buildings

MDPI

Article

Stability in Motion: Adaptive Strategies, Levels and Conditions of Domestic Acceptability in Compact Homes

Thomas Goessler *, Yamuna Kaluarachchi and Angela Connelly

Manchester Technology Centre, Manchester School of Architecture, Manchester Metropolitan University, Oxford Road, Manchester M1 7ED, UK; y.kaluarachchi@mmu.ac.uk (Y.K.); angela.connelly@mmu.ac.uk (A.C.)
* Correspondence: thomas.goessler@stu.mmu.ac.uk

Abstract

Urban housing pressure requires compact dwellings to support multiple domestic activities within limited floor area. Adaptive interiors can redistribute functions across time, but their value depends on whether recurrent spatial change remains understandable, controllable and workable in everyday life. This study compares adaptive residential strategies and conditions under which their spatial and functional benefits remain domestically acceptable. A sequential mixed-methods design combined a UK-based survey (N = 460), five focus groups (N = 36) and immersive virtual-reality (VR) testing (N = 35) of 15 prototypes at 15, 25 and 37 m^2. Outcomes included perceived spatial quality, perceived functionality, combined adequacy across six domestic functions and a composite ranking. Across all three study phases, bounded deterministic automated adaptation showed the most consistent balance between spatial and functional performance and domestic acceptability. In VR, Category 3 performed most favourably relative to the fixed baseline at 15 and 25 m^2, while at 37 m^2, this advantage narrowed or reversed across headline outcomes. Manual reconfiguration was constrained by repeated resident effort, while more open-ended systems attracted weaker support where behaviour was harder to anticipate. Adaptive value depends on matching the level and form of change to spatial need while preserving intelligibility, resident control and domestic stability.

Keywords: adaptive residential space; compact housing; bounded deterministic automated adaptation; domestic acceptability; human–building interaction; adaptive housing; time-dependent functional capacity; virtual reality

1. Introduction

1.1. Compactness as a Temporal Problem

In high-cost cities, housing pressure is felt not only through price, supply and floor area but also through the difficulty of accommodating many domestic activities within one limited footprint. Sleeping, paid work, dining, storage, exercise, retreat and social interaction may depend on the same layout and furniture. UK housing research has repeatedly linked dissatisfaction to insufficient usable space, storage and functional fit [1]. Recent research has also documented the growth and regulation of small homes in London and more widely in England [2,3]. The problem is not simply limited room size. The same area must support competing domestic activities at different times.

Compactness is treated here as a spatial, temporal and psychological condition, shaped not only by limited area but also by how competing activities are sequenced and experienced. A table may alternate between dining and work; a sleeping area may also need

Check for updates

Academic Editor: Haifeng Liao

Received: 26 August 2026
Revised: 11 October 2026
Accepted: 20 October 2026
Published: 23 October 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

to support social life; possessions may occupy circulation when dedicated storage is insufficient. Perceived lack of space cannot be explained by available floor area alone; it also depends on whether the dwelling can accommodate and separate everyday activities, furniture and storage [4]. These tensions suggest that compactness is not only a question of how much space is available but also of how spatial arrangements can respond to changing activities over time. Insights from adaptive architecture help frame this relationship. Jaskiewicz [5] describes adaptive architecture as an evolving relation between changing activities and spatial systems. Applied to housing, this shifts the question of capacity. The issue becomes not how many functions can be accommodated simultaneously, but how the same footprint can support coherent uses at different times [6].

This mechanism is termed time-based spatial allocation. Furniture and spatial-division elements move, fold, retract or reposition so that one footprint can provide several task-ready states at different moments [6]. The home does not acquire additional geometric area. It makes a greater proportion of its existing area available to the activity at hand. Clear circulation, open-floor moments and temporary separation can therefore become time-dependent properties of the plan. Earlier work on flexible and adaptable housing established the importance of reserve capacity, loose fit and user change [7–9]. It also showed that available flexibility may remain unused when reconfiguration is cumbersome or poorly integrated.

Spatial capacity also depends on how change is produced. An adaptive dwelling becomes more capable only if the required transitions are performed and if the resulting states remain useful. Manual systems transfer the work of transformation to the residents. Automated systems can reduce resident effort, but the burden does not disappear. It shifts to powered mechanisms, control interfaces, maintenance and reliable operation. If these systems fail, become difficult to control or cannot be readily understood, functions that depend on them may become temporarily unavailable or harder to access. The central question is therefore not simply whether adaptation can add capacity, but which level and form of adaptiveness can provide that capacity without imposing disproportionate resident effort, technical reliance, uncertainty or loss of control.

1.2. From Flexible Housing to Near-Term Adaptive Interiors

Adaptive housing has a long architectural lineage, ranging from flexible housing approaches to Archigram's plug-in visions of reconfigurable domestic environments [10]. Friedman's Flatwriter (1970–1971) [11] is particularly relevant to the present study because it treated domestic arrangements as user-selected configurations linked to patterns of occupation over time. It anticipated the idea that one dwelling can support different functional states at different moments [11,12]. In parallel, Pask (1969) [13] framed architecture as an interactive system capable of responding to its users. Together, these precedents shifted attention from the finished form towards frameworks, rules and systems that could accommodate change [13,14].

More recent research has developed these ideas along partly separate paths. Flexible-housing studies examine lifecycle change and resident modification [8,9]; smart-home research focuses on sensing, connectivity and environmental control [15,16]; and architectural robotics investigates movable partitions, modular systems and reconfigurable furniture [17]. A coherent comparison therefore needs to distinguish where change occurs, who or what produces it, and how legible and predictable the resulting spatial states remain.

Recent prototypes and commercial systems have moved bounded automated furniture from speculation towards near-term application. CityHome at the MIT Media Lab demonstrated how mechanically actuated furniture could stage sleeping, working, dining, storage and circulation through a compact repertoire of known transitions [18]. Ori Living [19] translated the same lineage into productised Cloud Bed, Pocket Closet and moving-wall

systems, while Bumblebee Spaces [20] developed ceiling-based storage and furniture mechanisms for compact apartments. Radha [6] and Radha, Tayib and Mohammed [21] similarly examined how large-element automation can alter functional flexibility and space occupancy. These examples do not establish long-term domestic performance, but they show that bounded automated furniture is no longer only a speculative proposition.

The adaptive residential strategy framework set out in Section 2.2 therefore spans different degrees of technological maturity, from established forms of flexibility to more speculative adaptive systems. Following Dunne and Raby [22], these are treated as a continuum from extrapolation of demonstrated products and mechanisms to propositions that remain primarily speculative.

