Frontiers of Architectural Research 15 (2026) 1219–1232

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journal homepage: www.keaipublishing.com/foar

REVIEW ARTICLE

Has behaviour left housing design? A literature review and research agenda

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Received 14 July 2025; received in revised form 12 November 2025; accepted 4 December 2025

KEYWORDS
Housing design;
Behaviour;
Use;
Architecture;
Spatial design

Abstract Despite previous calls for a more integrated approach to behavioural research in architecture, studies on housing design and behaviour have remained largely fragmented. While post-occupancy evaluative studies today constitute a significant part of housing design research, behavioural outcomes of housing design, remains largely under studied and represents a key research gap. It is against this backdrop that this literature review seeks to outline how the interaction between spatial design and behaviour is investigated by reviewing 32 recent architectural research publications. In addition to identifying critical gaps and challenges, this paper suggests that housing design and architecture scholars can draw upon studies from different disciplines as well as valuable data beyond academia. More importantly, it is also imperative to recentre theoretical and conceptual discussions when studying and analysing the relationship between housing design and behaviour. The methodological approaches and theoretical frameworks highlighted in this review can be useful points of departure for developing a more holistic approach to housing design research, which would in turn lead to better housing design that matches the changing needs and behaviours of the residents.
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Peer review under the responsibility of Southeast University.

https://doi.org/10.1016/j.foar.2025.12.004
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1. Introduction

Housing is a fundamental human need and is central to the planning of future societies. In addition to providing refuge to its inhabitants, there are increasing societal expectations on housing design to address climate change, resource scarcity, prepare for emergencies, and support care and health services in the home. More specifically, the rise in regional conflicts, extreme weather events, and global health crises including the COVID-19 pandemic is also indicative of how housing design has to continuously adapt to different needs by accommodating new functions such as remote work, online shopping and deliveries, different leisure and social activities, as well as providing protection and security. Designing homes that support daily activities, even as lifestyles and external conditions evolve, is in many ways crucial for fostering societal resilience. It is therefore essential to understand how human behaviour and spatial design relate and interact. For the purpose of this review, human behaviour can be understood as the way people act, occupy, use, and move through space. Spatial design, on the other hand, concerns how physical space is organised and designed in terms of its layout, lighting, and materiality. Even though standards, regulations, and guidelines for housing design have evolved over time with the aim to increase functionality, usability, and liveability, recent studies indicate that there is still a mismatch between how homes are designed and how they are actually being used by residents, highlighting the need for more evidence-based studies (Alonso and Jacoby, 2023; Özer and Jones, 2022). Moreover, while post-occupancy studies have become more common, the majority of such studies are centred on issues such as wellbeing, comfort, energy performance, and housing satisfaction rather than providing insights into the dynamics between housing design and user behaviour (Watson et al., 2016). This further points to a lack of integrated and systematic ways to study and theorise the relationship between user behaviour, space, and architectural design.

Already 40 years ago, Lawrence (1983) suggested in his critical review of architecture literature that the study of behaviours in architecture constitutes a broad and interdisciplinary field drawing on insights from architecture, social anthropology, geography, as well as social psychology. Although generally falling under the umbrella of behavioural research and the broad discipline of environmental psychology, scholars from different academic and professional backgrounds have adopted a wide range of methods and theories to study various aspects of behaviour in relation to architecture and building design. The goals of such research often include measuring psychological and physiological responses, identifying and studying behavioural patterns, or examining residential preferences and satisfaction levels. In spite of Lawrence's call for a more integrated and interdisciplinary approach to studying behaviour in architectural research, this review of recent literature suggests that studies on behaviour and architecture have, in the passing decades, remained largely fragmented in terms of disciplines, theoretical foundations, and methodological approaches. While Kopec's (2006) comprehensive work on environmental psychology in design has shed light on how designers can incorporate concepts and theories on behaviour in their practice, behavioural research in architecture and housing design is still largely underdeveloped.

It is against this backdrop that this paper sets out to examine recent housing design research that in various ways engages with user behaviour, exploring how the interaction between spatial design and behaviour is investigated and theorised within different disciplines and contexts by surveying recent publications in the housing design literature. In addition to identifying critical gaps within the literature, this paper also aims to discuss the lessons from which researchers can learn to advance behavioural research in architecture. The point of departure for this paper is thus the research specifically highlighting the interaction between behaviour and housing design. In other words, the paper is interested in literature across different disciplines that looks at both the ways in which spatial design of residential buildings affects how people behave and use their homes, as well as the manners in which the behaviour of residents is shaping and producing different spaces in their dwellings. This paper will first outline the methods used in collecting and analysing the journal articles included in this review, and provide a general overview of evaluative housing design research and substantiate the need for a better understanding of behavioural outcomes, which generally refers to the outcomes of housing design that accrue to residents in relation to their actions (Watson et al., 2016). Then, the paper will explore the link between housing design and behaviour in the relevant literature by discussing the various

themes and issues covered in the different empirical studies. Finally, this paper will discuss the challenges of studying behaviour in housing design and architecture research, the methodologies and theoretical frameworks that can be utilised in future research, as well as the impact and implications of understanding the interaction between spatial design and behaviour on the advancement of future housing design. It is clear from this review of literature that there is a growing need to understand and theorise the interactions and relations between people and built form, and it is the objective of this paper to contribute to the development of a research agenda that places behaviour and use in the centre of architecture and housing design research.

