

Balancing Smartness and Simplicity: Technological Complexity and Usability in Smart Products

Suryansh Kalkhande

DLF Public School, Ghaziabad, Uttar Pradesh, India

Abstract

Smart products are reforming conventional consumer products by integrating technology into everyday objects. Smartwatches, connected plumbing, smart vehicles, cleaning robots, etc. offer convenience, personalization, effectiveness, and independence compared to their regular counterparts. Unfortunately, increasing technological abilities do not necessarily translate into better user experience. When new functions, services, and configurations emerge, the user has to face more complicated cognitive tasks and understand more complex interfaces regarding product usage, leading to diminished predictability and increased difficulty in controlling user experience. Hence, it is not valid to simply see technological development from an engineering point of view if the problems of usability in high-tech products are considered. The article investigates the issue of the relationship between the complexity of technology and usability in high-tech products through a literature review of studies on smart products, traditional products, human-computer interaction, usability, and similar fields. The article describes a number of aspects of complexity including functional development, interface design, connectivity, automation, individualization, and human components interaction. To these aspects are added the concepts of the authors to develop the theoretical framework created for finding the balance between technical possibilities, understanding of technology by users, and managing control over its use. Here the focus is placed on the idea of progressive revelation of information, contextual assistance, adaptable interface and automation processes with the possibility of user intervention. In their paper the authors underline that the goal of the product design is not the elimination of technological complexity, as this element is quite often present because of the above-mentioned functionality, but rather the reduction of the quantity of complexity presented to the user at each moment of time. The framework created provides the ideas concerning the process of smart-product design.

Keywords: Smart Products, Technological Complexity, Usability, Automation, Human Centered Design, Progressive Disclosure.

1. Introduction

In the past technologies were something that could only be used through computers and gadgets made by people. Nowadays technology is incorporated into products that used to be purely physical objects. Thus, a washing machine has the ability to select its operational mode; a smartphone has the capability to constantly track users' major bodily activities and give relevant data; a robotic vacuum cleaner may scout its environment and adjust its behaviors, while modern cars can amalgamate sensing, computing,

connectivity, and automation in one system. All these technologies have one thing in common - ordinary products become computing platforms with the ability to sense the environment, compute information, connect with other devices, and change their behavior, sometimes even doing things without any input from the users [1, 2].

This change provides many opportunities for product innovation. Smart products have capabilities that were very difficult, if not impossible, to achieve via traditional products: remote monitoring, personalization, predictive maintenance, context awareness, autonomy, and permanent improvement of software [1, 3]. Rijdsdijk and Hultink [2], for example, interpret the smart product in terms of characteristics such as autonomy, adaptivity, reactivity, multifunctionality, collaboration with other products, and interaction with humans. The authors indicate a trade-off: the level of smartness brings a lot of advantages, yet increases the perceived riskiness and complexity of the product. Thus, the advancement of the product does not imply that it becomes more useful.

The difference noted here is significant, since technical competence and usability are different types of things. For example, a product can have advanced sensors, algorithms, telecommunication equipment, and decision-formation components but still be user-friendly. An insignificant amount of functions may irritate a user if they are presented improperly or if complicated configuring or automation is involved. According to Porter and Heppelmann [1], smart connected products are those that include various elements of a product, software, sensors, and algorithms. From the engineering point of view, these refer to additional components in a system. From the user's point of view, these are also decisions, controls, notifications, settings, or other interactions to be comprehended by a user.

So the issue is not that of the complexity of technology as such. What is more crucial is how much of that technology a user needs to grasp to carry out a task. In this context, it is crucial to distinguish system complexity from that of the user of such technology, particularly when consumer products are concerned. A robotic vacuum cleaner may have to deal with all sorts of processes: localization, mapping, obstacle detection, path planning, and management of the battery, but the user may merely select a room and press a button marked "start." It is also true that there can be sophisticated technology behind the interactions that the user has to perform. However, technology could become unnecessarily complex if the user were faced with all possible parameters that could be manipulated.

The impact an interface has on the user has long been acknowledged in human-computer interaction (HCI) studies, with Kieras and Polson [4], establishing a formal link between knowledge required for operating a system and interface design regarding cognitive workload demands by users. More recent HCI studies treat cognitive workload as a crucial aspect due to more and more interactive systems appearing. Complexity of an interface may cause difficulties in locating information, remembering actions, differentiating alternatives, or overcoming mistakes [5]. Thus, when adding a new feature, it is not enough to check if it works – one has to consider the further interaction and cognitive burden that this feature brings along.

