CHAPTER

11

Environmental experience design research spectrum for energy and human well-being

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Chapter outline

1. Overview of energy and human health and well-being in economically booming countries

The population in the world's urban areas has steadily been on the rise since 2000 (Kharas, 2017). Middle-income groups contribute significantly to the world's socioeconomic growth, and they are increasing faster in Asia than anywhere else in other continents (ADB, 2010; Kharas, 2010). These middle-income groups are taking part of the driving forces behind the economic growth in booming countries (ADB, 2010). By 2030, the number of middle-income groups is estimated roughly at 35%−45% of the total world population (Kharas, 2010, 2017; OECD, 2019). In 2015, the United Nations' member states set Sustainable Development Goals (SDGs). The SDGs reflect a worldwide demand to take actions to protect the earth, end poverty, and secure the world peace and prosperity in view of their 2030 Agenda for Sustainable Development (United Nations Department of Economic and Social Affairs, 2021).

In Organisation for Economic Co-operation and Development (OECD) countries, enormous pressure on middle-class families is growing due to the increasing demand for energy use, housing affordability, human health and well-being, and quality education. According to the OECD report in 2019, over the last 25 years, housing cost has been ramped up by approximately 49% faster than the

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average household income increase. From the global perspective, building sectors are also accountable for nearly 40% of energy use and about one-third of greenhouse gas emission scenarios (Zhang et al., 2015). In the capitalist urbanization, the housing sector is embracing a crucial social concern as to human health and well-being globally (Tinson and Clair, 2020). The COVID-19 outbreak has made the masses realize the importance of human experiences and relationships to enhance physical and mental health and well-being within confined built environments.

Developing and emerging economies are mainly facing energy and health-related challenges in the 21st century. China and Bangladesh are among the Asian economic booming countries encompassing the large human resources, land, and GDP (BRAC, 2017; Salam et al., 2020; Zhang et al., 2015). Young generation from middle-income groups is being considered as the main driving force to the rapid development of these countries. Yet, the inadequate policies related to energy and human health and well-being are to some extent affecting the overall development of these countries negatively (Salam et al., 2020; Li et al., 2016).

1.1 Energy, housing, and urbanization in Bangladesh

Bangladesh is experiencing the second fastest-rising economy in South Asia according to the report of World Bank entitled "South Asia Economic Focus, Fall 2019: Making (De) centralization Work" (Beyer, 2019). Recently, the United Nations Committee for Development Policy (UN CDP) recommended Bangladesh as a developing nation from a Least Developed Country (LDC) after 45 years. According to the UN CDP recommendation, this country is scheduled to become a developing country officially in 2026 due to the impact of the COVID-19 on its economy and until 2026, the country will continue to enjoy the trade benefits as an LDC. Currently, the per capita income of Bangladesh is 1.7 times higher ($2,064) than the required threshold. According to Human Assets Index criterion, the country score is 75.3 points where the minimum requirement is 66. Moreover, the Economic Vulnerability Index (EVI) value of this country is estimated at 27.3, and this figure is less than the required EVI value of 32 points. This sustainable economic growth creates an enlarged demand for energy, housing, and urbanization (United Nations, 2021).

In Bangladesh, the young generation is the key contributor to the country's economy and has a significant influence on the socioeconomic growth of the country (ILO, 2020; Khatun and Saadat, 2020). Bangladesh is ranked as seventh in the global population with an estimated population of 164 million and will become the 24th world's largest economy by 2030 (Beyer, 2019). Around 47.6 million (approximately 29%) of the total population has been identified as the young generation of Bangladesh, whose age is between 18 and 35 years old (Khatun and Saadat, 2020; UNFPA, 2014). Hence, the government is formulating multiple strategies for this young generation's overall progress in Bangladesh (Khatun and Saadat, 2020). Millions of people from this young community in Bangladesh fall into middle-income families, and they are the core economic contributors to the country (BRAC, 2017; Chun, 2010; Kharas, 2010; Sadeque, 2013). According to the income level, there are mainly three subcategories of middle-income families in Bangladesh, i.e., lower-middle, middle, and upper-middle income groups. At present, people within these income groups are considered as well trained and educated, covering a substantial portion of the country's population. The young generation tends to migrate to urban areas (mainly Dhaka city) in Bangladesh (Sadeque, 2013; Tariq and Ahmed, 2020).

Dhaka is the capital and main urban business center of Bangladesh and the 11th fastest growing megacity globally where a population of about 21 million living in a land of 1,528 km^2 (Ahmed et al., 2018; Alam, 2018; Rajuk, 2015; Swapan et al., 2017). Dhaka's population has increased rapidly from 1.37 million to 21 million between 1970 and 2020. By 2030, Dhaka will have a population of about 28 million (Sarker, 2020; Satu and Chiu, 2019). This city is a dense urban area with a density of 49,182 persons per square kilometer (RAJUK, 2015; Swapan et al., 2017). To find new livelihood and business opportunities, 2000 to 2,500 people migrate to Dhaka city every day from different areas across the country (Ahmed et al., 2018; Alam, 2018; BRAC, 2017; Sarker, 2020; Swapan et al., 2017). Because of the rapid population growth, Dhaka is facing extreme challenges to grapple with the increasing housing demands (Alam, 2018; BRAC, 2017; Parveen, 2017; Satu and Chiu, 2019). In Dhaka, house prices are also increasing despite the urgent housing needs of middle-income families (BRAC, 2017; Sadeque, 2013). Therefore, almost 70%−78% of these middle-income families, particularly lower-middle and middle-income groups cannot afford their own houses or apartments in the current market price of housing in Dhaka city, Bangladesh (BRAC, 2017; Sadeque, 2013; Shams et al., 2014). Due to excessive house rents and apartment prices including energy costs, most middle-income families need to adjust their other daily expenditures to afford their dwelling unit. For example, they tend to reduce expenditures for their clothing, entertainment, food, and education to cope with their excessive housing cost and energy demand (BRAC, 2017). Therefore, it is increasingly becoming difficult for middle-income earners to buy or secure a decent residential dwelling unit in an urban area like Dhaka (BRAC, 2017; Sadeque, 2013).