1.3. Acceptance as a Design Constraint

Adaptation affects more than spatial efficiency. Recurrent change can alter spatial quality, everyday routines, movement and residents' sense of control. These effects matter in the home, which also supports privacy, refuge, identity and continuity [23–26]. In compact dwellings, recurrent spatial change can place these qualities under particular pressure because the same limited area must accommodate multiple activities and states. Technical feasibility alone is not sufficient. For adaptive change to become part of everyday domestic life, it must remain acceptable, legible and predictable, while residents retain meaningful control over its initiation, interruption and outcome [5,27,28]. Recent co-design research with full-scale reconfigurable domestic environments similarly shows that the lived value of reconfigurability is shaped by tensions between empowerment and restriction, utility and experience, and futuristic ambition and practical viability [29].

Human–building interaction is especially relevant because adaptive interiors alter the spatial environment itself, not only the technologies operating within it [27,30]. As furniture and spatial divisions move, residents must understand what is changing and anticipate the resulting condition. Dragan, Lee and Srinivasa [31] distinguish between legible motion, from which an intended goal can be inferred, and predictable motion, which conforms to expectations once that goal is known. Studies of responsive architectural partitions similarly show that timing, feedback, shared control and override influence how autonomous spatial behaviour is experienced [28]. Nguyen et al. [32] further conceptualise acceptance as situated, proposing the Architectural Robot Acceptance Model (ARAM), in which responses to a specific adaptation depend on recognised personal need, perceived adaptation capability and social justification.

This focus places adaptive residential space within BioCognitive Architectural Design, which examines how architectural environments shape cognitive and behavioural outcomes and respond to human needs. Here, the relevant condition is not only the quality of individual spatial states but also how residents experience the transitions between them. This paper therefore uses domestic acceptability to describe whether recurrent spatial change remains understandable, manageable and compatible with everyday home life. An adaptive strategy may increase time-dependent functional capacity yet lose value. This occurs when the gain requires excessive resident effort, unclear or unpredictable transitions, or reliance on mechanisms and controls that residents cannot readily manage. Conversely, a stable dwelling may remain easy to understand and inhabit while providing insufficient functional capacity under severe spatial constraint. The central question is therefore the right level of adaptiveness: the level and form of adaptation at which additional spatial and functional capacity remain proportionate to the practical and psychological burdens of change.

1.4. Aim, Research Question and Contributions

The study compares adaptive residential strategies in relation to spatial and functional performance and identifies the psychological, operational, dwelling-size and user-related conditions under which their benefits remain domestically acceptable. It asks the following:

How do adaptive residential strategies compare in perceived spatial quality, perceived functionality and combined adequacy across six domestic functions, and under what psychological, operational, dwelling-size and user-related conditions do their benefits hold or diminish in compact urban homes?

The paper makes three contributions. First, it provides a comparative evaluation of adaptive residential strategies using survey and focus-group evidence alongside immersive testing of 15 prototypes across three dwelling sizes. Second, it distinguishes measured spatial and functional performance from time-dependent functional capacity and domestic acceptability, allowing adaptiveness to be understood as a conditional balance rather than a linear progression. Third, it synthesises an acceptability framework showing how effort, legibility, predictability, control, privacy, continuity, reliability and user context qualify adaptive benefit. The central argument is that adaptive value depends on matching the level and form of change to spatial need while preserving resident control and domestic stability.

2. Terminology and Theoretical Framework

2.1. Working Definitions

Here, adaptive residential space refers to an architectural concept describing a dwelling's capacity to respond to changing use through changes in spatial arrangement, functional configuration or spatial experience [5,33]. Adaptation describes this architectural capacity, whereas automation is one possible means through which spatial or functional change can be achieved. Adaptive capacity may therefore be realised manually or automatically; automation alone does not constitute spatial adaptation. Sensing, prediction and artificial intelligence are treated as possible layers of interaction and control rather than as defining characteristics of an adaptive strategy. Human–building interaction provides the broader analytical context for examining how occupants experience, interpret and control responsive spatial systems [27].

The study also distinguishes the measured outcomes from the broader architectural concepts they inform. Perceived spatial quality, perceived functionality and the combined adequacy index together describe spatial and functional performance. Time-dependent functional capacity refers to the dwelling's ability to support required domestic activities through the allocation and reallocation of space over time. It is evidenced most directly by perceived functionality and combined adequacy, while perceived spatial quality captures the experiential quality of the resulting spatial states. Domestic acceptability concerns whether these gains remain understandable, manageable and compatible with everyday domestic life. Together, these distinctions provide the analytical structure for the comparative evaluation that follows and are summarised in Table 1.

Table 1. Working terminology and analytical hierarchy used in the paper.

Term	Working Definition and Use in This Paper
Adaptive residential space	A dwelling that can reconfigure spatial arrangement, function or experience in response to use (adapted from Jaskiewicz [5]).
Perceived spatial quality	Overall experiential judgement of the space, including spaciousness and openness (author-defined; based on Tural and Tural [34]).

Table 1. *Cont.*

Term	Working Definition and Use in This Paper
Perceived functionality	Participants' judgement of how well the dwelling performs overall (author-defined).
Combined adequacy index	Composite measure of adequacy across living, sleeping, working, dining, open space and storage (author-defined).
Time-dependent functional capacity	The ability of a dwelling to support everyday activities when required (author-defined).
Time-based spatial allocation	Reallocation of a fixed footprint across activities over time (author-defined; based on Jaskiewicz [5]).
Acceptability framework	The conditions under which adaptive domestic systems remain understandable, manageable and compatible with everyday home life (author-defined; informed by human–building interaction and trust-in-automation literature [27,35,36]).
Task-ready state	A spatial state prepared for a particular activity (author-defined).
Right level of adaptiveness	The level and form of adaptation at which gains in spatial and functional capacity remain proportionate to the practical and psychological burdens experienced by residents within a given dwelling (author-defined).

2.2. Adaptive Residential Strategy Framework

The framework distinguishes a fixed static baseline comparator, five adaptive strategy categories and virtual extension as an adjacent perceptual layer, drawing on earlier conceptual work [33]. The categories do not represent a linear progression towards greater technological sophistication. Instead, they distinguish how adaptive capacity is provided, how effort and reliance on technical systems are distributed, how much control residents retain, and how broad the range of possible spatial states becomes (Figure 1).

