Guidance on the Application of Human Factors to Consumer Products

Division of Human Factors,
U.S. Consumer Product Safety Commission, Rockville, MD USA

Risk Assessment Division,
Consumer Product Safety Directorate,
Health Canada, Ottawa, ON Canada

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Prepared by: Alan Poston, Contract No: CPS-S-16-0065

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1. Introduction

This guidance document provides recommendations to improve the usability and reduce the use-related hazards associated with consumer products. *This document is not a rule and does not establish legally enforceable responsibilities*.

2. Purpose and Audience

The U.S. Consumer Product Safety Commission (CPSC) staff[1] and Health Canada's Consumer Product Safety Directorate ("Health Canada") have developed this guidance document to help consumer product manufacturers integrate human factors principles into the product development process.

Many product-related injuries can be prevented by better user-centered design. Providing the consumer product industry with general human factors principles and guidance, and how these principles can be applied to their products, can help reduce product-related incidents and reduce costly compliance and enforcement actions.

This document is intended for industry stakeholders, designers, and manufacturers in the consumer product sector. This guidance can be tailored to meet the needs of a particular product, recognizing that not all practices apply to all products.

As a first step in generating guidance on best-practices, Health Canada conducted a literature review to identify existing industry and government documents, standards, and guidelines related to human engineering, human systems integration, usability of consumer products, and human factors engineering in medical devices. The literature review was supplemented by a limited literature review of other government documents, as well as those published by non-government standards bodies. The results of the literature review can be found at. As appropriate and consistent with copyright limitations, material was extracted from the documents reviewed as input for this guidance document.

3. Overview

Understanding how people interact with consumer products and how user-interface design affects these interactions is the focus of human factors. Information on human factors professionals, training, and experience can be found in Appendix A.

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[1] This document was prepared under the direction of CPSC staff and has not been reviewed and does not necessarily reflect the views of the Commission.

Figure 1 (adapted from the Food and Drug Administration, *Applying human factors and usability engineering to medical devices*, 2016) illustrates that consumer product design and development involve four major components: (1) the product use environment, (2) the product users, (3) the product design or user interface, and (4) the tasks to be accomplished by the user. The interactions among the four components and the possible results are depicted graphically in the figure below.

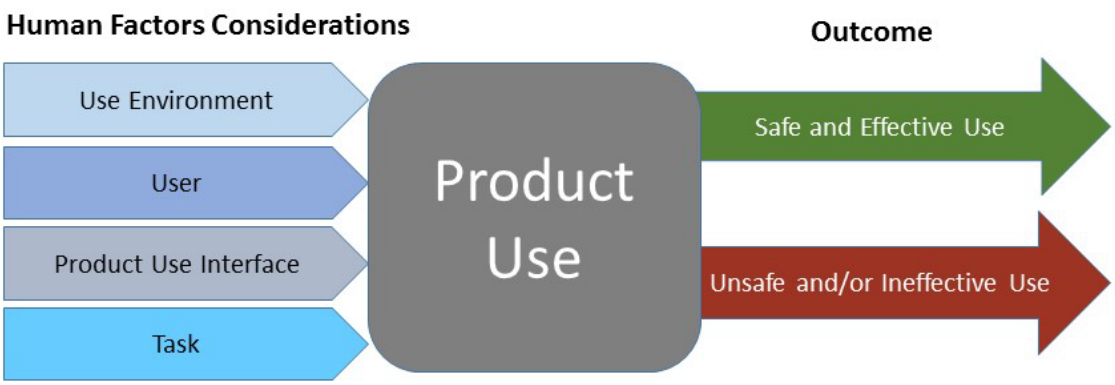


Figure 1. Factors that impact the safe use of the product

4. Definitions

For the purpose of this guidance, the following definitions apply:

a. **Context of use**. The users, tasks, hardware, software, and the physical and social environments in which a product is used.

b. **Critical task**. A task requiring human performance which, if not accomplished per manufacturer's intended use, could have adverse effects on system reliability, efficiency, effectiveness, or safety.

c. **Effectiveness**. The accuracy and completeness with which users can achieve specified goals.

d. **Efficiency**. The resources expended in relation to the accuracy and completeness with which users can achieve the desired goal(s).

e. **Human-centered design**. An approach to system design and development that aims to make products more efficient, effective, and satisfying, by focusing on the users and their needs and requirements. This is accomplished by applying human factors and usability knowledge and techniques.

f. **Human factors**. The scientific discipline concerned with the understanding of interactions among humans and other elements of a system. The human factors profession applies theory, principles, data, and methods to equipment, systems, software, procedures, jobs, environments, and training to produce safe, comfortable, and effective human performance. There are two components to human factors – human factors research (acquiring the information) and human factors engineering (applying the information).

g. **Human factors engineering**. The application of knowledge about human capabilities and limitations to product design and development to achieve efficient, effective, and safe performance considering cost, skill levels, and training demands. Human factors engineering ensures that the product design, required human tasks, and use environment are compatible with the sensory, perceptual, mental, and physical attributes of the user who will operate and maintain the product.

h. **Human factors test and evaluation**. All testing directed toward the evaluation of human factors analyses, studies, criteria, decisions, and design characteristics and features. Human factors testing may include engineering design tests, simulations, model tests, mockup evaluations, demonstrations, and subsystem tests. Human factors test and evaluation provides objective data concerning human performance with representative users operating and maintaining the product.

i. **Human performance**. A measure of human functions and actions in a specified environment, reflecting the ability of actual users compared to the product's performance standards.

j. **Product**. A generic term to represent a consumer product, system, subsystem, item of equipment, device, or component, as applicable.

k. **Satisfaction**. Positive attitudes about the use and performance of the product.

l. **Usability**. The extent to which a product can be used by intended users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.

m. **User experience**. A person's perceptions and responses that result from the use and/or anticipated use of a product. User experience includes the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, and behaviors that occur before, during, and after use. User experience can be a consequence of brand image, presentation, functionality, product performance, and interactive behavior.

n. **Vulnerable populations**. Subpopulations that could be at greater risk of harm from products due to their age, level of literacy, or physical and/or cognitive condition, or other limitations. Examples include children, persons with disabilities, or seniors.

5. Benefits of Applying Human Factors Principles

Designers and developers often fail to realize, or appreciate, that people with different aptitudes, abilities, and experiences will operate and maintain a product under a variety of conditions, configurations, and use scenarios. A human-centered approach that considers human characteristics, capabilities, and limitations within the context of use throughout the system design is essential to achieve safe and effective products. The main benefits of considering human factors are:

- *Improved usability and acceptance.* A product design solution that is developed based on human factors principles, consumer desires, and aesthetic requirements will result in a superior product with high usability (*e.g.*, efficient, effective, and easy to learn) and high user acceptance.

- *Increased safety.* User-centered design accounts for the context of use, improves the accuracy of planned user activities, and minimizes the likelihood of dangerous user activities that can result in injuries and deaths, such as when controls function contrary to expectations.