The relevance of this issue is increased by the increasing convergence of different functions in smart devices. If a gadget can perform a few functions, so does a smartwatch: it can track health and physical activities, communicate, navigate, coach in fitness, remind of notifications, control music, process payments, run applications, etc. Although each function can be justified, their combinations can lead to unnecessary complications and competition for the user's attention. The same concerns can be raised in terms of smart TVs, smart cars, home appliances, etc. All of these devices and environments apply a unified interface to function in a converging way. In this case, the cognitive load imposed by these

interactive systems corresponds with their complexity and the number of tasks that they make the user perform [5].

The issue at hand involves much more than the beauty of the user interfaces. Misunderstanding of complexity may impede the ability of the users to discover, understand, and utilize options that are at their disposal. For instance, a feature that exists, but is hard to find, is practically useless. On the other hand, an advanced feature that works but is troublesome because users don't understand how, when, and why it is functioning, is of no use, either. Study after study on the subject of technology acceptance has found that the adoption of a piece of technology by users and their subsequent utilization depend on more than mere technical capabilities of the technology [6]. This observation points to the necessity to consider the correlation between the system's functionality and the users of the technology in a smart product design process.

The introduction of automation adds another dimension to this issue. Nowadays, smart devices make more decisions for users as they advise on parameters, determine the importance of information, notice things, forecast behavior, and even act. The automation process lessens the burden on users and increases the usability of devices. However, too much automation reduces users' understanding of the system and the ability to identify when action is required. Studies in the field of adaptive automation have shown that delegating duties to either humans or machines can influence monitoring abilities as well which means that maintaining the possibility of human participation is essential [7]. Consequently, the issue of design is not limited to the question whether to automate the process or not but rather concerns the question of when to apply the automation system and how much users should know about it.

A human centered approach serves as a good starting point in combating these difficulties. Human-centered design moves the focus away from technology as the principle objective of design and instead emphasizes the user, and their needs, abilities, limitations, and context in design. The approach to intelligent products implies that it is essential not only to understand what technology can do, but also to consider what the user actually wishes to see, comprehend, set up and manage.

A potential way to handle this diversity is to employ adaptive interaction. This implies that rather than making all functionalities available to every user all the time, a smart product can come up with some simple core interaction pattern and reveal additional functionality only when the need arises. This principle bears close relation to the idea of progressive disclosure, according to which information or functionality is introduced incrementally instead of being made available all at once. Studies on progressive disclosure suggest that information and explanation can be more advantageous when offered to users depending on their needs and context rather than indiscriminately giving them access to all available options [8]. Recent work on hierarchical interfaces also indicates that the introduction of subsets of functionality can facilitate learning while providing advanced capabilities to the users if necessary [9].

These insights raise a key design question for smart consumer products: how might an increase in technological capability be balanced against the need for products that can be understood, learned, predicted, and controlled? Treating complexity as the removal of features is not a viable solution; users may indeed gain from the increased functionality and expert users may require it. A more effective design objective is to control the exposure of complexity so that sophisticated functionality exists but is not presented in a manner requiring every user to understand the full system underpinnings. Against this backdrop, this paper explores the relationship between technological complexity and usability in smart

consumer products. It views technological complexity as a multidimensional phenomenon encompassing functionality, interfaces, connectivity, automation, personalization, and interactions among system components. It explores how these dimensions might impact usability and discusses human-centered design, automation, user control, and adaptive interaction as approaches for managing the resulting burden. Finally, it proposes a conceptual framework to balance technological capability and user comprehensibility and control. The paper makes three key contributions. First, it synthesizes a number of related strands of research, which are often discussed independently, including smart-product design, usability, cognitive workload, human-centered design, automation, and adaptive interfaces. Second, it differentiates between internal technological complexity and user-facing interaction complexity and argues that the latter is the more relevant design factor when considering usability. Third, it proposes a set of design principles for managing complexity rather than simply eliminating it. The objective is not to argue that smart products should reduce their capability but that this capability should be presented in a manner that respects the user's cognitive resources, experience, context, and need for control.

2. Research Questions

The enhanced use of technical advances such as sensing, computing, connectivity, and automation within consumer goods leads to a contradiction between technological potentials and the accessibility of technology. In this way, this paper presents the following main research question:

RQ1: What is the way in which the increasing technology complexity influences usability of smart consumer products?

In addition to that, four additional questions were raised:

RQ1.1: Which features of smart products help to characterize their technology complexity?

RQ1.2: What should be the impact of newly added functionalities, controls, settings and automated functions on the user's ability to understand and use the product?