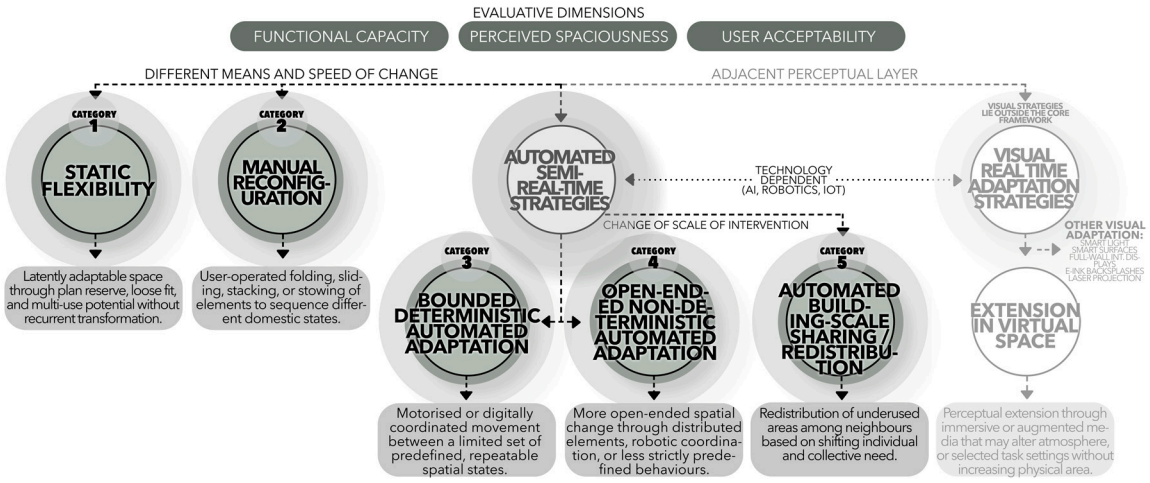

Figure 1. The adaptive residential strategy framework, showing the fixed static baseline comparator, five adaptive strategy categories, virtual extension and the principal evaluative dimensions.

The framework also spans different degrees of technological maturity. Static flexibility and manual reconfiguration are grounded in established practice, while bounded deterministic automated adaptation extrapolates from existing products and research prototypes

towards more integrated dwelling-scale applications. Open-ended non-deterministic automated adaptation extends towards experimental and more speculative forms of distributed spatial behaviour. Automated building-scale sharing or redistribution combines established forms of shared provision with less widely realised systems of automated access and allocation, while virtual extension applies existing extended-reality technologies to an emerging domestic role. Following Dunne and Raby [22], this distinction between established, extrapolative and speculative propositions is used to clarify their evidential status and to examine possible consequences rather than predict adoption. Technological novelty is therefore treated neither as a measure of architectural value nor as an assumed direction of progression.

2.3. Strategy Types and Representative Spatial Logics

2.3.1. Fixed Static Baseline Comparator

The empirical non-adaptive comparator is the fixed static baseline: a conventional compact flat whose layout remains materially stable in everyday use. Kitchen, bathroom, services and principal storage are fixed, while the remaining living area is usually organised around a dominant furniture arrangement and pattern of occupation. Loose furniture may be moved, but the dwelling includes no built-in mechanism for recurrent spatial reconfiguration. For residents, this material stability can make the layout straightforward to understand and anticipate, but competing functions must still be accommodated within the same fixed spatial arrangement. In the VR study, the fixed static baseline therefore serves as a comparator rather than as a strategy category in its own right (Figure 2).

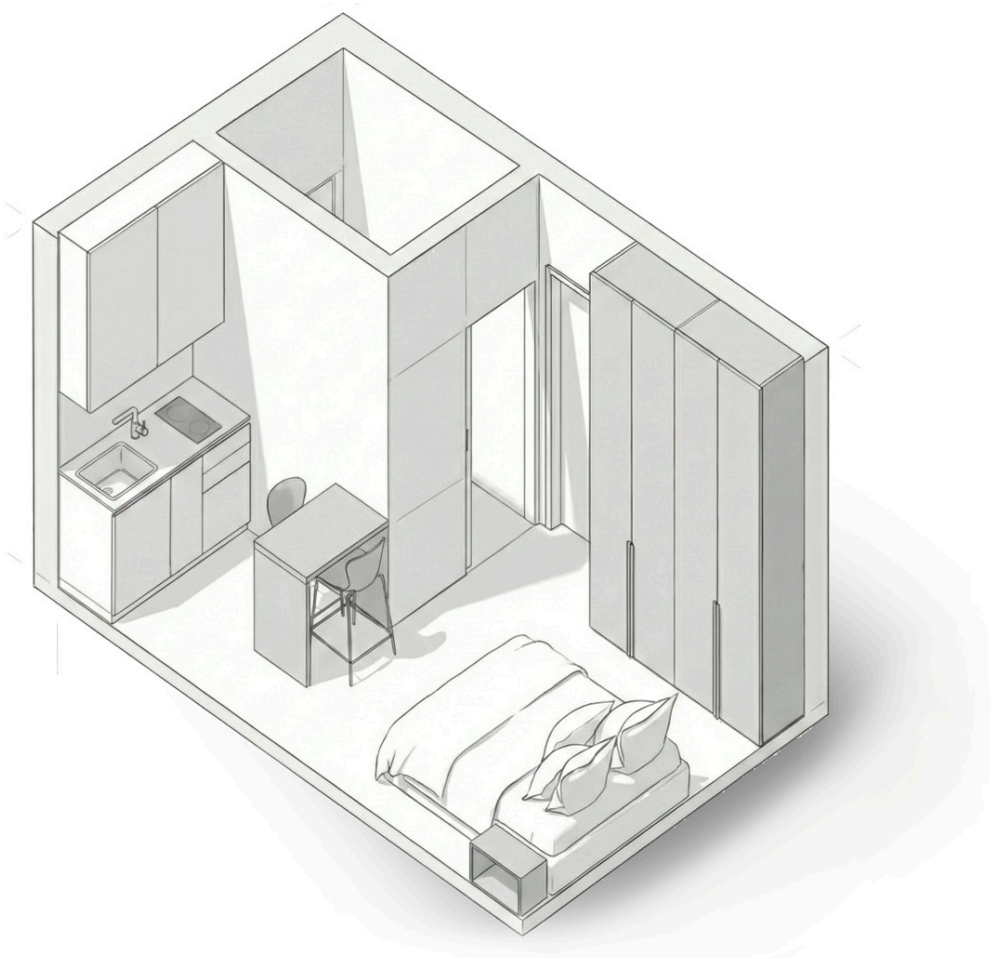

Figure 2. Fixed static baseline as the comparator condition.