- *Reduced lifecycle cost and risk.* Most lifecycle costs are determined by decisions made during the early stages of the product design process. Changes in design during the later stages of development are expensive. Identifying human performance components of the product's operation and maintenance during the initial stages of the product design process decrease program risks and long-term costs.

- *Reduced support and help desk costs*: Companies can allocate fewer resources to customer support and help desks when products are designed with usability in mind.

The overall performance of a product, and hence, the user's satisfaction and acceptance of that product can be thought of as a function of four components: (1) the probability that the product (including hardware and software) will perform correctly, (2) the probability that the foreseeable-use scenario will not adversely degrade product functionality, (3) the probability that accurate procedures (*e.g.*, assembly, operation, maintenance) have been developed for the product's use, and (4) the probability that the user will perform the foreseeable tasks correctly. User performance has the greatest variability. A product can operate perfectly from an engineering sense in a laboratory or during a demonstration, and then not perform well when it is operated by actual users in real-world settings. Enhancing the user's interactive experience with the product can increase user satisfaction, acceptance of the product, and safety. These components can be thought of as dynamic variables that interact with each other, requiring trade-off decisions to optimize operational product performance.

In the following sections, we outline the stages of the product design process and the activities that a human factors specialist can perform in each phase.

6. Human Factors Activities in Product Design Process

Product design includes the following six stages:

1. Product planning
2. Idea and concept generation
3. Design and development
4. Testing and validation
5. Production
6. Post-production evaluation

The depth and breadth of each stage might vary depending on the particular product, but every product will go through a similar, iterative process. The transition point between stages is not always clear. That is, there is rarely a specific point at which one stage ends and another begins. For example, product planning will occur throughout the entire process, and testing and validation activities will begin during design and may continue through post-production evaluation. Below we explain the stages and the types of activities that human factors specialists perform in each stage of the product design and development process.

6.1 Product Planning

The product planning stage is characterized by planning the necessary steps to bring the product to the marketplace and the subsequent assessment of the product's performance. Product planning is a vital function for any company for the following reasons:

- Every product has a limited life span and will need improvement or replacement after some time.
- The needs, desires, and preferences of consumers change over time, thus requiring adjustments or modifications in products.
- Competition and the advancement of technology create opportunities and demands for the design and development of better products.

During product planning, the company identifies:

- the market opportunity,
- the targeted user group(‘s) characteristics;
- the characteristics of non-targeted, but foreseeable user group(s);
- the high-level tasks and activities that need to be accomplished;
- the schedules for the tasks and activities;
- personnel resource requirements, including the number of people and any special skill requirements;
- facility requirements, including any special equipment needed;
- the testing and evaluation of the product as the design and development evolves;
- the estimated costs, including the source(s) of the funding;
- the design, manufacturing, and distribution approaches;
- how the product will be introduced into the marketplace;
- methods for assessing performance of the product once in the marketplace; and
- how the company will handle consumer complaints and recalls.

Product planning sets the tone for the life of the product and minimizes the “hiccups” that are bound to occur during the product’s lifecycle, because potential contingencies would have already been identified and corrective measures could quickly be put into effect. Product planning prepares for surprises that could require costly and time-consuming fixes that erode profits and delay entry into the marketplace.

Human Factors Activities in Product Planning Stage	
I.	**Identify the activities to be accomplished by the human factors specialist, including any studies or analyses;**
II.	**Determine the schedule for completion of the human factors tasks and activities; and**
III.	**Determine the resources required for completion of the human factors tasks and activities.**

6.2 Idea and Concept Generation

The product design process begins with brainstorming ideas for new products or changes to existing products and systematically screening them. This initial stage is characterized by searching for a gap between the needs and wants of the consumer and what is available in the marketplace, and determining possible ways to fill that gap. As part of the product development team, human factors specialists identify the range of end users of the product and the user requirements that are essential for the product to be useful and usable. During the concept-generation stage, ideas are translated into design concepts. Devising multiple preliminary designs allows the product development team to compare, select, and build on alternative design concepts.

Idea and concept generation can involve likely end users of the product. This is known as a "participatory design approach", which has taken advantage of the technology to collect user input. Users who are involved in this process should have capabilities, characteristics, and experience that reflect the range of users for whom the product is being designed. User involvement should be active, whether by participating in design, acting as a source of relevant data, or evaluating solutions. The nature and frequency of this involvement can vary throughout the product design process, depending on the nature of the product. The effectiveness of user involvement increases as the interaction with the design team increases. The opportunity for future consumers to have a direct influence on the design as it emerges can increase user acceptance and user commitment to the brand.

Human Factors Activities in Idea and Concept Generation Stage	
I.	**Identify potential users of the product.**
II.	**Determine user needs. Analyze competing products and search for a gap between what consumers want and what is available in the marketplace.**
	***Surveys, interviews, and focus groups.*** **Such user research techniques can be used to gauge the interest of the consumer, as well as to identify desired features of a new product.**

6.3 Design and Development

The design and development stage is characterized by identifying and analyzing the function(s) of the product. This stage includes the design and development of the system hardware, software, and associated user interfaces. The human factors effort converts the results of the analyses into a detailed design to create a human-system interface that will operate within human performance capabilities and meet the product's functional objectives.

6.3.1 Preliminary Analyses

Preliminary analyses and evaluations are performed to identify user characteristics, user tasks, user interface components, and use issues early in the design process. One of the most important outcomes of these preliminary analyses is the comprehensive identification and categorization of user tasks, leading to a list of critical tasks. Each task is analyzed to determine the human performance parameters; the criticality of the task in accomplishing the objective; the system, equipment, software and associated user interfaces; and the environmental conditions under which the tasks are conducted. Gaps between human performance requirements and target and foreseeable user capabilities and approach for mitigation should be identified. Users' strengths, limitations, preferences, and expectations should be considered when specifying which activities are carried out by the users and which functions are carried out by the product itself.

a) Identify User Characteristics

Once the target and other foreseeable user populations are identified for the product, human factors specialists should gather the user characteristics relevant for system design. These characteristics include the following:

- Physical capabilities and limitations
- Cognitive capabilities and limitations
- Sensory capabilities and limitations
- Knowledge
- Skills
- Experience
- Education
- Training
- Habits and preferences, including cultural norms

Types of human abilities and limitations are discussed in detail in Appendix B. People's understanding of products results from their experiences and the multiple ways they integrate products into their lives. In the design and development of a consumer product, designers should consider the user's expectations and mental models (*i.e.*, representation of the product, or the interaction that user has in mind.) The user should be able to identify easily the product's purpose, quickly identify any hazards, safety features, controls and displays, and immediately recognize their relationships. When features function contrary to the user's expectations, errors in use are bound to follow. A common design fallacy is to assume that the designer's mental model matches the user's mental model, when, in fact, the user's mental model may be qualitatively different due to different life experiences. A new product should build on the user's existing experience and mental models.

