

ORIGINAL ARTICLE

Open Access



# Adapting to changes in the COVID-19 pandemic: research and recommendations on spatial layout and resident experience in MURBs

Xin Bao<sup>1</sup>, Tao Zhang<sup>2\*</sup> , Qian Zeng<sup>1</sup> and Bart Julien Dewancker<sup>1</sup>

\*Correspondence:  
zhangtao841120@163.com

<sup>1</sup> Faculty of Environmental Engineering, The University of Kitakyushu, Kitakyushu 808-0135, Japan

<sup>2</sup> Innovation Institute for Sustainable Maritime Architecture Research and Technology, Qingdao University of Technology, Qingdao 266033, China

## Abstract

The COVID-19 epidemic is changing people's lives, so it is necessary to continuously update the design of the residence to adapt to the changing life. This study aims to investigate the impact of unit space layout factors in MURBs on residents' experiences during the COVID-19 pandemic. It also discusses the corresponding need for residential space renovations. Furthermore, this paper presents design adjustment recommendations for residents living in these constrained buildings and provides suggestions for future housing design to better meet the residents' housing needs. On the one hand, the layout of residential space should fully consider the use efficiency of space, with multi-functional and variable characteristics, so as to be suitable for different life cycles of the family. On the other hand, the spatial distance inside the house and the comfort of the environment should also be considered to help intergenerational communication, restore and improve the mental state of the residents, and promote the improvement of the quality of life of the residents.

**Keywords:** Development status, Design trends, Multi-unit residential building, Spatial layout, COVID-19

## Introduction

During the COVID-19 pandemic, many countries and regions implemented home isolation policies and people had to stay in their homes for longer periods of time. In different countries a few surveys and studies have described changes in people's values, habits (Gür, 2022; Wang et al. 2020; Richards et al. 2022), mental health (Peters & Halleran 2021), social activities (Gür, 2022); Zou et al. 2020), etc. These changes may lead to new expectations of where and how people live.

One year after the outbreak of the COVID-19 epidemic, in February 2021, CLV DESIGN (a Chinese housing research institution) released the "Report on Helping the Family to Fight the COVID-19 Epidemic", which confirmed the above, collected a total of 5,266 samples. The survey found that only 20% of households were very satisfied with their current housing, and 56% felt the need to improve residential quality by replacing

them (CLV.DESIGN 2020). In China, multi-unit residential buildings (MURBs) is the most common type of housing industry, accounting for about 90% of the total housing stock (Xu & Juan 2021). In other words, the housing referred to in the survey results are multi-unit residential. We noticed that often in building science or engineering journals MURBs were used to describe this housing type, while often in social sciences and humanities journals, apartment housing, multi-storey apartment buildings or high-rise residential towers also were terms used. In this paper we refer to it as housing or a residential or MURBs.

The layout of residential interiors can be used to represent people's expectations of housing in the simplest of images and to help people understand residential space in a more intuitive way. The characteristics of the spatial layout of residences include sunlight, room size, shape of space, and organization of space, etc. These features are decisive for the life of the home and the use of the room. Resident satisfaction is largely determined by design of residence aspects such as proximity to windows, spatial layout or the psychological impact of the controlled environment (Altomonte et al. 2017). In terms of color, furniture and appliances, residents can easily change or upgrade at any time according to their personal preferences. However, most spatial layout of residences are determined by the building structure or technical infrastructure, which is difficult to change after a building is built. Therefore, the spatial layout of residences will have a long-term impact on the residents (Manum 2006).

In general, homes play an important role in enhancing relationships among family members (Li & Wu 2019), quality of life (Wang et al. 2020), mental and physical health (Peters & Halleran 2021), and well-being (Morales-Bravo & Navarrete-Hernandez 2022). People's new expectations for the spatial layout of housing may be a key factor affecting the health and well-being of occupants. To date, 186 articles on housing space and resident health or well-being during the epidemic were retrieved for this review, including changes in residential activity, inadequate housing space, and the impact of environmental factors in housing on health. Therefore, This study summarises these aspects based on a search of the literature: (1) Examine activities and housing behaviors change during the pandemic, (2) Which housing indicators affect people's mental health. (3) Exploring ways to reassess and redesign the spatial layout of homes to accommodate changing housing needs. (4) Based on existing research, a design strategy for the spatial layout of housing is proposed that applies to the current situation in Chinese society.

### Review methods

The literature search strategy involved querying the Web of Science, Google Scholar, and ScienceDirect databases to retrieve articles within the research categories of architecture, environmental science, public environmental occupational health, and green sustainable science and technology.

- (1) Define the range of years of publication of the literature as 2020 to 2022.
- (2) The title contains terms related to dwelling and housing.
- (3) The description in the theme contains three areas [residential interior space, new crown events, health].
- (4) The article is written in English.

In order to conduct a comprehensive literature search, synonyms of the keywords were utilized to expand the search scope. The search string yielded relevant results, which are presented in Table 1, comprising a total of 186 articles. After excluding articles unrelated to the research topic, this study identified 37 articles specifically focused on the COVID-19 pandemic period. Furthermore, to address the research topic effectively, this study supplemented the analysis with 30 research reports, including survey reports and pre-pandemic articles.

The number of published articles was 15 in 2022, 16 in 2021, 6 in 2020. The mainly published journals were International Journal of Environmental Research and Public Health, Sustainability, Frontiers in Psychology, Archnet-IJAR international Journal of Architectural Research. It indicated the indoor spaces had received the certain attention during the COVID-19 epidemic in terms of the built environment, mental health, public health, and sustainability.

Articles related to housing and health during the COVID-19 outbreak were grouped into three categories: spatial, environmental factors, and functions and activity, based on the research area and research questions (Table 2). Similar studies were removed and a total of 37 representative articles were selected. 30 articles have been added based on this classification.

**Changes in residential unit space demands during the pandemic**

***Changes in residential behavior during isolation***

As the COVID-19 pandemic has spread globally, significant changes have occurred in people’s residential behaviors and lifestyle habits. This area has become an important focus of numerous studies aiming to explore the changes in residential behaviors and habits during the COVID-19 outbreak. The theories of environmental behavior and Kurt Lewin provide valuable perspectives to help us understand the changes in residential behaviors and habits during the COVID-19 pandemic. According to these theories, individual behavior is formed through the interaction between environmental characteristics and individual needs and preferences. During home confinement periods, individuals’ rearrangement of home spaces and functional requirements can be seen as positive adaptations to the living environment and manifestations of the interaction between individual behavior and the environment.

**Table 1** Search strings

Domains		Keywords
Title keywords		Housing OR Home OR Residen* OR Apartment OR Flat OR (Muti-unit Residential) OR Housing Quality OR House Type OR Dwelling AND
Subject keywords	Indoor	Living Space OR Indoor Spac* OR Spac* OR Latout OR Floor Plan OR Interior Design AND
	New Stressors	COVID-19 OR Pandemic AND
	Health	Well-being OR Health OR Psychology OR Mental AND
Time limit		2020–2022
Language limit		English

**Table 2** Research areas and questions

Scope	Research Areas	Research Questions
Activities	<ul style="list-style-type: none"> <li>·Working from home/Online class</li> <li>·Exercise(Indoor)</li> <li>·Cultivation an maintenance of plans</li> <li>·Social interaction</li> </ul>	What are the major changes in hygiene and healthy living behaviors in the home as a result of home isolation? Which activities are restricted by residential space? What are the implications of the new activities for people’s health?
Space	<ul style="list-style-type: none"> <li>·Flexible and variable space</li> <li>·Overcrowding and lack of space</li> <li>·Privacy of the space</li> </ul>	COVID-19 pandemic has re-raised questions about the negative effects of housing space issues on the mental health of residents? What spatial design principles contribute to the quality of residential space and the well-being of residents?
Environmental Factors	<ul style="list-style-type: none"> <li>·View quality</li> <li>·Daylight quality</li> <li>·Air quality</li> <li>·Acoustic quality</li> <li>·Green Space</li> </ul>	Does the WHO LARES report indicate that mental health symptoms are common in housing problems such as lack of daylight, unfavorable layout, poor views of buildings, noise, and lack of privacy? What spatial design principles are conducive to improving the interior environment of residential spaces? As people reevaluate housing layouts, space utilization, overcrowding, shelter, safety, and indoor air quality, could this serve as a catalyst for promoting healthy housing and sustainable building practices?