2.3.2. Category 1: Static Flexibility

Category 1 concerns static flexibility: the capacity of a dwelling to accommodate multiple uses without recurrent transformation of major elements. Adaptability is achieved through planning logic rather than movement: service concentration, clear circulation, built-in reserve and enough spatial tolerance for rooms to support more than one use without changing physical state. Compared with the fixed static baseline, Category 1 introduces greater latent capacity, but the dwelling remains materially stable and does not turn change into a daily task.

2.3.3. Category 2: Manual Reconfiguration

Category 2 uses recurrent, user-operated reconfiguration. Elements fold, slide, stack, stow, wheel, conceal or unfold so that one footprint can support more than one domestic state. Compared with Category 1, this strategy offers greater day-to-day adaptability because sleeping, working, dining, storage access and circulation can be sequenced more actively across the day. Its advantage is the potential to release usable floor area at relatively low technological complexity. Its limitation is effort: the dwelling becomes more capable only when the resident repeatedly performs the change (Figure 3).

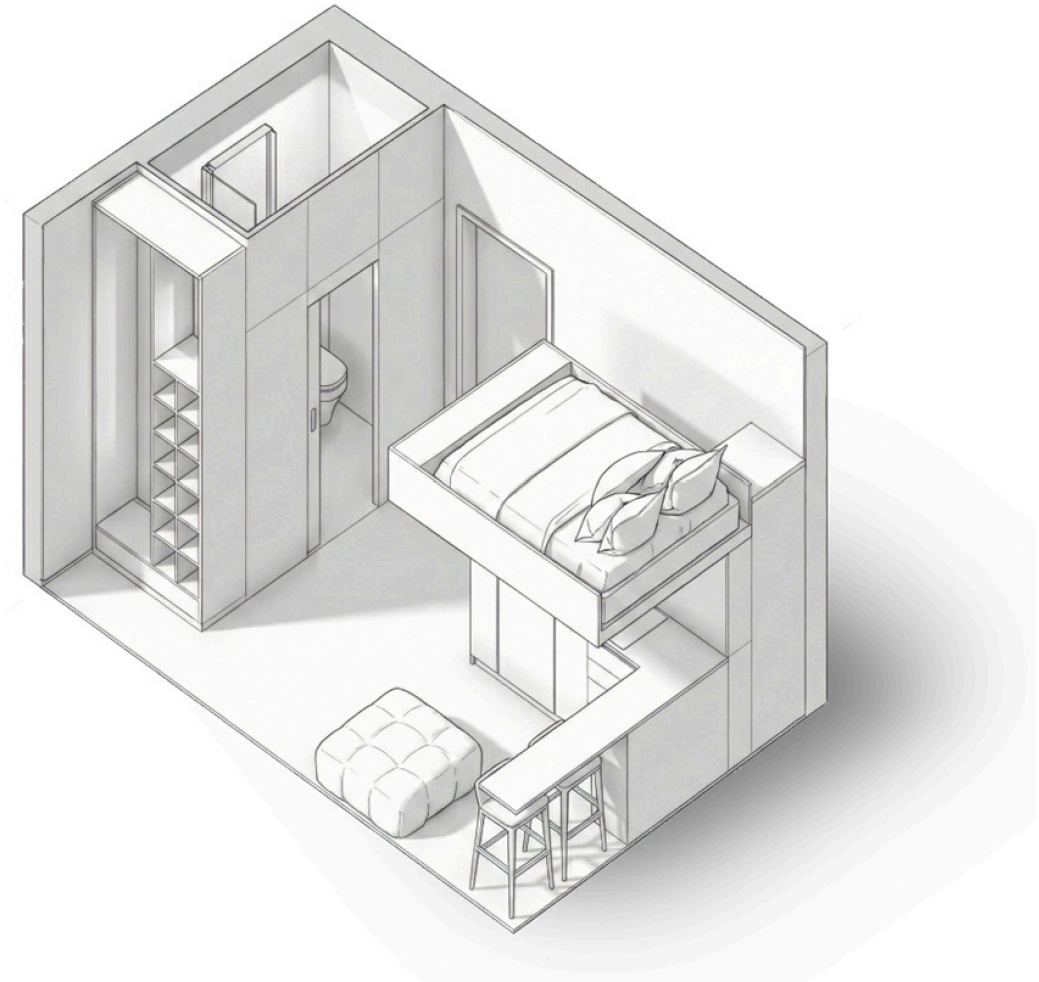

Figure 3. Category 2 manual reconfiguration.

2.3.4. Category 3: Bounded Deterministic Automated Adaptation

Bounded deterministic automated adaptation uses automated furniture and spatial-division elements to shift a dwelling between a limited set of predefined, repeatable and task-ready spatial states. The defining feature is boundedness: the dwelling does not generate open-ended configurations but offers a limited repertoire of legible transitions that residents can anticipate, interrupt and understand. Its main gain is reduced reconfiguration labour; its main trade-off is dependence on installation quality, maintenance, safety logic and intelligible control (Figure 4).