User experience is a function of the presentation, functionality, product performance, interactive behavior, and assistive capabilities of hardware and software. It is also a function of the user's prior experiences, attitudes, skills, habits, and personality. There is a common misconception that usability refers solely to making products easy to use. The concept of usability is broader, however, and when interpreted from the perspective of the users' personal goals, can include issues such as satisfaction. Designing for the user's experience involves considering, where appropriate, user manuals, online help, support and maintenance, training, long-term use, and product packaging. The user's experience of previous or other products and issues such as branding and advertising should also be considered. The need to consider these different factors and their interdependencies has implications for the project.

b) Conduct Task analysis

Task analysis is the process of identifying how people think about the tasks and how they complete them. Task analysis provides a basis for making design conceptual decisions and is an essential, early input to system design. Task-oriented design considers the differences that can be observed between the designed task and the way the task is actually performed. Activities in performing a task are affected by variations and changes in context, procedures, equipment, products, and materials. Design should take full account of the nature of the task and its implications for the user. This includes determining whether specific tasks or functions should be automated or performed by the user. The decisions are based on many factors, including the relative capabilities and limitations of humans versus technology.

An essential goal of the task analysis process is to identify *critical tasks* that users should perform correctly for safe and effective use of the product. The user tasks should be organized based on the severity of the potential harm that could result from usage errors. Risk-analysis approaches can be helpful tools for this purpose. The list of critical tasks is dynamic and can change as more data are acquired and the product design evolves. As interactions with the user interface become better understood, additional critical tasks will likely be identified and should be added to the list. The list of critical tasks is used to structure the human factors testing to ensure that it prioritizes the tasks related to product safety and effectiveness. Additional sources of user error may be uncovered through the human factors testing.

Each critical task should be analyzed to a level sufficient to identify potential areas that can adversely affect the user's ability to accomplish his or her objective, and to evaluate proposed corrective action(s). The product development team should correct the incompatibilities by modifying the design or restructuring the tasks. Task analysis should be repeated to remain current with the changes in the design and development efforts.

***Hierarchical Task Analysis.* The aim is to decompose the high-level tasks into subtasks and operations to better understand the process and pinpoint potential sources of error.**

c) Identify Context of Use

The extent to which products are usable and accessible depends on the context, *i.e.*, the specific users, having specified goals, performing specified tasks, in a specified environment. The characteristics of the user's tasks and environment are called the *context of use*. The context of use is a major source of information for establishing requirements and an essential input to the design process.

Environmental considerations include thermal conditions, lighting, noise, and spatial layout. In some applications, environmental considerations might be part of the design, such as adding lights on a snow blower so it can be used at night.

***User Observation/Field Studies*. Direct observations that are performed in real-word settings allow human factors specialists to discover more about the context of use and provide essential input to designing usable interfaces.**

***Contextual Inquiries.* Specific types of interviews for gathering field data from users in their context, when performing their tasks.**

***Think-Aloud Protocol.* Gathering data by asking the users to verbalize their thoughts, feelings, and opinions while performing tasks.**

6.3.2 Risk Management

Risk management procedures should be planned and implemented for the entire lifecycle of the consumer product. Issues related to human performance and human factors design criteria, and that involve potential technical, cost, or schedule risks should be identified, analyzed, and prioritized early to establish a process for eliminating or reducing the associated risks to acceptable levels. Risk management should:

- Identify potential cost, schedule, design, safety, and performance risks that result from design aspects of human-system integration;
- Quantify such risks and their impacts on cost, schedule, and performance;
- Define and evaluate sensitivity of potential risks as related to the human interface;
- Identify alternative solutions to human factors problems and define the associated risks of each alternative;
- Document the identified risks, their impact on the product, and the mitigation action(s) taken;
- Take actions to avoid, minimize, control, or accept each human factors risk; and
- Ensure that human performance risks are included in the overall product's risk-management process.

a) Risk reduction process

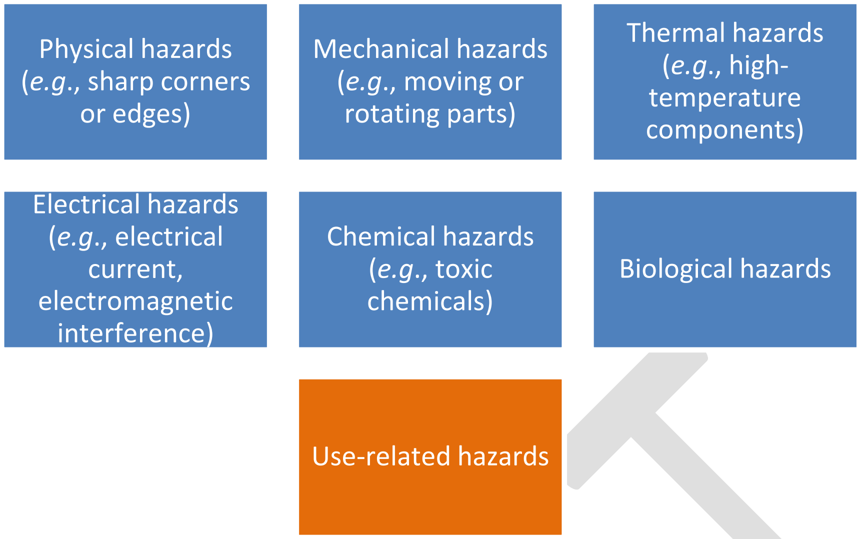
The order of priority for addressing risks should be as follows:

1. Provide an inherently safe design.
2. Provide guards and protective devices.
3. Provide information for users to use the product safely.

Inherently safe design features are the most effective step in the risk-reduction process. This is because protective features inherent to the characteristics of the product are likely to remain effective, whereas, even well-designed guards and protective devices can fail or be circumvented, and information for use might not be followed. Guards and protective devices should be used whenever design features do not remove hazards or fail to reduce risks sufficiently. The user has to be warned against the risks that cannot be eliminated. However, information for use should not be a substitute for the correct application of inherently safe design features or at least safer designs.

b) Hazards and risk

Eliminating or reducing design-related problems that contribute to or cause unsafe use is part of the overall risk management process. Hazards considered in risk analysis should include, but are not limited to, physical, mechanical, thermal, electrical, chemical, biological as well as use-related hazards:



Use-related hazards typically relate to one or more of the following situations:

- The product is used in unintended-but-foreseeable ways that the designer or manufacturer did not consider or dismissed.
- The product use requires physical, perceptual, or cognitive abilities that exceed the abilities of the user.
- The product is not designed to prevent use by consumers who lack the abilities needed to use the product safely.
- The product use is inconsistent with the user's expectations about the product's operation.
- The use environment negatively affects the product's operation.
- The use environment impairs the user's physical, perceptual, or cognitive capabilities when using the product.

c) Process to identify and mitigate use-related hazards

<u>Who are the potential users of the product?</u>

- Identify the potential users of the product, including the intended, as well as unintended users of the product. In particular, consider vulnerable consumers who may use the product without understanding the associated risks, and those who are less capable of avoiding the hazards. For example, a dresser might be purchased and used safely by adults, but children would also likely interact with the dresser, like climbing it, with limited ability to anticipate and avoid the dresser tipping over.

