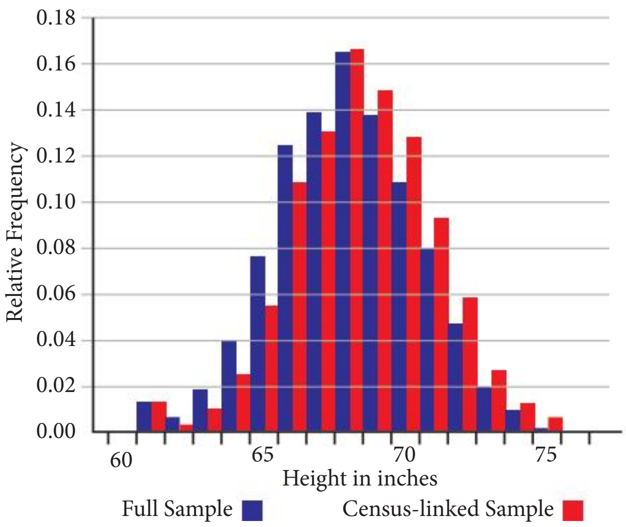

Figure C1.2.2a Range of Union Soldier heights linked to the 1850 Census [Wilson, S., & Pope, C. L. (2003). The Height of Union Army Recruits. Family and Community Influences. In Health and labor force participation over the life cycle: Evidence from the past (pp. 113-146). University of Chicago Press].

More recently ergonomists have used data obtained from measuring the human body to collect sufficient information to allow devices and products to be manufactured in a way that facilitates their ease of use. To design for a wider range of users, designers often consider a range of percentiles, like the 5th to 95th percentile, as discussed in Section A 1.1.4, to ensure that the product can accommodate a majority of the population. This is accomplished by:

- Utilising comprehensive anthropometric data to understand the full spectrum of human body dimensions to design products that can accommodate a wider range of users.
- Incorporating adjustable features into products whenever possible, allowing users to customize the fit to their specific needs.
- Depending on the product or service, identifying specific user groups and tailoring the design to fit their needs, considering factors like gender, age and potential physical limitations.

> C 1.2.3 Designers often use a 'design for extremes' strategy to develop solutions suitable for use by those with physical, sensory and cognitive impairments, which are also appropriate for the general population.
>
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Designing for extremes can lead to more inclusive, innovative and future-proof designs.

Advantages:

- **Inclusive design**. Designs for extreme users can benefit a wider audience. For example, voice commands for visually impaired users can benefit everyone who needs hands-free operation.
- **Innovative solutions.** Extreme users can provide unexpected perspectives that lead to new design opportunities.
- **Future-proof designs**. Addressing extreme cases today can prepare designs for future user needs.
- **Improved user experience**. Designing for extreme users can lead to better user experiences for everyone.
- **Inspiration**. Extreme users can inspire designers to rethink assumptions and break out of their comfort zones.
- **Improved accessibility**. Solutions for extreme users can make products more accessible and usable for everyone.

Examples

The Oxo Good Grips products, introduced in the 1990s, were inspired by Sam Farber seeing his arthritic wife struggle to hold a vegetable peeler. The OXO peelers (shown in Figure C 1.2.3a) incorporate a martensitic stainless steel, half-moon-shaped slotted swivel blade in a rigid nylon frame. This is fixed to an oversized non-slip handle made from the thermoplastic elastomer Santoprene. The large handle improves grip during use while also reducing hand strain, a particular advantage for those with arthritis. The handle also incorporates a unique 'soft spot' consisting of a scooped-out region with fins for the thumb and forefinger, which resulted in the need for only a light grip during use.

Figure C1.2.3a OXO Good Grips Straight and Y-shaped Vegetable Peelers

The OXO vegetable peeler was inducted into the New York Museum of Modern Arts (MoMA) collection in 1994.

Other examples:

- **Text messaging** and vibrating functions of smartphones allow people with hearing impairments to communicate easily over large distances.

- **Text to Speech** (TTS) technology: helps people with disabilities, particularly those with visual impairments or learning difficulties like dyslexia, by reading digital text aloud. This allows them to access information without needing to read it themselves, which can significantly improve their comprehension and engagement with written content.

