Chapter 2 / Capítulo 2

Sustainable balance between usability and aesthetics in hardware and software design within the organizational context
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Conceptual foundations of design and technological interfaces

Fundamentos conceptuales del diseño e interfaces tecnológicas

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ABSTRACT

This chapter examines the technological interface from a sociotechnical and interdisciplinary perspective. It describes the shift from the functionalist paradigm, which valued products by algorithmic performance, electronic stability and compliance with technical requirements, towards user-centred design, which holds that interactive systems must adapt to people's needs, cognitive limitations and contexts of use. Within this framework, usability and aesthetics are presented not as ornamental or independent attributes but as dimensions to be integrated. The chapter treats hardware and software as a single sociotechnical system: hardware provides the material canvas in which aesthetics first appears, while software shapes the interactive dynamics in which usability is experienced. The graphical user interface (GUI) is therefore addressed as the core of interaction, the space where functional and visual attributes converge. The approach is a conceptual, descriptive-analytical review of human-computer interaction literature, covering event-driven programming and GUI components such as icons, windows, pointing devices, menus and buttons, together with a brief historical account from Xerox PARC to the Macintosh and touchscreen devices. Drawing on this literature, the chapter states that interfaces based on visual metaphors and icons reduce the learning curve and cognitive load, and that an imbalance between hardware and software quickly undermines both aesthetics and actual usability. It concludes that a holistic, interactive approach grounded in user needs is required for products to be competitive, with user-centred design proposed as the framework for integrating usability and aesthetics in organizational settings.

Keywords: Cognitive load; Digital ergonomics; Visual metaphors; Sociotechnical system

RESUMEN

El capítulo estudia la interfaz tecnológica desde una perspectiva sociotécnica e interdisciplinaria. A medida que avanza el software empresarial, la industria deja atrás el enfoque funcionalista, centrado en la potencia del back-end de los equipos, para transitar hacia el Diseño Centrado en el Usuario. Este horizonte implica aceptar que hardware y software funcionan como un único sistema; por ello, el foco se desplaza hacia la interfaz gráfica de usuario (graphical user interface, GUI), espacio en el que conviven la usabilidad y la belleza. El objetivo es analizar la transición epistémica del diseño tecnológico a partir de la articulación entre la arquitectura física, las funciones lógicas y los componentes de la interfaz gráfica, así como los elementos que optimizan la eficiencia interactiva en el entorno organizacional. En cuanto al método, se declara un análisis conceptual y descriptivo-analítico basado en la revisión de la literatura sobre interacción humano-computadora, que abarca los marcos de programación orientada a eventos y los componentes de la GUI, examinados mediante una matriz analítica para valorar su impacto en la experiencia de usuario (UX). Según el texto, las interfaces basadas en metáforas visuales minimizan la curva de aprendizaje y la carga cognitiva; sin embargo, cuando existe un desbalance entre el hardware y el software, se afectan rápidamente la estética y la usabilidad real. Como conclusión, se sostiene que es necesario un enfoque holístico e interactivo basado en las necesidades del usuario para que el producto sea competitivo.

Palabras clave: Carga cognitiva; Ergonomía digital; Metáforas visuales; Sistema sociotécnico

2.1. THE PARADIGM SHIFT: FROM FUNCTIONALISM TO THE USER-CENTERED APPROACH

The design and development of interactive hardware and software products is considered not merely the result of a chronological sequence of engineering innovations. Rather, it is a fundamental shift in the epistemic structures, mental models and approaches that shape the relationship between human beings and computational systems (SHIFTA, 2025).

Historically, the development of this discipline has been structured around a central tension between two major theoretical paradigms: the functionalist paradigm and the user-centredparadigm. Our starting idea has been transformed, giving rise to another. It is precisely in this shift from one concept to the other that it becomes possible to bring together usability and aesthetics, in a balanced way, as critical factors in the competitiveness of digital organisations. This is the foundation for the analytical categories used throughout the article (Admin, 2024; Canal, 2023).

The functionalist model, which predominated in the early stages of modern computing, defined the absolute value of a product in terms of algorithm functioning and performance, electronic stability, operational capacity, and compliance with the technical requirements themselves (Admin, 2024). From this perspective, technology was regarded as the goal of action.

Engineers focused their efforts on optimizing the backend and meeting the rigid technical requirements of devices. Comfort, usability, and user experience became irrelevant, secondary, or simply auxiliary concerns. From this perspective, interaction was seen as something imposed: since the first computer was designed only for technicians, the person using it had to undergo lengthy training and was forced to adapt their mental schemas to the complex, already operational demands of the machine (SHIFTA, 2025).

This approach proved feasible as long as computing was confined to specialized environments, but the diversification of interactive profiles brought about a conceptual shift in the field that would mark a turning point. Through the work of interaction designers, it gradually became evident that technology cannot be regarded as an autonomous entity but rather has a purpose; more precisely, it is a means intended to enhance human activity and boost human performance (Patel, 2024).

Therefore, this premise, which stems fundamentally from the field of Human-Computer Interaction, radically inverts the previous functionalist thesis to formulate User-Centered Design (UCD). Methodologically, UCD holds that it is the interactive system that must adapt flexibly to people's real needs, biological capacities, cognitive limitations, and specific contexts of use (Canal, 2023; Patel, 2024).

The advent of user-centered design made it possible to dispel the myth that usability and visual aesthetics were merely ornamental attributes, or that they were independent of each other in the development life cycle. Once digital products moved beyond the exclusive domain of technical experts and took their place within production structures worldwide, the quality of the user experience became a key element.