<u>How do people use this product?</u>

- <u>Identify known use-related problems</u>: Historical data relating to the product under development or similar products can provide invaluable insights into use-related problems. Sources of information on use-related problems include customer complaints, the knowledge of training, sales, or maintenance personnel, and previous human factors or usability engineering studies conducted on earlier versions of the product or on similar existing products.
- <u>Determine foreseeable uses of the product</u>: A foreseeable-use analysis considers the potential ways that a consumer will interact with and/or operate a product. It is a critical step in designing a safe consumer product. Foreseeable use includes the use as intended by the manufacturer, and also use in ways that were not intended but can reasonably be expected to occur. The foreseeable use analysis should also identify potential uses that the product may allow because of the clues provided by the product or its context. For example, it is foreseeable that a stool intended for sitting could also afford use as a step stool; and if the product is not designed to be stable under such conditions, it may collapse and potentially harm the user.

<u>What are the conditions in potential-use environments?</u>

- Consider all aspects of the environment in which the product might be used. Some examples are lighting, temperature, noise, and vibration.

<u>What are the risks to users?</u>

- Estimate and evaluate the risk to the affected user group(s). Pay attention to the differing characteristics of the various user groups. Evaluation should include comparison with similar products.

<u>What are the potential ways to mitigate the risk?</u>

- Determine ways to eliminate or reduce the risk. Where hazards or hazardous situations with multiple risks have been identified, ensure that preventing a risk does not result in creating another risk.

Failure Modes and Effects Analysis (FMEA) **and** ***Fault Tree Analysis (FTA)*** **are two of the risk-assessment tools that human factors specialists can use to identify, prioritize, and mitigate potential use-related hazards from the system.**

6.3.3 Product Development

a) Product-user interface

The product-user interface consists of all points of interaction between the user and the product. A product-user interface might occur while the user sets up the product (*e.g.*, unpacking, assembly, set up), uses the product, or performs maintenance on the product (*e.g.*, cleaning, replacing a battery, repairing parts). The product-user interface includes:

- Size, weight, and shape of the product;
- Elements that provide information to the user, such as indicator lights, displays, and auditory and visual alarms;
- Graphic user interfaces of product software components;
- The form in which information, including feedback, is provided to the user;
- Packaging and labeling, including operating instructions, training materials, and other information;
- Components that the user connects, positions, configures, or manipulates; and
- Components the user handles to control the product's operation, such as switches, buttons, and knobs.

The most effective strategies to reduce or eliminate use-related hazards involve modifications to the product-user interface during product design. To the extent possible, the "look and feel" of the user interface should be logical and familiar. A well-designed user interface will facilitate correct user actions and will prevent or discourage actions that could result in harm. Addressing use-related hazards by modifying the product design is more effective than revising the labeling or training. In addition, labeling might not be accessible when needed, and training depends on memory, which might not be accurate or complete.

An important aspect of the user interface is the extent to which interaction with the product is consistent with the users' expectations, abilities, and likely behaviors at any point during use. Users approach a new product expecting the product's components to operate in ways that are consistent with their experiences with similar products or user interface elements. The potential for use-related error increases when this expectation is violated.

Heuristic Evaluation. **Human factors specialists evaluate the usability of the system early on in the design process, based on established human factors guidelines and principles, then record their observations and rank them in order of severity. The method provides recommendations for design improvements.**

b) Models and mockups

Three-dimensional computer models, rapid prototyping, and computer-aided design methods can be used to support the design of products for which human performance will be a major factor in user acceptance and satisfaction. Additionally, the use of rapid prototyping of user interface designs can be considered. Computer models can provide relevant information, such as a suitable range of body sizes and postures for evaluating proposed designs and design changes. However, computer models should not be used for compliance testing of human performance and human factors design. When used for predictive purposes, such models should produce outputs that are accurate and empirically repeatable.

c) Evaluating with users

User feedback is a critical source of information in user-centered design. Iteratively evaluating designs with users and improving them based on user feedback better ensures the product will meet the users' needs. Such evaluation allows preliminary design solutions to be tested against "real-world" scenarios, with the results being fed back into progressively refined solutions. User-centered evaluation should also take place as part of the final review of the product to confirm that requirements have been met. See section 6.4.1 on how to choose participants and conduct testing.

d) Human-System Interface

Human factors principles should be applied to human-system interface design including hardware and software. A style guide should be used in the development of software user interfaces to define the general principles and specific rules that guide the design and consistency of individual components. To the degree practical, the use of models, simulations, and prototypes should be used to support human-system interface development.

e) Technical documentation and instructions

Human factors principles should be applied to the development of technical documentation (electronic and hard-copy) to ensure thoroughness, technical accuracy, suitable format of information presentation, appropriate reading level, appropriate level of technical sophistication, clarity, and quality of illustrations. The instructions should include the assembly, use, cleaning, maintenance, dismantling, and destruction or disposal of the product, as appropriate. All foreseeable hazards associated with using the product need to be identified.

Warnings should be conspicuous, legible, durable, clear, concise, and motivating. Product safety signs and labels should be understandable to end users in all intended countries of use. The content of a warning should vividly describe the product hazard and the consequences if the warning is not followed. Effective warnings attract attention by using signal words (*e.g.*, “Danger,” “Warning,” or “Caution”), safety alert symbols, if applicable, and a font in a type size and color that is suitable to the product hazard.

The instructions should provide users with the means to avoid harm caused by a product hazard that has not been eliminated. Effective instructions help product users to make appropriate decisions concerning the use of the product, and provide directions to avoid misuse of the product. Instructions may also indicate remedial action if an accident occurs, *e.g.*, spilling gasoline while refueling a lawnmower.

Instructions for use are an integral part of the product and should:

- Clearly identify the product;
- Define the intended use of the product, its function and operation, including any considerations for certain populations, *e.g.*, access by children;
- Contain all information required for correct and safe use of the product, *e.g.*, transport, handling, lifting weight, assembly, installation, and storage conditions;
- Contain all information required for cleaning, maintenance, fault diagnosis, signs of deterioration, and repair of the product;
- Identify the potential safety hazards;
- Contain consumer-relevant technical specifications; and
- Include a source of further contact information, such as a phone number, website , and email address of the manufacturer.

Additionally, instructions for use should convey information about environmental aspects of the product, including disposal, recycling, contaminants or pollutants, noise, and consumption and conservation of energy and other resources.

For additional guidance on developing instructions, you can refer to Manufacturer’s Guide to Developing Consumer Product Instructions, CPSC, 2003.

f) Traceability

Manufacturer documentation should provide traceability of design decisions from initial identification of requirements to verifying requirements during test and evaluation. Traceability assists in:

- Assessing compliance with applicable laws and regulations;
- Developing and tracking lessons learned;

- Managing change and evolution of the design; and
- Prioritizing and justifying requirements.