The changes in lifestyle habits during the COVID-19 pandemic are crucial for improving residential spaces. Extensive research findings demonstrate significant alterations in household hygiene and behavioral practices due to home confinement (Navas-Martín et al. 2021). These changes encompass various aspects such as working and studying from home (Macciotta et al. 2022), exercise and leisure activities (Marianme Clark. Deborah Lupton 2021), social interaction (Gür, 2022), and rest patterns (Wang et al. 2020), among others. Similar challenges are faced by households worldwide.K

Numerous companies and educational institutions have adopted flexible work and learning arrangements during periods of home isolation, utilizing residential spaces as alternatives to traditional offices and schools. This shift towards telecommuting and online education aims to mitigate the spread of disease and minimize the loss of life. The work at home (WFH) model is rapidly developing (Zou et al. 2020). In China, most houses do not have a separate room for office. Sometimes people have to work in the bedroom or the kitchen instead of a separate office. During the pandemic, home office and online education are often carried out at the same time, making it difficult to draw a clear boundary between the office and learning environments (Manzi et al. 2022). Such issues have garnered increasing complaints within residential settings (Beno 2021). Furthermore, there exists a certain level of permeability between family members and their respective social roles, as well as between office spaces and areas designated for rest, and between leisure and work times (J. Gao et al. 2022). These dynamics underscore the complex interplay between the physical and functional aspects of residential spaces during the pandemic. Experts have emphasized that failure to detach and mentally disconnect from work can have detrimental effects on individuals, including reduced productivity, decreased motivation, heightened stress levels, and compromised mental well-being(American Psychiatric Association., n.d.; March 2020). Furthermore, it is worth noting that the burden of working from home (WFH) and studying from home (SFS) predominantly falls on working women, who face the challenging task of juggling both professional and educational responsibilities (Beno 2021), Women report higher

levels of stress and experience more neck and shoulder pain compared to men, while men tend to encounter increased levels of conflict between their family and work obligations (Guo, Xingzhou 2022; Oakman et al. 2022). These gendered dynamics are increasingly observed on a global scale.

Recognizing the importance of maintaining proper hygiene practices, the World Health Organization (WHO), governments, and scientific advisory committees (SAC) have issued warnings and guidelines. Studies conducted worldwide indicate a significant shift in people's awareness regarding the necessity of improving hygiene practices, such as maintaining social distance, frequent handwashing, disinfecting their homes, and wearing masks (Gür, 2022). During the pandemic, there has been a nearly threefold increase in handwashing frequency in Poland. Additionally, research on social distancing and hand hygiene has revealed that younger individuals, those with higher levels of education, and women exhibit greater attention to hygiene practices (Wise et al. 2020).

During periods of home isolation, individuals are compelled to stay at home and spend the majority of their time indoors. Research conducted in the UK has indicated that limited indoor space restricts children's engagement in sports activities and contributes to an increase in sedentary behavior (Richards et al. 2022). To counteract the sudden rise in sedentary behavior, many individuals have adopted new exercise routines within their residential interiors. The availability of digital fitness and wellness devices and media has been gradually expanding, facilitating the integration of these technologies into home environments (Marianne Clark, Deborah Lupton 2021). Research relating to residential space also suggests that more adaptable domestic spaces are more conducive to the use of these devices and technologies. Fitness exercises during the epidemic occurred in any space in the house, the living room, the balcony, the kitchen, the bedroom and even the stairwell. Most families are unable to exercise adequately due to housing space constraints. The decline in public activities and the increase in sedentary behavior have led to a rethinking of the spatial layout of residential to allow for physical activities (Richards et al. 2022).

The COVID-19 pandemic has also brought the global food supply system under scrutiny, leading to concerns about potential food shortages and subsequent panic buying and hoarding by consumers. A Canadian study explores the current surge in home food gardening and its association with the COVID-19 pandemic. Among long-term gardeners, a significant proportion (70.6%) expressed that gardening served as a means of relaxation, while 57.6% considered it an excellent form of physical exercise (Mullins et al. 2021).

#### ***The impact of home isolation on residential health***

MURBs have become the most common type of housing in the Chinese residential industry, accounting for approximately 90% of the total residential stock in China (Xu & Juan 2021). Compared to single-family dwellings, MURBs have some disadvantages, such as having more floors, smaller living spaces, and fewer rooms. Multiple studies have indicated that MURBs units face several issues in terms of space, including overcrowding, inadequate space allocation, lack of privacy, ventilation, noise, and insufficient natural lighting (Astolfi & Pellerey 2008; Cuerdo-Vilches et al. 2021; Kearns et al. 2000; Mullins et al. 2021).

A survey conducted during the COVID-19 lockdown in China revealed that individuals residing in smaller living spaces engage in lower-intensity physical exercise (Wang et al. 2020). Living in more crowded housing also exacerbates the association between life stress and depression (Macciotta et al. 2022; Shih et al. 2022). This sense of housing congestion also diminishes people's ability to cope with life stress. The COVID-19 pandemic has sparked a strong demand for private living spaces.

In addition, indoor environmental conditions are an important factor in the health of the occupants (Andargie et al. 2019). Any interference from external environment or stressors can threaten family health and, consequently, diminish the psychological and social functioning of households (Kearns et al. 2000). Unlike single-family residences, residents of MURBs may be exposed to various sources of noise, including airborne and impact noise from neighboring units, shared spaces, and other service systems. Apart from causing annoyance and discomfort, exposure to such noise can result in severe long-term health issues, including cardiovascular diseases, dementia, and mental health problems (Cantuaria et al. 2021). Prolonged isolation at home makes it challenging for individuals to connect with nature, and people generally desire the integration of natural and living elements, such as plants and sunlight, through windows, balconies, or terraces (Mullins et al. 2021; Pouya Molaei, Parisa Hashempour 2021). Some studies indicate gender differences in respondents' residential preferences for indicators such as "landscape quality," "daylight quality," "acoustic quality," and "air quality." All these factors are deemed more important to women than to men (Mullins et al. 2021). A study based on survey findings has identified the most crucial indoor environmental quality factors that impact overall comfort and health of residents in MURBs. The conclusions drawn from other types of residential constructions align with the findings, highlighting thermal conditions and air quality as the two most significant factors influencing the comfort of MURBs (Astolfi & Pelleray 2008; Humphreys 2005; Wong et al. 2008).

During the pandemic, numerous studies have explored the impact of home isolation on residential health, drawing attention to the importance of healthy living environments and adaptable indoor spaces. Akbari et al., categorized housing indicators related to psychological well-being into four categories: housing type, space, environmental factors, and functionality and activities. A preference survey revealed that environmental factors were more significant than space and activities, with air quality, daylight quality, and landscape quality identified as the highest priority (Akbari et al. 2021). In another study, Zarrabi M et al., conducted a questionnaire survey to assess indicators related to physical health, psychological well-being, and socio-economic lifestyle changes in apartment interiors. The study not only established the priorities within these indicators but also highlighted the significance of natural light, landscape, acoustics, and open or semi-open spaces for residential health (Zarrabi et al. 2021). MURBs typically consist of multiple floors, and numerous studies have shown that floor levels significantly impact the comfort and health of occupants. In comparison to lower floors, residents on higher floors report higher levels of comfort and acceptability regarding indoor conditions (Kang S J, 2000; Lee et al. 2012).

