

Human Computer Interaction (HCI)

1.1 Introduction

Human–computer Interaction (HCI) involves the **study, planning, and design of the interaction between people (users) and computers.**

It is often regarded as the intersection of computer science, behavioral sciences, design and several other fields of study. The term was popularized by Card, Moran, and Newell in their seminal 1983 book, "The Psychology of Human-Computer Interaction", although the authors first used the term in 1980, and the first known use was in 1975. The term connotes that, unlike other tools with only limited uses (such as a hammer, useful for driving nails, but not much else), a computer has many affordances for use and this takes place in an open-ended dialog between the user and the computer.

Because human–computer interaction studies a human and a machine in conjunction, it draws from supporting knowledge on both **the machine** and **the human side**. On the machine side, techniques in computer graphics, operating systems, programming languages, and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and human factors such as computer user

satisfaction are relevant. Engineering and design methods are also relevant. Due to the multidisciplinary nature of HCI, people with different backgrounds contribute to its success. HCI is also sometimes referred to as man–machine interaction (MMI) or computer–human interaction (CHI).

Attention to human-machine interaction is important because poorly designed human-machine interfaces can lead to many unexpected problems. A classic example of this is the Three Mile Island accident, a nuclear meltdown accident, where investigations concluded that the design of the human–machine interface was at least partially responsible for the disaster.

Similarly, accidents in aviation have resulted from manufacturers' decisions to use non-standard flight instrument and/or throttle quadrant layouts: even though the new designs were proposed to be superior in regards to basic human–machine interaction, pilots had already ingrained the "standard" layout and thus the conceptually good idea actually had undesirable results.

1.2 Goals of Human–computer Interaction

A basic goal of HCI is to improve the interactions between users and computers by making computers more usable and receptive to the user's needs. Specifically, HCI is concerned with:

- Methodologies and processes for designing interfaces (i.e., given a task and a class of users, design the best possible interface within given constraints, optimizing for a desired property such as learnability or efficiency of use).
- Methods for implementing interfaces (e.g. software toolkits and libraries; efficient algorithms)
- Techniques for evaluating and comparing interfaces
- Developing new interfaces and interaction techniques
- Developing descriptive and predictive models and theories of interaction

A long term goal of HCI is to design systems that minimize the barrier between the human's cognitive model of what they want to accomplish and the computer's understanding of the user's task.

Professional practitioners in HCI are usually designers concerned with the practical application of design methodologies to real-world problems.

Their work often revolves around designing graphical user interfaces and web interfaces.

Researchers in HCI are interested in developing new design methodologies, experimenting with new hardware devices, prototyping new software systems, exploring new paradigms for interaction, and developing models and theories of interaction.

1.3 Differences with related fields

HCI differs from human factors (or ergonomics) as HCI focuses more on users working specifically with computers, rather than other kinds of machines or designed artifacts. There is also a focus in HCI on how to implement the computer software and hardware mechanisms to support human–computer interaction. Thus, human factors are a broader term; HCI could be described as the human factors of computers – although some experts try to differentiate these areas.

HCI also differs from human factors in that there is less of a focus on repetitive work-oriented tasks and procedures, and much less emphasis on physical stress and the physical form or industrial design of the user interface, such as keyboards and mouse devices.

Three areas of study have substantial overlap with HCI even as the focus of inquiry shifts. In the study of personal information management

(PIM), human interactions with the computer are placed in a larger informational context – people may work with many forms of information, some computer-based, many not (e.g., whiteboards, notebooks, sticky notes, refrigerator magnets) in order to understand and effect desired changes in their world. In computer-supported cooperative work (CSCW), emphasis is placed on the use of computing systems in support of the collaborative work of a group of people. The principles of human interaction management (HIM) extend the scope of CSCW to an organizational level and can be implemented without use of computer systems.

1.4 Design principles

When evaluating a current user interface or designing a new user interface, it is important to keep in minds the following experimental design principles:

- Early focus on user(s) and task(s): Establish how many users are needed to perform the task(s) and determine who the appropriate users should be; someone who has never used the interface, and will not use the interface in the future, is most likely not a valid

user. In addition, define the task(s) the users will be performing and how often the task(s) need to be performed.

- Empirical measurement: Test the interface early on with real users who come in contact with the interface on an everyday basis. Keep in mind that results may vary with the performance level of the user and may not be an accurate depiction of the typical human-computer interaction. Establish quantitative usability specifics such as: the number of users performing the task(s), the time to complete the task(s), and the number of errors made during the task(s).
- Iterative design: After determining the users, tasks, and empirical measurements to include, perform the following iterative design steps:
 - **Design the user interface**
 - **Test**
 - **Analyze results**
 - **Repeat**

Repeat the iterative design process until a sensible, user-friendly interface is created.

1.5 Design methodologies

A number of diverse methodologies outlining techniques for human–computer interaction design have emerged since the rise of the field in the 1980s. Most design methodologies stem from a model for how users, designers, and technical systems interact. Early methodologies, for example, treated users' cognitive processes as predictable and quantifiable and encouraged design practitioners to look to cognitive science results in areas such as memory and attention when designing user interfaces. Modern models tend to focus on a constant feedback and conversation between users, designers, and engineers and push for technical systems to be wrapped around the types of experiences users want to have, rather than wrapping user experience around a completed system.

- **Activity theory:** used in HCI to define and study the context in which human interactions with computers take place. Activity theory provides a framework to reason about actions in these contexts, analytical tools with the format of checklists of items that researchers should consider, and informs design of interactions from an activity-centric perspective.
- **User-centered design:** user-centered design (UCD) is a modern, widely practiced design philosophy rooted in the idea that users must take center-stage in the design of any computer system.