Middle-income people are the main driving force of the country's economy. A significant portion of middle-income families is facing different health and well-being difficulties in Bangladesh due to a high level of energy demand, environmental pollution, living density, social uncertainty, and economic constraints in housing affordability (BRAC, 2017; Mridha and Moore, 2011; Satu and Chiu, 2019; TBS, 2019). Because of the socioeconomic restrictions, most middle-income families are living in small and congested dwelling spaces or apartments in the urban areas, where physical building design elements or components are the primary consideration of today's local high-density residential developments—not user experiences in the design decision-making process. These small living conditions create clumsiness leading to the deterioration of indoor environmental quality (IEQ) (e.g., no or less privacy) and indoor air quality (IAQ) (e.g., heavy CO_2 concentration and $PM_{2.5}$) (Chowdhury et al., 2020; Larcombe et al., 2019). Almost 55% of the total energy is consumed in the building sectors in Bangladesh because of the rising urbanization. Bangladesh had experienced an increase of approximately 30% in buildings' energy consumption (383 TWh as of 2017) since 2006 with an annual incremental rate of 3% (Salam et al., 2020; WEO, 2017). Residential electricity use in the urban areas is increasing rapidly with a rate of 48% annually. The households' energy consumption for active space cooling is also increasing drastically. These situations may negatively be affecting the people's health and well-being, as well as their productivity in the workplace driven by manpower that is a key booster of the local economy.

Urbanization is contributing to the drastic hike of energy demand in the city centers (Salam et al., 2020). It is expected that by 2050, about 50% of the total country population will be shifted to the urban centers in Bangladesh (Salam et al., 2020). Accordingly, the Government of Bangladesh is taking various initiatives including energy-saving building codes to alleviate energy demand in the building sectors (Salam et al., 2020; Hassan et al., 2012). To address this situation, both public and private housing sectors are now changing their target group from high and upper-middle income households to lower-middle and middle-income family groups through developing high-density small-sized apartments (Barua et al., 2010; BRAC, 2017; Kamruzzaman and Ogura, 2007). Consequently, in recent years, the demand for vertical expansion of high-density tall building developments in Dhaka has been ramped up exponentially, while the horizontal growth is weakened due to the buildable land shortage in the metropolitan areas (RAJUK, 2015; Seraj and Islam, 2013; Siddika et al., 2019; Swapan et al., 2017). Because of limited budget restrictions and comparatively high rents, the middle-income groups in Dhaka tend to live in small domestic environments. Notably, most lower-middle and middle-income families tend to live in tiny congested domestic spaces in high-density apartments due to housing affordability constraints. To accommodate the market trends, the builders only focus on exploring physical design elements (e.g., room numbers, sizes, building configurations, and floor layouts) in the architectural design decision-making process today (BRAC, 2017; Kamruzzaman and Ogura, 2007; Sadeque, 2013; Satu and Chiu, 2019). Nonetheless, these congested living spaces without consideration of user experiences may diminish the indoor environment and air quality that generates an impact on occupants' health and well-being (Fig. 11.1). However, because of middle-income families' socioeconomic limitations in Bangladesh, modifying their existing design elements or components that lead to some financial burdens may not be taken easily particularly by housing renters. Even so, the way of living in built environments can be changed through the adjustment of occupants' subjective perception and behavior including a sense of attachment to place in their domestic settings given—i.e., "domestic environmental experience" (Chowdhury et al., 2020).

1.2 Regional developments for climate mitigation in China

Urbanization has been accelerating in China since 1990, and about 40% of the population lives in the urban areas today. This equates to roughly 260 million population. The cities are growing rapidly with the aim of accommodating the expansion in the urban areas. Despite the several benefits of rapid urbanization, China continues to face severe resource and environmental degradation along with the speedy urbanization negatively affecting environmental problems and human health and well-being (Li et al., 2016). This rapid urbanization contributes to changing people's living standard or experiential quality that affects their health and well-being. Moreover, indoor air and environmental quality concerning temperature, humidity, lighting, noise, and pollutants in the built environment yield the complementary impact (Li et al., 2016). The building energy consumption in China has increased approximately 7% during the last decade. Therefore, energy efficiency in building sectors has become a key priority regarding energy security in reducing the demand for end users (Zhang et al., 2015).

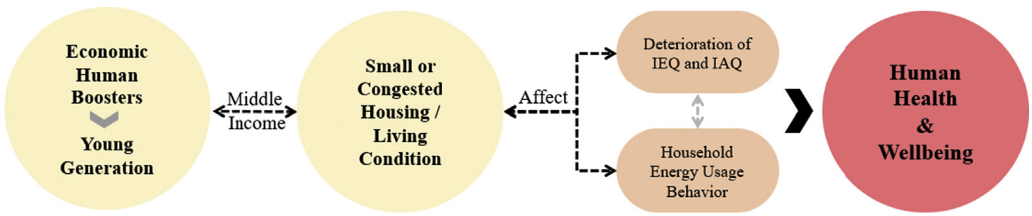

FIGURE 11.1

Living environment and human health scenario of middle-income families in Bangladesh.

Moreover, due to rapid urbanization and climate change, the country targets the development of high-density tall buildings and such high-rise constructions have grown exponentially over the last 10 years. Zhang et al. (2015) indicate some limitations as to a clear and consistent understanding of occupants' behavior and experiences around energy consumption in the buildings. Yet, the study explains that overall energy consumption in China's building sector was 350 Mtce in 2000, accounting for 27.5% of the total energy. By 2020, the energy usage was predicted to be 1089 Mtce (Tu, 2006). There is a growing need to grasp the more accurate energy consumption in Chinese building sectors and analyze occupants' behavior and experiences of the usage (Zhang et al., 2015).

As set out in the World Economic Forum on January 25, 2021, China will continue to work with the international community to actively implement the Paris Agreement and make greater contributions to the global response to climate change. Building energy efficiency is an important factor contributing to reducing carbon emissions in China in the coming years. It is forecasted that 35% of China's final energy will be used in the building sector by 2030 (Li, 2008). Within China, the regional difference in building energy-related carbon emissions is immense, with more emissions in the eastern region than those in the central and western regions. This is mainly because the economy in the eastern region is more developed, and people's living standards are higher with large living space and electricity-consuming appliances (Lin and Liu, 2015). To mitigate climate change, more efforts should be made in eastern regions to reduce building energy consumption and carbon emissions. To successfully achieve the targets set out in the Paris Agreement by the Chinese government, it is necessary to identify the innovative design and construction approaches for the implementation and integration of low-carbon building technologies. These building design and construction innovations can help mitigate climate change, bring down energy costs, create sustainable jobs, and lift economic productivity.