2. Data collection process and method

The literature review can be best characterised as what Xiao and Watson (2019) refer to as a narrative review, which generally entails a less formal and systematic data extraction process (Fig. 1). An initial search using a combination of the keywords "residential architecture," "housing," "dwelling," "apartment," "design," "transformation," "use," and "behaviour" with Boolean operators[1] identified over 10,000 publications on two of the main databases for academic publications: 3,254 on *Scopus* and 8,375 on *Web of Science*. The search is then refined by limiting the results to include only journal articles published in English from 2000 to 2023 (1,719 on *Scopus* and 7,377 on *Web of Science*). A first screening process was undertaken by reviewing the titles and abstracts of the top 500 results from each platform based on relevance, and a selection was made based on a number of inclusion and exclusion criteria. The first inclusion criterium is thematic relevance. Only papers that discuss both spatial design and user behaviour are included in the review. For example, studies that examine building performance without considering use or consumption without assessing the role of spatial design, are excluded. The second inclusion criterium relates to the setting of the research. It was decided to only include studies on multi-residential housing since the mismatch between design and use tends to be the most prevalent in apartments due to the more standardised nature of apartment design and construction (Warouw et al., 2010; Wong, 2010). Comparing to single family houses and villas, apartments are seldom designed for specific users and are generally less conducive to customisation and adaptations. Moreover, the decision to focus on apartments—and exclude single-family houses and villas—is also a reflection of the growing academic and public interests in compact and sufficient living in urban areas. In addition, duplicated results that appeared in both searches were discarded, along with papers published by publishers that are considered to be predatory or lack scientific rigour based on a set of widely adopted criteria that includes pay for publishing only, high self-citation rate, non-existent peer review process, lack of transparency, etc.

[1] The search string used is ("housing*" OR "apartment*" OR "residential architecture*" OR "dwelling*") AND ("design*" OR "layout*") AND ("change*" OR "transform*" OR "impact*" OR "shape*") AND ("use*" OR "behaviour*" OR "behavior*").

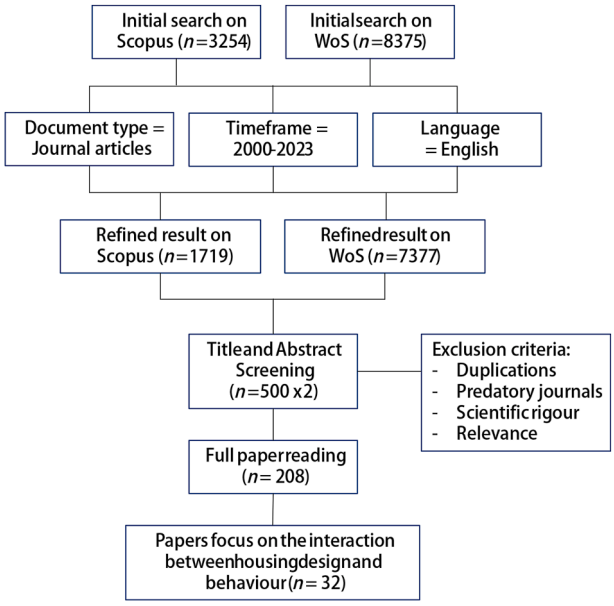

Fig. 1 Data collection process.

(Beall, 2015; Grudniewicz et al., 2019; Oviedo-García, 2021). As a result, 208 papers were selected for full reading.

The 208 papers selected are diverse in terms of methodological approach, geographical context, as well as thematic focus. In terms of methodology, almost half of the publications (94) are quantitative studies, 62 studies used mixed methods, 34 articles are qualitative studies, and 18 are review and theoretical papers. Geographically, 81 studies are centred on Europe, 69 on Asia, 23 on Oceania, 12 on North America and Africa respectively, 3 on South America, and the rest are comparative studies or studies without specific geographical contexts. In addition to diverse methodologies and geographical contexts, the literature examined also comes from a wide range of disciplines, which include architecture and housing design, environmental psychology, energy research, urban studies, as well as public health. While these 208 papers provide valuable insights into how spatial design and behaviour are discussed in relation to a wide range of issues including housing satisfaction, energy consumption, as well as health and wellbeing, not all studies directly address the interaction between spatial design and behaviour, which constitutes the main inquiry for this literature review. For instance, a number of studies have looked at how the energy performance of apartments can be impacted by both spatial design and user behaviour without going into detail how spatial design and user behaviour shape each other (Guerra-Santin and Itard, 2010; Yousefi et al., 2017; Ekim et al., 2023). In a similar vein, other scholars suggest that spatial design and behavioural changes are both contributing factors to housing satisfaction without examining the interaction between design and behaviour (Ornstein et al., 2011; Gao et al., 2013). Out of the 208 papers, only 32 address the different ways in which housing design and behaviour interact and relate to each other and were thus selected for detailed analysis (Table 1).

3. Results: the interaction between housing design and behaviour

A variety of themes and issues emerge from the selected core of 32 papers, which were divided into two main groups. The first group of literature looks at the ways in which user behaviours of the residents have changed the spatial design and configuration of their homes. This includes publications on various residential adaptations and transformations as well as the emerging literature on post-pandemic housing. The second set of literature examines the changing behavioural outcomes of housing design, which is centred around the design of special-purpose housing and transitional spaces such as communal spaces of apartment complexes and balconies.

3.1. Housing adaptations and transformations

As McDermott et al. (2007, p. 259) suggest, "human behaviour can affect the environment in two ways, either through different types of use or by changing the environment itself." Spatial adaptation thus constitutes not only a reaction to changing circumstances, but an important aspect of the interaction between behaviour and spatial design. The transformation and adaptation of physical space within private dwellings is often the result of increasing mismatch between spatial design and living needs that is driven by lifestyle changes, evolving household composition, or shifts in spatial functions (Agyefi-Mensah et al., 2020; Minami, 2007). In addition to changes to physical and spatial design, adaptations can also include renovations undertaken to incorporate different aesthetic and design decisions, to replace or upgrade existing fittings and fixtures, as well as to improve energy efficiency. Focusing on energy efficiency and consumption, Judson and Maller (2014) utilise practice theory to examine the relationship between mundane daily behaviours and renovations among Australian homeowners. Conceptualising renovations such as kitchen renewal and addition of working or living space as a reflection of changing social practices, according to Judson and Maller (2014, p. 509), can facilitate "the analysis of the interactions between people and buildings." By centring the behavioural aspect and social dimension of renovations, they contend that programmes and policies on energy efficiency should shift from solely focusing on technical interventions to also incorporate social behaviour.