RQ1.3: How can designers combine automation, functions, and necessary awareness on the user's side?

RQ1.4: Is there any way to take advantage of human-centered and adaptive approaches with the purpose of decreasing the users' barriers related to technology complexity while using smart technologies?

The list of questions presented above reflects our conceptual analysis. The points made in our paper suggest that it is necessary to differentiate between the complexity of the technical architecture of the product and the complexity experienced by the user making the product less complicated.

3. Understanding Smart Products

Throughout product design, engineering, information systems, and marketing, the term 'smart product' has a variety of meanings; however, its definition is not always precise. According to Raff, Wentzel and Obwegeser [3], the term is used in the literature for products with different features and therefore, it is necessary to establish clear borders. The authors offer four archetypes of smart products, namely digital, connected, responsive and intelligent, which help demarcate smart products from traditional ones. In practical sense, a smart product is understood as a product whose function or operation is improved by means of computation, sensing, software, connectivity and data processing. Rijdsdijk and Hultink [2] present a number of features of such products, which can include autonomy, adaptability, reactivity, multifunctionality and collaboration with other products. In a similar idea, Porter and Heppelmann [1] refer to smart, connected products as systems consisting of physical components, sensors, processors and software.

The distinguishing feature of a smart product is not simply the fact that it contains more electronic elements. While conventional products typically execute a fixed set of functions based on user input, smart products are capable of gathering and analyzing data, communicating with other systems, and modifying their behavior. For instance, in the case of a traditional washing machine, the users would need to select a washing cycle manually, while a smart appliance connected to the Internet has sensors that can make recommendations and analyze the data by itself.

The simple structure of any smart product consists of four interacting components: sensing, computation, connectivity, and interaction/actuation. The first two elements are responsible for information gathering (sensors) and processing this information (computational components), while the latter two components guarantee communication with other devices (connectivity) and the implementation of the communication process (interfaces and actuators). It is possible that a user would not be able to identify these four components as separate units.

This distinction has a profound impact on the user experience. It is not just the physical product that the user deals with but an entire system whose functioning is influenced by software, data, connectivity, and decision-making. Consequently, the complexity of the product cannot be evaluated solely by examining its physical controls. The interaction between the technical system and the user must also be considered.

Table 1: Comparison of Conventional and Smart Products

Dimension	Conventional Product	Smart Product
Primary functionality	Relatively fixed and predefined	Software-enabled and potentially expandable
User interaction	Mainly direct physical controls	Physical and/or digital interaction
Sensing	Limited or absent	Sensors collect information about product or environment
Processing	Limited embedded computation	Software-based processing and decision-making
Connectivity	Usually operates independently	May communicate with devices, networks, or services
Adaptation	Generally limited	Can respond to context, data, or user preferences
Automation	Primarily user-directed	Can perform selected actions autonomously
Updates	Mainly hardware-dependent	Software can modify or extend functionality

As Table I indicates, smart products improve the functions of a classical product with the help of computational and informational capabilities. However, these facilities cause additional relationships and interactions too. Thus, this is the basis for the investigation of the origin of technological complexity and ways it is exposed to users.

4. Technological Complexity in Smart Products

The technological complexity found in a smart product doesn't come from one specific feature or component. It comes from the amount of functionality provided by a system, and even more importantly,

from how those functionalities relate to each other. Thus, a product featuring a lot of functionalities that operate independently can be relatively simple, whereas many of the capabilities within one single product tend to be interrelated, and complexity of managing and understanding those features increases considerably. The authors analyzed the concept in detail and established an initial connection between system structure and user complexities (Kieras and Polson 1990) [4].

Functional complexity arises out of the various functions that users have at their disposal. Smart products usually combine functions that were earlier done by separate products. For example, a smartwatch can come in handy when one has to take care of health, communicate, navigate, track fitness, make payments and control audio. Rijdsdijk and Hultink [2] state that multifunctional features can also have disadvantages when increased smartness results in increased complexity.

The complexity in terms of interface occurs when a product must make the users go through several menus, controls, or screens before they can use some features or functions. Though these functions and features may be of great importance, user interface design affects the amount of knowledge needed in order to perform a specific task correctly.

The complexity of connectivity arises when the functionality of a product depends on connectivity to smartphones, networks, cloud storage, user accounts, etc. When it comes to connectivity, the product becomes functional, but in this case the complexity is in the connections. The concept of automation complexity states when intelligent systems are able to do a lot of work with little human interference. Automation usually reduces the number of actions performed by people, but makes the actions that the system itself takes not quite clear.