### ***Changes in demand for indoor environmental factors***

The long-term home quarantine under the epidemic has inspired many housing issue such as "disturbance", "sense of depression", "insufficient storage space", and "unreasonable indoor traffic flow". A few housing research institutions in China have conducted research on housing demand during the epidemic.

From 2020 to June 2022, regardless of the city level, 3LDK (three bedrooms, living room, dining room, and kitchen) has become the most sought-after type of housing, with the highest proportion of transactions in the 110–140 square meter range (CRIC Product Research 2022). Prior to this period, people tended to choose housing products below 90 square meters in size (X. Gao et al. 2013).

A survey from CLV.DESIGN shows how dissatisfied people are with residential spaces. Sort according to the degree of dissatisfaction is (1) Single function of living room. (2) Dinner room is too small. (3) The kitchen is missing function. (4) Insufficient storage in master bedroom. (5) No separate room for study. (6) Children's room is too small. (7) Having a bathroom is not enough. (8) Entrance is too small. (9) No separate room for clean. (10) No south-facing balcony (CLV.DESIGN 2020). According to the "Survey Report on the Demands of Chinese Residents under the Epidemic" formed by CRIC, China's largest real estate information integrated service provider, on the data of 194 cities under key monitoring in 2022, 35% of potential buyers said that the upgrade of household type was attractive for buying houses (CRIC Research Institute 2022). The survey report reflects the residential indoor space expectations of Chinese households during the outbreak, which residential indoor space needs to meet the requirements of spatial adaptation, redistribution of tasks, and organization due to changes in residence behaviors and habits.

The "2022 Report on the Intention to Improve Home Environment during the Pandemic," jointly released by QiJia Research Institute and Sina Home, reveals that 58.7% of respondents expressed a desire to enhance their living environment after the pandemic. Due to constraints such as renovation costs and time, 50.5% of participants indicated a preference for low-cost, short-duration partial renovations that do not disrupt normal living. The survey findings also highlight the balcony, living room, and kitchen-bathroom area as the top three spaces that respondents wish to renovate. Among them, those who wished to renovate their balconies mainly aimed to cultivate vegetables and flowers. Furthermore, there is a heightened demand for the functional versatility of living room spaces, with expectations for them to be transformed into coffee areas, fitness zones, tea rooms, and more. Achieving these functionalities primarily involves flexible adjustments to furniture layout or the addition of more practical furniture. Additionally, there is an increased demand for rooms that can adapt to multiple functions, such as storage for cleaning supplies, home gyms, study rooms, walk-in closets, and pet areas (2022 Report on the Intention to Improve Home Environment during the Pandemic 2022). The report highlights a strong intention among respondents to improve their home environment after the pandemic, with a focus on low-cost, partial renovations and a preference for transforming spaces such as balconies and living rooms into functional areas like gardening and multipurpose zones.

A survey report on home-based learning and work during the COVID-19 pandemic reveals that there has been a widespread trend of home renovations to accommodate

changes in domestic activities and habits (J. Gao et al. 2022). People have been transforming their living rooms into family activity centers, using furniture to create segmented spaces and minimize disturbances among household members, and relocating work desks to the master bedroom (J. Gao et al. 2022).

Numerous survey reports indicate that an increasing number of people are inclined to purchase larger residential properties with more rooms. Moreover, homebuyers' expectations for housing have shifted from single and low-level to a focus on quality, complexity, and healthy living, marking a prevailing trend of comprehensive upgrades in residential products. Although several Chinese real estate companies have initiated research on housing products in alignment with the current social, economic, and cultural development processes, these studies predominantly rely on sales experience and lack comprehensive data and theoretical support in analyzing factors influencing people's housing demands and purchase intentions. Significant disparities still exist between existing residential products and residents' actual living needs. Considering the prolonged duration of home isolation and its impact on the course of the pandemic, other features of housing will also influence its progression. Therefore, the need for new design concepts to improve spatial layouts is imperative. A household survey conducted during the pandemic revealed that residents' primary concerns regarding indoor spaces are focused on environmental quality, spatial functionality, spatial relationships, and indoor equipment and facilities. Urban residents in areas with higher severity of the pandemic have higher quality expectations for spaces such as corridors, bathrooms, living rooms, and master bedrooms.

#### **Design recommendations for spatial layout**

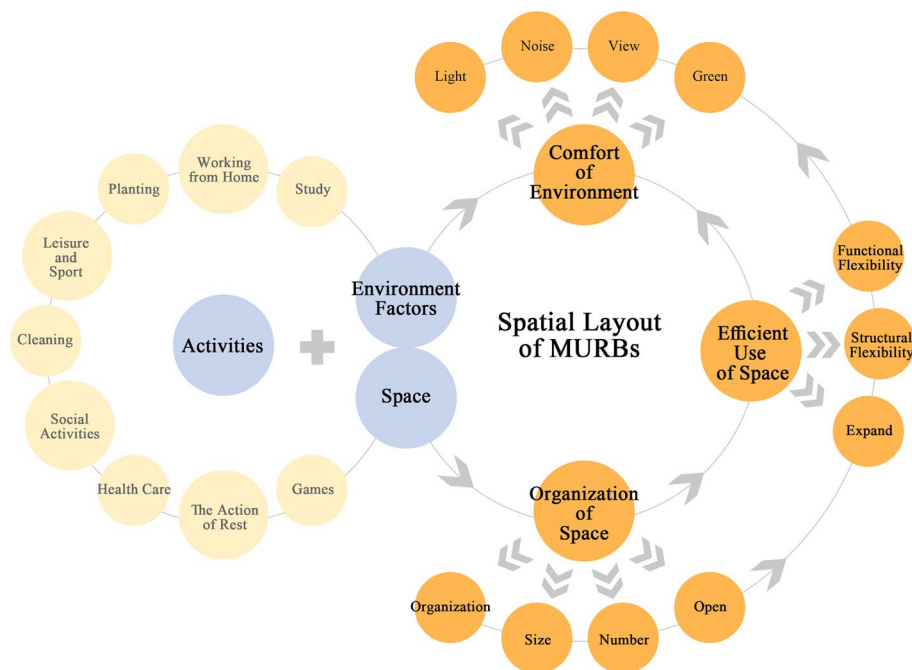
Studies conducted during the pandemic have shed light on the impact of home isolation on people's habits and activities, as well as the negative effects of residential spaces and environmental factors on people's health. However, existing spatial layout design methods often lack qualitative and quantitative studies, and recommendations are often based on anecdotal evidence. Therefore, this study aims to address these gaps by examining past research on space to identify potential solutions.

The spatial layout of residential areas needs to consider three key aspects: function and activity, space utilization, and the environment. By reviewing the existing literature, we have identified three major trends in residential space layout that have emerged in response to the COVID-19 pandemic, taking into account nine different perspectives (Fig. 1).

#### ***Improve efficiency in the use of space***

A flexible house refers to a residential layout that can adapt to changing needs and usage patterns, encompassing both technical and social aspects (Raviz S R H, Eteghad A N, Guardiola E U, 2015). Flexible space layouts have the potential to enhance the functionality of a residence, particularly in situations where space is limited, by improving space utilization (Abdulpader et al. 2014). Additionally, such layouts can accommodate the evolving roles of family members. The following are trends in residential space planning for different rooms.