Residential adaptation became particularly prevalent in the aftermath of the COVID-19 outbreak. The initial outbreak of COVID-19 and subsequent lockdowns have resulted in significant lifestyle changes that exacerbated the mismatch of spatial needs in our homes (Bettaieb and Alsabban, 2021; ElZein and ElSemary, 2022; Gür, 2022; Özer and Jones, 2022). A growing body of literature has looked at uses and behavioural changes in private dwellings as a result of the COVID-19 pandemic and how such changes have both shaped and been shaped by the physical spaces of our homes. As people stay at home for longer periods of time and use it for a wider range of activities, apartments have to be appropriated and repurposed to accommodate their needs in the post-pandemic world (Alonso and Jacoby, 2023; Khalil and Eissa, 2022; Özer and Jones, 2022). Working and schooling from home, for example, has suddenly become a necessity and norm in many places as a consequence of mandatory lockdowns and social distancing measures (Özer and Jones, 2022). Such drastic lifestyle changes often require not only rearranging or adding furniture in homes (Alonso and Jacoby, 2023) but also improving privacy as well as other spatial qualities such as lighting and sound isolation (Kleeman and Foster, 2023). In addition to the heightened spatial need for working and studying, many apartments have also become sites for different outside and new indoor activities such as physical exercises and gardening (Alonso and Jacoby, 2023; ElZein and ElSemary, 2022; Gür, 2022; Valizadeh and Iranmanesh, 2022). To accommodate the increasing spatial need for various activities, residents often had to "reclaim," "appropriate," and "negotiate" their use of not only regular living spaces, but also unprogrammed and overspill spaces such as storage, hallways, and balconies (Khalil and Eissa, 2022; Özer and Jones, 2022).

The extensive literature on the pandemic has not only shed light on the changing lifestyles and spatial needs, but also highlighted the importance of adaptability in housing design. In their study of apartment adaptability and flexibility based on layout changes done by the residents, Femenias and Geromel (2020, p. 481) suggest that adaptability refers to the building's capacity to accommodate future changing needs. Despite the advantages, "adaptability is seldom part of the design concept of apartment designs" due to the higher up-front cost and uncertainty of actual economic gains. Focusing on the layout of apartments, they contend that modern floor plans have characters that do not support a general use, and the capacity of apartments to adapt for future changes is largely dependent on the size, spatial form, and how the rooms relate to each other. This further points to some of the structural and spatial constraints that can impact the adaptability of apartments and the ability for residents to cope with future changes in spatial needs.

To increase housing adaptability, builders and designers have adopted different adaptable systems and incorporating flexible design features. An open building approach to apartment design and construction, for instance, aims to facilitate residential adaptations by separating the building into fixed elements and changeable elements (Warouw et al., 2010; Wong, 2010). In a study of 80 apartments in Hong Kong, China, Wong (2010) examines how the open building approach is adopted and utilised by residents. By knocking down and building new walls before moving in, residents can change the layout of their apartments to meet their varying housing needs. Similarly, Warouw et al. (2010) also explore the ways in which the open building system of an apartment building in Jakarta, Indonesia offers residents the opportunity to customise not only the layout, but also the appearance and quality of their homes before moving in. While the open system allows for some customisation prior to moving in, it is less conducive to post-occupancy appropriations due to the significant cost and disruptions that such renovations can incur. Unlike the open building approach, the incorporation of flexible design features in housing design allows residents to shape their homes according to their uses and needs after moving in without undergoing major renovations. Looking at spatial alterations in Japanese apartments, Minami (2007) suggests that the main driver for the residents to adjust the

Table 1 List of publications reviewed.

Year	Authors	Title	Journal	Context	Methodology	Data
2004	B. N. West; S. Emmitt	Functional design? An analysis of new speculative house plans in the UK	Design Studies	UK	Qualitative	Floor plans with furniture dimensions
2006	S.-C. L. Huang	A study of outdoor interactional spaces in high-rise housing	Landscape and Urban Planning	Taiwan, China	Mixed	Observation
2007	H. McDermott; R. Haslam; A. Gibb	The interaction between design and occupier behaviour in the safety of new homes	Accident Analysis & Prevention	UK	Qualitative	Interviews, observation
2007	K. Minami	A Post—Occupancy Evaluation of Layout Changes Made to KEP Adaptable Housing	Journal of Asian Architecture and Building Engineering	Japan	Mixed	Questionnaire, floor plans, observation, photos
2009	S. Danziger; H. Chaudhury	Older Adults' Use of Adaptable Design Features in Housing Units: An Exploratory Study	Journal of Housing For the Elderly	Canada	Qualitative	Interviews
2010	F. Warouw; H. Kobayashi; J. Jung	A Study on the Open Building System for Multi-Storey Housing in Indonesia	Journal of Asian Architecture and Building Engineering	Indonesia	Qualitative	Floor plans, interviews, observation
2010	J. F. Wong	Factors affecting open building implementation in high density mass housing design in Hong Kong	Habitat International	Hong Kong, China	Mixed	Questionnaire, interviews, floor plans, measurement data
2014	E. P. Judson; C. Maller	Housing renovations and energy efficiency: insights from homeowners' practices	Building Research & Information	Australia	Qualitative	Interviews, observations (go-alongs)
2016	E. Marcheschi; M. Johansson; T. Laike; D. Brunt	Housing design and people with severe mental illness: An observational approach to the investigation of supported housing facilities	Scandinavian Journal of Psychology	Sweden	Quantitative	Observation, measurement data
2017	S. Nordin; K. McKee; M. Wallinder; L. von Koch; H. Wijk; M. Elf	The physical environment, activity and interaction in residential care facilities for older people: a comparative case study	Scandinavian Journal of Caring Sciences	Sweden	Mixed	Observation, interviews, environmental assessments
2019	R. Bamzar	Assessing the quality of the indoor environment of senior housing for a better mobility: a Swedish case study	Journal of Housing and the Built Environment	Sweden	Mixed	Observation, checklist, questionnaire, interviews
2020	P. Femenias; F. Geromel	Adaptable housing? A quantitative study of contemporary apartment layouts that have been rearranged by end-users	Journal of Housing and the Built Environment	Sweden	Mixed	Questionnaire, interviews, floor plans (furniture layout drawn by participants),

(*continued on next page*)

Table 1 (*continued*)

