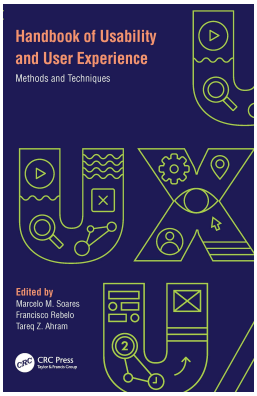

Handbook of Usability and User Experience Methods and Techniques

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A Human-Centered Architecture

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Considering Usability and User Experience in Architectural Design

Elisângela Vilar, Francisco Rebelo, Paulo Noriega and Ernesto Filgueiras

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12.1 INTRODUCTION

At the beginning of the 21st century, according to a research sponsored by the U.S. Environmental Protection Agency and carried out by Klepeis and colleagues (2001), about 87% of peoples' daily time is spent indoors. This data is overwhelming and clearly shows the importance of built space in human lives. In fact, as stated by Winston Churchill when debating the project of Giles Gilbert Scott for the reconstruction of the British Commons Chambers, "we shape our buildings, and afterwards our buildings shape us" (Brand 1994).

Considering the effect that the built environment has on world development, it was on the agenda of the World Economic Forum (WEF) Annual Meeting 2017 in Davos-Klosters, and the initiatives such as the "Future of Construction" were discussed. According to the report of the WEF (World Economic Forum 2017), this initiative, started in 2015, aims to analyze the implications of change in architecture, engineering and construction (AEC) through technology on business strategy,

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skills and organizational design, financing and risk allocation and other fundamental areas. Among others, the WEF established as fundamental area, flexibility, livability and well-being, which is related to creating infrastructure and buildings that improve the well-being of end users. Additionally, the report from WEF also presents and discusses ten innovative initiatives in the AEC area, from buildings to start-ups, that adopt technology-based solutions, mainly related to the use of building information modeling (BIM), 3D printing, wireless sensing and autonomous equipment solutions. It also points that over the past 50 years, no fundamental change occurred in the AEC industry and that new technologies have been slowly adopted.

With the new global challenges, such as climate change, resource shortage and rapid demographic shifts in emerging and developed countries alike, thinking about how the built environment can evolve as an affordable, sustainable and happy place, promoting well-being, for many people is of paramount importance, and new technologies could be of great value for tackling these challenges.

Technological advances already affected the way people plan and use the built environment, so considering technology as a motor for change is not a recent fact. The evolution of a new thought, the intensification in production and massification of some materials, such as iron, coal and cotton, contributed, in the 19th century, to the massive changes in infrastructure and architecture of the cities. For example, with new supporting technologies, such as the steel skeletal structure, new building designs emerged (Moon 2005), together with a new way to interact with the built environments; the small buildings were gradually replaced by increasingly tall skyscrapers, while the pedestrians and horses gave their space to the cars, also changing the way people interact with the urban space.

In 2020, a new challenge was faced with the new coronavirus SARS-CoV-2 causing a pandemic due to its rapid global spread, and its impact on our buildings and cities is still unknown. With lack of knowledge about this new virus and with the necessity of social distancing, massively adopted as the main strategy to diminish the virus spread, telework and the reduction of mobility were encouraged. So, the changes in the daily dynamic made people to spend more and more time in their houses, and to prefer open to closed urban spaces, boosting the adoption of strategies that reduce the chances of the contagion. Thus, what has been seen nowadays is a huge amount of people who used to leave their homes during most part of the day for doing several types of activities, from going to work to having dinner with friends, adopting a more homely behavior supported by an increase of digital habits. For example, physically going to the supermarket was replaced by shopping through the Internet, as well as physical meetings were replaced by online ones. Additionally, bicycles have been even more recognized as an efficient transportation method as they promote mobility through the city while also increasing social distance. In this way, the house has integrated new functions, such as supporting teleworking and distance learning, as well as the urban space, that need to be adapted to support social distance and outdoor activities.

The use of technology was already considered by Groat and Wang (2002) when examining research in architecture. According to the authors, the global economic trends are influencing many professions, including architecture, and research on the scope of architectural practice, in the light of new technological advances, needs special urgency.

Besides, some authors (e.g., Noguchi, Ma, Woo, Chau, & Zhou, 2018) argue that design decisions are misaligned with the users' needs, expectations and experiences, mainly due to overvaluation of the prescribed building codes. And that considering users in the center of the architectural design process should decrease the discrepancies between users' needs and built environment opportunities (Verma, Alavi, and Lalanne 2017).