The definition of configuration complexity shows that systems provide the chance to configure and personalize them extensively. Configuration allows the system to meet the preferences of the user; however, the complexity can be placed on the user instead of the system. Finally, interaction complexity is created when different functions interact and affect each other. This means that one function can influence another one or that an automated action can be performed based on data from multiple functions. In these situations, the user might not be aware of what is going on. Nonetheless, the dimensions mentioned above cannot be viewed as separate. It is necessary to mention that adding a feature will usually mean employing new elements in the interface, that connectivity will allow automation, that automation will imply feedback, and that personalization will bring about further development in configuration. The complexity of a smart product is that it combines interaction of functions, rather than being determined by the number of features it has in it.

Figure 1: Six Interacting Dimensions Contributing to Technological Complexity in Smart Consumer Products

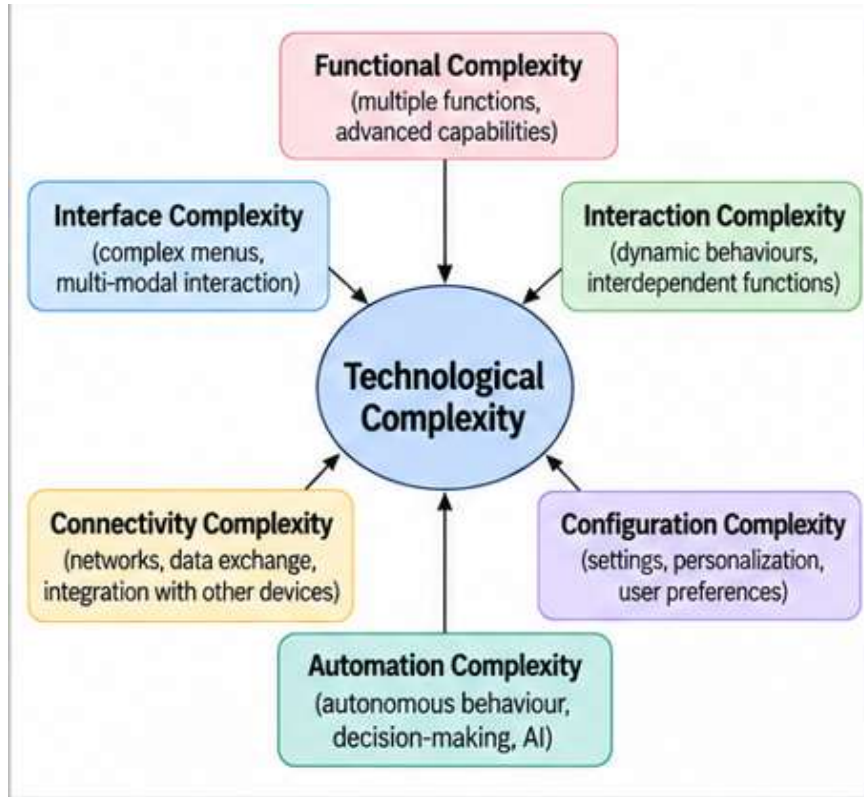


Table 2: Sources of Technological Complexity and Potential Usability Consequences

Source of complexity	Description	Potential usability consequence
Functional complexity	Increasing number and diversity of functions	Feature overload; difficulty identifying relevant functions
Interface complexity	Multiple menus, controls, screens, or interaction modes	Higher learning effort and cognitive workload
Connectivity complexity	Dependence on networks, cloud services, or other devices	Configuration burden and additional failure points
Automation complexity	System performs actions or decisions automatically	Reduced predictability and uncertainty about system behavior
Configuration complexity	Numerous settings and personalization choices	Decision fatigue and increased setup effort
Interaction complexity	Functions influence or depend on one another	Unexpected outcomes and troubleshooting difficulty

Table II makes an important distinction between technological complexity and complexity from the user's point of view. Technological and user-facing complexity do not always coincide. A smart product can possess advanced technology, but a user would never realize it. On the other hand, a simple technological device may have a very user-friendly design at the same time.

This point is vital to clarify, because the primary objective of smart-product design should not be the removal of technological complexity (that would eliminate a lot of features that would make products attractive). It should rather investigate what parts of this complexity have to be obvious to the user, when it should be done, and how much control should be given to them.