The building design strategies toward climate mitigation mainly focus on improving building envelope and ventilation systems and optimizing the use of renewable energy sources. By using highly insulated building envelopes and increasing building airtightness, the heating and cooling load of buildings can be reduced (Lin et al., 2020). Natural ventilation strategies like cross ventilation, stack ventilation, ventilated facade, and solar chimney are applied to buildings for the passive cooling while maintaining the IAQ. The selection of appropriate window size, opening position, and opening method are important design parameters for natural ventilation in buildings. Solar energy is the primary renewable energy source that has widely been applied to buildings for solar thermal and photovoltaic (PV) systems. Wang et al. (2016) proposed a new type of solar house structure using a heat collection and storage roof. It was found that flat and 45 degree slope roofs could increase the average room temperature by 5.0 and 8.3°C, respectively.

As for the building construction method, prefabricated buildings have been promoting in China in recent years as they are not only highly efficient, high quality, and low cost but also they effectively minimize construction waste (Kong et al., 2020). Although prefabricated construction has some potential benefits, the practice is still limited to an initial stage in China. A study on factors affecting prefabricated construction promotion in China shows that the policy plays a dominant role, while the management and market aspects are also significant for promotion of prefabricated buildings (Jiang et al., 2020). The urban action plan in China recognizes prefabrication as a key component of climate mitigation strategy. In a government report, it is mentioned that prefabricated buildings are expected to account for 30% of the new buildings over the next 10 years (Xu and Zhang, 2019).

China has a vast territory and complex topography, and therefore, the building design and construction approaches in different climatic regions vary with their characteristics and often take full advantage of natural ecological resources in local areas. For example, PV-integrated buildings are more widely used in China's central and southern provinces, where more solar radiation is received than the other regions, and nearly 40% of peak load is coming from the cooling demand in summertime (Li and Colombier, 2009). In Qinghai-Tibet Plateau where solar radiation is abundant, it is found that the buildings equipped with Trombe walls can store 52.6 MJ more energy during the day and achieve 72.8% energy-saving compared to the buildings with normal walls (Wang et al., 2013). Chinese quadrangles with a central courtyard that are often found in Beijing in the northern part of China can minimize solar radiation entry to the rooms during the summer, while maximizing solar radiation use for space heating and lighting as well as wind protection during the winter (Sun, 2013). Chinese quadrangles are typical vernacular dwellings that successfully reflect traditional Chinese architectural techniques and provide human thermal comfort throughout the whole year. To mitigate climate change, building design may need to integrate both modern technologies and traditional design methods. While the abovementioned building design and construction innovations can help mitigate climate change, they can also bring down energy costs, creates sustainable jobs, and lifts economic productivity. With the process of urbanization, some villages have become deserted due to the drastic and constant migration of rural residents to city areas in China. To revitalize the rural areas, the Chinese government has initiated some policies that aim to reduce the gap between urban and rural regional development. Housing is an important factor to narrow the gap between urban and rural living standards. The connotation of "housing" here includes the quality of the house, indoor environment, service life, impact on residents' lifestyle, and the surrounding environment. The residents in rural areas in China generally build houses by themselves, where the thermal comfort level of these self-built houses is very low. Houses in the southern part of China generally do not have heating facilities, and energy consumption of the building is at a low level. The residents in northern China tend to apply active heating methods. For example, the heating is powered using electricity, coal, firewood, or natural gas, resulting in various quality levels of the indoor environment. In recent years, there is a growing concern about human-centric passive design for houses in rural areas in China. The first passive house project in rural areas was developed in a village in Yanshou Town, Changping District, in Beijing in July 2017. The first floor of the house is equipped with a polystyrene board insulation system, and the outer wall uses 250 mm thick graphite polystyrene boards to form the insulation layer. The second layer adopts 40 mm thick vacuum insulation boards. The outer opening is a high-efficiency thermal insulation plastic steel window which can avoid forming the thermal bridge. Fresh air is maintained through the high-efficiency heat recovery system, which can reduce the supply of energy by recycling the heat in the exhaust air. In winter, a gas wall-hung furnace is used for floor heating. The furnace is equipped with a temperature controller to independently set the indoor temperature (Gao, 2019).

After the completion of the project, the Beijing Kangju Certification Center has been testing and tracking the indoor environment and energy consumption of passive houses. The field measurement results show that the residents choose the heating temperature in winter according to their own needs or preferences, and the indoor winter temperature is controlled between 18 and 25°C. The highest indoor temperature in summer is 27°C without the need of turning on air conditioning systems. The indoor relative humidity is kept in the range of 40%–60% throughout the year. A fresh air system delivers outdoor air to the room, and the indoor carbon dioxide concentration is controlled to maintain below 1,000 ppm (Gao, 2019).

The human-centric passive houses in rural areas not only improve the occupants' living environment and reduce energy consumption but also bring good economic and social benefits. Passive houses are an effective means of alleviating operational utility cost burdens while revitalizing the countryside's livelihood. The service life of ordinary houses in rural areas is estimated at about 15 to 20 years. Due to the poor performance of building materials and structural defects, the conventional houses tend to require for reconstruction after 15 years of the operation. On the other hand, the passive houses have a much longer service life, and the overhaul time is considered to be about 40 years after the construction. In comparison to the short-lived ordinary houses, durable passive houses may have the capacity for accommodating multiple generations.

Despite the benefits of passive houses, the promotion of passive design and relevant construction techniques is still very challenging in rural areas in China. First, most people in rural areas do not understand what a passive house is, and it is impossible to build a passive house for themselves. Some wealthy people can afford to conduct interior decoration upgrades or pursue an increase in building area. Nonetheless, they tend not to consider improving the building's thermal performance or the IEQ. Therefore, it is necessary to popularize the basic knowledge of passive house capacities in the rural areas and let the masses understand the benefits and values. Second, passive house construction requires a professional design and construction team. At present, there are only a few design and construction companies that have the expertise and experience for the delivery of passive houses in China. It is very common that construction workers do not grasp the passive house design and construction methods. Therefore, there is a clear and urgent need for professional passive house design and constriction training courses in China.