In this context, this chapter will discuss people's interactions with built environments, and how the new technologies are changing this interaction and also changing the architecture. In the light of user experience (UX) and usability concepts, and considering the experience already accumulated in the human factors and ergonomics area and its relation with architecture, the human-building interaction (HBI) is analyzed and some examples of human-centered architecture are given.

12.2 UX AND USABILITY AND HUMAN-CENTERED DESIGN CONCEPTS

Much has been said about UX and usability in the built environment. However, usability and UX concepts were first basically related to ergonomics and human–computer interaction (HCI), mainly considering the relationship between users and software or technological products.

According to Schackel (2009), with the widespread use of microcomputers from 1980 and portable computers from 1990 by all types of users and for many different purposes, the usability problems when interacting with those devices became more evident. Also, users become more aware and much more selective, partly due to experiences of poor usability.

Thus, in 1998, usability was incorporated in a standard and the International Organization for Standardization (ISO) defined it as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (International Organization for Standardization 1998).

As usability was more correlated with performance aspects, with authors linking the failure in usability with monetary loss, low productivity and time wastage (Madan and Dubey 2012), the term user experience evolved into a more emotion-related aspect of the products.

In 2010, ISO 9241-210 (International Organization for Standardization 2010) was revised and the UX definition was included, considering it as "user's perception and responses that result from the use and/or anticipated use of a system, product or service." The same ISO also refers that the perceptions and responses are related to users' emotions, beliefs and preferences.

While usability is considered a product-related aspect, UX is an interaction-related feature. The revision of the ISO 9241-11 (International Organization for Standardization 2018), in 2018, incorporated the built environment in its scope, in a way that the concepts of UX and usability should also be applied to situations where people use the built environment.

Together with the new demand that arose from the heterogeneity of the new users—with different levels of knowledge, expertise and expectations—and the development and dissemination of new technological products, namely, personal computers, a new paradigm for design based on human, called human-centered design (HCD) arose and led to notable differences in the resulting product, system or service.

In their edited volume, Norman and Draper (1986) recommend considering the user at the center of a design process. In this book, the authors directly put the emphasis on people, not on technology, through a set of chapters in which the invited authors write around this central point, setting the base for the human-centered design methodology.

This new paradigm for interactive systems' design was later systematized in an ISO standard (International Organization for Standardization 2019), and the HCD definition was set as an approach focused on users, considering their needs and requirements, to develop usable and useful interactive systems by applying ergonomics and usability knowledge and techniques.

Despite the fact that the HCD is still directed to the computer-based interactive systems (International Organization for Standardization 2019), it can be applied to a broad range of systems with which humans can interact. According to ISO 9241-11 (2018), HCD is "an approach to system design and development that aims to improve usability, accessibility and user experience and avoid harm from use, by focusing on the use of the system."

HCD is described as an iterative development cycle in which people and their relations are considered in the center of the design process according to some key principles (International Organization for Standardization 2010):

- Increasing the productivity of users and the operational efficiency of organizations;
- Being easier to understand and use;
- Increasing usability for people with a wider range of capabilities and thus increasing accessibility;
- Improving user experience;
- Reducing discomfort and stress;
- Providing a competitive advantage;
- Contributing toward sustainability objectives.

In fact, this new paradigm was highly influenced by the ergonomics field of study. According to Dul and Weedmeester (2008), the International Ergonomics Association defines ergonomics as

> the scientific discipline concerned with understanding of the interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance.

It focuses on optimizing the interaction system in a way to meet health, safety and performance criteria. Ergonomics has a multidisciplinary human-centric approach