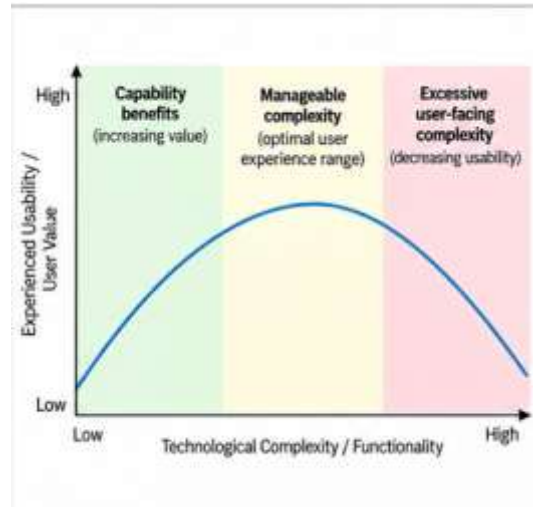
5. Technological Complexity and Usability

The relationship between usability and functionality is not a straightforward one. For instance, including a particular function can result in a more useful product once it is used in practice, but can also mean extra decisions to make and buttons to press. Thompson et al. [10] describe this phenomenon as feature fatigue, which indicates that consumers may initially find products with a lot of functions appealing, but will later find these same functions burdensome. This is particularly true for smart products because software makes it easy to implement new features after the basic product has already been developed. Thus, the problem is related not only to the quantity of features, but also their diversity and interrelation. In their study, Fürst et al. [11] conclude that the complexity of a product depends on the diversity of its functions and the relationships among various functions. Thus, two products can have the same number of features, but what is important is the fact that during the process of using them there may be different levels of cognitive load imposed by the features of these products.

Difficult systems in a product can lead to an increase in information load for users while interacting with a product. Cognitive load is influenced by the efforts put into processing information, making decisions and performing actions by users [5]. When users try to find information through numerous menus, remember sequences of actions, comprehend unusual feedback or find the feature responsible for behavior, the complexity of a product is transferred to the user. This gives rise to a practical failure: although there may be advanced features present, they might not be used. Users are likely to miss the features if they are not available for easy access and understanding. This makes complexity not equal to the value of the product. In smart products, this issue is even worse because features might depend on other features, services or automatic processes that the user does not control. Rijdsdijk and Hultink [2] pointed out that different aspects of smartness may have positive or negative effects, with multifunction study causing the greatest catch of negative perception.

Therefore, we should not think of usability as the lack of capabilities. Even a complicated device can be user-friendly if the complexity is presented in a right way. In this respect, Norman's [12] studies of perceptual affordances are significant because he makes it clear that one needs to present possible actions in an understandable way. Judging from this point of view, the designers should aim at ensuring that the user does not have to comprehend the whole technical system in order just to accomplish some minor task. This gives rise to two important points concerning smart product design: a system can be complicated while an interaction is simple. A technologically advanced device does not have to provide a user with the knowledge about the principles of its operation. Good design can conceal unnecessary complexity, use logically set defaults, open advanced options on demand and give sufficient feedback.

Figure 2: Conceptual Relationship between Technological Complexity and Experienced Usability



The resulting design objective is therefore not to minimize technological sophistication, but to minimize **unnecessary user-facing complexity** while preserving access to useful functionality.

6. Human-Centered Design in Smart Products

Human-centered design provides a significant answer to the complications brought by smart products through shifting the design inquiry from “What does the technology accomplish?” to “What should the user achieve and how should technology assist that?” ISO 9241-210 concentrates on examining users, tasks, surroundings, and human behaviors during the designing process instead of merely regarding usability as an end-stage assessment. This perspective is particularly relevant in the case of smart products as the speed of the technological growth might surpass the users’ level of understanding the technology.

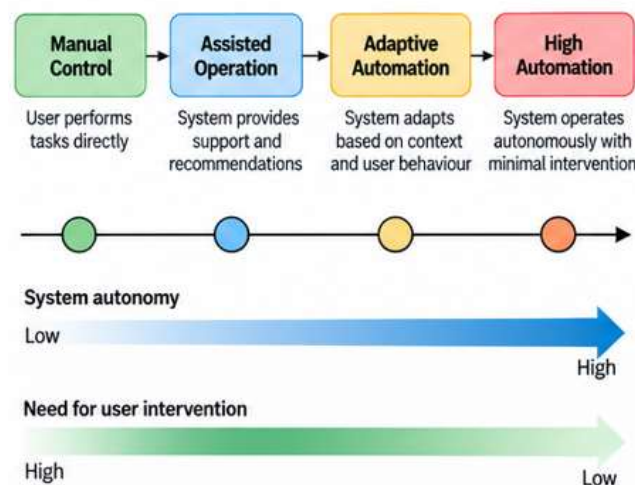
The human-centered approach to design takes into account the differences between users. What might be reasonable for one user, may be too demanding for another. Accessibility, learnability, meaningful feedback, and consistency become essential methods of avoiding the transformation of technological complexity into interactional one, especially important for products making automatic actions. Feedback is of great significance in relation to products acting automatically since the users need to be properly informed about what the system is doing and why.