**Fig. 1** Changes in spatial layouts during the COVID-19 pandemic

(1) Functional flexibility

Several authors have classified flexibility into functional and structural types (Bettaieb & Alsabban 2021). Functional flexibility refers to the ability to modify conditions without professional intervention by assigning new functions. However, there has been limited discussion on how residents in MURBs can self-segregate within separate rooms. Designing flexible housing that supports self-segregation within residential units becomes crucial for containing the spread of COVID-19 or future pandemics. Designing flexible housing that can support self-segregation within residential units is essential to contain the spread of COVID-19 or future pandemics (Peters & Halleran 2021). In situations where a family member needs to undergo home quarantine, having an independent room in the house becomes necessary to ensure their separation from other household members. Such a room should cater to not only sleeping but also living, bathroom, and workspace needs. Similarly, changes in the family life cycle may necessitate additional independent bedrooms for adult children living with their parents, fulfilling their privacy requirements. Additionally, each room’s size should allow for user substitution. For instance, a children’s bedroom can serve as an adult bedroom if required, provided the space is appropriately arranged.

Consider incorporating a dedicated multifunctional room within the residential unit, designed to adapt its functions based on the evolving needs of different families. This room can serve as an undisturbed office space and a private lounge, offering versatility and privacy. Another strategy is to expand the size of the bedroom and enhance its functionality to accommodate the demands of a home office, study, and living space, effectively mitigating any conflicts that may arise.

In many residential units, the presence of only one bathroom poses challenges during home quarantine as family members are unable to use the bathroom individually, thus hindering optimal isolation (Sehgal et al. 2021). To address this issue, it is advisable to incorporate both a full bathroom and a half bath during the design stage, allowing for more efficient usage and ensuring the highest level of isolation (Steidl & Hoffmann 1979).

The porch serves as a transitional space connecting the indoor and outdoor areas of the residence. In light of the current health and hygiene requirements, it becomes essential to integrate new disinfection and sterilization functions within the porch storage cabinet (Liu 2022). This adaptation aligns with the demands of the new era and ensures a safe and hygienic living environment.

In the Chinese housing market, enhancing the spatial layout of MURBs often involves considering the renovation of existing units. The interior transformation of old residential spaces is typically achieved through modifications of non-load-bearing walls. Flexible furniture arrangement can help optimize space utilization and functional zoning to meet residents' diverse needs. By selecting and arranging furniture thoughtfully, it is possible to create additional storage areas, workspaces, and leisure zones, maximizing the potential of the space. For instance, the use of movable partitions, folding tables and chairs, and adjustable furniture allows for changing the spatial layout as needed, enhancing flexibility and multifunctionality. By selecting and arranging furniture thoughtfully, it is possible to create additional storage areas, workspaces, and leisure zones, maximizing the potential of the space. For instance, the use of movable partitions, folding tables and chairs, and adjustable furniture allows for changing the spatial layout as needed, enhancing flexibility and multifunctionality.

## (2) Structural flexibility

Structural flexibility extends beyond mere structural changes to encompass physical alterations within the interior space of a house. Residents have the ability to modify their homes according to their specific needs, often with the assistance of professionals. During the epidemic, studies conducted on residents revealed that partition walls within apartments could be removed or repositioned to create more flexible spaces. This is achieved by establishing new areas with varying spatial relationships through the sequencing and interconnection of spaces, utilizing sliding doors, walls, and flexible elements. These adaptable spaces effectively cater to the residents' requirements, which stem from the activities of family members throughout the day and night (Seyed Reza Hosseini Raviz, Ali Nik Etghad, Ezequiel Uson Guardiola, 2015).

The concept of an open living room design can be advocated, where the living room serves as a transitional area connecting the dining room, kitchen, and balcony, collectively forming an open space. This home space is commonly referred to as LDKB (Fig. 3). The absence of fixed building structures allows for easier alterations in space function based on actual needs. In situations where the number of occupants feels overwhelming, the distribution of shared space is carefully planned according to the individual needs and number of people. For instance, a foldable dining table can be extended into the kitchen and living room area to accommodate larger dining gatherings. Beyond work,

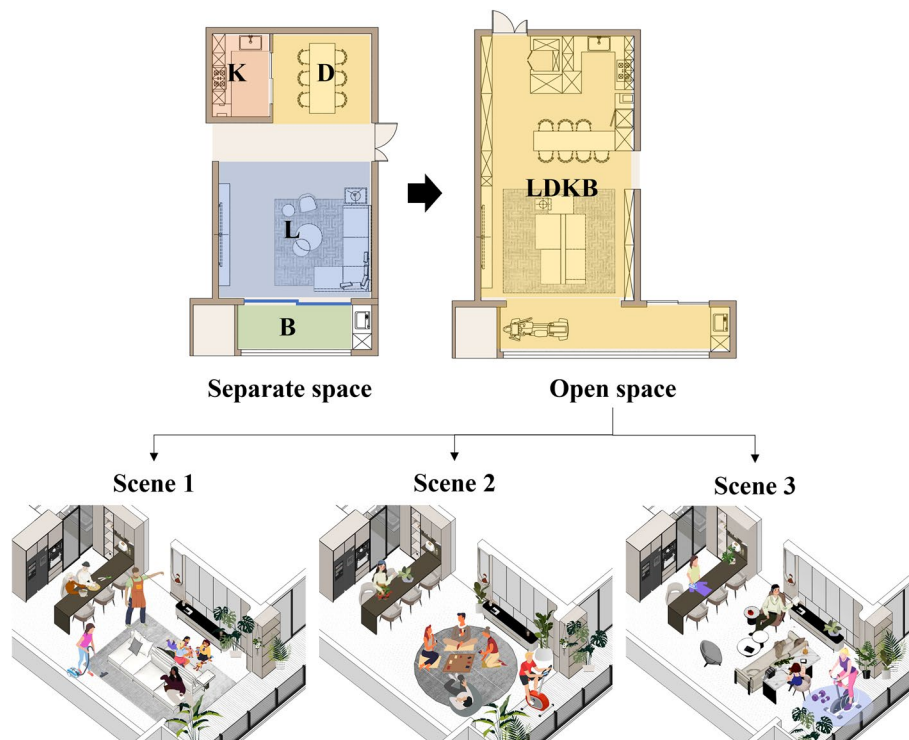
studying, and dining, the furniture in the open space can be moved to transform it into a family fitness area. Moreover, the living room seamlessly connects to the balcony, creating a new functional zone within the living space. During such times, the living room, dining room, kitchen, and balcony can all serve as complementary expansion areas for each other, accommodating a wide range of family activities (Fig. 2).

(3) Expand Function

In addition to enhancing space versatility and flexibility, expanding the functionalities of residential areas can also optimize the utilization of space. For instance, the balcony can be effectively utilized as an extension of the living room, where a small coffee table and comfortable cushions can be placed, creating a sunlit tearoom or a well-lit study space. Furthermore, maximizing the utilization of compact spaces is essential. For instance, meticulous design of the entrance storage space can incorporate dedicated cabinets for storing emergency food supplies and personal protective equipment (Sehgal et al. 2021).