Year	Authors	Title	Journal	Context	Methodology	Data
2020	S. Agyefi-Mensah; Z. E. Kpamma; D. E. Hagan	Residential adaptations as users' tacit means of communicating spatial needs in housing design	Journal of Engineering, Design and Technology	Ghana	Mixed	Questionnaire, observation, photos, floor plans
2020	W. H. M. S. D. Bandara; R. Rathnayake; P. K. S. Mahanama; N. Wickrama arachchi	An investigation on community spaces in condominiums and their impact on social interactions among apartment dwellers concerning the city of Colombo	Social Sciences & Humanities Open	Sri Lanka	Mixed	Observation, questionnaire
2020	J. Kuoppa; N. Nieminen; S. Ruoppila; M. Laine	Elements of desirability: exploring meaningful dwelling features from resident's perspective	Housing Studies	Finland	Qualitative	Focus group interviews guided by photos (photo-elicitation)
2021	D. Aydin; G. Sayar	Questioning the use of the balcony in apartments during the COVID-19 pandemic process	Archnet-IJAR: International Journal of Architectural Research	Turkey	Quantitative	Questionnaire
2021	D. M. Bettaieb; R. Alsabban	Emerging living styles post-COVID-19: housing flexibility as a fundamental requirement for apartments in Jeddah	Archnet-IJAR: International Journal of Architectural Research	Saudi Arabia	Qualitative	Literature review, interviews
2022	A. Abed; A. Al-Jokhadar	Common space as a tool for social sustainability	Journal of Housing and the Built Environment	Jordan	Mixed	Questionnaire, floor plans, observation, expert interviews
2022	M. Eranil; M. Ö. Gürel	Social Housing as Paradoxical Space: Migrant Women's Spatial Tactics Inside Toki Uzundere Blocks	Home Cultures	Turkey	Qualitative	Interviews, observation, drawings, photos
2022	M. Gür	Post-pandemic lifestyle changes and their interaction with resident behavior in housing and neighborhoods: Bursa, Turkey	Journal of Housing and the Built Environment	Turkey	Mixed	Observation, questionnaire, interviews, photos
2022	M. Khalil; D. Eissa	Balconies during COVID-19 lockdown: exploring the change in patterns of use in Cairo	Open House International	Egypt	Mixed	Questionnaire, interviews, photos
2022	P. Molaei; P. Hashempour; L. M. Tang	Semi-open spaces of apartments considering COVID-19 pandemic: General expectations of balcony design in the post-pandemic world	Architectural Engineering and Design Management	Iran	Quantitative	Questionnaire
2022	P. Valizadeh; A. Iranmanesh	Inside out, exploring residential spaces during COVID-19 lockdown from the perspective of architecture students	European Planning Studies	Cyprus	Quantitative	Questionnaire
2022	S. Özer; A. Jones	Changing socio-spatial definitions of sufficiency	International Journal of Housing Policy	UK	Mixed	Questionnaire, interviews

Table 1 (*continued*)

Year	Authors	Title	Journal	Context	Methodology	Data
		of home: evidence from London (UK) before and during the Covid-19 stay-at-home restrictions				
2022	Z. ElZein; Y. ElSemary	Re-Thinking Post-Pandemic Home Design: How Covid-19 Affected the Perception and Use of Residential Balconies in Egypt	Future Cities and Environment	Egypt	Quantitative	Questionnaire, literature review
2023	A. Abed; B. Obeidat; I. Gharaibeh	The impact of socio-cultural factors on the transformation of house layout: a case of public housing - Zebdeh-Farkouh, in Jordan	Journal of Asian Architecture and Building Engineering	Jordan	Mixed	Questionnaire, interviews, floorplans
2023	A. Kleeman; B. Giles-Corti; L. Gunn; P. Hooper; S. Foster	The impact of the design and quality of communal areas in apartment buildings on residents' neighbouring and loneliness	Cities	Australia	Quantitative	Questionnaire, floor plans
2023	A. Kleeman; S. Foster	'It feels smaller now': The impact of the COVID-19 lockdown on apartment residents and their living environment — A longitudinal study	Journal of Environmental Psychology	Australia	Mixed	Questionnaire
2023	D. Eissa	Socio-spatial appropriations in dwellings of Cairo during lockdown: lessons learned for the post-pandemic era	Open House International	Egypt	Mixed	Interviews, questionnaire, floor plans
2023	E. Bayazit Solak; S. Kisakurek	A study on the importance of home and balcony during the COVID-19 pandemic	Environment, Development and Sustainability	Turkey	Quantitative	Questionnaire
2023	L. Alonso; S. Jacoby	The impact of housing design and quality on wellbeing: lived experiences of the home during COVID-19 in London	Cities & Health	UK	Qualitative	Interviews
2023	S. F. Mousavinia	Effects of housing layout and perceived behavioral control over social distancing in relation between social isolation and psychological distress during pandemic of COVID-19	Journal of Housing and the Built Environment	Iran	Quantitative	Questionnaire

layout of their apartments is the changes to their household composition due to their children moving out. Through the use of a movable partitioning system called KEP, families were able to adjust the sizes and arrangements of different rooms by removing and reinstalling the KEP movable partitioning walls according to their changing lifestyles. However, the insufficient sound insulation of the panels and their degradation over time suggest that such adaptable design features often fail to anticipate practical use in the long term.

In addition to investigating the practices of residential adaptation and the different design features that facilitate them, some scholars have also used residential adaptations to examine the changing spatial needs in housing. As Agyefi-Mensah et al. (2020, p. 1596) argue, residential adaptations constitute "a form of interaction between residents and their dwelling environment [...] that represent[s] tacit expressions of spatial needs." Using two public apartments in Ghana as case studies, they observe that even though the units investigated are mostly adequate in size, many do not meet the sleeping and dwelling requirements of the residents. The various forms of residential adaptations, which include spatial rearrangements and illegal alterations, represent a concrete means to understanding spatial needs in different cultural contexts. In a similar vein, Abed et al. (2023, p. 1196) argue that layout transformations are reflections "of the physical, behavioural, environmental, social, and cultural aspects of the residents' needs" and studying them can shed light "on the relationship between the motivational factors of human needs and the housing unit." In their study of public apartments in Jordan, they argue that socio-cultural factors such as the social role of residents and levels of gender segregation in communities play a particularly important role in layout transformations and how residents perceive their housing needs and satisfaction. Eranil and Gürel (2022), on the other hand, examine culturally specific residential adaptations undertaken by migrant women in social housing units in Turkey. Using de Certeau's spatial tactics to conceptualise the changes in furniture arrangement and spatial use, Eranil and Gürel (2022, p. 42) suggest that the reinterpretation of domestic interior spaces through their daily practices is not only evident of the women's agency in their social and domestic lives, but is also indicative of the need for housing developers and designers to consider "local user profile and socio-cultural structures."