All data, such as plans, analyses, drawings, checklists, design and test notes, and other supporting background documents reflecting actions and decision rationale, should be maintained for meetings, reviews, audits, demonstrations, testing and evaluation, and related functions.

Human Factors Activities in Design and Development Stage	
I.	Identify all possible users; determine user characteristics
II.	Conduct task analysis
III.	Identify foreseeable use and misuse scenarios and hazards associated with those scenarios
IV.	Estimate and evaluate the risk level for each identified hazard
V.	Determine ways to eliminate or reduce the hazard
VI.	Convert the results of task analysis data into a detailed design to create a human-system interface that will operate within human performance capabilities, meet the desired functional requirements, and accomplish the product's objectives
VII.	Review layouts and drawings for all designs with potential impact on the human-system interface, and identify for corrective action those designs that may induce use-related error or be unsafe
VIII.	Apply human factors principles to the engineering drawings and computer-aided design representations to ensure the final product can be used effectively, efficiently, reliably, and safely
IX.	Ensure that the human functions and tasks identified through human factors analyses are organized and sequenced for efficiency, safety, and reliability, and provide inputs to the technical documentation
X.	Participate in developing the look, feel, and content of controls and displays, including multifunction displays, to ensure that the user interface supports efficient data input and retrieval, access to required information, and execution of decisions and commands

6.4 Testing and Validation

Testing and validation should occur throughout the design lifecycle such that, as the design evolves, undesirable features can be identified and rectified while the monetary and temporal costs of remediation are lower. As the last stage before production, final tests are conducted to validate that the product meets established requirements before the product reaches the market. The goals of testing and validation include the following:

- Verify that the product or design can be properly operated and maintained by the anticipated user population, having the expected personnel attributes, in the intended operational environment(s);
- Obtain quantitative measures of performance that are a function of the human interaction with the hardware, software, and associated user interfaces;
- Confirm attainment of overall system performance requirements;
- Verify that proposed instructions, illustrations, and job aids provide adequate training and access to reference information; and
- Determine whether undesirable design or procedural features have been introduced.

Maximum use should be made of any data collected from prototypes and demonstrations. Both qualitative and quantitative data can be used to support the test and validation effort. The fact that individual testing and evaluations may occur at various stages in the design and development process should not preclude a final test and validation of the complete system.

6.4.1 Human Factors Testing

Human factors testing is conducted to demonstrate that the product can be used by the intended or foreseeable users without serious use errors or problems, for the intended or foreseeable purpose, and under the expected or foreseeable use conditions. The testing should be comprehensive in scope, adequately sensitive to capture errors afforded by the design of the user interface, and the results must be generalizable to real-world use by consumers. The human factors testing should be designed such that:

- The test participants represent the realistic (actual) users of the product.
- At a minimum, all critical tasks are performed during the test.
- The product user interface represents the final design.
- The test conditions are sufficiently realistic to represent actual conditions of use.

Test planning should include an identification of the critical tasks, *i.e.*, those most frequently performed and those with the most potential for harm, and the method(s) that will be used to collect data on the test participants' performance and assessment of the critical tasks. The results of the testing should facilitate analysis of the root causes of use errors and other problems found during the testing.

Testing can be conducted under conditions of simulated use, but data should also be collected under conditions of actual use, when simulations are inadequate to evaluate users' interactions with the product.

Screening tests can be performed to increase the likelihood of acquiring a representative sample, thereby increasing the generalizability of the testing and the accuracy of the results. Demographic variables relevant for testing may include age, gender, location, and occupation. Screening tests can also gauge participant knowledge, skills, abilities, and other characteristics to help ensure that the sample has capabilities representing the target population. An unrepresentative sample can be worse than having no sample, fostering misleading expectations about the target population.

A detailed test can also prove useful, accounting for all dimensions of a consumer product or design (*e.g.*, using a mock-up, prototype, or other physical model), in relation to body size dimensions of the user (*e.g.*, considering a 5^{th} percentile female height or grip size.)The selection of body size dimensions depends on the features of the product or design under test. The duration of a detailed test should be long enough to give a good representation of the intended use of the product, including foreseeable, non-regular use, such as emergency use and maintenance. A screening test is not as complete or accurate as a detailed test but can be used in the preliminary assessment of the usability of consumer products and designs for a defined intended user population.

6.4.2 Tasks and Use Scenarios

Human factors testing should include, at a minimum, all critical tasks identified in the preliminary analyses. Tasks that logically occur in sequence when using the product (*e.g.*, product set-up, data entry, calibration) can be grouped into use scenarios. Use scenarios in the testing should include all necessary tasks and should be organized in a logical order to represent a natural workflow. Products with a large number of critical tasks might need to be assessed in more than one human factors test session (*e.g.*, repetition with the same test participants or testing with different participants). The level of performance that represents success for each task should be defined.

For products that are used frequently and/or have a learning curve that requires repeated use to establish reasonable proficiency (*e.g.*, the proper setting of a camera based on the subject to be photographed and the lighting conditions), it may be necessary to have each test participant use the product multiple times to gauge accurately typical use of the product. Similarly, in testing a product that requires frequent input, such as a television remote, repeated performance testing could reveal a high frequency of incorrect button selection caused by the button layout being inconsistent with typical user expectations.

Use scenarios involving critical tasks that have a low frequency of occurrence (*e.g.*, changing the oil in a lawnmower) require careful consideration. When tasks are performed infrequently, users may place increased burden on their memories to determine the proper course of action. This can lead to missed steps and misuse of the product. Intuitive mapping and clear instructions become all the more important when users are expected to depend on recollection for critical tasks.

6.4.3 Selection of Test Participants

The most important consideration for test participants in human factors testing is that they represent the population(s) of end users. The number of test participants involved in human factors testing depends on the purpose of the test, the likelihood of use error, the severity of use error, and the complexity of the user interface.

The human factors test participants should be representative of the range of characteristics within their user group. Individual differences (range of abilities) will vary to some extent among test subjects, but the test participants should reflect the actual user population(s) to the greatest extent possible.

Target populations may be distinct from one another, having different characteristics and environments that affect their interaction with the product. If different user groups will perform different tasks or will have different knowledge, experience, or expertise that could affect their interactions with the product, and therefore have different potential for use error, these users should be separated into distinct user populations when selecting and testing participants. The ways in which users differ from one another are unlimited, so the focus should be on user characteristics that could have a particular influence on their interactions with the product, such as age, education, sensory and physical impairments, and occupational specialty. To minimize potential bias introduced into human factors testing, company employees and suppliers should not serve as test participants. For example, a smart phone could have users that are preteens, teenagers, adults, and senior citizens, each with varying needs and capabilities. Also, although they may not be target users, it may be likely for parents to allow toddlers, with their varied needs and capabilities, to play with the phone.

Some products require specific body size dimensions for safe and effective use. Test participants should represent the relevant dimensions of the intended user population. That is, if a clearance-dimension is to be tested, the test participants should, as far as possible, represent the larger persons for that dimension. If a reach-dimension is to be tested, the test participants should, as far as possible, represent the smaller people, while also considering the risk that a longer reach from largest users may afford contact with a hazard.