***Distinguish between private and public of spatial organization***

The COVID-19 pandemic has had a profound impact on living spaces as people began to prioritize hygiene and sanitation. The experience of entering a home has changed drastically, with the familiar sense of intimacy and warmth being replaced by a more detached and distant atmosphere. However, to adapt to this new reality, family members have had to adjust their activities and the use of indoor spaces. The entrance area, or foyer, has



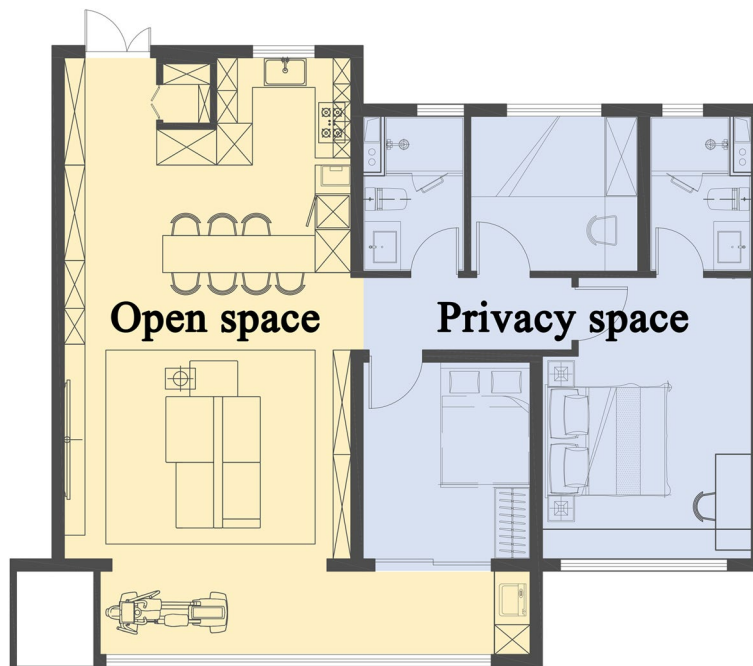
**Fig. 2** Flexibility of LDKB space

become a critical zone that needs to be divided into different functional areas, such as a housekeeping zone, laundry area, and handwashing area. The process of entering the house has also changed, with people following a new sequence of actions: first, changing shoes; then, removing coats; next, placing dirty clothes in a basket; and finally, washing hands. Such arrangements help maintain cleanliness and hygiene indoors while reducing the risk of virus transmission (Juran interior decoration, n.d.; Sehgal et al. 2021). Furthermore, when a household member needs to undergo home isolation, a separate room is required that serves not only as a sleeping space but also as a living area, bathroom, and workspace. This design ensures the separation of isolated individuals from other family members while meeting their various needs during the isolation period. It is necessary to have at least one multifunctional bedroom in the residential layout and ensure a convenient path from the entrance to this room to facilitate the daily lives of residents (Sehgal et al. 2021).

During the COVID-19 pandemic, there has been an increased focus on research regarding housing size and spatial organization (Ferreira et al. 2022). One study suggests that improving the quality of indoor communal spaces to provide safe environments for passive and active family interactions has become a way to address the psychological issues people face during home isolation (Peters & Halleran 2021). Providing open spaces for family activities, such as adopting an open-plan living, dining, kitchen (LDKB) design that offers unobstructed sightlines and improved communication, is one solution. Additionally, incorporating balconies integrated with the living room expands the visual scope indoors, making it easier for residents to appreciate outdoor views and reducing mental fatigue (Pouya Molaei, Parisa Hashempour, 2021). Such spatial layouts help alleviate stress, provide more opportunities for socialization and relaxation, and increase awareness of the natural environment (Ribeiro et al. 2021).

In China, multigenerational households are quite common, making the clear delineation of public and private spaces particularly important (Li & Wu 2019) (Fig. 3). Studies have shown that designing bedroom spaces to resemble independent houses can enhance privacy within rooms (Ishikawa et al. 2011). To meet the need for independent isolation, residential units can be arranged with separate areas, including independent bedrooms, living rooms, and bathrooms (Sehgal et al. 2021). This design is especially useful when family members require isolation or independent living. Additionally, there is a solution called "dual-key home" suitable for multigenerational households (Fig. 4). This layout connects a larger unit with a smaller one, allowing different generations of family members to live separately and improving privacy concerns (Han 2010; Yang et al. 2022).

In summary, the COVID-19 pandemic has brought significant changes to living spaces as people prioritize hygiene and sanitation. Family members have had to adhere to a series of protective measures, resulting in a different experience when entering the home. To adapt to this new reality, individuals have adjusted their activity sequences and the layout of indoor spaces. Researchers have also proposed solutions, including improving the quality of indoor communal spaces, providing open space designs, and clearly delineating public and private areas, to meet people's residential needs during the pandemic.



**Fig. 3** Regional division of residence



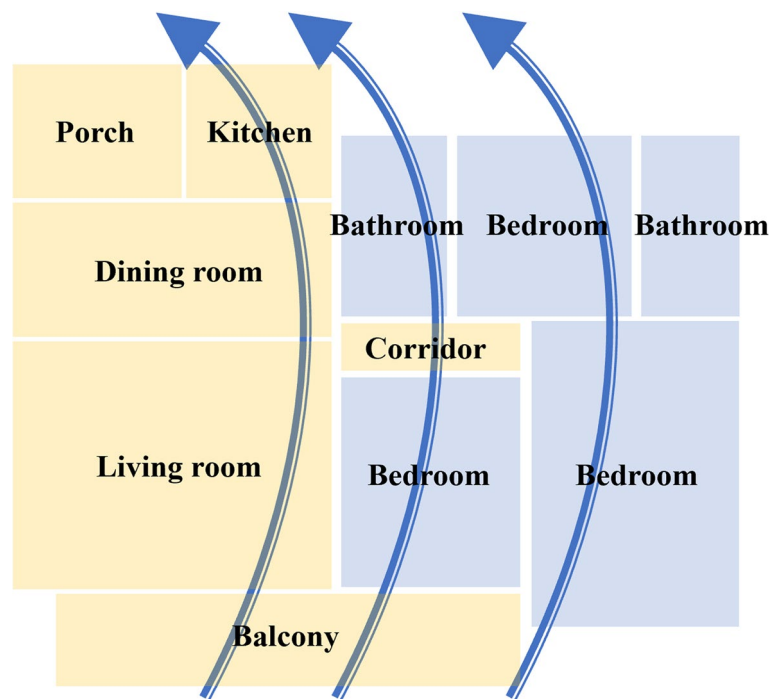
**Fig. 4** The "dual key" spatial layout of residence

**Consideration of environmental comfort**

A substandard indoor environment in residential settings has been linked to an increased risk of depressive symptoms during lockdown (Amerio et al. 2020). Within the realm of healthy housing research, various factors such as views (Kaplan R, 2001), noise (Jensen et al. 2019), and natural light (Kang et al. 2013; Garrido-Cumbrera et al. 2022), access to green spaces (Sima 2015), and connection to the outdoor environment (Foster et al. 2020) have been utilized as indicators of mental well-being within housing.

(1) Increase ventilation and lighting

Creating an efficient living, working, or studying environment is an essential requirement for occupants to maintain their well-being and productivity. Therefore, it is crucial to improve indoor air quality to enhance productivity and prevent the spread of viruses (Sun & Zhai 2020). Natural ventilation is widely acknowledged as the optimal approach to ensure occupant comfort (Su et al. 2009). The orientation of building is an important property of a residence. One notable advantage is that south-facing houses receive extended hours of natural light and improved ventilation. The LDKB spatial organization, characterized by large bays and compact layouts, facilitates the optimal utilization of sunlight and natural airflow, creating a comfortable residential environment (C. M. Tam, 1 Tony Y. N. Tso 2015; X. Gao et al. 2013). Bright kitchens and bathrooms have gained increasing popularity in residential units. These areas, prone to dampness, require sufficient ventilation and lighting to prevent the accumulation of dirt and ensure fresh air quality (Fig. 5).



**Fig. 5** The window opening position is diagonal to the door to increase ventilation

## (2) Connect with Natural Environment

During the quarantine period, balconies, windows, and private outdoor spaces have emerged as crucial components of residential settings. They not only provide access to sunlight and fresh air but also establish a connection between occupants and the external environment by offering panoramic views. This connection to the outdoors has assumed paramount importance during the ongoing COVID-19 pandemic, as it not only fosters mental well-being but also contributes to the management of the persistent endemic nature of the disease (Pouya Molaei, Parisa Hashempour, 2021; Dzhambov et al. 2021; Pouya Molaei, Parisa Hashempour 2021; Olszewska-Guizzo et al. 2021).

Research has demonstrated that pleasant views and ample natural light from the outside enhance visual comfort, while the incorporation of natural sounds like animal calls, breezes, and fountains contributes to auditory comfort (Garrido-Cumbrera et al. 2022). Moreover, individuals residing in proximity to green natural environments exhibit higher overall levels of health compared to those living in less verdant surroundings (Ribeiro et al. 2021).