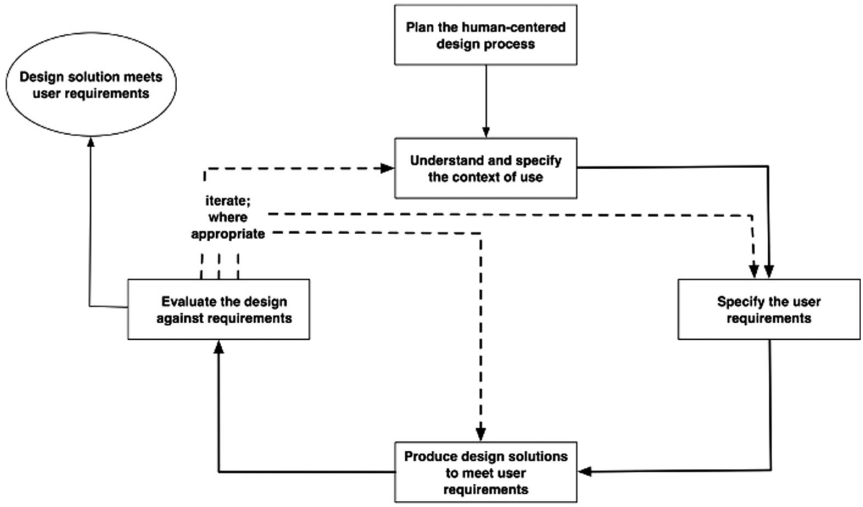

FIGURE 12.1 Interdependence of HCD activities.

and does not have a specific domain. Thus, it considers cognitive, environmental, organizational, physical and all other relevant aspects of the interactions between the human and other elements of the system (e.g., other humans, tools, technology and environment).

In this way, the human-centered design methodology, considering the ergonomics' systemic approach, is an iterative process that comprises six main phases. This process starts with a planning phase, followed by a set of interdependent activities that occur in an iterative cycle (International Organization for Standardization 2010), as can be seen in Figure 12.1.

When considering architecture, all goals established for HCD are also the focus of the architectural process. However, while HCD puts humans and all their contextual interactions at the center of the process, architecture has its basis in facility programming—that is, a set of functional areas and patterns of use of space—and since the 1980s, some architectural schools have changed its focus from form-making to buildings shape (Cherry and Petronis 2016). Thus, architecture still overvalues facility programming and regulation codes (Noguchi, Ma, Woo, Chau, & Zhou, 2018), and the human factor is considered only in terms of functional needs.

12.3 BUILT ENVIRONMENT AND HUMAN BEHAVIOR

The built environment can be understood as a manmade surrounding in which activities can be performed, from large-scale public areas to personal spaces. According to Moffat and Kohler (2008), conventionally, the built environment is usually analyzed as a piece of private property (the parcel), or as a collection of properties with their buildings infrastructure and constructed open spaces. Handy and colleagues (2002) also state that the built environment is a changeable system that can be defined in

terms of their subsystems: urban design, land use and transportation system, including records of human activity within the physical environment.

The built environment comprises three interconnected aspects: physical, spatial and social. Thus, the physical elements of a building (physical aspect such as walls) create the space (the spatial element in which human activity occurs), and each of them has a social value (social element) (Hillier 1996). These social values are in the physical aspect, for example, in the shaping and decoration elements with their functional and/or cultural significance; and in the spatial aspect, by providing spatial patterns of activities and relationships (Alavi et al. 2016).

A central point in the built environment definition is human activity, as it could be influenced by the built environment, but it should also shape the way the built environment is planned and used. Thus, understanding this mutual relationship between human activity and the built environment could be crucial to improve mutual interaction.

For this, knowledge of the needs of the built environment users should be the central point of the architectural process. John Zeisel, in 1975 (Zeisel 1975), had already pointed out that, since the Industrial Revolution, knowing users' real needs while interacting with new large buildings daily used by a diverse type of visitors (such as universities, office buildings, hotels, hospitals, factories, apartment buildings) become more difficult to the architects. It happens because, with the new buildings' demand that arose with the new industrialized city, there was a change in the architect's client, with the emergence of a new relationship, turning it from an architect–user/owner relationship into an architect–owner/paying client–user client relationship. Architects have now two main clients, the one who pays for and the others who use the product of their design. Thus, in this situation, architects are familiar only in a general sense with the type of people who will use their buildings, relying on a dialogue with the paying client. Zeisel also argues that it may create a large communication gap, which the architects try to minimize by designing buildings according to their concept of function. According to the author, it could be better solved if social research would be more integrated with architectural design, in a way that the human activity could be better investigated and understood in order to be applied to the architectural project.

Some authors (e.g., Appleyard, 1980; Whyte, 1980) have already focused their research on human behavior to understand how the built environment can influence users' satisfaction, performance and even health in urban areas.