Users, designers and technical practitioners work together to articulate the wants, needs and limitations of the user and create a system that addresses these elements. Often, user-centered design projects are informed by ethnographic studies of the environments in which users will be interacting with the system. This practice is similar but not identical to participatory design, which emphasizes the possibility for end-users to contribute actively through shared design sessions and workshops.

- **Principles of user interface design:** these are seven principles of user interface design that may be considered at any time during the design of a user interface in any order: tolerance, simplicity, visibility, affordance, consistency, structure and feedback.

1.6 Display designs

Displays are human-made artifacts designed to support the perception of relevant system variables and to facilitate further processing of that information. Before a display is designed, the task that the display is intended to support must be defined (e.g. navigating, controlling, decision making, learning, entertaining, etc.). A user or operator must be able to process whatever information that a system generates and displays; therefore, the information must be displayed according to principles in a

manner that will support perception, situation awareness, and understanding.

Thirteen principles of display design

Christopher Wickens et al. defined 13 principles of display design in their book *An Introduction to Human Factors Engineering*.

These principles of human perception and information processing can be utilized to create an effective display design. A reduction in errors, a reduction in required training time, an increase in efficiency, and an increase in user satisfaction are a few of the many potential benefits that can be achieved through utilization of these principles.

Certain principles may not be applicable to different displays or situations. Some principles may seem to be conflicting, and there is no simple solution to say that one principle is more important than another. The principles may be tailored to a specific design or situation. Striking a functional balance among the principles is critical for an effective design.

Perceptual principles

1. Make displays legible (or audible). A display's legibility is critical and necessary for designing a usable display. If the characters or objects being displayed cannot be discernible, then the operator cannot effectively make use of them.

2. Avoid absolute judgment limits. Do not ask the user to determine the level of a variable on the basis of a single sensory variable (e.g. color, size, loudness). These sensory variables can contain many possible levels.
3. Top-down processing. Signals are likely perceived and interpreted in accordance with what is expected based on a user's past experience. If a signal is presented contrary to the user's expectation, more physical evidence of that signal may need to be presented to assure that it is understood correctly.
4. Redundancy gain. If a signal is presented more than once, it is more likely that it will be understood correctly. This can be done by presenting the signal in alternative physical forms (e.g. color and shape, voice and print, etc.), as redundancy does not imply repetition. A traffic light is a good example of redundancy, as color and position are redundant.
5. Similarity causes confusion: Use discriminable elements. Signals that appear to be similar will likely be confused. The ratio of similar features to different features causes signals to be similar. For example, A423B9 is more similar to A423B8 than 92 is to 93. Unnecessary similar features should be removed and dissimilar features should be highlighted.

Mental model principles

1. Principle of pictorial realism. A display should look like the variable that it represents (e.g. high temperature on a thermometer shown as a higher vertical level). If there are multiple elements, they can be configured in a manner that looks like it would in the represented environment.

2. Principle of the moving part. Moving elements should move in a pattern and direction compatible with the user's mental model of how it actually moves in the system. For example, the moving element on an altimeter should move upward with increasing altitude.

Principles based on attention

1. Minimizing information access cost. When the user's attention is diverted from one location to another to access necessary information, there is an associated cost in time or effort. A display design should minimize this cost by allowing for frequently accessed sources to be located at the nearest possible position. However, adequate legibility should not be sacrificed to reduce this cost.

2. Proximity compatibility principle. Divided attention between two information sources may be necessary for the completion of one task. These sources must be mentally integrated and are defined to have close

mental proximity. Information access costs should be low, which can be achieved in many ways (e.g. proximity, linkage by common colors, patterns, shapes, etc.). However, close display proximity can be harmful by causing too much clutter.

3. Principle of multiple resources. A user can more easily process information across different resources. For example, visual and auditory information can be presented simultaneously rather than presenting all visual or all auditory information.

Memory principles

1. Replace memory with visual information: knowledge in the world. A user should not need to retain important information solely in working memory or retrieve it from long-term memory. A menu, checklist, or another display can aid the user by easing the use of their memory. However, the use of memory may sometimes benefit the user by eliminating the need to reference some type of knowledge in the world (e.g. an expert computer operator would rather use direct commands from memory than refer to a manual). The use of knowledge in a user's head and knowledge in the world must be balanced for an effective design.

2. Principle of predictive aiding. Proactive actions are usually more effective than reactive actions. A display should attempt to eliminate

resource-demanding cognitive tasks and replace them with simpler perceptual tasks to reduce the use of the user's mental resources. This will allow the user to not only focus on current conditions, but also think about possible future conditions. An example of a predictive aid is a road sign displaying the distance from a certain destination.

3. Principle of consistency. Old habits from other displays will easily transfer to support processing of new displays if they are designed in a consistent manner. A user's long-term memory will trigger actions that are expected to be appropriate. A design must accept this fact and utilize consistency among different displays.

1.7 Human–Computer Interface

The human–computer interface can be described as the point of communication between the human user and the computer. The flow of information between the human and computer is defined as the loop of interaction. The loop of interaction has several aspects to it including:

- **Task environment:** The conditions and goals set upon the user.
- **b**
- **Areas of the interface:** Non-overlapping areas involve processes of the human and computer not pertaining to their interaction.

Meanwhile, the overlapping areas only concern themselves with the processes pertaining to their interaction.

- **Input flow:** The flow of information that begins in the task environment, when the user has some task that requires using their computer.
- **Output:** The flow of information that originates in the machine environment.
- **Feedback:** Loops through the interface that evaluate, moderate, and confirm processes as they pass from the human through the interface to the computer and back.