Furthermore, personal green spaces have proven to have a significant impact on residents' levels of depression and anxiety during the COVID-19 pandemic, serving as a viable alternative during periods of home isolation (Garrido-Cumbrera et al. 2022). The dimensions, proximity to the surrounding landscape, and orientation of balconies, windows, or private outdoor spaces play crucial roles in determining the visual and auditory comfort experienced within these personal green areas.

## (3) Incorporating Green Plants

During the COVID-19 pandemic, there has been a noticeable surge in the popularity of home gardening, particularly in the cultivation of foliage plants in containers, which have become a prevalent feature in living rooms. This trend has prompted a growing interest in small-scale planting gardens on balconies, offering individuals an enhanced connection with nature (Cerdeja et al. 2022). Notably, the integration of foliage plants on balconies, seamlessly connecting public and functional spaces, has emerged as a highly favored approach. Foliage plants are preferred due to their adaptability to higher temperatures and lower levels of light (Kim & Lee 2022). Compared to the pre-pandemic period, there is a growing awareness among individuals regarding the significance of balconies. Consequently, there is a strong desire to optimize the location and size of balconies, with the concept of "double balconies" becoming an ideal configuration for homes. Balconies are now assigned additional roles, such as serving as pet parks, family farms, gardens, sunrooms, and even home gyms, among other functionalities.

## Discussion and conclusion

In recent years, there has been a sustained increase in income among Chinese residents, resulting in a strong desire to improve living environments and conditions. Additionally, the prolonged pandemic has significantly altered residents' housing preferences and accelerated changes in the residential sector. Urban housing is the predominant residential type in Chinese cities and directly impacts residents' living experiences and quality

of life. This study analyzed 67 research papers and journal articles related to residential space layout and examined the influence of COVID-19 on housing from the perspectives of architectural design, environmental psychology, sociology, and health. Through this analysis, three design trends were identified that contribute to improving people's quality of life.

Firstly, a high-quality residential spatial layout requires more effective space planning to enhance versatility and flexibility, meeting diverse housing needs. During the design process, considerations should be given to the proper division of different functional areas, enabling clear delineation between communal and private spaces, thus enhancing the quality of different functional spaces. Additionally, in terms of renovating older houses, flexible furniture arrangements are commonly used to improve spatial layouts by strategically placing furniture to delineate different functional zones and meet residents' needs.

Secondly, by increasing the openness of public spaces and allocating a reasonable physical distance between private and public spaces, residents' desired privacy can be enhanced. Adequate storage space should also be provided to enhance the overall residential experience. In the design of mixed-use residential buildings (MURBs), emphasis is placed on creating spacious and transparent public spaces to facilitate social interaction among residents, thereby enhancing the residential experience. Special attention should be given to the spatial needs of multi-generational households and activities involving children, providing appropriate spaces for communication and activities to meet the requirements of different age groups. Considerations may include the incorporation of open kitchens conducive to communication, shared leisure areas, indoor activity spaces, or children's play facilities to promote interaction among residents.

Thirdly, good natural lighting and indoor ventilation are crucial for residential spatial layouts. In housing design, obtaining sufficient natural light is important, achieved through strategic window placement and lighting design to allow ample sunlight to illuminate indoor spaces. Simultaneously, optimizing the design of indoor ventilation systems ensures the circulation of fresh air and improves indoor air quality. Additionally, incorporating green plants as interior decorative elements not only provides aesthetic enjoyment but also helps improve indoor air quality, enhancing the comfort of the living environment.

China's residential spatial layouts need significant reform to achieve sustainability. Through the utilization of advanced technologies such as Building Information Modeling (BIM) and virtual reality, designers and residents can better visualize and experience residential spaces, facilitating more accurate planning and decision-making to improve housing efficiency and sustainability. Future research can further explore customer preferences regarding MURBs spatial layouts by employing survey methods to gain in-depth understanding of customer preferences at the current stage of MURBs unit spatial layouts. By comparing differences among regions and population groups, a better understanding of residents' preferences for MURBs unit spatial layouts can be achieved.

Continued research and practice will drive continuous improvements in housing design, providing people with better living environments, improving their quality of life and well-being. By focusing on the needs and expectations of residents and integrating the latest technologies and design concepts, housing units that cater to diverse needs can



be created. Only by doing so can we truly achieve the goal of enhancing the residential experience, improving residents' lives, and aligning with the development demands of modern society. Through the study of MURBs spatial layouts from different approaches and perspectives, we can continuously refine and optimize designs, providing residents with more comfortable, healthy, and satisfactory living spaces.

#### Authors' contributions

Conceptualization, methodology, investigation, Writing-original draft, visualization, writing-review, and editing, X.B.; Conceptualization, methodology, resources, investigation, writing-review, and editing, T.Z.; Resources, supervision, writing-review, and editing, funding acquisition, B.J.D. All the authors have read and agreed to the published version of the manuscript.

#### Funding

This research received no external funding.

#### Availability of data and materials

The data that support this study are available from the corresponding author upon reasonable request.

#### Declarations

#### Competing interests

The authors declare no conflict of interest.

Received: 14 December 2022 Accepted: 1 August 2023

Published online: 30 August 2023

#### References

- 2022 Report on the Intention to Improve Home Environment during the Pandemic. (2022). <https://mp.weixin.qq.com/s/x6AD7xeENHf9OGzkdMrYg>
- Abdulpader, O. Q., Sabah, O. A., and Abdullah, H. S. (2014). Impact of Flexibility Principle on the Efficiency of Interior Design Currently at School of Housing, Building and Planning, Universiti Sains Malaysia, MALAYSIA. *Management, and Applied Sciences and Technologies*. 2014. *International Transaction Journal of Engineering*, 5(3). <http://tuengr.com>
- Akbari, P., Yazdanfar, S. A., Hosseini, S. B., and Norouzian-Maleki, S. (2021). Housing and mental health during outbreak of COVID-19. *J Building Engineering*, 43(March), 102919. <https://doi.org/10.1016/j.jobe.2021.102919>
- Altomonte S, Saadouni S, Kent MG, Schiavon S (2017) Satisfaction with indoor environmental quality in BREEAM and non-BREEAM certified office buildings. *Archit Sci Rev* 60(4):343–355. <https://doi.org/10.1080/00038628.2017.1336983>
- Amerio A, Brambilla A, Morganti A, Aguglia A, Bianchi D, Santi F, Costantini L, Odone A, Costanza A, Signorelli C, Serafini G, Amore M, Capolongo S (2020) Covid-19 lockdown: Housing built environment's effects on mental health. *Int J Environ Res Public Health* 17(16):1–10. <https://doi.org/10.3390/ijerph17165973>
- Andargie, M. S., Touchie, M., and O'Brien, W. (2019). A review of factors affecting occupant comfort in multi-unit residential buildings. *Building and Environment*, 160(April), 106182. <https://doi.org/10.1016/j.buildenv.2019.106182>
- American Psychiatric Association. (n.d.). *Working remotely during COVID-19: Your mental health and well-being*. <https://workplacementhealth.org/Employer-Resources/Working-Remotely-COVID-19>
- Astolfi A, Pellerey F (2008) Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. *The Journal of the Acoustical Society of America* 123(1):163–173. <https://doi.org/10.1121/1.2816563>
- Beno, M. (2021). Working from the home office and homeschool(-ing): Experiences of austrian employees (parents) in the time of Covid-19. *J Edu Social Res*, 11(4), 73–83. <https://doi.org/10.36941/jesr-2021-0078>
- Bettaieb DM, Alsabban R (2021) Emerging living styles post-COVID-19: housing flexibility as a fundamental requirement for apartments in Jeddah. *Archnet-IJAR* 15(1):28–50. <https://doi.org/10.1108/ARCH-07-2020-0144>
- Cantuaria ML, Waldorff FB, Wermuth L, Pedersen ER, Poulsen AH, Thacher JD, Raaschou-Nielsen O, Ketznel M, Khan J, Valencia VH, Schmidt JH, Sørensen M (2021) Residential exposure to transportation noise in Denmark and incidence of dementia: National cohort study. *The BMJ* 374:12–15. <https://doi.org/10.1136/bmj.n1954>
- Cerda, C., Guenat, S., Egerer, M., and Fischer, L. K. (2022). Home Food Gardening: Benefits and Barriers During the COVID-19 Pandemic in Santiago, Chile. *Frontiers in Sustainable Food Systems*, 6(March). <https://doi.org/10.3389/fsufs.2022.841386>
- Clark Marianme, Lupton Deborah. (2021). Pandemic fitness assemblages: The sociomaterialities and affective dimensions of exercising at home during the COVID-19 crisis. *Convergence*, 27(5): 122. <https://doi.org/10.1177/13548565211042460>
- CLV.DESIGN. (2020). "Survey on Helping Families Fight the Epidemic." CLV DESIGN WeChat Official Account. <https://mp.weixin.qq.com/s/ledLecsdIoYy6LIYfsOGA>
- CRIC Product Research. (2022). *CRIC Summary and Outlook for the First Half of 2022*. <https://baijiahao.baidu.com/s?id=1737110378032306932&wfr=spider&for=pc>