The built environment encompasses a system of energy and environment being occupied by the masses, whose behavior affect the consequences. To accommodate diverse needs and demands of individuals and societies, it needs to be customized or personalized. In parallel to studies on technological advancement, human-centric environmental experiences should be researched much further to ensure the delivery of socially, economically, environmentally, and humanly sustainable built environments that can be applied to privileged and unprivileged families, communities, and nations that are sharing our common future.

2. Indoor environmental quality on human well-being and productivity

To examine the effects on human well-being and productivity, IEQ will be explored in this section, yet focusing on the four selected factors: i.e., thermal, visual, and acoustic environment and IAQ. Poor IAQ accompanied by ineffective ventilation and thermal discomfort, as well as inadequate light and noise may yield negative effects on human well-being and productivity. Economic calculations indicate that the improved IEQ is cost-effective when the financial value of well-being and productivity benefits are considered (Fisk et al., 2011; Wargocki and Djukanovic, 2005). Improvement in occupants' well-being and productivity presumably leads to wider benefits; thus, it motivates building owners and tenants to pursue better IEQ. In this chapter, the term "well-being" is used to reflect accepted definitions of comfort and health—i.e., the "condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation" (ASHRAE, 2017) and "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity"

(WHO, 1946), respectively. The effects of the abovementioned selected IEQ factors on well-being will be summarized below.

Thermal environment: Thermal comfort is influenced by air temperature, mean radiant temperature, air velocity, humidity, personal metabolic rate, and clothing-induced thermal insulation. Elevated temperatures that caused thermal discomfort have been shown to produce acute subclinical health symptoms such as itchy, throat irritation, headache, fatigue, and difficulty in concentrating (Lan et al., 2010, 2011a; Fang et al., 2004). Raised temperature also can result in measurable changes in physiological responses including increased sympathetic nervous system activity (Lan et al., 2010). Warm and humid indoor environments encourage mold and fungus to grow (Spengler et al., 2001). Alternatively, low humidity and temperature alter the disease transmission of infectious disease particles, such as the influenza virus (Lowen et al., 2007). Low relative humidity (5%–30%) in office, for instance, increased the prevalence of complaints about perceived dry and stuffy air and sensory irritation of eyes, as well as aggravated eye tear film stability and the osmolarity of upper respiratory airways (Wolkoff, 2018).

Indoor air quality: IAQ refers to air quality within buildings, especially as it relates to the occupants' health and comfort. IAQ is influenced by pollutants generated indoors and outdoors, and the building systems that impact on ventilation. Depending on the presence of pollutants, the concentration levels, and the exposed time, poor IAQ leads to acute effects, such as asthma, fatigue, irritation, dizziness, fatigue, and headache, as well as chronic effects, such as cancer, some respiratory diseases, and heart disease (Cedeño-Laurent et al., 2018). Ventilation in buildings brings in fresh air from outside and dilutes pollutants generated indoors. Thus, it plays an important role in creating and maintaining healthy IAQ. The increase of ventilation levels helps decrease the percentage of subjects dissatisfied with the air quality and the intensity of odor, improve the perceived air freshness, and lower the intensity of subclinical health symptoms, such as dry mouth and throat, difficulty to think, and feeling bad (Wargocki et al., 2000).

Light and view: Nowadays artificial light can cover off visual needs despite the absence of natural light in buildings. Light not only provides visual function but also acts as a modulator of nonvisual functions, such as mood regulation, alertness, and work performance. Yet, the nonvisual function of light can be highlighted by the circadian rhythmic modulation. A normal synchronized circadian rhythm is essential for well-being, since the disrupted rhythm could lead to diseases, such as diabetes, obesity, depressive disorders, and Alzheimer in addition to tumor appearance (Stevens et al., 2007). Light controls a biological clock of the body through releasing a hormone (or melatonin). It induces sleep and regulates mood and mental abilities. Among all factors of lighting, illuminance and color temperature are the two factors considered to be most influential. A low or high color temperature corresponding to a low or high level of illuminance is empirically assessed as being pleasant or neutral (Kruithof, 1941). In general, the studies indicate that lower illuminance and color temperature (warm color) are more likely to enhance positive mood (Hsieh, 2015). However, elevated illumination suppressed the melatonin release significantly, which is linked to higher alertness.

Noise: Noise and its nonauditory effects are pervasive in the urban environment. The nonauditory effects including annoyance and psychological stress are widely suspected to cause some disability worldwide. Noise annoyance can result from sound interfering with daily activities, feeling, and thought, and it might lead to humans' negative emotional responses, such as anger, displeasure, exhaustion, and other stress-related symptoms (Basner et al., 2014). High exposure to environmental noise can play a role in cardiovascular disease. Noise can raise blood pressure, change heart rate, and release stress hormones. Consistent changes of these conditions can lead to risks for hypertension, arteriosclerosis, and even more serious events, such as a stroke or myocardial infarction (Basner et al., 2014; Münzel et al., 2018). Studies also suggest that traffic noise and air pollution exposure may interact with each other and with traditional risk factors, such as hypertension and type 2 diabetes (Münzel et al., 2017). Sleep deprivation is another aspect of health risk that is triggered by environmental noise. Noise exposures shorten sleep period, cause awakenings, and reduced two important stages of sleep, i.e., slow-wave and rapid eye movement sleep (Muzet, 2007).

2.1 IEQ effects on productivity

Since the cost of people in an office is an order of magnitude higher than the cost of maintaining and operating the building, spending money on improving the work environment may be considered as the cost-effective way to improve their productivity. IEQ was estimated to be more influential on productivity than job dissatisfaction or stress management (Roelofsen, 2002). The effects of the above-mentioned IEQ factors on productivity will be summarized below.