In 1980, Whyte (1980) wrote a seminal book which is a manual about why some urban areas work and others don't. Using direct observation techniques (very little used at this time to study the dynamics of an urban area), he started studying parks and playgrounds in New York City motivated by an emerging concern over urban crowding. However, the main findings from direct observation suggested a lack of crowding in many of these areas, even in neighborhoods with a very high density of people, while some streets were full of children playing, contradicting the assumption that children play on the streets because they lack playground spaces. The authors expand their research to the plazas built in the light of an incentive bonus given to builders by New York City since 1961. So, builders could add 10 square feet

of commercial floor space for each square foot of plaza they provided. Researchers recorded human activity involving plazas in order to acquire daily patterns of use and inquired users about the frequency they used the plaza, what they thought of it, where they worked and where they came from. The findings suggest that most users were young office workers and that most of them were not workers from the plaza's building. The reason for this dynamic is that workers want to keep some distance from their work, creating an interesting movement of people. According to Whyte (1980), this dynamic highlights a key factor: supply creates demand.

Whyte's studies about the way human activity can shape urban space, and how urban space can influence human behavior were of paramount importance for architectural thinking mainly regarding putting the users at the center of the architectural design process.

Unfortunately, according to Handy and colleagues (2002), when discussing about urban planning, the direct assessment of the relationship between human activity and the built environment and its influence on the individuals is still rare. Noguchi and colleagues (2018) also argued that, despite the high impact that the architectural design has on users' physical and perceived comfort levels in the built environment, the notion of such influence and the design of this experience is barely applied to the practices of architecture today.

However, with the increased incorporation of technology-produced materials, and also the concepts of UX, usability and human-centered design in the architecture project, architectural thinking is also evolving in a more human-centered experience.

Nowadays, architecture evolved in a way that the idea of an adaptative architecture, as proposed by Cedric Prize in his Fun Palace (Mathews Hobart and Smith Colleges 2005), could be considered plausible, thanks to the use of new technological systems and to the growing awareness by the architects that the user is now not seen as a spectator. In this sense, some architects have already recognized that the human factors/ergonomics field, with its research and design methodologies, mainly those related to the human–computer interaction, could be a helpful ally to architectural design. In the same way, the human–computer interaction field evolved and its research challenges have also changed, from a restricted focus on technological systems to the recognition of its relevance to other disciplines, incorporating other knowledge and expanding the human–computer interaction approach.

With the spread of ubiquitous computing, turning the built environment into a large-scale technological product, as well as the increasing consciousness of users about the quality of a product/built environment, the HCD approach has been adapted for a broad range of applications, including architecture. Incorporating these concepts could be an influential support for architectural practice, providing professionals with beneficial tools and methods to achieve a better communication and understanding of the needs and requirements of architectural product users.

12.3.1 UX, Usability, HCD and Architecture

Architecture has increasingly incorporated concepts from areas such as ergonomics, environmental psychology and information technology, moving closer to the UX

and usability concepts and fostering the emergence of new approaches to planning the built environment. From the developmental phase, with the introduction of a building information model (BIM) and computer-aided design (CAD), modeling, visualization, presentation—with virtual reality (VR), augmented reality (AR) and 3D printing—and approval of new materials and functions, such as the introduction of sensors/actuators systems or monitoring visitors and adapting buildings to their needs, to the construction phase—with using new techniques and process—new technologies are being incorporated in the AEC industry. In this context, it is interesting to look at the built environment as a place for interaction frameworks that are planned and designed considering the users' needs and motivations.

Dade-Robertson (2013) argues that the built environment is being conceived more and more as a user interface. The users of the space—visitors of a building, consumers in a mall, workers at an industry, and many others—are now considered as a major part of a project model, in which their interactions with the built environment, mediated and/or optimized by technology, are key factors for the architectural design process. Thus, there is a need for closely knowing users' needs, capacities and expectations to promote their effectiveness, efficiency and satisfaction and, as an ultimate goal, to enhance UX with and within the built environment (where the human behavior can be mediated and/or optimized by technology).

Even with a still ambiguous attitude of the architects toward the participation of users in the architectural planning activities because of the dual nature (i.e., artistic dimension and social dimension) of architectural design, the participation of users has increased in the last decades (Attaianese and Duca 2012). The social dimension of architecture, in which the product of an architect's work is the stage for social activities and sharing experiences, encourages these professionals to involve users in the architectural process from the beginning, even with the pressure of the artistic dimension that is many times considered as an activity of individual inspiration.

According to Zeisel (2006), the control of the effects that design decisions can make on user's behavior should be the architect's ultimate desire, despite that the main objective of their work is to change physical settings through the architectural design. So, the product of their work should meet its users' social, psychological and developmental needs. Additionally, with the introduction of technological features into the architectural design, it is crucial for the architects to understand the new interactions that these new technological environments can allow. The development and introduction of technology into the built environment can radically change the architecture project, changing also the way architects deal with the design process.