- CRIC Research Institute. (2022). A survey report on Chinese real estate customer needs under the epidemic. In *CRIC Product Evaluation WeChat Public Account*. [https://mp.weixin.qq.com/s/a6F14Rpx4\\_gsk9eHJB7gJQ](https://mp.weixin.qq.com/s/a6F14Rpx4_gsk9eHJB7gJQ)
- Cuerdo-Vilches, T., Navas-Martín, M. Á., March, S., and Oteiza, I. (2021). Adequacy of telework spaces in homes during the lockdown in Madrid, according to socioeconomic factors and home features. *Sustainable Cities and Society*, 75. <https://doi.org/10.1016/j.scs.2021.103262>
- Dzhambov, A. M., Lercher, P., Browning, M. H. E. M., Stoyanov, D., Petrova, N., Novakov, S., and Dimitrova, D. D. (2021). Does greenery experienced indoors and outdoors provide an escape and support mental health during the COVID-19 quarantine? *Environmental Research*, 196(November 2020), 110420. <https://doi.org/10.1016/j.envres.2020.110420>
- Ferreira, P., Sheila, D. M., Ornstein, W., and Azambuja, G. (2022). Privacy and housing : research perspectives based on a systematic literature review. In *Journal of Housing and the Built Environment* (Vol. 37, Issue 2). Springer Netherlands. <https://doi.org/10.1007/s10901-022-09939-z>
- Foster, S., Hooper, P., Kleeman, A., Martino, E., and Giles-Corti, B. (2020). The high life: A policy audit of apartment design guidelines and their potential to promote residents' health and wellbeing. *Cities*, 96(July 2018), 102420. <https://doi.org/10.1016/j.cities.2019.102420>
- Gao X, Asami Y, Zhou Y, Ishikawa T (2013) Preferences for Floor Plans of Medium-Sized Apartments: A Survey Analysis in Beijing. *China Housing Studies* 28(3):429–452. <https://doi.org/10.1080/02673037.2013.759542>
- Gao J, Kenyon B, Leichter HJ (2022) Blurred boundaries: an examination of learning and working in the home during the COVID-19 pandemic. *Current Issues in Comparative Education (CICE)* 24(2):31–49. Special Issue
- Garrido-Cumbrera, M., Foley, R., Correa-Fernández, J., González-Marín, A., Braçe, O., & Hewlett, D. (2022). The importance for wellbeing of having views of nature from and in the home during the COVID-19 pandemic. Results from the GreenCOVID study. *Journal of Environmental Psychology*, 83(August). <https://doi.org/10.1016/j.jenvp.2022.101864>
- Guo, Xingzhou, and Y. C. (2022). Comparing Impacts of Indoor Environmental Quality Factors on Satisfaction of Occupants with Different Genders and Ages between Office-and Home-Based Work Environments. *Construction Research Congress*.
- Gür, M. (2022). Post-pandemic lifestyle changes and their interaction with resident behavior in housing and neighborhoods: Bursa, Turkey. In *Journal of Housing and the Built Environment* (Vol. 37, Issue 2). Springer Netherlands. <https://doi.org/10.1007/s10901-021-09897-y>
- Han, S. T. W. (2010). *Dual key apartments in Singapore*. <https://scholarbank.nus.edu.sg/handle/10635/222779>
- Humphreys MA (2005) Quantifying occupant comfort: Are combined indices of the indoor environment practicable? *Building Research and Information* 33(4):317–325. <https://doi.org/10.1080/09613210500161950>
- Ishikawa T, Nakata S, Asami Y (2011) Perception and conceptualization of house floor plans: An experimental analysis. *Environ Behav* 43(2):233–251. <https://doi.org/10.1177/0013916509356874>
- Jensen HAR, Rasmussen B, Ekholm O (2019) Neighbour noise annoyance is associated with various mental and physical health symptoms: results from a nationwide study among individuals living in multi-storey housing. *BMC Public Health* 19(1):1–10. <https://doi.org/10.1186/s12889-019-7893-8>
- Juran interior decoration. (n.d.). *The pandemic has prompted considerations on the design of home circulation patterns*. <https://zhuanlan.zhihu.com/p/337948170>
- Kang NN, Lee TK, Kim JT (2013) Characteristics of the quality of Korean high-rise apartments using the health performance indicator. *Indoor and Built Environment* 22(1):157–167. <https://doi.org/10.1177/1420326X12470344>
- Kang SJ, S. S. H. (2000) A study on the effect of infants in different residential environment between super-high rise and low rise apartment. *J Architectural Institute of Korea* 16(2):1–9
- Kaplan R (2001) The nature of the view from home: psychological benefits[J]. *Environ Behav* 33(4):507–542
- Kearns, A., Hiscock, R., Ellaway, A., & Macintyre, S. (2000). "Beyond four walls": The psycho-social benefits of home: Evidence from West Central Scotland. *Housing Studies*, 15(3), 387–410. <https://doi.org/10.1080/02673030050009249>
- Kim WJ, Lee TK (2022) Greenness Index and Preferences for Interior Landscapes in Residential Spaces. *Sustainability (switzerland)* 14(9):1–14. <https://doi.org/10.3390/su14095183>
- Lee TK, Cho SH, Kim JT (2012) Residents' adjusting behaviour to enhance indoor environmental comfort in apartments. *Indoor and Built Environment* 21(1):28–40. <https://doi.org/10.1177/1420326X11420120>
- Li, L., & Wu, X. (2019). Housing price and intergenerational co-residence in urban China. *Journal of Housing Economics*, 45(August 2018), 101596. <https://doi.org/10.1016/j.jhe.2018.08.001>
- Liu, Y. (2022). Porch Design Based on Family Health Needs. *Journal of Architectural Research and Development*, 6(1), 45–50. <https://doi.org/10.26689/jard.v6i1.3549>
- Macciotta, A., Farinella, D., Dell'aversana, G., Fornili, M., Petri, D., Baglietto, L., Baccini, M., Montiel, C. B., Fiorentino, G., Severi, G., Ricceri, F., Campolo, M. G., & Bruno, A. (2022). Remote Working and Home Learning: How the Italian Academic Population Dealt with Changes Due to the COVID-19 Pandemic Lockdown. *Sustainability (Switzerland)*, 14(13), 1–21 <https://doi.org/10.3390/su14138161>
- Manum, B. (2006). Apartment Layouts and Domestic Life; The Interior Space and its Usability. In *A study of Norwegian Apartments Built in the Period 1930–2005. The Oslo School of Architecture and Design. OSLO*. [http://www.aho.no/Global/Dokumenter/Forskning/Avhandling/Manum\\_avhandling.pdf](http://www.aho.no/Global/Dokumenter/Forskning/Avhandling/Manum_avhandling.pdf)
- Manzi C, Koc Y, Benet-Martínez V, Reverberi E (2022) Identity integration matters: The case of parents working from home during the COVID-19 health emergency. *Self and Identity* 21(8):914–938. <https://doi.org/10.1080/15298868.2021.2004217>
- March, A. G. (2020). The productivity pitfalls of working from home in the age of COVID-19. *Stanford News*, 2020, 1–4. <https://www.tdla.org/resources/Documents/Speaker>
- Molaei Pouya, Parisa Hashempour, L. M. T. (2021). Semi-open spaces of apartments considering COVID-19 pandemic: General expectations of balcony design in the post-pandemic world. *Architectural Engineering and Design Management*, 1–18.
- Morales-Bravo, J., and Navarrete-Hernandez, P. (2022). Enlightening wellbeing in the home: The impact of natural light design on perceived happiness and sadness in residential spaces. *Building and Environment*, 223(February), 109317. <https://doi.org/10.1016/j.buildenv.2022.109317>