Nonetheless, human-centered design not necessarily means giving greater amounts of information. It has been shown that excessive information can itself become a source of unnecessary complication. Research on transparency in automation illustrates that users’ being able to take advantage of additional transparency is doubly important [13]. This position corresponds to the main idea upheld in the current paper: user-oriented design should be concerned with the distribution of information and functions according to user needs, rather than with demonstrating the full range of possibilities of the system. As far as smart products are concerned, this means offering solutions to easy tasks, providing relevant feedback, being able to adjust according to user experience, and giving advanced options while preventing their realization for the vast majority of users. A natural follow-up question is what degree of control should the user keep if the technology is allowed to act on user’s behalf.

7. Automation and User Control

Automation is one of the most important functions of an intelligent device, as it relieves the user from repetitive choices and reduces the user's workload. A thermostat can automatically monitor temperature, a car can assist in driving processes, and a robotic vacuum can choose the path for movement. All these products perform one or other segment of the task and delegate the responsibility to the machine. Although automation relieves the user from performing certain functions, the role of the user is changed. According to Parasuraman, Sheridan and Wickens [14], automation can be described as a collection of different functions that can be executed by either humans or machines. It is not a question whether to automate or not, but rather which functions to automate and how much power to give to the machine. Automated behavior may cause problems when the user cannot make a reasonable prediction about the actions of the system. In cases when the bot's decision is unexpected for the user, he will have to think about the logic of the machine's behavior. The problem arises when the intelligent product is not sufficiently transparent and does not give enough feedback. Kaber et al. [15] emphasize that usability of interface design, situation awareness, workload, and transparency when designing adaptive automation. Case individuals do a certain task on their own infrequently, it may be that they do not know how to perform it anymore or do not know how to act if there is a problem. Parasuraman [16] pointed out this universal human factors problem related to automation design, where higher efficiency is correlated with difficulties in supervision and intervention. As for consumer goods, the best solution here is not to return to completely manual procedures but to provide the user with an adequate amount of control over important actions. It is necessary for the user to understand the status of his/her device according to the important indicators and to be able to make right decisions or interfere into the automation process when possible. This is aligned with user-oriented approaches to automation. [17]. Thus, automation can be defined as needed without giving up agency. The solution must deal with automated routine tasks but always keep the user in the loop and in the position to intervene if needed.

Figure 3: Automation–User Control Continuum Illustrating Increasing System Autonomy and the Corresponding Need for Appropriate Awareness and Intervention Mechanisms

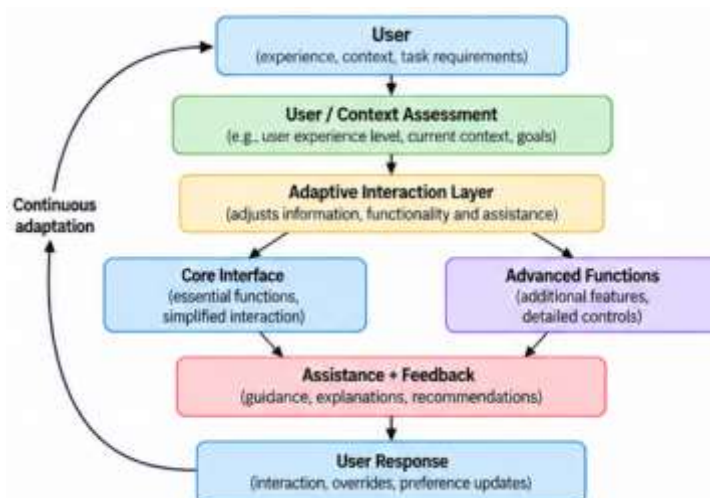


8. Adaptive Technology as a Possible Solution

With smart devices, the person with different levels of skill and knowledge may have to work with the same interface, which might hinder his or her ability to accomplish the task. Adaptive technology can come to the rescue by providing alternative solutions. It is also important to note that simply introducing functions is not enough for the user to benefit from the capabilities offered by such devices, but it is also important to ensure that they are applied in an appropriate way. An example of using adaptive technology to address the needs of users with different levels of expertise is the implementation of progressive disclosure. This concept is discussed by Springer and Whittaker [8], who show how this approach allows the user to obtain the information he or she needs without overwhelming him or her with excessive data, which could confuse instead of guide the person. Thus, for a novice user who is unfamiliar with the features of the product, a simplified interface will be available to them, which will allow them to proceed to the more complex levels gradually.