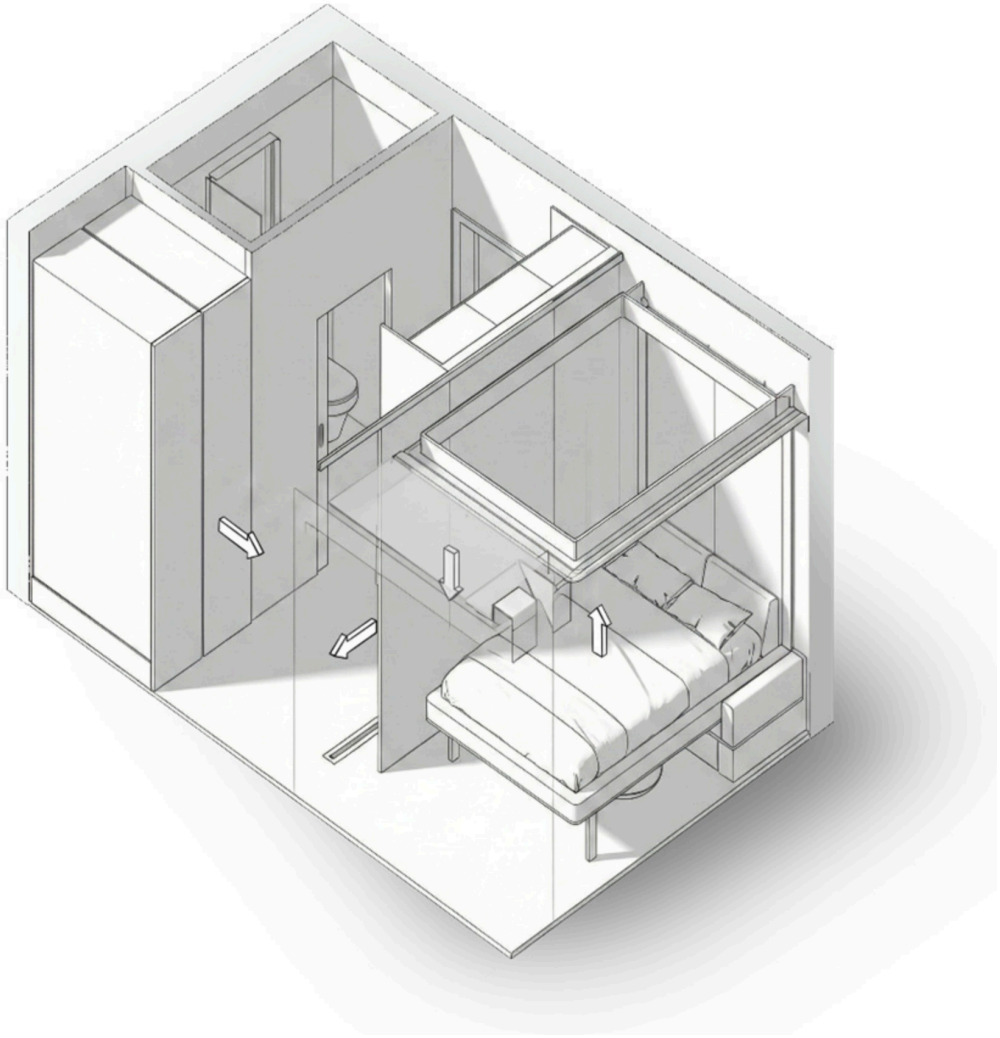

Figure 4. Category 3 bounded deterministic automated adaptation(arrows indicating movement.)

CityHome, Ori Living and related bounded systems share this operational logic: sleeping, working, dining, storage and open-floor use are staged through known transitions rather than accommodated simultaneously in a fixed arrangement [18,19]. Radha [6] similarly identifies large-element automation as a means of increasing functional flexibility. Boundedness may reduce uncertainty, but it is only one condition of performance. Base-plan quality, circulation, storage integration, the usefulness of each state, transition speed and reliable control remain equally important.

2.3.5. Category 4: Open-Ended Non-Deterministic Automated Adaptation

Category 4 concerns open-ended non-deterministic automated adaptation: spatial change moves beyond a small set of known states and is distributed across many smaller elements, agents, materials or computational behaviours. In principle, it offers greater degrees of freedom than Category 3 because spatial states can be composed dynamically rather than selected from a fixed menu of layouts. Existing examples remain largely experimental research systems [17,37,38]. Their wider range of possible states may make future spatial outcomes harder for residents to anticipate than in a bounded system with predefined transitions [31,36]. This proposition is examined empirically in Section 4.5, where focus-group participants associated more open-ended behaviour with greater uncertainty, reduced predictability and concerns about domestic stability. The key evaluative question is therefore whether systems with greater configurational freedom can remain legible, safe and acceptable in domestic use. Roombots and RoomShift show how modular or swarm-like robotic systems can assemble, relocate or simulate furniture at room scale [17,37,38]. As research precedents, they demonstrate a wider range of possible spatial states than bounded systems with predefined transitions. The same openness also changes the interaction problem. As the number of possible elements, movements and spatial states increases, residents may have more system behaviour to interpret and fewer predefined transitions on which to base expectations (Figure 5).

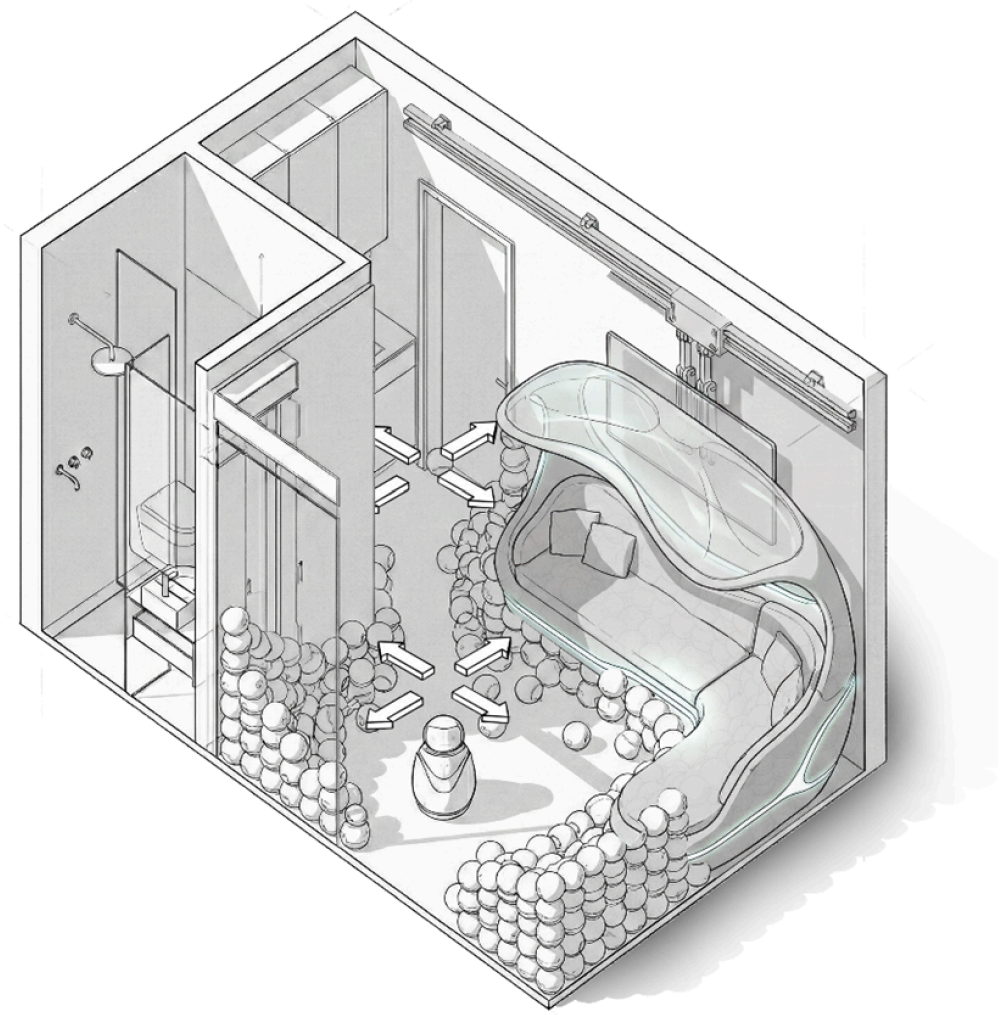

Figure 5. Category 4 open-ended non-deterministic automated adaptation(arrows indicating movement.)