While the reviewed literature on housing adaptation and transformation points to the increasing attention to adaptability in housing design, it also highlights the fact that user behaviour and behavioural changes are not always accommodated for in apartment design. Importantly, it is often the residents who have to bear the responsibility to close the gap between housing design and use through various adaptations, which can not only incur substantial financial costs, but also result in unnecessary material consumption. Despite being discussed in some research, how socio-cultural norms impact residential adaptations remain relatively under-examined in most of the studies reviewed. Furthermore, even though it is evident from the literature that residential adaptations can alleviate some of the mismatch of spatial needs, the different constraints conditioning adaptations as well as their wider implications—behavioural, financial, and environmental impacts—are rarely foregrounded. Questions such as who get to undertake such residential adaptations and at what costs are also not often explicitly discussed. In many ways, the differing adaptability of homes and living spaces as well as the varying health and wellbeing outcomes of residents during the lockdown are indicative of the worsening housing inequalities that should also be taken into account when conducting research on housing design and behaviour.

3.2. Behavioural outcomes of housing design

In addition to residential adaptations and transformations, the interaction between behaviour and housing design also entails the ways in which housing design shapes behaviours. While behavioural outcomes are largely under-studied amongst housing design scholars (Watson et al., 2016), one area of housing design research where it is more prevalent involves studies on supported housing that caters to vulnerable groups such as the elderly and people with special needs. Data on behaviours and uses in senior housing or other residential care facilities is particularly valuable as it often has direct consequences on the safety and wellbeing of the residents. Behavioural research on supported housing thus tend to focus on the ways in which specific objects or design features contribute to different safety issues in relation to behaviours and uses. McDermott et al. (2007), for example, explore the interaction between behaviour and various safety design features in their study of UK homes. Safety design features such as self-closing fire door or window restrictor, they find, are often interfered with by the residents, and can result in various accidents. It is therefore important that the implementation of such safety design features to "consider the user side of this interaction" (McDermott et al., 2007, p. 266) in order to minimise safety risks as a result of unsafe user behaviour. Focusing on senior housing in Sweden, Bamzar (2019, p. 24) similarly sets out in her study to "examine how the physical features of the indoor environment of older adults' houses may influence and be related to their use of space, experience of falls, and safety perception." Bamzar (2019) points out that in addition to housing design and layout, how the interior spaces are furnished and decorated can also have an impact on the behaviour and safety of the residents. How safe an apartment is, according to Bamzar (2019), is thus largely dependent on the mutual interaction between user behaviour and the physical space. As such, policies and regulations pertaining to housing safety can benefit from a greater understanding of the behavioural outcomes of housing design.

A number of scholars are also interested in the ways in which housing design can promote or hinder physical activities and social interactions. As Nordin et al. (2017, p. 727) argue, "the physical environment is essential for supporting older people both physically and cognitively." By examining two residential care facilities in Sweden using a mixed methods approach, they contend that there is a strong correlation between the design of the physical environment and the ways in which the residents act and interact. Accessible and useable design that utilises environmental facilitators such as open plan design, automatic doors, and smooth flooring, according to Nordin et al. (2017), are particularly key to stimulating social activities and interactions among older people. Similarly, Danziger and Chaudhury (2009) set out to evaluate qualitatively

the local Adaptable Design Guidelines by understanding how housing units adapted for senior living are perceived and used by older adults in North Vancouver, Canada. While changes such as increased accessibility and better placements of switches, controls, and panels for wheelchair users have to some extent facilitated independence among the senior residents, other design features such as countertop heights and location of kitchen cabinets are less user-friendly for some residents. As Danziger and Chaudhury (2009) suggest, these findings will not only inform future modifications to the housing units but also contribute to the development of future design guidelines. In addition to senior housing, scholars interested in the link between housing design and behaviours have also studied the use of supported housing for other vulnerable groups. Marcheschi et al. (2016), for example, investigate the affordances of supported housing facilities for people with mental illness. Using an observational approach, they argue that housing design with "greater perceived affordances" tend to have "larger numbers of and greater quality of interactional behaviours" among its users (Marcheschi et al., 2016, p. 18). All in all, it is clear in this review that behaviour and use constitute an important aspect of housing design when safety and wellbeing is a particular concern in homes and facilities for vulnerable groups such as the elderly and other people with special needs. Even though special housing tends to follow very different design standards, the safety guidelines and policies informed by the special housing literature will, to varying degrees, influence future design of different housing types. Moreover, the correlation between spatial design and behaviour found in these studies, as well as the methods and theoretical frameworks used, can also inform behavioural research in all housing contexts. As such, special housing not only represents an important area of housing design research where behavioural outcomes are actively studied, but should also be seen as valuable resources from which housing design scholars can draw upon.

Another area of focus where behavioural outcomes is studied in the housing design literature is the communal spaces of residential complexes and apartment buildings. Although they do not fall within the confines of the private dwellings and homes, semi-public communal spaces such as corridors, lift lobbies, inner courtyards, and playgrounds constitute important areas of apartment developments and have been studied by housing design scholars (Abed and Al Jokhadar, 2022; Bandara et al., 2020; Kleeman et al., 2023). As Huang (2006, p. 194) suggests, they are "essential places that enable residents to establish social interaction and recognition." These semi-public spaces not only serve as circulation or transitional spaces but are also important interactional spaces that play an important role in sustaining the liveability and sociability of apartment complexes. Although the presence of communal spaces alone can provide the necessary opportunities for social interactions among residents, how such spaces are designed, laid out, and maintained can also influence the ways in which residents use and interact. As Kleeman et al. (2023, p. 2) argue, certain spatial arrangements "can promote use and encourage social interaction between neighbours," whereas poorly designed communal spaces often hinder "the development of social connections between residents." The literature suggests that the design of communal spaces in apartment developments can have important implications on not only how the residents behave socially, but also their psychological and mental wellbeing and should therefore not be overlooked in housing design research.