In fact, buildings were always a large-scale scenario for interaction, in which human activity and building's physical, spatial and/or social aspects can mutually affect each other. For example, opening a window can affect the temperature and light of a room, changing the physical aspect can influence user's comfort and well-being, as well as rearranging the furniture to reconfigure the space for a meeting promotes change in the spatial aspect, which also promotes new social interactions. Even when designed to be unchangeable, buildings are adapted constantly by their usages that are also constantly changing (Brand 1994). Contradicting the idea that architecture is permanent is the main focus of debate in Brand's book *How Buildings*

Learn. This book starts with a cover history about two neighboring buildings which had an identical design when they were built in the 19th century, but they are completely different (even in their use) in the 20th century. With this, the author argues that considering a building only as a matter of space, forgetting the temporal dimension and all changes that this dimension brings (such as cultural and usage changes), is inviable and even impossible, as building always will be adapted and changed, physically, spatially and socially.

Nowadays, with the advance of new technologies, such as Internet of Things (IoT) and sensing, some simple interactions are also changing. For example, the development and improvement of voice interaction and personal assistants—such as Alexa from Amazon, Google Assistant from Google and Siri from Apple—have enabled their users to change room temperature and lighting, call friends, change the channel of television, change music and so on only through voice commands. And, with more sophisticated systems, based on sensors and actuators, the environment can adapt itself to the user only by sensing their physiological data or by learning with their patterns of behavior.

The smart environment concept, such as smart cities, smart homes and smart buildings, although more focused on sustainability, effectiveness or cost (Alavi et al. 2019), has also enabled its users to effectively use the space and socially interact within the space. An example is the new dynamic created in space use by the employees of Deloitte's headquarters at Amsterdam. With the use of sensors that inform employees about empty desks or other places (like tables and sofas in the cafeteria or library areas) and the policy of "take a free place and work where you want" adopted by the company, a new pattern of use was set. Despite the fact that the building has areas planned for office work and others planned for meetings, employees prefer to use the area of the cafeteria and open spaces in the halls to work or have informal meetings. Additionally, as they can be informed by an app about the location of colleagues, they also start to work at the same place as their working group, enhancing the creation of work teams (World Economic Forum 2017).

Thus, with the increasing incorporation of new technologies that promote interactivity with and/or within the built environment, new outlines and demands have emerged when considering UX in architecture (Verma, Alavi, and Lalanne 2017). HCI research and design can effectively contribute to architecture to understand these new spatial-temporal dynamics and user's demands that arise with those new opportunities and interactions, in a way to chase the utopic dream of a user's adaptable building.

The main questions that arise are those related to humans and their experience with the built environment, mainly considering human values, needs and priorities to reflect, according to Alavi and colleagues (2019), the complexity of human interaction and social experiences with and within built environments. With this in mind, a new area has been developed, the human-building interaction.

12.3.2 The Human-Building Interaction Concept

According to Alavi and colleagues (2019), HBI is an emergent area that seeks to examine the involvement of HCI in studying the evolution and shaping of built environments. It emerges with the increasing incorporation of technology in the built

environment, allowing several new forms to interact with it. In this way, a definition of HBI could derive from the HCI's concept and could be set as the study of the human part of the interaction between the individuals and the built environment in order to understand their needs and expectations, orienting all project phases, from designing to construction and maintenance, promoting and optimizing human interaction with and within the built environment in a way that it can be achieved with effectiveness, efficiency and satisfaction, and ultimately enhancing UX.

Thus, designing for HBI should provide interactive opportunities for the occupants to shape the physical, spatial and social impacts of their built environments (Alavi et al. 2016). For this, HBI also considers a multidisciplinary approach, adding knowledge from several fields, to map user's requirements and expectations, and design solutions that meet these requirements, always aiming to enhance UX. Dade-Robertson (2013) made a parallel between HCI and architecture considering that both are supported by technical rigor and artful practice with the main objective of solving diffuse and complex problems.

So, according to Alavi and colleagues (2017), HBI is an intersection of three main domains, architecture and urban planning, HCI and new technologies (mainly ubiquitous computing), to promote usability and UX in built environments and to anticipate the questions that may arise with the new complexity of our interactive experiences with the built space (Figure 12.2).