2.3.6. Category 5: Automated Building-Scale Sharing or Redistribution

Category 5 shifts adaptability from the apartment to the building scale through automated sharing or redistribution. Instead of requiring one unit to contain every function, selected domestic functions are provided through shared rooms and amenities accessed through managed allocation. Guest rooms, work rooms, workshops, laundries, gyms, storage areas and overflow social spaces may therefore form part of the dwelling's effective domestic capacity without being permanently housed inside it. The advantage is spatial reach; the trade-off is dependence on entitlement, scheduling, governance and the actions of others. For that reason, this category functions as a limit case rather than as a straightforward substitute for private domestic space (Figure 6).

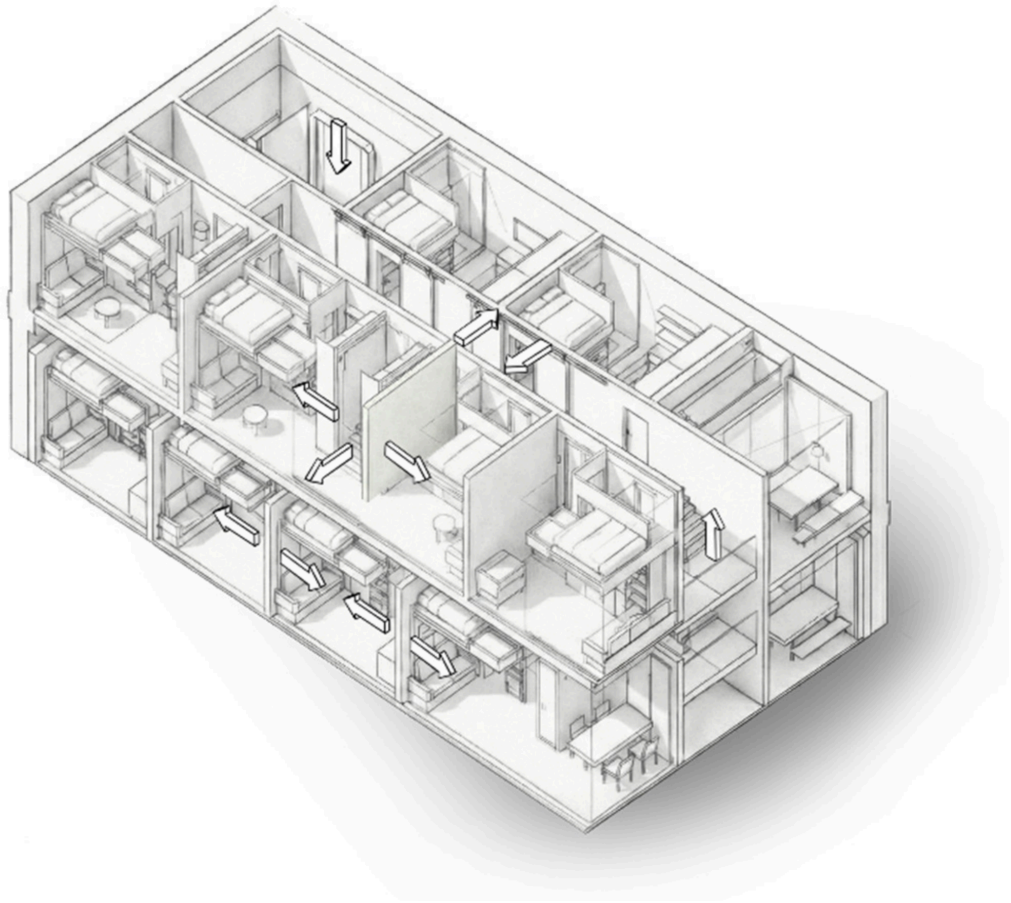

Figure 6. Category 5 automated building-scale sharing or redistribution(arrows indicating movement.)

2.3.7. Virtual Extension

Virtual extension sits outside the taxonomy of physical reconfiguration because it changes spatial experience without reallocating physical area. Immersive or augmented environments may modify outlook and atmosphere, support mediated social presence or provide selected task settings. Mixed-reality, immersive and telepresence studies suggest that digital layers can modify spatial perception and mediated presence [34,39,40]. They do not, however, provide equivalent material capacity for sleeping, storage, dining, circulation, acoustic separation or privacy. Virtual extension is therefore treated as a perceptual and episodic layer rather than a physical redistribution of domestic functions (Figure 7).

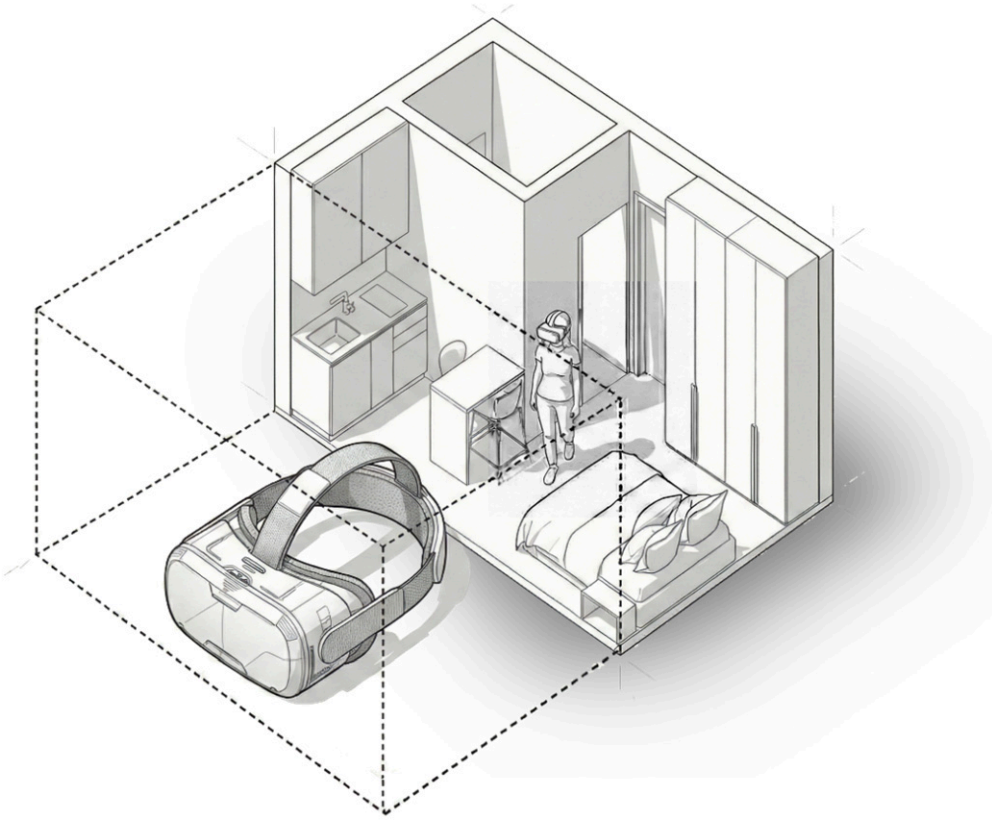

Figure 7. Virtual extension as an adjacent perceptual layer.