Thermal environment: In general, thermal environment is regarded as one of the important indoor environmental factors that affect human performance. Thermal discomfort caused by low or high ambiance air temperature reduced productivity (Lan et al., 2009, 2010). Seppänen et al. (2006a,b) established a relationship between air temperature and productivity based on the results of past studies that had used objective indicators of performance that were likely to be relevant to office work activities. The relationship indicates that the performance tends to increase with the room temperature up to 21−22°C, while decreased by the temperature above 23−24°C. The highest productivity was achieved at temperatures around 22°C (Seppänen et al., 2006). An index that integrates the effect of different thermal criteria would be considered as a useful tool in the assessment of productivity. Roelofsen (2002) used this approach and related the loss of performance with PMV. His relationship was created by regressing equal thermal sensations based on a Gagge's two-layer model against thermal comfort sensations in the thermal comfort model proposed by Fanger. Lan et al. (2011b) established a quantitative relationship between thermal environment characterized by thermal sensation votes and task performance. This relationship follows a bell-shaped curve centered around the conditions that are optimal for performance, and it suggests that a slightly cool environment and avoidance of moderately elevated temperatures will create conditions that are optimal for productivity (Fig. 11.2). This applies even to subjects, who are acclimatized to higher temperatures by living in tropical climates (Tham, 2004). Based on the relationship shown in Fig. 11.2, the impact of changes in clothing insulation during the summer and winter on the air temperature for optimum performance was shown in Table 11.1. When predicting the thermal sensation votes, the mean radiant temperature was assumed to be equal to air temperature (i.e., operative temperature equals the air temperature), in which the activity level was estimated at 1.2 Met, air velocity at 0.15 m/s, and the relative humidity was at 50%. In summer, the indoor air temperature for optimum performance can be increased from about 23.5 to 25.4°C, when people wear a short-sleeved shirt with walking shorts (whose clothing combination corresponds to 0.36 clo) instead of a short-sleeved shirt with trousers (0.61 clo). The indoor air temperature for optimum performance can be decreased from about 21.9 to 18.9°C in winter, when a long-sleeved shirt, thick long-sleeved sweater, T-shirt, suit jacket, and a long underwear bottoms, as well as trousers were worn (1.30 clo) instead of a long-sleeved shirt, and a thin long-sleeved sweater, as well as trousers (0.86 clo). A recent study suggests that moderately elevated

FIGURE 11.2

The relationships between thermal sensation and productivity.

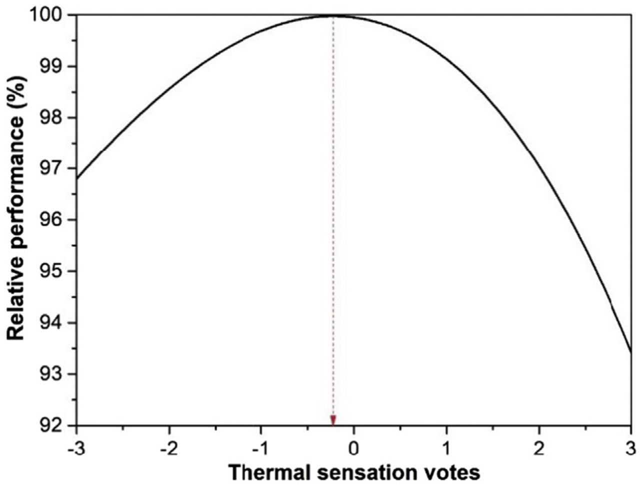

Table 11.1 The air temperature for optimum performance at different clothing insulation levels in summer and winter.

Season	Clothing with estimated insulation level	Optimum air temperature (°C)
Summer	Short-sleeved shirt, walking shorts, 0.36 clo	25.4
	Typical clothing in summer, 0.5 clo	24.3
	Short-sleeved shirt, trousers, 0.57 clo	23.9
	Long-sleeved shirt, trousers, 0.61 clo	23.5
Winter	Long-sleeved shirt, thin long-sleeved sweater, trousers, 0.86 clo	21.9
	Typical clothing in winter, 1.0 clo	21.2
	Long-sleeved shirt, thick long-sleeved suit jacket, thick sleeveless vest, trousers, 1.19 clo	19.7
	Long-sleeved shirt, long-sleeved sweater, T-shirt, suit jacket, long underwear bottoms, trousers, 1.3 clo	18.9

temperatures despite the achievement of thermal comfort can still lessen user performance (Lan et al., 2020). Such effects deserve further studies.

Indoor air quality: Reducing the pollution load in indoor air proved to be an effective means of improving productivity of building occupants (Wargocki et al., 1999; Bakó-Biró et al., 2004). IAQ can also be modified by changing the ventilation rate. Seppänen et al. (2006a,b) reviewed the literatures relating productivity with ventilation rate, and most of the studies explored concluded that higher ventilation rates tend to contribute to increasing performance. They established a quantitative relationship between outdoor ventilation rate and productivity. It indicates that typically, a 10 l/s-person increase in outdoor air ventilation rate improves performance by 1%–3%. The performance improvement per unit through increasing the ventilation rate yet below 20 l/s-person is more significant than over 45 l/s-person.

Light and view: Lighting effect on productivity is determined by several light parameters. Among them mainly are the illuminance level (LL) and correlated color temperature (CCT). The effects of LL and CCT could be interacted, as shown in the Kruithof curve, which illustrates a region of LL and CCT that are often viewed as comfortable or pleasing to an observer (Kruithof, 1941). Nonetheless, in real terms, research outcomes relating to the effect of lighting environment on productivity tend not to be constant (Souman et al., 2018; Lok et al., 2018). Some studies observed beneficial effects of increased illuminance on cognitive performance, such as sustained attention, response inhibition, and working memory. The others did not find any significant improvement of sustained attention and working memory. For instance, Viola et al. (2008) concluded that daytime blue-enriched light (17,000K) could improve occupants' self-reported alertness and work productivity, while Vandewalle et al. (2007) and Smolders and de Kort (2017) admitted that such positive effects were not observed in their studies.

Noise: It is generally accepted that noise has negative effects on productivity. Yet, Smith (1989) reviewed the effects of noise on performance and concluded that noise effects are still not clear, and that beyond intensity issues, researchers need to analyze the questions of what type of noise at what intensity affects which type of task performance. Most researchers concerned high intensity of noise, such as above 80 dB, that is not commonly experienced in modern offices, where a 55–70 dB range of noise tends to be accepted. The limited research focusing on the effect of noise of such levels on performance has come to inconsistent results. For example, Witterseh et al. (2004) found that noise of low intensity decreased work performance by 3%. Delay and Mathey (1985) discovered that a subject's performance for a time estimation task increased as the noise intensity level was ramped up from 50 to 80 dB. Evans and Johnson (2000) did not find any effect of low intensity of office noise on typing performance during a well-designed 3 h experiment. There is still a clear need for further methodological research that helps examine a compelling quantitative relationship between productivity and ambiance noise.