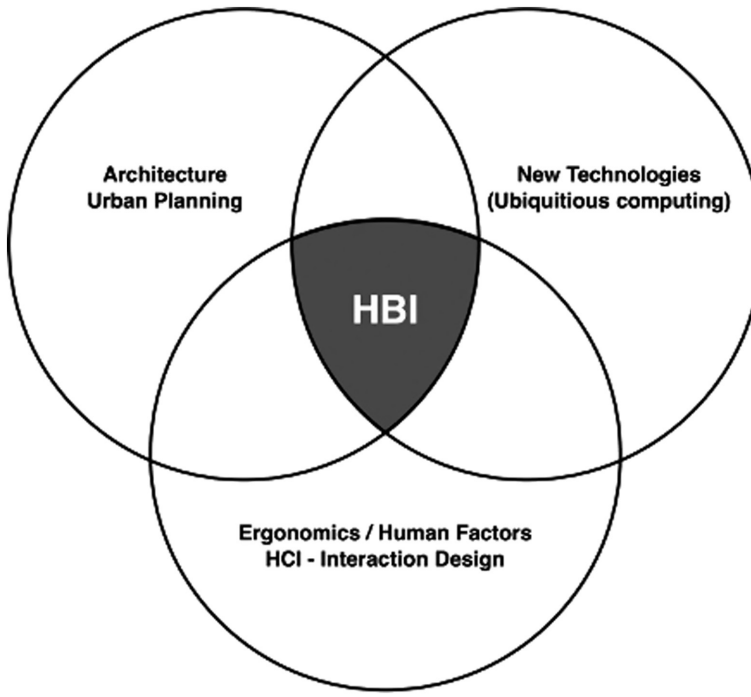

FIGURE 12.2 Human-building interaction as an intersection of three main areas.

From the beginning, studies in the HBI area were mainly in building performance research, considering resources management and energy saving, in a way that the building could adapt itself to user's needs in order to manage the use of energy resources, increasing building performance (e.g., Hsu et al., 2010; Jazizadeh et al., 2012; Malkawi & Choudhary, 1999; Malkawi & Srinivasan, 2005). However, we agree with Alavi and colleagues (2016) in considering a broader and human-oriented perspective.

This perspective also defines the extent of this human-building interaction, in order to prevent users from inconvenience that may arise from considering all data that can be acquired and used. An interesting approach to this issue was carried out by Urquhart and colleagues (Urquhart, Schnädelbach, and Jäger 2019). In their work three adaptive architecture applications based on IoT were considered in the light of emerging information privacy and security regulations. Although regulatory concerns are not the focus of this chapter, it is important to reflect on some implications of creating smart environments.

Additionally, technology can allow changing the state of the environment, as the potentially harmful situations could be created with the poor design of this new interaction, affecting the safety of built environments' users (Dasgupta et al. 2019). Consider, for example, a smart building in an emergency situation like a fire. Previous studies (e.g., Vilar, Rebelo, Noriega, Duarte, & Mayhorn, 2014; Vilar, Rebelo, Noriega, Teles, & Mayhorn, 2013) have already shown that often people rely more on architectural features than on emergency signage systems. What smart solutions could be considered to enhance compliance rates with the emergency signage system? Should the emergency signage paradigm change? What's the good of a smart alarm system if people do not trust the alarm or take longer than necessary to start the emergency evacuation process? So, it is not about technology-based environments, but it is about understanding users while planning the whole system.

Predictions of new interactive experiences with and within the built environment are growing, and the smart agenda is really evolving with projects in many countries. However, in a recent study about Rio de Janeiro's Smart City project, it was concluded that applying the smart city paradigm itself is not enough without considering the real context. In fact, it could potentialize socioeconomic and political divides (Gaffney and Robertson 2018).

Some research has been done with the aim of understanding human behavior (e.g., Vilar et al., 2020, 2014) and emotions (e.g., Dias, Eloy, Carreiro, Proença, et al., 2014; Dias, Eloy, Carreiro, Vilar, et al., 2014; S. Dinis et al., 2013) within the built environment, space use (e.g., Verma et al., 2017), universal design (e.g., Noguchi et al., 2018) and building performance (e.g., Hsu et al., 2010), adding knowledge to the HBI area. However, there is a lack in clarifying and unifying concepts to strengthen HBI as a field of research. It could be one of the reasons why much of the work that has been done in this area involves many other fields of knowledge.