2.4. Spatial and Functional Performance, Domestic Acceptability and the Right Level of Adaptiveness

Spatial and functional performance is assessed through perceived spatial quality, perceived functionality and the combined adequacy index. The measures are related but distinct. Perceived functionality and combined adequacy provide the most direct evidence of time-dependent functional capacity, while perceived spatial quality captures the experiential quality of the resulting spatial states.

Domestic acceptability concerns whether those spatial and functional gains remain workable in everyday life. It is shaped by effort, legibility, predictability, control, privacy, safety, reliability and domestic stability. These conditions qualify performance: functional gains have limited value if the adaptation required to achieve them is difficult to live with.

Performance and acceptability are therefore treated as analytically distinct but interdependent: a strategy may perform well spatially while remaining less acceptable if its operation introduces disproportionate effort, uncertainty or loss of control.

The right level of adaptiveness is conceptualised as the point at which gains in capacity remain proportionate to the practical and psychological burdens experienced by residents. The balance varies with dwelling size, user needs, household composition and architectural resolution.

Conversely, where existing spatial capacity already accommodates everyday activities adequately, additional adaptation may provide limited benefit relative to the effort and technical reliance it introduces.

3. Materials and Methods

3.1. Sequential Mixed-Methods Design and Paper Scope

The empirical programme followed a sequential mixed-methods design, progressing from broad attitudinal mapping to qualitative explanation and embodied spatial compari-

son [41,42]. Architectural research methods informed the integration of precedent analysis, user evidence and design evaluation [43]. Shared constructs linked the three empirical phases, allowing each to extend and qualify the others; the overall study sequence is summarised in Figure 8.

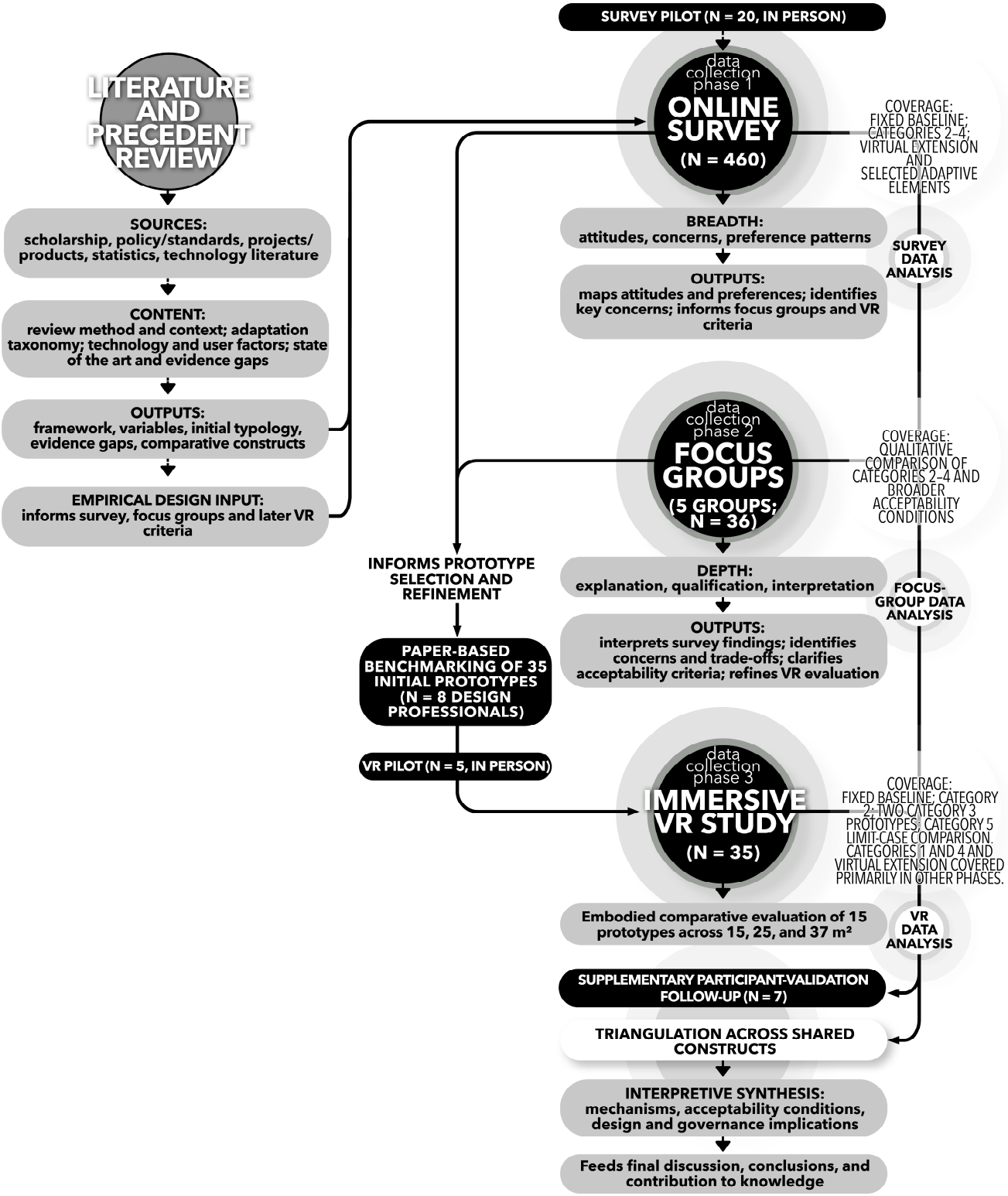

Figure 8. Research design framework showing the progression from literature and precedent review to survey, focus groups, immersive virtual-reality evaluation and mixed-methods synthesis.

The analysis presented here focuses on comparative strategy and prototype performance together with the psychological, operational and user-related conditions of domestic acceptability.