Similar to communal spaces, balconies can also be seen as transitional and in-between spaces that have attracted growing scholarly and popular attention in recent years. As a result of the widespread lockdown and limited access to outdoor spaces, balconies in apartments became important mediatory spaces between the residents' homes and the outside world (Aydin and Sayar, 2021; Bayazit Solak and Kisakurek, 2023; Khalil and Eissa, 2022). In addition to providing residents the opportunity to be physically outside during lockdowns, balconies also became some of the few social spaces where interactions with other people could take place. The COVID-19 pandemic has therefore transformed the pattern of use of balconies in different contexts, both in terms of "frequency of use and in the type of activities practiced" (Khalil and Eissa, 2022, p. 244). In some cities, balconies were used for a wide range of leisure and social activities such as musical performances, religious ceremonies, as well as displays of solidarity and enthusiasm through clapping, flag waving and anthem singing (Aydin and Sayar, 2021; ElZein and ElSemary, 2022). Balconies thus functioned as an essential means for residents "to connect to the city, while keeping physical distances" (ElZein and ElSemary, 2022, p. 12). As Aydin and Sayar (2021) suggest in their study of balcony use in Turkey, the newly discovered usability of the balconies transformed them from residual spaces into places that contribute greatly to the health and well-being of the residents during COVID-19 lockdown. However, how different residents use and perceive their balconies are largely dependent on the spatial design of the balconies including their sizes and other attributes such as lighting, views, and the environments of the immediate surroundings (Khalil and Eissa, 2022; Molaei et al., 2022). In other words, how balconies are designed will have profound implications on not only their use, but also the health and well-being of the residents.

As Valizadeh and Iranmanesh (2022, p. 212) contend, the pandemic-induced changes in behaviour and needs have not only transformed the spatial experience of the residents but also challenged "the accepted conceptions of public, private, abstract, and concrete" spaces in relation to homes and dwellings. Exemplified by the growing emphasis on transitional and outdoor spaces in recent years, it is clear that the behavioural changes driven by the COVID-19 pandemic has a lasting impact on the ways we organise our homes and dwellings. This also points to the increasingly urgent need for architects and housing designers to contribute to a safer and healthier living environment under challenging circumstances by having a better understanding of how housing design can shape residents' behaviour. Furthermore, as living spaces in apartments become smaller in urban areas, transitional and communal spaces constitute an increasingly important part of housing design that can help facilitate the transition to compact and sufficient living. It is therefore crucial for housing design scholars to consider the behavioural outcomes of not only the design of the private living space

inside the apartments but also the different semi-outdoor transitional and communal spaces found in residential complexes and apartment buildings.

4. Discussion

In an attempt to engender further discussions on behaviour and use in housing design research, this review paper analysed empirical studies that in various ways examine the interaction between housing design and behaviours in apartment buildings across the world. Despite not necessarily being the main line of inquiry for architectural and housing design researchers, it is clear that behaviour and use play an important role in a wide range of issues in relation to spatial design, and it is therefore crucial to centre future housing evaluations on the interaction between design and behaviour.

4.1. Challenges of behavioural research

Building on Watson et al.'s (2016) observation that behavioural outcomes of spatial design are a critical gap in housing design research, this paper suggests that the reason behind the limited behavioural focus in the literature is twofold. Firstly, it is difficult to study behaviours and uses in a domestic setting in an in-depth and meaningful manner that goes beyond charting simple behavioural and spatial patterns. Unlike indoor environments, energy consumption, and to a certain extent comfort levels and satisfaction, how people behave and use their homes are generally not quantifiable and measurable and are therefore less conducive to large scale housing surveys or post-occupancy studies. More importantly, behavioural outcomes tend to involve mundane everyday practices that can be challenging to examine without intruding on people's privacy. While studies on offices, healthcare facilities, commercial spaces and other public spaces can often be conducted through observations and other forms of monitoring, housing design researchers rarely have similar opportunities and access to observe behaviours and uses in domestic and private settings due to ethical concerns. In addition to developing an ethically robust methodological approach to housing design research, this paper follows Sharpe's call for a dedicated set of ethical guidelines or code of conduct for collecting behavioural data that "protect the interests of study participants" (Sharpe, 2019, p. 327).

Secondly, behavioural outcomes in the housing context depend on many different factors. Although it is clear that physical space and housing design can in various ways affect the way people live and behave, behavioural outcomes and lifestyle changes tend to be a result of a wide range of factors. It can therefore be difficult to pinpoint the impact of housing design on any behavioural changes without fully grasping the wider contexts. In other words, to understand and establish the correlation between housing design and behaviour, it is important not to simply look at the interaction in isolation but also to take into account different factors. As Abed et al. (2023) contend, economic, social, and cultural factors can all result in lifestyle transformations and behavioural changes, which can in turn have implications for the spatial configurations of the dwellings. As such, future research on housing design and behaviour would require a more nuanced and situated understanding of behavioural outcomes and everyday practices in relation to not only residential architecture and housing design, but also the broader social, economic, and cultural contexts. Doing so demands a set of spatial and behavioural theories that can explain and make sense of the interaction between housing design and behaviours while taking into account different external factors.

4.2. Beyond traditional methodologies and data

Amidst the various challenges facing housing design and architecture researchers in studying use and behaviour in private residential spaces, the literature reviewed in this paper shows that inspirations and lessons can be drawn from a broad range of studies within and beyond the field of architecture and building design, and that there are different methodological and analytical tools that can be utilised when studying behavioural outcomes of housing design. As exemplified in this review of housing design literature, investigating behavioural outcomes and uses of homes often requires a wide range of methods. Eight of the 32 publications analysed in this review can be considered as purely quantitative studies. Quantitative methods such as surveys and modelling can be useful to capture broader behavioural trends and evaluate usability in apartments with a large sample size, as well as to provide statistical data to support previous findings and observations in a deductive manner. However, to fully understand and explore any behavioural changes and uses of apartments, it is important to go beyond quantitative methods or descriptive statistics. As Khalil and Eissa (2022) contend, many factors related to behaviour and housing design such as motives and spatial qualities are often not quantifiable or measurable and would need to be explored and substantiated qualitatively. Qualitative methods including interviews and document reviews constitute the main method for data collection for nine of the reviewed publications. Although these qualitative studies tend to have a smaller sample size, they provide more in-depth analysis on the interaction between space and behaviour. Finally, 15 publications—about half of the publications analysed in this review—adopted a mixed methods approach that combines statistical data with an array of qualitative methods such as interviews, focus groups, observations, as well as reviews of documents.