Usability and aesthetic design are no longer regarded as competing engineering priorities; instead, they are conceived as an inseparable whole. In this book, user-centered design is presented as the methodological framework that ties these elements together and through which organizations can realize this symmetry, moving from purely instrumental engineering toward the creation of interactive ecosystems with high added value and strong competitive impact.

2.2. HARDWARE AND SOFTWARE INTERACTION AS AN INTEGRATED SOCIOTECHNICAL SYSTEM

For a holistic understanding of the balance between usability and visual appearance from a user-centered standpoint, it is necessary to move beyond the atomistic study of computer components and view hardware and software as a sociotechnical system. In the literature on human–computer interaction, the operator does not perceive the attributes of a digital product as separate elements but experiences the technological solution as a unified whole, in which the material and logical dimensions continuously co-determine each other to shape the user experience (GeeksforGeeks, 2025).

From an analytical and formal perspective, hardware is understood as a set of electronic, physical and mechanical components that make up the structure of a device. Within the organizational ecosystem, hardware is the element that, as its name suggests, is responsible for

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making the abstract processing carried out by applications and program instructions visible to the human operator.

Its structural components are organized into central processing units (CPUs), which determine processing speed; storage systems (memory units, USB devices); and input/output peripherals such as the screen and keyboard. First, hardware design establishes the initial physical constraints of the product (the material canvas, the screen size, or the input modalities), which form the basis on which aesthetics (form, texture, and materials) first manifests physically to the user. Software is the abstract and logical component of the system. In theoretical terms, it is defined as the set of programs, rules, or structured instructions that tell a computer's architecture how to execute a specific operational task.

In the business environment, software is sharply divided into system software, which comprises operating systems and drivers for the computer's resources, and application software, which addresses business needs, such as word processors, spreadsheets, browsers or analytical tools. In a design, the software algorithmically regulates the navigation flow, response to commands and visual feedback, and defines the product's dynamic interaction possibilities. It is, essentially, the dimension in which dynamic interaction and operational usability are experienced.

The proper integration of both components gives meaning and viability to the digital solution, since the correct functioning of a device depends on the proper combination of hardware and software (UNIR, 2026). Cutting-edge studies warn of the effects of a technological solution's failure when that failure is associated with a severe imbalance between the two dimensions: for example, powerful hardware coupled with poorly designed software (or vice versa) immediately disrupts the perceived usability and the overall visual assessment of the solution.

For the purposes of this research, hardware constitutes the material canvas on which aesthetics are manifested, whereas software formulates the interactive dynamics within which usability takes place. Accordingly, the strategic design balance demanded by the contemporary market is achieved only when hardware and software are conceived not as layers but as an integrated, interacting whole.

2.3. THE GRAPHICAL USER INTERFACE (GUI) AS THE CORE OF INTERACTION

In the field of human-computer interaction (HCI), the graphical user interface (GUI) is both the physical symbolic space and the interactive space that simultaneously displays usability and aesthetics, that is, the functional dimensions and the visual attributes, respectively (IONOS, 2021). Far from being merely a decorative element or an ornamental finish, a GUI theoretically represents the mediating space whose function is to translate the abstract back-end code of a computing machine as clearly as possible for the user, while also making the user's everyday tasks within the organization easier.

GUIs have changed how people communicate with computers through visual metaphors, icons and other graphical representations, so that a diverse range of [users] can understand what needs to be done without having to develop complex manual CDs or use abstract instructions. Without a GUI, the operator would be forced to rely on tedious and highly complex command sequences to run programs.

The structured design of a modern GUI effectively combines the aesthetic design of typographic and chromatic elements with the functions of programming logic. It consists of an operational surface made up of buttons, drop-down menus, navigation fields, title blocks, search fields, windows, canvases, frames, and icons. Each of these elements of analysis is causally related to the methodological categories of usability and aesthetics that we have developed.

Icons and symbols eliminate the user's cognitive load through immediate visual recognition. They act jointly on aesthetics (visual legibility of the interface) and on usability (speed of identifying the action). Windows are spatial structures that facilitate multitasking and visual organization. They directly affect usability, which enables efficient switching between organizational workflows.

Pointing devices and gestures enable direct manipulation of computer objects on the screen via the mouse or touch. According to Ionos (2021), these criteria ensure that the interaction experience is natural and fluid. Menus and buttons formally organize the actions that the user can execute. They require a careful balance between clarity in the visual design of interfaces (aesthetics) and ease of quick access to functions (usability).

Historically, the earliest principles of the graphical user interface emerged in the 70s at the Xerox PARC laboratories. These early concepts led to the creation of the Xerox Alto, at that time the first computer to have a graphical environment. Apple later popularized the concept

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on a mass scale in the 80s with the introduction of the Macintosh personal computer. With the emergence of smartphones and tablets at the beginning of the twenty-first century, the GUI paradigm underwent a radical shift with the arrival of touchscreens, which are controlled directly through intuitive gestures and finger movements.

The theoretical literature on interface engineering establishes that a well-structured graphical user interface significantly reduces the system's learning curve, thereby making it easier for users without advanced technical knowledge to access complex functional and operational applications. GUIs cannot be programmed in a strictly linear manner, since human actions and decisions are unpredictable. Therefore, event-driven programming is the engineering foundation that ensures a dynamic, interactive response.

Today, user interfaces (UIs), or interfaces in software applications, offer highly useful strategic advantages to companies. For example, they are simple, easy to use, and visually appealing. Moreover, they allow users with less computer expertise to use the digital application autonomously.

They also make documents and information quick and easy to locate. Finally, they respond to the organizational order through images, which were the easiest to understand and follow. As a result, the graphical user interface (GUI) emerges as the integrating surface of user-centered design, combining the functional effectiveness of usability with the cognitive delight of aesthetics.

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