The latest studies on adaptive autonomy prove the importance of this concept. In their systematic review of the human factors research, Hauptman [18] stated that adaptive systems have been looking for ways to consider human and task conditions in the process of automation design, but a lot of challenges still exist in this area. The same is argued by Bernabei and Costantino [19], who refer to adaptive automation as a process of allocating functions depending on the system status and human characteristics. In the case of smart products, it is important to apply adaptation carefully. Constantly changing interfaces may pose additional challenges to users, who ought to know the reasons for the change and feel like the controls act predictably. The adaptation process applies, thus, the rules of being limited, explainable, and reversible. This means that the principle of design can be to adhere to the notion of stable basic interface design, while modifying only the extra functions, assistance, and information density.

Figure 4: Adaptive Interaction Model in Which User Experience, Context, and Task Requirements Influence the Level of Functionality, Assistance, and Feedback Presented by a Smart Product



9. Discussion

The literature reviewed in this paper suggests that technological sophistication and usability should not be mutually exclusive goals. Of particular interest is the nature of the mapping between technological complexity and the interaction. Smart products may well hide complex technical architectures behind

simple looking interactions. In addition, simple bits of technology may also be made into complex interaction experiences if their complexity is exposed. Three observations can be made based on the analysis. First, feature growth leads to diminishing usability benefits as adding more features increases cognitive and interactional demands. Both the research on feature fatigue [10] and product complexity [11] establish that functionality is not assessed in isolation from the effort required to manage it. Second, automation changes complexity rather than removes it. While a system that does things for the user means that there are fewer actions to take, it may also require that the user understands system states and behavior, and can intervene when the automation does not act as expected [14, 16]. Thus, reducing the number of actions does not necessarily reduce the overall cognitive demand.

Thirdly, adaptation can offer the possibility of dissociating the capacity of the system from its user-facing complexity. Rather than all users having to grapple with all functions, a product could be aware of which functions, explanations, and controls were applicable in the current context. This is compatible with the goals of human-centered approaches to design that stress human control, transparency, and appropriate allocation of functions [17,18]. The observations above are consistent with the main point of the paper: the aim of smart-product design should not be to make technologically complex systems simple in the sense of being technically comprehensible, since that could entail the loss of valuable capabilities. Rather, the aim should be to make complexity workable, appropriately exposed, and responsive to users. A consequence of this view is that the traditional approach to usability evaluation should be supplemented, for smart products, with criteria focused on supporting users' understanding of automatic behavior, prediction of significant system actions, recovery from unexpected behaviour, and maintenance of appropriate control. The resulting viewpoint is summarized in the proposed framework in the next section.

10. Proposed Principles for Better Smart-Product Design

This paper puts forward the idea of a Complexity-Aware Smart Product Design Framework (CASPDF), based on the preceding assessment. The framework seeks to relate technical competence to ease of use through regulation of the complexity exposure rather than eliminating the complexity from the underlying technology. The framework is built on five principles:

10.1 Separate Technical Complexity from Interaction Complexity

A product may require sophisticated algorithms, sensors, connectivity, and decision-making internally. However users should not have to understand them except in the cases when they are useful for accomplishing a certain task. Therefore, technical complexity should be insulated whenever possible.

10.2 Make the Common Path Simple

Commonly performed tasks should require the least effort in interaction. Some advanced configuration should be provided, but it should not make it difficult to take routine use. This principle is based on the logic of progressive disclosure [8] and the division of system capabilities and user-facing complexity presented in this study.

10.3 Use Automation Selectively

Automation must be used whenever it can lower user efforts substantially, but without causing intolerable loss of control or awareness [14, 16].

10.4 Preserve Awareness and Override

Important automated actions must be conveyed through useful feedback. The user should be able to understand the status of the system and take measures whenever needed. Human-centric automation is

concerned with meaningful control over the actions of machines, not their absolute replacement by machines [17].

10.5 Adapt Without Becoming Unpredictable

Interfaces and assistance may change depending on experience, situation, and needs, but not the process of adaptation itself.