In this way, efforts can be made to envision possible scenarios and plan for them, and according to Alavi and colleagues (2016), it is important to understand and reflect about HBI contributing to the generalized understanding of human interaction with the building environment. For this, the authors suggest the necessity of

developing more innovative design instances and improving the knowledge in the area, by, for example, design heuristics and strong conceptualizations. The development of cumulative understanding of evolving human living and working behaviors in a new scenario of interactions that the introduction of new technologies can promote would be possible with the incorporation and assimilation of knowledge and methodologies from the three main domains in the HBI field of study (D'oca et al. 2019), as shown in Figure 12.2.

12.3.3 The Human-Centered Architecture

With the increasing incorporation of new technologies in the buildings, allowing a myriad of new interactions between users' and the built space, the need for knowing users and filling the communication gap is obvious, as illustrated in Figure 12.1. Adopting an HCD paradigm could be an interesting approach to make it possible. As a problem-solving approach focused on the human perspective during all problem-solving processes, HCD uses methods and techniques imported from a broad range of social sciences, such as observation, interviews, focus groups, questionnaires and others, to understand users' needs, defining requirements and testing solutions against these requirements.

According to Schulzová and Bošová (2019), the main components of indoor environments are mainly related to physical aspects (i.e., thermal and humidity microclimate, lighting, acoustics, indoor air quality, electromagnetic, electroionic, electrostatic and ionization microclimate) and psychological aspects (i.e., users' well-being). However, even if all physical aspects are controlled and attended to in the architectural project, there is no guarantee that the psychological well-being of the user will be achieved. Promoting good user experience could be a key factor for achieving well-being. In this way, adopting a methodology that allows knowing users and putting them at the center of the architectural process can contribute to the architects' work, allowing them to design the built environment not only in terms of functionality, but also as a place that promotes good UX, and thus promoting well-being.

In this sense, works related to the built environment with the concepts of UX, usability and HCD can be found in literature, and the following are some examples.

In a recent study carried out by Van der Linden and colleagues (2019), the UX methods and the HCD process were used to make the people's spatial experience part of the architects' design process. Thus, elements like persona[1] and scenarios[2] were considered and adapted to the particularities of architectural design to have a new integrated approach to support professionals in designing human-centered environments. This new approach suggested by Van der Linden and colleagues (2019) is in line with the new perspectives that arose with the evolution of the HBI concept.

Although project promoters are still disconnected from real end users, tackling with some difficulty in acquiring and understanding their needs, there are some successful examples of user-oriented projects for new buildings. A good example is The Edge, designed for Deloitte, a global financial firm. This new building aimed to accommodate the company's employees spread across multiple buildings in the city.

An HCD approach was considered and interviews with the employees about their preferences and needs, as well as observation of their work at their previous workplaces, were carried out. According to the WEF report (World Economic Forum 2017), this HCD orientation was maintained during all project phases with a constant focus on enhancing employees' UX. Planned to be a smart building, the project was developed considering a set of sensors/actuators. Additionally, an application was developed and the building's users could interact with it through a smartphone or a tablet to, for example, personalize temperature or lighting levels, book a room for a meeting or find a free desk to work. Through the app, users can also find a parking lot, navigate into the building, manage work schedules, find others, report problems and so on. This building is also considered the greenest until the date, according to the BREEAM green building certification scheme (Fytrou-Moschopoulou 2017).

An example of how new interactions can shape the built environment is the "ExoPranayama" (Moran et al. 2016). In this project, biofeedback of yoga practitioners was used to develop an environment that, according to the authors, physically manifests users' breathing in yoga. The "ExoPranayama" was developed considering direct observations of yoga class and an HCD approach. The tests with the environment revealed an improvement in self-awareness and allowed teachers to better know their students and help with the new class. However, the authors point as a drawback the social concerns related to exposure of what they called "invisible inner-self" that they related with competitiveness and deviation from the spiritual aspect of the practice.

Conceptual frameworks to answer the demand created with the HCI research and design in architecture were also proposed. An example is the human–environment approach developed by Ma and colleagues (2017) called Environmental Experience Design (EXD). It was designed to identify the main objectives of the project, analyze user perception, propose design strategies and solutions (Noguchi et al. 2018) and encompass objective physical parameters, such as environmental quality data and subjective user perception, for example, the human emotions. An aged care facility was chosen as a case study to apply the EXD, and, based on it, physical (indoors environmental quality data) and psychological parameters such as freedom, connection to the natural environment, belongingness and individual dignity were considered. These parameters feed the methodology of the function analysis system. This methodology aims to identify the performance of a user function and to refine design as a function of the users' requirements by asking what functions users need and how design can achieve these. The methodology's result is a diagram (FAST—Function Analysis System Technique) that helps to explore users' physical and psychological needs and demands. The EXD framework derives from the FAST diagram and encompasses related design criteria, design settings, objectives, design elements, opportunities and design solutions.