The mechanism that mediates the effects of IEQ on human well-being and productivity has not been enough elucidated (Wargocki and Wyon, 2017). It is hypothesized that the IEQ affects human through complex interactions among physiological responses, psychological reactions, and cognitive function. Accordingly, the following section will focus mainly on exploring the human mental responses to the built environment and how the occupants' subjective needs and demands can be incorporated into the architectural design decision-making process.

3. Human psychological responses to built environments

The built environment triggers human perceptions (McClure et al., 2011). Every space creates opportunities for the users' everyday activities and experiences (Goldhagen, 2017; Kopec, 2018; Noguchi et al., 2018; Norman, 1988). Every single element in the built environment tends to contribute to linking human perceptions to their surrounding physical settings (Evans, 2003; Kopec, 2018; Ulrich et al., 1991). Therefore, the built environment has capacities for creating physical, biological, and psychological impacts on human health and well-being, directly or indirectly. The built environment embraces different ideologies, and it is a space where people live and connect to diverse sociocultural and environmental factors that affect human health and well-being (Evans, 2003; Goldhagen, 2017).

Humans perform in their living environment with diverse habits, and their perceptions differ from one another (Graham et al., 2015; Gosling et al., 2014). Humans tend to adjust or adapt to surrounding environments to achieve their needs and demands within different settings. Human satisfaction regarding feelings, moods, and emotions in indoor and outdoor living quality is essential (Amérigo and Aragones, 1997).

According to Mehrabian (1974), pleasure, arousal, and activation are the main human emotional responses to any spatial experience. Reflecting all those emotional responses through experiences resulting in satisfaction affects human behavior. Human mental responses to spatial settings are complex phenomena being difficult to define precisely (Pallasmaa, 2005; Ittelson et al., 1976). Even so, the identification of such perceptions and correlations seems to be desirable when spatial settings that affect humans' physical and mental responses are planned (Fig. 11.3).

Today's theories related to human emotion focusing mainly on physiological stimulation and activation characteristics define the fundamental responses of human subjective emotive states (Mehrabian and Russell, 1974). The emotions swing with peripheral trials in the built environment, and stimulation variations influence human biological aspects. Surrounding environments influence human emotional states even after they leave the space (Goldhagen, 2017; Mallgrave, 2018; Mehrabian and Russell, 1974). Seemingly, human emotional states stimulate cognitive memories and responses to mental situations in numerous ways (Mallgrave, 2018; Sussman and Hollander, 2021). In this respect, human sensory organs perform a core role that contributes to turning the recognition of physical settings into the notion of environmental experience (Fig. 11.4) (Mallgrave, 2018).

Moreover, human always perceives their environment involving six sensory attributes, i.e., vision, hearing, smell, skin-sense of air, haptic, and kinesthesia (Mallgrave, 2018; Goldhagen, 2017; Sussman and Hollander, 2021; Mehrabian and Russell, 1974). Any physical setting enhances human sensory

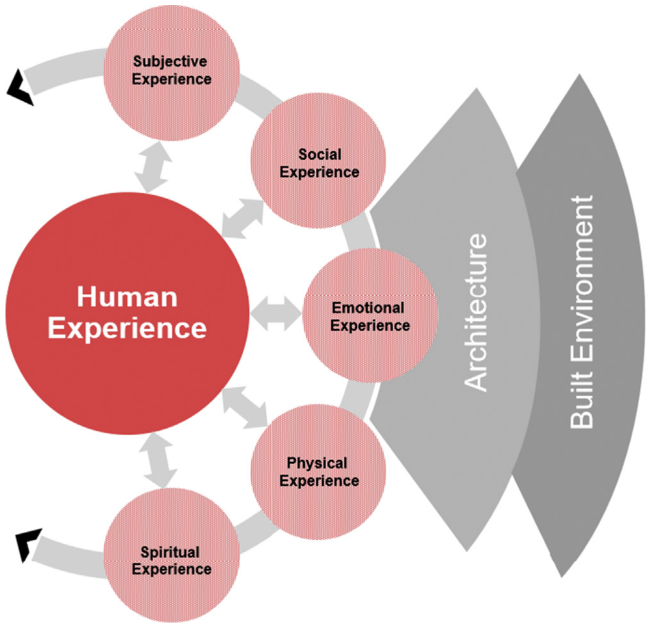

FIGURE 11.3

Human experiences in the built environment.

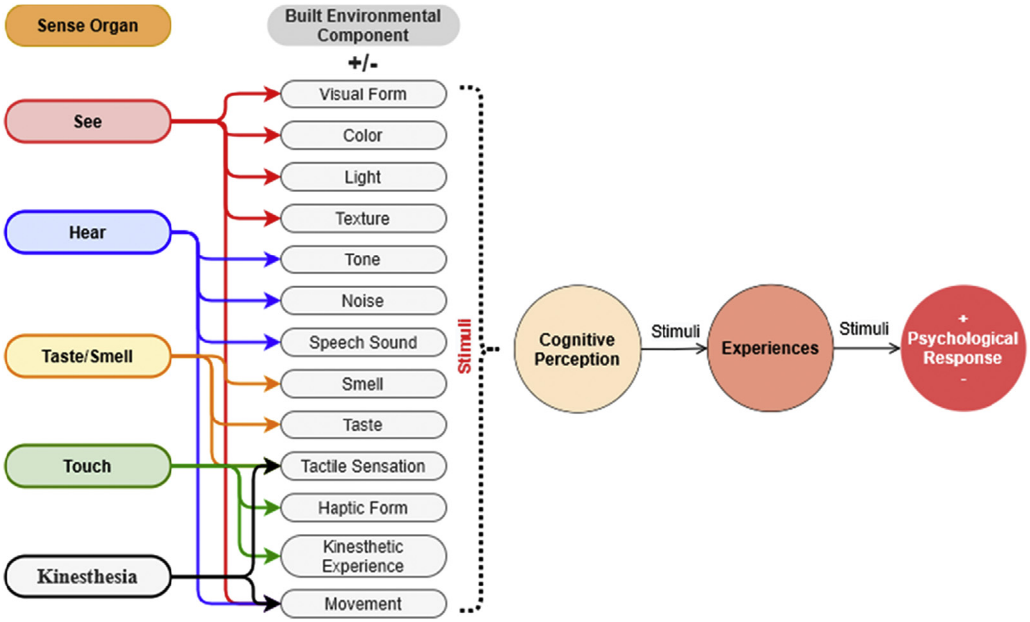

FIGURE 11.4

Relationship between the built environment and human response.