The global region to which a product is marketed may influence its reception by users. User expectations and performance may be affected by culture-based heuristics, regulations, and laws. For example, culture may affect the interpretation and effectiveness of product instructions. Other factors to consider are language barriers and units of measurement. For the results of the human factors testing to demonstrate safe and effective use by users in a particular global region, the test participants should reside in that global region.

6.4.4 Test Cycle

Any individual test should cover at least one entire use cycle for each element of the product under assessment (*e.g.*, adjustments, displays, controls, visibility). The reliability of some tests can be improved by repeating them several times (at least three times is recommended). Guidance for specific tests might be found in similar product standards or data sheets.

6.4.5 Simulated-Use Human Factors Testing

Simulated-use testing involves systematic collection of data from test participants using a product in realistic-use scenarios under simulated conditions. Simulated-use testing can explore user interaction with the product overall, or it can investigate specific human factors considerations identified in the preliminary analyses, such as infrequent or particularly difficult tasks or use scenarios, challenging conditions of use, use by specific user populations, and adequacy of the technical documentation.

The conditions under which simulated-use testing is conducted should be sufficiently realistic so that the results of the testing are generalizable to actual use. The requisite level of fidelity is driven by the analysis of risks related to the product's specific intended use, users, use environments, and the user interface; *i.e.*, higher risk requires higher realism to tease out design features that may cause injury. To the extent that environmental factors might affect users' interactions with elements of the product, the environmental factors should be incorporated into the simulated-use environment (*e.g.*, dim lighting and cold weather).

During simulated-use human factors testing, test participants should be given an opportunity to use the product as independently and naturally as possible, without interference or influence from the test moderator. If users would have access to technical documentation in actual use, it should be available in the test; however, the test participants should be allowed to use the technical documentation as they choose and not be "forced" to use it. Test participants may be asked to evaluate the technical documentation as part of the test, but this evaluation should be done separately, after the simulated-use testing is completed. If the users would have access to a telephone or Internet help line, it may be provided in the test but it should be as realistic as possible; *e.g.,* the help line portrayer should not be in the room and should not guide the test participant through specific test tasks. The objective is to understand how typical end users will use the product. If participants neglect the technical documentation and help line, then typical end users may also forego these supplementary options, in which case the design features of the product are even more important for inviting proper use and preventing misuse.

The simulated-use testing methods can be tailored to suit specific needs. Data can be obtained by observing test participants interacting with the product. Automated data capture, *e.g.*, participants wearing an eye tracking device, can also be used if interactions of interest are subtle, complex, or occur rapidly, making them difficult to observe. Observations can include any instances of hesitation or apparent confusion. Test participants should be interviewed after using the product to obtain their perspectives on use of the product and any problems that occurred.

6.4.6 Instructions for Use and Labeling

Human factors testing can serve to assess the adequacy of the instructions for use of the consumer product, including the test participants' understanding or knowledge regarding critical aspects of use. The goal is to determine the extent to which the instructions for use support the users' safe and effective use of the product. If the product instructions are inadequate, it might result in participant's poor performance or subjective feedback. Ambiguities and inconsistencies in both the written and illustrated instructions are common concerns. For example, the user should not have to guess the orientation of the product in an illustration, nor should they have to make assumptions about parts being referenced.

The design of the product labeling used in human factors testing should represent the final design. Minor differences between the tested and actual labels can have unexpected effects on user awareness of and adherence to labels, so they should be high fidelity. This applies to the labels on the product and any accessories, and information presented on the product display, product packaging, instructions, user manuals, package inserts, and quick-start guides.

Human Factors Activities in Testing and Validation Stage	
I.	Plan the human factors test to identify the data to be collected, the test procedures, test criteria, and the reporting process.
II.	Prepare the test documentation (*e.g.*, checklists, data sheets, test participant descriptors, questionnaires, and operating procedures), and make it available at the test location.
III.	Determine the tasks to be performed (to include critical tasks at a minimum), or a simulation thereof, if actual performance is not feasible.
IV.	Determine criteria for acceptable performance or rejection of the test results.

V.	Recruit participants who are representative of the range of the intended or foreseeable user population(s) in terms of aptitudes, skills, capabilities, experience, size, and strength; and who wearing suitable clothing and equipment appropriate to the task.
VI.	Conduct human factors tests to demonstrate that the consumer product will be efficient, effective, and safe in the hands of the user. Collect task performance data in actual operational environments or in simulated environments, if collection in the actual operating environment is not feasible.
VII.	Review the failures that were recorded during testing to differentiate among failures of hardware/software alone, failures resulting from human-system incompatibilities, and use-related failures.
VIII.	Analyze use-related errors to determine the reason for their occurrence. Identify the design characteristics or procedures that may contribute use-related errors.
IX.	Determine appropriate corrective action.

6.5 Production

This stage is characterized by manufacturing the product, introducing it to the consumer, and bringing it to the marketplace. The manufacture of safe and reliable consumer products is a function of many factors, including physical working conditions. A satisfactory working and processing environment (*e.g*., good lighting, controlled temperature, and humidity) are important for the manufacture of safe products. Supporting technical documentation, such as drawings, replacement parts data, production, inspection, testing and repair instructions, and operating handbooks, must be current with design. Obsolete documents and data should be removed from all places where they might be used inadvertently.

Instructions for assembly, packaging, and shipping operations affecting safety, *i.e.,* work instructions, should be maintained and readily available to personnel. Work instructions can prove vital in the improvement of production and the identification of problems. Work instructions take many forms, including work orders, operation sheets, inspection logs, repair logs, test procedures, and process specifications. They may specify the equipment to be used for particular operations and traceability arrangements identifying the person(s) who performed each of the operations. Work instructions can also include forms for recording quantitative data, such as test readings and dates accomplished.

If a manufactured product is potentially hazardous, it may be discarded or repaired. If repair is chosen, adequate precautions must be taken to ensure that the repaired product effectively eliminates the identified safety hazard and that changes made to the product do not present new safety hazards. The repair may require using more skilled workers, more precise equipment, or more closely controlled materials. Repair operations performed by distributors or other representatives of the manufacturer should be subject to the same controls as would apply to products repaired in the production facility, or the differences in controls should be considered in determining the adequacy of the repair and the instructions and procedures for carrying it out.

6.5.1 Quality Assurance and Inspection

Quality assurance refers to a systematic process taken throughout manufacturing to detect and prevent product deficiencies and product safety hazards. Accepted quality management processes and systems can be implemented by manufacturers of all sizes. A quality assurance system is specific to a manufacturer's operations and addresses product safety matters.

It is imperative that consumer products be inspected and tested prior to distribution in order to verify their conformance to established requirements. If components or subassemblies are not accessible for inspection and testing post-assembly into parent units, then such items should be inspected and tested prior to assembly. Trained personnel should conduct inspections and tests that are meaningful, objective and uniform, and record and maintain results. Similarly, any inspection that must be performed by the user before operating the product should be clearly indicated and described in the product documentation.