- Mullins, L., Charlebois, S., Finch, E., and Music, J. (2021). Home food gardening in Canada in response to the covid-19 pandemic. *Sustainability (Switzerland)*, 13(6). <https://doi.org/10.3390/su13063056>
- Navas-Martin, M. Á., López-Bueno, J. A., Oteiza, I., & Cuervo-Vilches, T. (2021). Routines, time dedication and habit changes in spanish homes during the covid-19 lockdown. A large cross-sectional survey. *Intern J Environ Res Public Health*, 18(22). <https://doi.org/10.3390/ijerph182212176>
- Oakman J, Kinsman N, Lambert K, Stuckey R, Graham M, Weale V (2022) Working from home in Australia during the COVID-19 pandemic: cross-sectional results from the Employees Working From Home (EWFH) study. *BMJ Open* 12(4):1–10. <https://doi.org/10.1136/bmjopen-2021-052733>
- Olszewska-Guizzo, A., Fogel, A., Escoffier, N., & Ho, R. (2021). Effects of COVID-19-related stay-at-home order on neuropsychophysiological response to urban spaces: Beneficial role of exposure to nature? *Journal of Environmental Psychology*, 75(March), 101590. <https://doi.org/10.1016/j.jenvp.2021.101590>
- Peters T, Halleran A (2021) How our homes impact our health: using a COVID-19 informed approach to examine urban apartment housing. *ArchNet-IJAR* 15(1):10–27. <https://doi.org/10.1108/ARCH-08-2020-0159>
- Raviz SRH, Eteghad AN, Guardiola EU, A. A. A. (2015) Flexible housing: the role of spatial organization in achieving functional efficiency. *Int J Archit Heritage* 9(2):65–76
- Raviz SRH, Eteghad AN, Guardiola EU et al (2015) Flexible housing: The role of spatial organization in achieving functional efficiency. *ArchNet-IJAR: Int J Architectural Res* 9(2):65
- Ribeiro, A. I., Triguero-Mas, M., Jardim Santos, C., Gómez-Nieto, A., Cole, H., Anguelovski, I., Silva, F. M., & Baró, F. (2021). Exposure to nature and mental health outcomes during COVID-19 lockdown. A comparison between Portugal and Spain. *Environment International*, 154. <https://doi.org/10.1016/j.envint.2021.106664>
- Richards, A. B., Minou, M., Sheldrick, M. P., Swindell, N., Griffiths, L. J., Hudson, J., & Stratton, G. (2022). A Socioecological Perspective of How Physical Activity and Sedentary Behaviour at Home Changed during the First Lockdown of COVID-19 Restrictions: The HomeSPACE Project. *Int J Environ Res Public Health*, 19(9). <https://doi.org/10.3390/ijerph19095070>
- Sehgal AR, Himmelstein DU, Woolhandler S (2021) Feasibility of separate rooms for home isolation and quarantine for covid-19 in the united states. *Ann Intern Med* 174(1):127–129. <https://doi.org/10.7326/M20-4331>
- Shih KK, Anderson AE, Brown J, Schuren N, Lyles MY, Williams J, Ross Y, Hampton M, Chen M, La Cruz VD, Nelson C, Stanton P, Shelal Z, Bruera E (2022) Stay Home, Work Safe: Attitudes and Beliefs of Members of a Department of Palliative Care, Rehabilitation, and Integrative Medicine Regarding Remote Work during the COVID-19 Pandemic. *J Palliat Med* 25(5):757–767. <https://doi.org/10.1089/jpm.2021.0343>
- Sima L (2015) A study on small apartment design in China: Evaluation on the impressions of and preferences for the floor plans. *J of Asian Architecture Building Engineering* 14(2):307–314. <https://doi.org/10.3130/jaabe.14.307>
- Steidl RE, Hoffmann ME (1979) Adaptability of Bedroom Space to Family Diversity. *Housing and Society* 6(3):161–176. <https://doi.org/10.1080/08882746.1979.11429837>
- Su X, Zhang X, Gao J (2009) Evaluation method of natural ventilation system based on thermal comfort in China. *Energy and Buildings* 41(1):67–70. <https://doi.org/10.1016/j.enbuild.2008.07.010>
- Sun, C., and Zhai, Z. (2020). The efficacy of social distance and ventilation effectiveness in preventing COVID-19 transmission. *Sustainable Cities and Society*, 62(July), 102390. <https://doi.org/10.1016/j.scs.2020.102390>
- Tam CM, 1 Tony Y. N. Tso, 2 and K. C. Lam3. (2015). *Feng Shui and It's Impacts on Land and Property Developments*. 97(2008), 602–617.
- Wang X, Lei SM, Le S, Yang Y, Zhang B, Yao W, Gao Z, Cheng S (2020) Bidirectional influence of the COVID-19 pandemic lockdowns on health behaviors and quality of life among chinese adults. *Int J Environ Res Public Health* 17(15):1–17. <https://doi.org/10.3390/ijerph17155575>
- Wise, T., Zbozinek, T. D., Michelini, G., Hagan, C. C., and Mobbs, D. (2020). Changes in risk perception and self-reported protective behaviour during the first week of the COVID-19 pandemic in the United States: COVID-19 risk perception and behavior. *Royal Society Open Science*, 7(9). <https://doi.org/10.1098/rsos.200742>
- Wong LT, Mui KW, Hui PS (2008) A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices. *Build Environ* 43(1):1–6. <https://doi.org/10.1016/j.buildenv.2007.01.001>
- Xu Y, Juan YK (2021) Design Strategies for Multi-Unit Residential Buildings During the Post-pandemic Era in China. *Front Public Health* 9(October):1–14. <https://doi.org/10.3389/fpubh.2021.761614>
- Yang, H., Oldfield, P., & Easthope, H. (2022). Influences on Apartment Design: A History of the Spatial Layout of Apartment Buildings in Sydney and Implications for the Future. *Buildings*, 12(5). <https://doi.org/10.3390/buildings12050628>
- Zarrabi, M., Yazdanfar, S. A., & Hosseini, S. B. (2021). COVID-19 and healthy home preferences: The case of apartment residents in Tehran. *J Building Engineering*, 35(May 2020). <https://doi.org/10.1016/j.jobee.2020.102021>
- Zou P, Huo D, Li M (2020) The impact of the COVID-19 pandemic on firms: a survey in Guangdong Province. *China Glob Health Res Policy* 5(1):4–13. <https://doi.org/10.1186/s41256-020-00166-z>

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.