In addition to using and combining typical data collection methods, a number of studies have also adopted innovative methodologies to explore behavioural outcomes and changes of housing design. Visual data such as photos and technical drawings can be particularly useful to understand behaviour in relation to spatial design. West and Emmitt (2004, p. 278), for instance, superimposed standard furniture dimensions onto floor plans to "identify notional spaces for furniture and convenient use" in their analysis and evaluation of apartment functionality in the UK. Femenias and Geromel (2020), on the other hand, have solicited information on apartment layout changes by collecting plans drawn and annotated by residents, which were then analysed quantitatively using space syntax. Even though floor plans represent useful visual data that can

illustrate spatial use, they tend to only capture two-dimensional use in a specific time or scenario. Therefore, in order to uncover changes of use over time as well as the reasons behind them, they will need to be combined with other qualitative methods such as interviews or qualitative surveys. In addition to visual data, others have also utilised different forms of self-reporting, including journal entries, as well as walk-alongs that combine interviews with observations (Soilemezi et al., 2017). While various form of self-reporting methods can generate valuable behavioural data without compromising privacy and ethical concerns, they tend to require more time and effort from the participants comparing to traditional data collection methods and may therefore need to be better incentivised.

4.3. Bridging research and practice

Besides looking towards different disciplines for methodological lessons, inspirations can also be drawn from what can generally be referred to as grey literature and other non-academic studies, which include reports, policy documents, white papers, etc. Even though the nature of this review paper meant that these studies, including ones that concern use and behaviour, fall outside of the scope of this review, it is important to acknowledge the amount of housing design research that is being conducted outside of academia. This is especially the case in Sweden, where government agencies, developers, and architects have a long tradition of commissioning, funding, and conducting various types of studies on housing and housing design. The Centre for Housing Architecture (CBA) in Sweden, for instance, has undertaken a number of studies on houses and apartments in partnership with different building companies and architects (Granath et al., 2021). Such practice-based or industry-led housing studies, which tend to include resident surveys, as well as analysis of drawings and photos, are often published in the public domain as reports. In many ways, the proliferation of such grey literature is also representative of the fragmented nature of knowledge production in architectural research. Despite not necessarily being published in scientific journals, these studies are often rich in empirical data and material that can be useful for academics. Moreover, the tacit knowledge and experience architectural practitioners have on spatial design are also valuable to housing design research and needs to be better utilised. The drawing, reading, and interpretation of floor plans and other technical drawings, for example, require specific skills that housing scholars from other disciplines might lack. As such, it is important for the development of architectural and housing design research to bridge the gap between industry and academia and improve knowledge synergy.

In addition to closer collaboration between scholars and practitioners, there needs to be better dissemination of studies that are now only available in grey literature. On the one hand, it is important for housing design researchers to look beyond academic publications and incorporate different insights, data, and perspectives from grey literature in future housing design studies. On the other hand, architectural scholars and practitioners should also publish more in academic journals. This will require not only strengthening the methodological and theoretical rigour of practitioners but also fostering a broader cultural shift amongst architecture scholars from focusing on practice and utility to engaging in academic and scientific discussions. Furthermore, academic journals should also encourage more submissions from the industry by simplifying the publication process or dedicating specific sections to practice-based research to facilitate better exchange of knowledge between academia and industry.

4.4. Re-centring concepts and theories

In addition to using appropriate data collection methods for studying behaviours and uses, the adoption of certain theories and concepts can also be beneficial to advancing behaviour and housing design research. Judson and Maller (2014), for instance, draws on sociology by using practice theory to investigate renovations as a form of social practice by the residents. Shifting their focus from individuals to practices, they argue that a practice-based approach enables "a deeper understanding of socio-technical issues associated with renovations" by incorporating the everyday lived experiences of the residents (Judson and Maller, 2014, p. 509). While practice theory places emphasis on materiality and material arrangements, it tends to obscure power, inequality, and other structural constraints that can impact social practices. Mousavinia (2023), alternatively, uses theory of planned behaviour from psychology to explore how perceived behavioural control over social distancing is impacted by housing layout and can exacerbate psychological distress for the residents during the COVID-19 outbreak. Despite being useful for predicting behaviour, the lack of an explicit spatial component makes theory of planned behaviour less effective in linking uses and behaviours to housing design. To address that gap, several scholars have turned to the concept of affordances from environmental psychology to discuss spatial needs and uses in various studies (Eissa, 2023; Kuoppa et al., 2020; Marcheschi et al., 2016; Özer and Jones, 2022). Affordances of a space, generally refers to the activities and behaviours that the space potentially allows for. Crucially, the affordances of a space are not only "dependent on the specific user's perception and behaviour" but are also "influenced by the dwelling's design" (Eissa, 2023, p. 306), making it a useful and holistic lens to examine the interaction between housing design and behaviour. However, it is critical to distinguish between potential and realised use as affordances can sometimes be perceived but unused due to different factors including socio-cultural contexts and power dynamics.

Other scholars seek to centre notions of power as well as socio-cultural contexts in their studies on housing design and behaviour by adopting socio-spatial theories from urban studies. Eranil and Gurel, for example, draw on Michel de Certeau's conception of spatial tactics, which describes the ways in which people subvert dominant discourse and power structures by creating alternative spaces through their daily practice, to "re-read the power balances of gender relations in the domestic space while examining how women can transform intangible aspects of domestic interiors" (Eranil and Gürel, 2022, p. 25). Looking at how migrant women appropriate the intended use and

furniture arrangement of their apartments, Eranil and Gürel emphasise the need for sensitivity for gender and socio-cultural context in housing design. Agyefi-Mensah et al. (2020), on the other hand, posit their study on residential adaptation against Lefebvre's theoretical framework of production of space (Lefebvre, 1991). Space, according to Lefebvre, is not just a container where different activities take place but is itself a social product that is constantly shaped and shaping social practices. By combining Lefebvre's production of space with activity theory, Agyefi-Mensah et al. (2020) examine residential adaptation as a spatial practice that is shaped by its specific socio-cultural context. Despite being conceived to theorise and understand urban processes, the literature suggests that the socio-spatial theories of de Certeau and Lefebvre can be adapted to the housing level and provide important insights into the interaction between housing design and behaviours.