An effective product safety system requires records in sufficient detail to permit timely detection of safety hazards and trends, and for traceability of the assembly operations and components involved. For these purposes, the following records are particularly helpful:

- The results of inspections, tests, and calibrations;
- Consumer complaints, comments, and related actions;
- Actions taken to correct product and system deficiencies; and
- The location of products within the production and distribution systems so that prompt and effective recall can be accomplished, if required.

To help prevent potentially dangerous products from being delivered to consumers, it is crucial that manufacturers have established procedures for taking prompt corrective action. This action includes determination of the cause(s) of the hazard, prevention of their reoccurrence, and removal of affected units from production and distribution channels. By maintaining work instructions, the manufacturer can identify more quickly the affected units and the causes of the hazards. For example, defective units may be limited to a specific batch, and by examining records, the affected batch can be identified quickly and isolated, rather than halting all batches of the product.

6.5.2 Packaging and Advertising

Human factors principles can be applied to the design of the product packaging as well as advertising to improve the appeal of the product to potential users. Consideration should be given to whether the packaging or advertising may appeal to unintended users (such as children outside of the intended age range). Consider the following examples:

- Color is used to attract attention, group elements, indicate meaning, and enhance aesthetics. Color can make designs more interesting visually and can reinforce the organization and meaning of elements in a design. However, if applied improperly, color can seriously harm the design’s form and function.
- Icons are pictorial images to make actions, objects, and concepts easier to find, learn, and remember. Icons can be used for identification, serve as a space-saving alternative to text, and draw attention to an item within a display.
- The old adage-- “a picture is worth a thousand words,” is true in most cases. Pictures are generally recognized more readily and recalled easier than text. Instructional and technical material should accompany text with supporting pictures to lessen the ambiguity of tasks and controls.
- Mnemonic devices are used to reorganize information so that the information is simpler and more meaningful, and therefore, more easily remembered. Mnemonic devices involve the use of imagery or words in specific ways to link unfamiliar information to familiar information that resides in one’s memory.
- People are predisposed to perceiving certain forms as humanlike, specifically forms and patterns that resemble faces and body proportions. This tendency, when applied to packaging and design, is an effective way of getting attention, establishing a positive attitude about interactions, and creating a relationship based on emotional appeal.

Human Factors Activities in Production Stage	
I.	Participate in the design and development of work stations to ensure that physical working conditions are satisfactory including environment (*e.g.*, good lighting, controlled temperature, and humidity) for the manufacture of safe products.
II.	Maintain the instructions for assembly, packaging, and shipping operations affecting safety, *i.e.,* work instructions.
III.	Incorporate human factors principles into the design and development of packaging and advertising materials.

6.6 Post-Production

This stage is characterized by evaluating the product's performance in the marketplace, and identifying and addressing any issues or concerns with use of the product. Human factors specialists recognize that customer feedback is a critical source of information. The percentage of returns can be an indication of customer dissatisfaction with the product. The percentage of repairs can be an indication of problematic components. Findings from customer satisfaction surveys can identify customer concerns and suggestions for improvements. Incident reports and complaints to customer service can uncover use-related issues of the product, and determine avenues for both remediation and enhancement. This review should pay particular attention to the following:

- The number of calls to the help desk/complaints to customer service;
- Complaints about the product not working properly;
- Questions about how to perform a particular function or operation; and
- Indications that the product is being used in unintended ways.

This data can reveal manufacturing defects, uncover trends in assembly error due to ambiguous or insufficient instructions, and it can indicate that the results of the foreseeable use analysis need to be revisited. Properties of the product may allow, or even invite, dangerous use. Design changes, safeguards, and warnings may be required to reduce the likelihood of dangerous use; and without consulting customers as a source of information, the product can fail, and customers can be injured.

6.6.1 Recalls

By incorporating human factors principles during the design and development of the product, a company can improve customer satisfaction with its products and decrease the risk of a product recall.

A product recall involves both direct and indirect costs. Direct costs could include:

- conducting the recall,
- communication costs,
- loss of sales,
- business-interruption costs,
- inventory losses,
- refunds and compensation,
- logistics costs, and
- fines and lawsuits.

- Indirect costs could include:loss of market share,
- future loss of sales,
- negative impact to brand image,
- cost to rebuild image,
- cost to rebuild company reputation,
- potential collapse of the company, and
- negative impact on morale.

Communication during a recall is paramount to the success of the recall and prevention of product-related injuries. Companies should ensure that their notices advertising recalls are likely to reach the affected consumers and motivate consumers to comply with the recall notice.

The most effective methods of communicating product recalls are communication channels that allow direct contact between the supplier and consumers. Internet blogs and social networking sites are useful tools to advertise recalls, due to the growing popularity among various consumer demographics. For more information, see the CPSC Recall Guidance, including guides to planning, social media, at: https://www.cpsc.gov/Business--Manufacturing/Recall-Guidance).

Recall notices should be easily recognizable and easily understood, and provide all of the information consumers need to know about the recall. The wording, tone, and design of a recall notice may need to be vivid to capture attention and motivate consumers to comply with the recall. Insufficient information, inappropriate features, and weak language can create barriers to consumer compliance. Returning or fixing a product places a burden on the consumer, and the consumer may ignore the recall notice. Thus, it is imperative that companies take an approach that motivates compliance with the recall.

Companies should protect their interests by establishing full traceability of their products, both by maintaining a method for tracking where the product will ultimately be used, sold, warehoused, and transported, and by identifying the product in an accessible and unambiguous manner. User-friendly product identification is crucial for consumers and companies to determine quickly whether they possess the products included in a recall. Identifying information should be recognizable by color and shape, it should be readable, and it needs to be permanently affixed to the product in a noticeable location.

Human Factors Activities in Post-Production Stage
I. Analyze the returns to determine if the reason for the return is related to the product-

	use interface;
II.	Examine the repair data to determine the reasons for repairs of the product and the fix applied;
III.	Evaluate customer satisfaction surveys, incident reports, and calls to the help desk to determine if any trends emerge relating to the use of the product;
IV.	Verify that recall communication is clear and motivates compliance; and
V.	Improve traceability of products in the event that affected units must be quickly identified and collected.

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APPENDIX A

Human Factors Professionals:

1. Education

Many colleges and universities provide courses in human factors, and many offer degree and certificate programs in this field. These may be at the undergraduate or graduate level, but degree programs are typically at the graduate level. Depending on the college or university, the relevant courses could be provided via a human factors curriculum, or within industrial engineering or engineering psychology curricula. Additionally, courses dealing with user-computer interface design, experimental design, and statistical analysis may be beneficial.

2. Practical experience

Proper application of human factors principles and guidelines results in products that are usable, safe, and well-received. Poor product design can result in bad publicity, monetary costs, and injury, even death. While coursework in human factors can provide a foundation for strategic product design, it is no substitute for practical, real-world experience. As consumer products can present a variety of challenges, having practical experience in the strategic design of a wide array of consumer products can to those overcoming those challenges rather derailing the effort.