organs and promotes mental responses to whether they are auditory, tactile, or visual stimuli (Sussman and Hollander, 2021; Mehrabian and Russell, 1974). For example, lighting levels affect human moods and feelings that stimulate mental strain and alternate circadian rhythms (Ergan et al., 2018). Moreover, poor indoor lighting levels tend to reduce human psychological growth (Cooper et al., 2014; Lawrence, 1984). Noise affects individual privacy within living environments. Noise problems in the built environment may lead to a negative impact on human behavior (Evans, 2003; Ittelson et al., 1976). Human memory is also connected to the smell of any place whereas odors influence the human mind (Cooper et al., 2014). Several studies identify the psychological benefits of gardening and indoor–outdoor connectivity in the living environment (Kaplan, 1995). Nature tends to revive environmental quality as well as to provide visual satisfaction. Studies indicate that outdoor connectivity promotes environmental stimuli and human psychological relief from mental distress (Kaplan, 1995). Alongside this, spatial ergonomics related to shape, size, height, dimension, fixture, and density affect human psychological perceptions positively or negatively within living environments (Graham et al., 2015; Iavicoli et al., 2010).

Built environments stimulate human lives through their experiences (Goldhagen, 2017; Ittelson et al., 1976). In 1970, the publication entitled *Environmental Psychology: Man and His Physical Setting* by Proshansky, Ittelson, and Rivlin highlights the significance of relationships between human perceptions, behaviors, and built environments. This study concerns humans' physical, psychological, and sociocultural dimensions in built environments (Kopec, 2018; Maslow, 1971; Proshansky et al., 1970). Perhaps, these human factors can be considered as key variables in environmental design that influence individual mental responses, e.g., feelings, emotions, and moods, within the built environment. Several theories exist in the environmental psychology domain, and they study human responses to built environments (Graham et al., 2015; Mallett, 2004). For example, the theories include Brunswik's model of probabilistic lens, Gibson's model of affordance, Berlyne's model of aesthetics, social learning theory, integration theory, control theory, behavior setting theory, simulation theory, and attention restoration theory. Indeed, these theories articulate human–environment interactions (Goldhagen, 2017; Lawson, 2013; Proshansky et al., 1970).

Designing physical settings in the built environment may need to consider human psychological perception and well-being (Kopec, 2018; Goldhagen, 2017). Furthermore, its research approach specifies the built environment in numerous ways, such as independent variables of interpersonal effect, behavioral aspect, phenomena, and psychological context (Altman, 1992). Environmental psychology is also a core arena of understanding human relationships and connections associated with sociophysical settings in the built environment. It merges physical and social sciences and examines the relationship between humans' perceptions and their surrounding environments by making use of multidisciplinary theoretical models (Gifford et al., 2011). Recent research focuses on sustainability, and the understanding of everyday life experiences is becoming prominent, yet controversial (Sussman and Hollander, 2021; Ulrich et al., 2010). Environmental psychology is becoming more crucial than ever in light of user behavior that affects human health and well-being, as well as climate change mitigation and adaptation (Saegert, 2004). Wapner and Demick (2002) further interpreted this concept of contextualism considering six contexts: social, physical, psychological, natural, interpersonal, and cultural aspects of the built environment. Furthermore, Gifford et al. (2011) illustrated three dimensions, such as place, person, and psychological process in the built environment research. Goldhagen (2017) in the book entitled *Welcome to Your World: How the Built Environment Shapes Our Lives* reveals a need for the establishment of a conceptual framework that aims to understand human experiences according to individual needs and demands in built environments. In short, human factors in the architectural design process may need to be associated with users' sociocultural backgrounds, as well as their preferences and restrictions.

Today's architectural design approach experiences a gap between users' spatial needs and demands and psychological satisfaction (Chowdhury et al., 2020). The "environmental deterministic theory" describes the physical environment's impacts on human behavior (Vischer, 2008). This theory excludes or limits users' social and cultural contexts. On the other hand, the "social constructivism theory" engages with users' social and cultural perceptions as a challenge to measure the effects of built environments (Vischer, 2008). A human-centric design approach emerged positioning itself between the environmental deterministic and social constructivism theories, and it is to some extent addressing the effects of users' social, cultural, and environmental aspects on the architectural design process (Norman and Draper, 1986).

3.1 Environmental experience design research trajectory

Norberg-Schulz's "existential and architectural space" reflects the meaning of place and human perceptions and Relph's "place and placelessness" expresses cultural and emotional attachment within the built environment (Mallgrave, 2018). Kling (1977) coined the term "user-centered design (UCD)," which reflects a person-centric philosophical design approach that focused on human cognitive interaction with objects, products, and things. In 1986, the concept of UCD became widely popular as "user experience (UX) design" due to the publication entitled *User-Centered System Design: New Perspectives on Human-Computer Interaction* by Donald A. Norman at the University of California, San Diego (Norman and Draper, 1986). Human-centered design is a design philosophy starting with understanding and realizing human needs and demands where the design is projected to achieve through observations and user experiences (Norman, 1988).

Additionally, in a book entitled *The Design of Everyday Things*, Norman (2004) expanded the concept of "experience design" to the industrial design domain and elaborated the concept of human psychology within design thinking and articulated the importance in everyday human lives in consideration of product usability and usefulness. He also articulated four basic product design considerations, such as easy to determine, easy to evaluate, visible, and natural setting for experience design (Norman, 1988). As well, the author proposed seven design strategies, such as goal setting, planning, specification, performance, perception, interpretation, and comparison to systematize a product design decision-making process (Norman, 1988). Designing needs to interact between people and technology where discoverability and understanding are the two essential features of a good design (Norman, 1988). In the book entitled *Design for Experience: Where Technology Meets Design and Strategy*, Kim (2015) stated that the user is a focal point in experience design. The design incident is subjective and theories falling into humanities and social science may somewhat cover these issues. UX/UCD/UI concepts help form fundamental user experience design logic.