Despite some notable exceptions, the overall emphasis in the literature remains heavily empirical, which limits the ability to move beyond isolated empirical observations to a more general level by interpreting, explaining, and comparing findings across housing studies. As Lawrence suggests (1983), the advancement of behavioural research in housing design and architecture is largely dependent on the development of interdisciplinary methodological and theoretical approaches that not only describe behaviour and use empirically but can also explain the findings and, in turn, help advance different behavioural and socio-spatial theories. In other words, having a set of behavioural and socio-spatial theories that can be used to investigate the interaction between behaviour and housing design is key to the development of not only behavioural research in housing design but also housing evaluations in general. While not without their limitations, the theories highlighted in this review can constitute an important basis for developing a unified theoretical framework for future housing design research. As illustrated in this review, the interdisciplinary nature of housing design research suggests that such an endeavour will require greater collaborations across different disciplines.

5. Conclusion

Although usability and liveability are discussed extensively in housing design and are widely incorporated into guidelines and standards, there is still an apparent discrepancy between how apartments are designed and the ways in which they are actually being used by the residents. Such a mismatch is exemplified by the considerable number of studies on residential adaptation and transformation analysed in this review. Moreover, the extensive post-pandemic housing literature is also indicative of how behaviours and lifestyles are constantly changing and being shaped by different external factors. To avoid unnecessary reorganisation and retrofitting, it is pertinent that future housing design incorporates functional and adaptable solutions that can accommodate changing behaviours with minimal resource-intensive interventions. While transformative events such as the COVID-19 pandemic have understandably driven the debate and rethinking of housing design, this review paper contends that it is important for housing design scholars to look beyond post-pandemic housing by examining the mundane everyday practices of home use and behaviour in different contexts. In addition, the current situation with climate change and political instability can also bring about behavioural changes that housing design needs to accommodate for. As such, understanding the residents' behaviour and use of homes in these challenging times will be key to closing the gap between design intention and actual use in future housing developments. Following Lawrence's call for an integrated and interdisciplinary approach to behavioural research in architectural and housing design research, this paper suggests three key considerations when conducting future housing design research:

First of all, this paper contends that housing design research will benefit from a more holistic conceptualisation of behaviour and spatial design. As evident in the literature reviewed, behaviour is simultaneously both shaping and being shaped by spatial design. On the one hand, housing design and spatial configurations can not only affect how people behave and live, but they can also condition physical activities and encourage social interactions. On the other hand, residents often have to shape their homes according to their changing spatial needs through renovations, adaptations, and appropriations. While socio-spatial dialectics have been studied extensively by urban geographers and sociologists, the co-constitutive nature of the interaction between housing design and behaviour has remained under-developed in the existing architecture and housing design literature. Instead of seeing physical space and behaviour as independent categories, a more nuanced and integrated understanding of their interaction would be particularly beneficial to housing design research as well as the drive for better and more sustainable housing.

Secondly, this paper calls for better utilisation of innovative data collection methods in housing design research. As discussed in the paper, navigating ethical and privacy issues represent one of the main challenges in collecting behavioural data in domestic environments. The methods highlighted in this review can be useful points of departure for a more holistic approach to studying behaviour in housing design research. The solicitation of floor plans with furniture layout drawn by the residents is particularly useful in visualising how different spaces are used without intruding on the participants' privacy to the same degree as on-site visits or photographs. While floor plans can indicate spatial use, they need to be combined with qualitative surveys or interviews to uncover and understand the residents' behaviour in more detail. As such, this paper suggests that a combination of survey, interview, and floor plans would not only overcome privacy and ethical challenges,

but also provide valuable visual and in-depth data that is central to behavioural research in housing design.

Thirdly, this paper argues that it is important for housing design and architecture scholars to contribute to a more holistic scholarship on architecture and behaviour by linking empirical data to theory. In addition to documenting empirical findings and patterns, scholars should also seek to develop and advance theories for housing design research. It is only with a strong theoretical foundation that we can not only understand behaviours and uses of homes, but to also explain why such findings are important, how we can use them, and what they mean in the wider social and urban context. While theories that do not adequately incorporate spatial form, power, or culture risk misrepresenting or oversimplifying the interaction between behaviour and spatial design, a more unified theoretical framework that is sensitive to different socio-cultural contexts, power dynamics, as well as the spatial affordances that shape behaviour and use will be key to advancing housing design research. As such, this paper contends that adapting and building on existing theoretical frameworks such as theory of affordances and production of space in future housing design and architecture research can be a particularly useful departure point.

To conclude, housing design informed by evidence-based behavioural research can not only improve safety, energy efficiency, housing quality, and residential satisfaction, but also contribute to environmental sustainability by meeting housing sufficiency and reducing the need for future demolition and reconstruction of homes. By sketching out what theories and methodologies such an approach to housing design research might entail, the findings of this literature review will help advance a research agenda that is firmly rooted on behaviour and use. While a wide range of housing design studies can greatly benefit from incorporating behavioural research (Fig. 2), one area where such research can be particularly advantageous lies in the growing trend of "living small" in cities around the world (Harris et al., 2023). As extremely small apartments and other novel forms of micro-living become increasingly common, how they shape user behaviours and drive lifestyle changes not only represents a timely and critical research agenda for housing design and architecture scholars, but will also be key to developing better housing standards, policies, and regulations that support new forms of living.

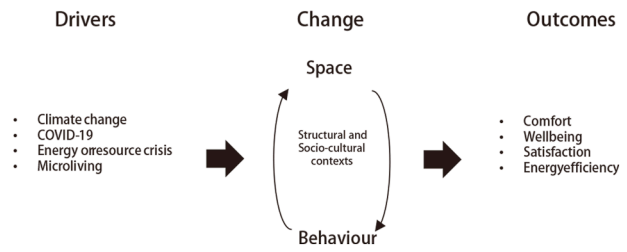

Fig. 2 Conceptual model for future housing design research agenda.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by the Swedish Energy Agency (Grant No. P2022-00907).

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