3. Certification

Although not essential to becoming a qualified human factors professional, a professional certification provides the company an added level of comfort that the individual being considered possesses the desired skills and qualifications. The Board of Certification in Professional Ergonomics (BCPE) and the Chartered Institute of Ergonomics & Human Factors (CIEHF), among others, provide professional certification for practitioners of human factors and ergonomics who demonstrate expertise and a comprehensive understanding of the discipline. With such certification, employers and consumers may have greater confidence that they are working with a professional who has met rigorous standards.

Certification is increasingly important in a world where expertise is ever-more valuable to employers, consumers, and individuals. Employers who hire a certified professional may be confident that the individual has a recognized baseline of knowledge and competence. In a crowded field of practitioners, certificate holders distinguish themselves by earning an internationally recognized certification.

4. Finding qualified human factors professionals

Several organizations and their websites may help you find qualified human factors professionals. The most recognizable professional organization dedicated to human factors is the Human Factors and Ergonomics Society (HFES) (www.hfes.org). The HFES promotes the exchange of knowledge concerning the characteristics of human beings that are applicable to the design of systems and products of all kinds. The HFES furthers serious consideration of knowledge about the assignment of appropriate functions for humans and machines, whether people serve as operators, maintainers, or users in the system. Furthermore, it advocates for the systematic use of such knowledge to achieve compatibility in the design of interactive systems of people, machines, and environments to ensure their effectiveness, safety, and ease of performance. The HFES maintains a searchable directory of human factors consultants for use by potential clients. Both individuals and companies are listed. One can search for consultants by name of individual or company name, specialty or expertise area, and geographical location.

Other professional organizations that may have human factors professionals among their membership are the American Psychological Association (www.apa.org), the Chartered Institute of Ergonomics and Human Factors (www.ergonomics.org.uk), the International Association of Applied Psychology (www.iaapsy.org), and the International Ergonomics Association (www.iea.cc).

APPENDIX B

Designing Products to Accommodate Users with a Range of Abilities

The needs and abilities of people change as they advance from childhood to old age, and the abilities of individuals in any particular age group can vary substantially. Functional and cognitive limitations vary from comparatively minor impairment, to more extreme forms.

One of the vulnerable populations to consider is children. Children are not merely small adults. Children are much more willing to simply try something and often use trial-and-error interactions. Children do not think in terms of achieving an objective, and often, they can find, and continue to use, inefficient paths to their desired result.

Reductions in sensory, physical, and cognitive abilities are often associated with older users, but such impairments can occur to individuals at any age. Product design should consider and accommodate these differences. Listed below are some of the human abilities that tend to diminish with age. Please refer to the CPSC staff report titled, *"Older Consumer Safety: Phase I,"* for additional details and suggested product-related interventions to compensate for these abilities.[2]

1. Sensory and Perceptual Abilities

a) Vision. Reduced visual acuity and field of vision; reduced color sensitivity, depth perception, and speed of adaptation to changing light levels are some of the deteriorating abilities. People with a visual impairment are at an increased risk of hazards from sharp points and edges on products; unstable items that might fall, uneven surfaces that may result in slip, trip, and fall hazards, and visual warnings that rely solely on color, with poor contrast between text and background.

b) Hearing. Hearing relates to sensing the presence of sounds and distinguishing the location, pitch, loudness, quality, and comprehension of the sound. As people age, they tend to lose the ability to detect higher-frequency sounds. People with hearing loss are at an increased risk if spoken instructions and warnings are not loud or intelligible enough for them, or if frequencies are too high to detect.

c) Touch. As people age, they generally lose sensitivity and can no longer rely on touch and pain to give early feedback on temperature or injury. When operating a product in the dark,

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[2] The report can be accessed via www.cpsc.gov/PageFiles/103904/older.pdf

such as in emergency situations, or when the user is otherwise visually impaired, touch may be the only way to detect a control.

d) Smell. Smell relates to the use of receptors in the nose to sense odors. The ability to detect odors decreases somewhat as people age. Impairment of the sense of smell can reduce the body's defense against toxic materials. For example, people with a decreased sense of smell may not be as easily alerted to certain hazards, such as smoke or natural gas leaks.

e) Balance. The ability to maintain balance and avoid falling depends on the interaction of visual stimuli, feedback from the balance mechanism in the ear, and movement of the limbs. The incidence of balance impairments, and thus falls, increases with age.

2. Physical abilities

a) Strength. Strength relates to the force generated by the contraction of a muscle, or muscle group, when carrying out an activity. Limited strength is a common reason for people being unable to operate objects. For example, impairment of grip strength can make it difficult or painful to operate an object against resistance or torque.

b) Fine motor skills. Fine motor skills, or manual dexterity, relates to activities of hand and arm use, particularly coordinated actions of handling objects, picking them up, and manipulating them. Operations that require sustained pressure and twisting of the wrist, such as pushing and turning, may be painful or difficult for people with limited dexterity. The size, shape, and location of controls should be designed to account for these people.

d) Movement. Movement relates to activities of maintaining and changing the body position and transferring oneself from one area to another using legs, feet, arms, and hands. Examples include limited ability to bear mass on the legs, reduced step length and/or height, and restricted range of movement in the joints of arms, legs, and spine. Some people are assisted by equipment, such as wheelchairs or walking aids, which may require extra space around them to allow for approaching and maneuvering.

e) Voice. Voice relates to the sound produced by the vocal organs, usually as speech. The main consequence of speech impairment is the barrier to communication. Alternative forms of communication, such as sign language, or devices, such as speech amplification, speech synthesis, or use of keyboards, may assist.

3. Cognitive abilities

a) Cognition. Cognition is the understanding, integrating, and processing of information. The information includes abstraction and organization of ideas and time management. The design of consumer products should recognize that cognitive processes use accumulated knowledge and prior experience. Individuals can vary in their understanding of consumer products, both in terms of the functionality they offer, and the ways in which they are operated.

b) Intellect. Intellect is the capacity to know, understand and reason. Conditions such ass dementia and Alzheimer's disease lead to progressive intellectual decline, confusion, and disorientation. Written text used to label or explain interfaces should use easy-to-understand, common words, and direct wording. Where the intended user group includes users of low literacy, self-explanatory pictograms should be used, whenever possible, in addition to text.

c) Memory. Memory relates to specific mental functions of registering and storing information and retrieving it, as needed. Failing memory affects people's ability to recall and learn things and may also lead to people being confused. Memory impairment can lead to a hazard if an uncompleted task results in a dangerous situation, such as the gas supply turned on, but not ignited. Design needs to ensure that systems are "fail-safe."

d) Language. Language and literacy are the specific mental functions of recognizing and using signs, symbols, and other components of a language. Aging may affect a person's language ability. When people have a stroke, for example, their language ability may be affected. They may be able to think in the same manner but be unable to express their thoughts in words. People of all ages with dyslexia have difficulties in reading and writing. People with language impairment may be at risk if they are unable to comprehend written warnings or significant instructions.