- **Language Translation Apps** such as Google Translate: facilitate communication with others who speak different languages, particularly in situations where they might not have access to a professional interpreter. This enables the user to participate more fully in society and access services like healthcare, education and government agencies regardless of language barriers.

- '**Rumble Strips**' also known as Audio Tactile Lane Markings (ATLM): typically placed on the edge lines and centrelines of roads are designed to generate a distinct noise and tactile sensation when a vehicle drives over them, alerting drivers if they are drifting out of their lane, particularly when drowsy or distracted, allowing them to correct their course and avoid potential accidents.

- **Braille dots on banknotes**: Raised dots on the polymer banknotes of Australia (see Figure C1.2.3b), Canada and the UK provide a tactile feature that helps the vision impaired to identify note denominations. Paper-based banknotes also allow similar tactile functionality by using intaglio printing.

Figure C1.2.3b 'Braille' dot Tactile features on banknotes

- Currency Identification apps driven by AI such as CashReader and MCT Money Reader use the camera in a smartphone to identify bank notes for people with visual impairments.

- **Tactile pavements**: help people, particularly the visually impaired, by providing a textured surface on walkways, which can be detected with a cane or by foot, alerting them to potential hazards like road crossings, platform edges, or changes in direction, allowing them

  to navigate more safely and independently.

Linking questions

- To what extent is a deep understanding of ergonomics important when engaging with inclusive design? (A1.1)

- To what extent can designers remove personal bias when using user-centred research methods? (A2.1)

- How can products integrate mechanical systems to improve accessibility and usability in an inclusive design approach? (A3.3, B3.3)

- To what extent can the inclusion of electronic systems in products enhance accessibility and usability for all end-users? (A3.4, B3.4)

- Which aspects of inclusive design benefit from the designer going beyond usability when designing products? (C1.3)

- How important is accessibility and usability when conducting product analysis and evaluation? (C3.1)

BEYOND USABILITY (HL)

Contents

C1.3

HL

Guiding question

How do designers go beyond accessibility and usability to address a wider range of issues to improve products and services? © IBO 2025

> C 1.3.1 The four-pleasure framework can act as a critical component to determine how users interpret and interact with a product.
>
> © IBO 2025

The four pleasure framework is a user-centred design method that helps to consider how products and services can be pleasurable to use by catering to a consumer's emotions. The framework was developed by Canadian anthropologist Lionel Tiger in 1992 in the book *The Pursuit of Pleasure*.[1]

The four pleasures are:

- **Physio-pleasure**: Pleasure derived from the physical experience of using a product, such as its feel, smell or taste
- **Socio-pleasure**: Pleasure derived from relating to others, such as through social status, belonging or communication
- **Psycho-pleasure**: Pleasure derived from the cognitive and emotional experience of using a product, such as how easy it is to understand
- **Ideo-pleasure**: Pleasure derived from how a product appeals to a user's values and beliefs

1. (see Tiger, L. (1992). *The Pursuit of Pleasure*. Little, Brown and Company.

The four pleasure framework can be used to classify different types of pleasure and to guide product design. For example, a product that is easy to use, aesthetically pleasing or made from sustainable materials can be considered pleasurable.

Researchers have investigated product aesthetics and have established a response from product users called the theory of aesthetic pleasure. This theory identifies a link between users and the entire range of effects generated by the product experience. This set of effects includes the degree to which our senses are satisfied including visual gratification and feelings (emotions).

The original design for the Coca Cola Bottle (Figure C 1.3.1a) is one of the most often quoted in this field - the organic-shaped, twin-sphered body and the way it fits neatly into the hand. The smooth, ribbed grip on a cold and wet glass bottle still conveys confidence, while the retro design appeals to a sense of nostalgia.

Figure C1.3.1a Coca-cola bottle nagualdesign, CC0, via Wikimedia Commons

Another more recent example where aesthetics have influenced consumer behaviour is the rise of the digital **Smartwatch** (Figure C1.3.1b). This was introduced by Seiko in 1998. Seiko is now only a minor participant as the smartwatch market is dominated by Apple and Samsung, although an increasing number of competitors such as Huawei, Imoo, Noise, Google, Garmin, Xiaomi, Oppo and Vivo have appeared.