These principles can be represented as a continuous design loop:

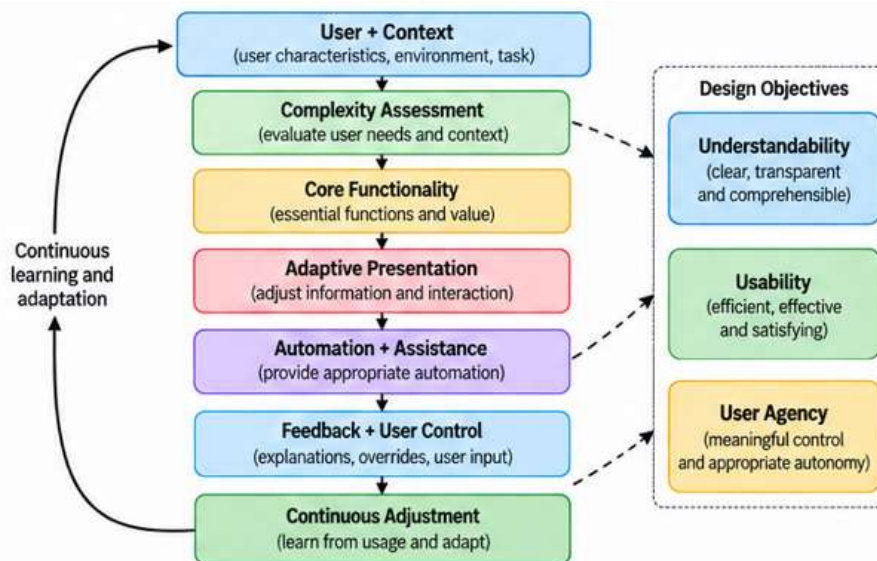
User and Context → Complexity Assessment → Core Functionality → Adaptive Presentation → Automation and Assistance → Feedback and User Control → Continuous Adjustment

There is no recommended level of complexity that smart products need to comply with in this framework. However, complexity must be proportionately shared among the system, the smart product, and the user. A smart system should include as much complexity as it could, while revealing enough information for the user to understand the behavior of the product and manage unfolding actions.

Table 3: Proposed Design Principles

Complexity Challenge	Design Response	Intended Outcome
Too many features	Progressive disclosure	Lower cognitive burden
Complex configuration	Sensible defaults	Easier routine operation
Unclear automation	Meaningful feedback	Greater predictability
Excessive automation	User override	Preserved agency
Different user abilities	Adaptive assistance	Improved accessibility
Changing interfaces	Stable core controls	Greater learnability
Interdependent functions	Consistent system logic	Fewer user errors

Figure 5: Complexity-Aware Smart Product Design Framework (CASPDF)



11. Limitations and Future Scope

The theoretical context of the topic was the basis for the framework of the paper, which means that it should be treated as a collection of ideas rather than a usability framework that has been justified and tested through a controlled study.

In addition, smart products vary considerably in terms of risks and complexity as well as the context of their usage, which means that the best ratio of automation versus user control will be very different for an automatic vacuum cleaner, on one side, and a car or a medical device, on another. With this in mind, it is necessary to validate the framework in practice using various items of smart products.

Future studies of the effects of adaptive interfaces will show whether they enable users to complete their tasks faster with smaller cognitive load and lower abandonment ratio while making sure that users keep their trust and control over the process. At the same time, the methods of experimental comprising static interfaces and adaptable systems according to the level of complexity might be used for future research.

Future work could ultimately convert the proposed framework into a quantitative evaluation model combining measures of functionality, interaction complexity, cognitive workload, automation transparency, learnability, and user control.

12. Conclusion

As physical products gain smartness due to the introduction of the capability to sense, calculate, connect, software and automate, their intelligence grows. At the same time, the emergence of these technologies may create not only practical benefits, but also new problems, due to the fact that with more new functions, users have to face more cognitive and interactional challenges as they operate smart devices. This paper argues that complexity of technology may not always be related to usability issues. Instead, the critical question is how the complexity actually becomes known to the user, because even a high-tech product can be easy to use if there is not excessive level of complexity disclosed to the person, easy and logical steps for implementation are carried out automatically or through the device interface, and the capability to intervene into the process is still preserved. This review presents the achievements of human-centered design, progressive dissemination of information, transparent design or automatization technologies, adaptive assistance approaches and their implementation in most complex technologies, which is the basis for the foundation of the proposed theory of design for the management of complexity.

So, instead of being limited to making a decision about either functionality or simplicity when designing smart products, it would be more beneficial to think of the kind of devices that would, on behalf of users, deal with complicated situations while providing them with the necessary information, control, and flexibility in situations that require complexity. Thus, the success of smart products is not determined by their level of technological sophistication, but rather by the extent to which the technology is used effectively without any significant engagement of the user.

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