Sandman and colleagues (2018) proposed the incorporation of HCD methods in two sustainability models. They also applied these models in two case studies; they proposed a new one in which the four dimensions of sustainability (i.e., environmental, economic, social and cultural) have an equal balance, highlighting the aspects that need the inhabitant's engagement. According to them, to reach this balance,

architects need to understand people in depth, by having an empathic involvement with the users.

HBI being a recent area, studies that encompass this field are still sparse and are usually found in correlated areas, such as publications on HCI, building automation, building engineering, sustainability and energy research. Despite HBI being an emergent field, with a lot of new research being produced, there is still much work to do in the direction of incorporating more human-oriented processes into architecture.

12.4 CONCLUSIONS

New opportunities also bring new problems and new challenges. What is going to happen when full building automation occurs? Could people live in a place where technology decides for us if our window should be open or closed? Will we rely on a safety information that changes according to the circumstances of an emergency? And what about our privacy when the built environment, being urban spaces or indoors, is able to store all information about our physiological data, patterns of behavior and also emotions? How a new built environment should be designed considering all the adaptive opportunities that new technology could allow? There are many questions that could arise from a reflection on the subject of smart environments and all new demands that they could allow.

Nowadays, with the evolution of sensing technologies, both human and environment can be monitored and communicate with each other allowing the optimization of their interaction. These new technology-produced products can also affect architectural thinking and promote changes in the design process. According to Lester and colleagues (2008), sensing platforms are being increasingly used and the number of potential users and applications being developed continue to expand. With this, a number of data—some collected by environmental sensors considering more traditional aspects such as air quality and temperature and others collected through users' devices such as mobile phones, considering, for example, users' activities and locations—can be related with each other to inform and optimize the interactions between the users and the built environment.

From the architecture point of view, considering the new interactions and all opportunities and disadvantages that could arise is a new demand that professionals from this area need to deal with. And with new demands, also new ways of thinking about problems and solving them are also necessary.

Some authors (i.e., Ma et al., 2017) agree that architecture requires interdisciplinarity and a human-centered process, but, unfortunately, thinking about the user experience while interacting with or within the built environment has barely been applied to architectural practice.

This chapter deals with these new demands and presents some concepts that are helping architects to change the architectural process to incorporate more human-oriented strategies to solve complex problems in architectural design.

Interaction design and architecture are increasingly interconnected, from the mid-1980s, with the first attempts to design computer-aided design (CAD) tools, to the

incorporation of technologies that are designed to be part of the built environment, using the architecture as support for new digital technologies (Wiberg, 2017). Thus, new technologies can allow new interactions with the built environment, such as temperature controllers, aperture controllers and presence sensors, that can change space use, and also ultimately alter the architectural design.

McCullough (2004) argues that the digital world is mixing with the real world as ubiquitous computing has to be inscribed into the social and environmental complexity of the physical built environment. This makes digital networks bonded with architecture and opens a new paradigm for architectural design. However, with new grounds, new ways of thinking about problems also emerge, and new theories tend to unify perspectives among disparate groups, generally introducing a few widely applicable problem-solving strategies. All these exchanges and intercommunications among disciplines and fields of knowledge allow generating shared assumptions and concepts underlying a common frame, also producing a more consistent and coherent set of models and techniques (Moffatt and Kohler 2008).

In this way, contributions from HCI to HBI field are mainly related to research and design methodologies that are aimed at understanding user's needs, requirements and expectations, focusing on enhancing UX and usability. For this, it is important to identify, to understand and to organize in a framework the converging aspects of HCI and architecture to establish new knowledge on the HBI area allowing all interested in this area to predict and shape the future of living.

NOTES

1. "Personas, are detailed, composite user archetypes that represent distinct groupings of behaviors, attitudes, aptitudes, goals, and motivations observed and identified during the research phase" (Cooper et al. 2014).
2. A scenario is a concise description of a persona using a product to achieve a goal (Cooper 2004).

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