The smartwatch offers not only traditional timekeeping but additional wearable tech functionality in the form of health/fitness tracking and internet connectivity primarily through cellular (Wi-Fi/5G) or Bluetooth-based connectivity with a smartphone. Standalone smartwatches, featuring built-in cellular capabilities, can function independently from a phone for calls, messages and data access.

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Consumers increasingly view smartwatches not only as a technology innovation but as a fashion accessory, seeking stylish designs and diverse options. The electronic nature of the watches in many instances allows the watch face to change its appearance to accommodate the user's preferences and style.

Figure C1.3.1b Smartwatches with multiple faces available

The four pleasure framework relates to other design principles, such as Donald Norman's three levels of design appeal: visceral, behavioural and reflective outlined in 2003 in 'Emotional Design'. Norman believed that designs that engaged the emotions improved the user experience. He suggested such designs should invoke three emotional responses:

- Visceral (immediate sensory reaction),
- Behavioural (functional usability),
- Reflective (meaning and personal value),

Essentially Norman suggested that a well-designed product should provide pleasure at each level of interaction depending on the user's perception and experience with it; with physical sensations like touch and aesthetics relating to visceral, ease of use and functionality to behavioural and personal connection or societal impact to the reflective level.

Key points of alignment between the Four Pleasures and Norman's Three Levels of Design:

- **Physio-pleasure (Visceral)**: Most closely aligns with Norman's 'Visceral' level, as it focuses on the immediate sensory experience of a product, like its texture, smell or visual appeal.
- **Psycho-pleasure (Behavioral)**: Correlates with Norman's 'Behavioural' level, as it relates to the pleasure derived from successfully completing a task or interacting with a product intuitively.
- **Socio-pleasure (Reflective)**: Connects to the 'Reflective' level of Norman's design, as it pertains to the social meaning and personal value a user associates with a product, like status or belonging within a group.
- **Ideo-pleasure (Reflective)**: Also aligns with the 'Reflective' level, as it encompasses the deeper meaning and personal values associated with a product, like sustainability or ethical considerations.

Example: A luxury car:

- Visceral level (Physio-pleasure): The smooth leather interior, sleek design and engine sound upon start-up.
- Behavioural level (Psycho-pleasure): The ease of driving, responsive handling and advanced technology features that enhance the driving experience.
- Reflective level (Socio & Ideo-pleasure): The prestige associated with owning a high-end brand, reflecting the user's success and status.

Example:

Phillippe Starck Juice Salif:

In the postmodern era, the product aesthetic became the driving force. Objects took on creative or arbitrary forms. Functionality took a back seat to appearance. These products were often marketed as 'unique' or 'collectable'. The most publicised example of this style is the 1980s Philippe Starck designed lemon squeezer, or 'Juicy Salif '.

This product soon became an iconic, albeit expensive 'must have' and is hailed as a design classic.

Figure C1.3.1c Phillipe Starck's 'Juicy Salif' [Niklas Morberg CC 2.0]

- Visceral level (Physio-pleasure): The smooth sleek rocket ship design is aesthetically pleasing, while the three legs have also been suggested to give the juicer an organic form, reminiscent of a 'squid', that appeals to the emotions.
- Behavioural level (Psycho-pleasure): While the tapered shape and ribbed design is intuitive in its operation and allows juice to be directed to a waiting container below, the retro-style rocket ship device is notoriously difficult to use successfully.
- Reflective level (Socio & Ideo-pleasure): The striking futuristic design has a sculptural quality that suggests a sophisticated owner, while limited edition and expense, compared with other juicers enhanced its desirability. When fielding criticism of his creation, Starck is alleged to have said, 'My juicer is not meant to squeeze lemons; it is meant to start conversations'.

C 1.3.2 The attract/converse/transact (ACT) model is a framework used by designers to improve the relationship between a user and a product.

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The A.C.T. Model

The ACT model was developed by Trevor Van Gorp and Edie Adams as a tool to help designers create designs that intentionally trigger emotional responses. The model was outlined in their 2012 book *Design for Emotion*.

The ACT model describes the process through which an emotional response can be stimulated and some of the factors that should be considered when designing for emotion. The model shown in Figure C 1.3.2a, suggests that product design that produces an emotional response begins with attracting attention through features such as colour, texture, sound, etc.

Once the user's attention has been gained, the product design must create feelings of control and reliability. In other words, the user must be able to converse with the product, it must conform with our sense of usability.