UX/UCD/UI definitions can be applied in numerous ways, yet all focus on exploring the users' perspective in the design process based on their needs and demands. In the ISO standard 9241-210, the UCD process has been considered as an interactive system based on people's perceptions and responses (Linden et al., 2019). According to the authors, the user-product interrelates with sociocultural factors in a precise context (Linden et al., 2019). UCD raised a philosophical agenda of users' expectations and experiences. Thüring and Mahlke draw attention to three design factors of user experiences, such as instrumental factors, noninstrumental factors, and emotional responses to form a complete decision and regulate user behavior (Linden et al., 2019). The authors also mentioned that user experiences emphasize on human perceptions, preferences, and emotional responses while a product or service is in use. Considering these factors, experience design can be regarded as an extension of the human-centered design domain. Pallasmaa (2005) stated that an architect's design requires to incorporate basic human needs of feelings and emotions where phenomenological analysis of these human factors is a prominent part of design decisions. According to Pallasmaa (2005), architectural phenomenology is a purely theoretical approach to interpreting human-environmental perceptions. McLellan (2000) mentioned that functionality, engagement, stimulation, enjoyment, and memory are the goals of experience design. The book entitled *The Handbook of Interior Design* also highlighted that reflection of user experiences enhances the quality of indoor living environment (Thompson, 2015). Reflecting the notion of experience design approaches, Ma et al. (2017) and Noguchi et al. (2018) introduced the term and concept of "environmental experience design (EXD)" (Fig. 11.5). Their EXD studies led to proposing a research framework applied to aged care facilities in Australia. Following the emergence of an EXD concept, Chowdhury et al. (2020) defined the term "domestic environmental experience" as "users' experiences of cognitive perceptions and physical responses to their domestic built environment." Furthermore, a conceptual correlation of the domestic environmental parameters (i.e., environmental design factor, spatial factor, and user context) was illustrated based on user perceptions.

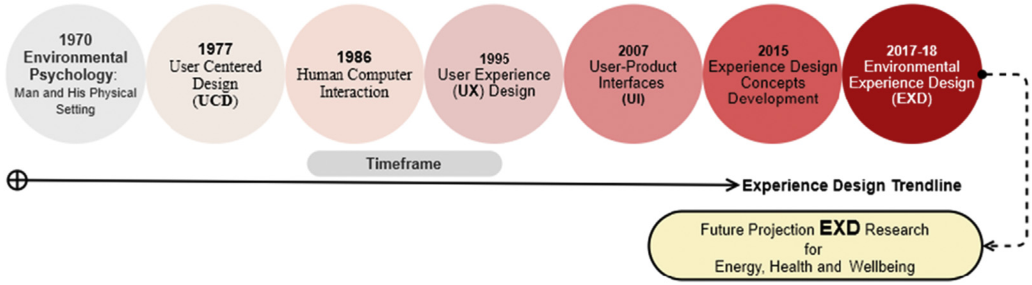

FIGURE 11.5

EXD research trajectory.

Today, architectural design research and practices tend to neither reflect multidimensional human factors nor encompass user experiences (Chowdhury et al., 2020). The design of built environments may be required to incorporate human-centered EXD approaches that aim to accommodate the occupants' individual needs and demands with the aim to enhance their health and well-being (Fig. 11.6) (Noguchi et al., 2018).

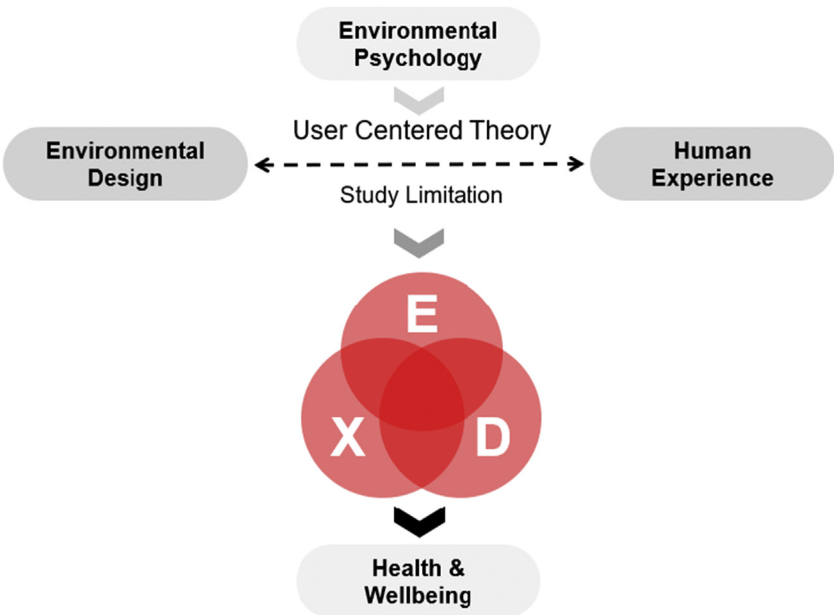

FIGURE 11.6

Environmental experience design disciplinary prospect.

4. Conclusions

Human behavior in built environments is stimulated not only by spatial settings but also by the users' perception within their sociocultural contexts. The user-centered design (UCD) may require an understanding of human perception and behavior within the built environment. Over the last years, environmental psychologists had a tendency to focus mainly on examining negative human responses (e.g., depression, anxiety, and stress) to built environments. Today, the study has begun exploring a culture of positive human thinking and feeling within defined spatial contexts. The research arena touches upon individual and societal well-being, such as pleasant, happiness, and meaningful life. Also, the new paradigm of human cognition is shifted to an image of human experiences in built environments where the users' mind and body interact. Human experiences generally indicate cognitive perceptions and physical responses to spatial settings where different types of individual experiences coexist. The built environment is indeed a system of energy and environment being occupied by the masses where their perception and behavior impact on the consequences. It can be enriched through the implementation of environmental experience design (EXD) that aims to accommodate users' needs and demands for enhancement of their health and well-being. EXD implementation may also have a significant potential for users' perceptual and behavioral changes toward energy savings. This chapter conceptualized an EXD research spectrum and the potential effects on energy and human well-being within the contexts of built environments. The demonstration and validation are required for further EXD studies.

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