Finally, if the product satisfies the requirements of usefulness and functionality, the consumer will move to commit to its continued use. In other words, a transaction will occur between the user and the product.

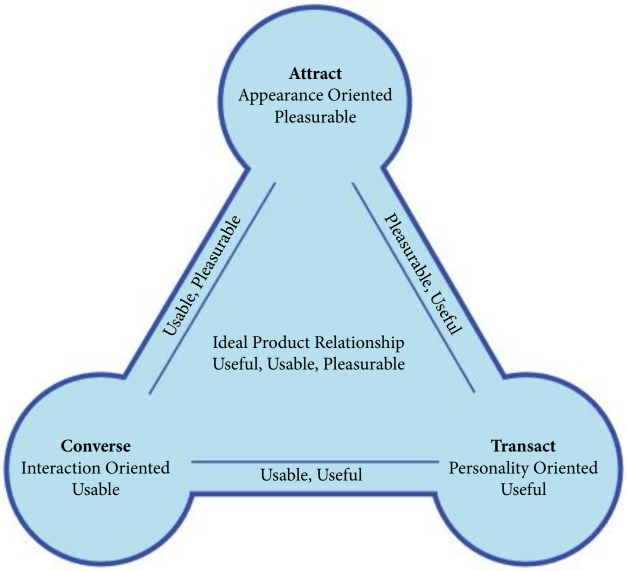

Figure C1.3.2a The ACT Model (©Van Gorp, T., & Adams, E. (2012). Design for emotion. Elsevier.)

The 'ACT' model (Attract, Converse, Transact) aligns with Norman's three levels of design by focusing on creating emotional engagement with a product or service through its initial visual appeal ('Attract' - Visceral level), the interaction and usability during use ('Converse' - Behavioral level) and the deeper meaning and connection the user builds with the product over time ('Transact' - Reflective level) - essentially addressing the user's emotional response at each stage of interaction with a design.

Attract (Visceral level): This initial stage focuses on the aesthetics and sensory perceptions of a design, similar to how Norman's Visceral level emphasizes first impressions based on looks, feel and sound, aiming to draw the user in with visual appeal.

Converse (Behavioural level): This stage relates to the usability and interaction with the product, aligning with Norman's Behavioural level where the user experiences the functionality and ease of use, determining their pleasure and effectiveness while interacting with the design.

Transact (Reflective level): This final stage pertains to the deeper meaning and emotional connection a user develops with a product, corresponding to Norman's Reflective level where the user reflects on their experience, considering its personal value and significance.

By addressing all three levels of the ACT model, designers can create a more comprehensive and emotionally engaging user experience, mirroring the approach of Norman's three levels of design.

Linking questions

- Which aspects of the four-pleasure framework are heavily influenced by ergonomic considerations such as smell, sound, touch, taste, emotion and aesthetics? (A1.1)
- How can material selection be used to trigger physio- or ideo-pleasure? (B3.1)
- To what extent does the ACT model promote inclusive design? (C1.2)

Sample Questions

1. Positive responses to a product that are generated by human senses are examples of?

   A. ideo-pleasure

   B. socio-pleasure

   C. physio-pleasure

   D. physio-pleasure.

2. The "ACT" model acronym translates to

   A. Attract, Converse, Transact Align

   B. Arrive, Convene, Trespass

   C. Attract, Contract, Transcend

   D. Arrive, Converse,

3. Universal design may also be called?

   A. inclusive design

   B. exclusive design

   C. acceptable design

   D. all for one design.

4. Governments enforce standardisation and safety considerations through

   A. tariffs

   B. taxes

   C. legislation

   D. guidelines

5. The Brundtland report was important for designers because it…

   A. solved sustainable development issues

   B. reduced their need to consider sustainable design

   C. raised environmental problems in the city of Brundtland

   D. addressed concerns about environmental degradation and its relationship to development

6. Outline the guiding principle behind 'Kaizen'

7. Explain the differences between functional and technological obsolescence.

8. What strategies do companies employ to achieve planned obsolescence?

9. Explain how countries ensure products meet safety and quality benchmarks.

10. Describe the advantages and disadvantages for consumers and manufacturers associated with planned obsolescence.

11. Outline the advantages of designing for extremes

    for designers, manufacturers and consumers.

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