Operationalisation followed methodological fit rather than imposing equivalent tests across all strategies. Category 1, Category 4 and virtual extension were evaluated through other phases of the mixed-methods programme rather than through equivalent VR prototypes. The immersive experiment therefore supports prototype-level comparison among the fixed baseline, Category 2, two Category 3 implementations and Category 5 within each dwelling-size strand. Strategy-level interpretation draws on triangulation where evidence is available across methods. The source of individual findings is identified in the text, tables and figures, and VR-specific results are reported as such. No single prototype is therefore treated as representative of an entire strategy category. Broader category-level interpretations are developed, where supported, by triangulating prototype findings with survey and focus-group evidence and are examined in the Discussion. Category 1 does not depend on recurrent physical transformation, virtual extension does not redistribute physical space, and imposing a fixed VR state repertoire on Category 4 would have reduced the open-ended behaviour that defines it. This approach retained the full comparative framework without reducing perceptual or open-ended strategies to artificial experimental equivalents. Category 5 is treated as a limit-case comparison because it extends adaptive capacity beyond the apartment boundary. For example, adaptive capacity could extend to shared or redistributed space between adjacent dwellings, while its apartment-level consequences remained spatially testable in VR.

3.2. Prototype Development and Selection

The VR prototype set was developed through design speculation, precedent analysis and architectural benchmarking. An initial pool of 35 concepts translated the strategy framework and preceding survey and focus-group findings into candidate spatial configurations. Eight design professionals then evaluated, scored and annotated the plans and axonometric views. They identified layout and visual shortcomings and assessed spatial utilisation, experiential quality and practical plausibility. These professional assessments were considered alongside model-derived spatial-efficiency measures and survey-derived ratings of individual adaptive elements to inform prototype development and shortlisting. These evidence streams informed a structured shortlisting process, with the resulting scores used as decision support rather than as a mechanically binding selection rule; final inclusion also reflected architectural judgement, strategy coverage, cross-size comparability and implementation feasibility. This process produced the final 15 prototypes for immersive testing. Five prototypes were evaluated within each of the 15, 25 and 37 m^2 dwelling-size strands: a fixed static baseline, one Category 2 prototype (manual reconfiguration), two Category 3 prototypes (bounded deterministic automated adaptation) and one Category 5 prototype (automated building-scale sharing or redistribution). Within each dwelling-size strand, the floorplan outline and window ratio were held constant across prototypes, so comparison focused on differences in internal organisation, reconfiguration logic and functional provision rather than changes in envelope geometry or glazing. The paired Category 3 prototypes represented alternative architectural implementations of the same operational strategy, allowing within-strategy variation to be examined rather than treating a single design as representative of the category. The resulting 15-prototype set and associated questionnaire were subsequently checked in the five-participant VR pilot before formal data collection.

3.3. Online Survey

Before the main survey was launched, an in-person pilot with 20 participants tested questionnaire clarity, length, sequencing and the accompanying visual material. Pilot feedback informed instrument refinement, and pilot responses were not included in the main dataset. The main survey was distributed between November and December 2023 through professional, institutional and student networks using purposive, non-probability recruitment [43,44]. Recruitment was UK-based, with outreach concentrated in Greater London and Manchester while allowing wider UK participation. These locations provided a shared national housing and planning context while drawing respondents from both the capital and a major regional urban centre, where questions of compact urban living and spatial pressure are particularly relevant. Of 464 completed responses, four were excluded because of incomplete or inconsistent responses, yielding a final analytical sample of $N = 460$. The sample therefore supports structured within-sample comparison rather than population-level estimation.

Only a subset of survey evidence relevant to this paper is reported here: overall strategy ratings and selected measures concerning recurrent effort, automated adaptation, movement, permanence, control and psychological response. The survey evaluated the adaptive strategies as overarching concepts as well as individual elements within each strategy. Both were presented through 2D visual material and rated on five-point scales. The remaining reported survey items used question-specific five-point scales; lower values generally indicated stronger endorsement or a more favourable evaluation. The measures were study-specific design-evaluation items derived from the theoretical framework and precedent review. The 20-participant pilot refined their wording, comprehension and sequencing; the items were not treated as a single validated psychometric scale. For the online survey, the principal overarching strategy-rating item asked, "How do you rate the following overarching strategies to increase space efficiency and living quality in your residential space?", using a scale from 1 = Very good to 5 = Very poor.

Selected items were summarised descriptively using counts, percentages, distributions and, where appropriate, means and standard deviations. Because the survey measures were predominantly ordinal, exploratory within-sample comparisons reported in this paper used Kruskal–Wallis H tests for three or more groups, while Spearman's rank correlation (ρ) was used for ordinal associations. Effect sizes are reported as ε^2 for Kruskal–Wallis tests, with 95% confidence intervals for correlations where available. Related follow-up comparisons were adjusted for multiple testing using the Holm method [45]. Inferential results are interpreted alongside effect size, uncertainty and substantive architectural relevance rather than as binary evidence of effect [46,47]. Given the non-probability design, these analyses are treated as within-sample evidence rather than population estimates [48].

3.4. Focus Groups

Five focus groups were conducted in London and Manchester between March and June 2024 ($N = 36$), comprising two student groups, two expert/professional groups and one mixed non-professional group. Purposive sampling was used to capture contrasting perspectives relevant to compact living and adaptive domestic space rather than to achieve demographic representation [49]. Sessions lasted approximately 90 min and were moderated by the doctoral researcher using a common semi-structured discussion guide and visual prompts. Participants compared manual reconfiguration, bounded deterministic automated adaptation and more open-ended automated adaptation, alongside questions of control, predictability, privacy, safety, reliability, affordability and domestic fit.

Audio recordings were transcribed, checked against the recordings and analysed in NVivo 20.8.0.3 using directed qualitative content analysis with inductive refinement [50–53].

Initial codes were derived from the research questions, discussion guide and analytical framework, then refined iteratively as additional concerns emerged. Transcripts were segmented into meaning-bearing excerpts and compared within and across groups to identify recurrent patterns and boundary conditions. Reported theme counts refer to coded excerpts rather than participants and indicate analytical salience, not prevalence or representativeness [54,55]. Quotations were selected where they clarified the mechanism underlying a quantitative or recurrent qualitative pattern rather than implying prevalence. Verbatim quotations are identified by focus group and anonymised participant code (e.g., FG1-P5 denotes Focus Group 1, Participant 5). The doctoral researcher coded all transcripts. Credibility was supported through repeated checks against the recordings and iterative refinement of the codebook rather than formal inter-coder agreement.

3.5. Immersive VR Experiment

The immersive VR experiment used purposive sampling to combine specialist and non-specialist perspectives on domestic space. The final sample comprised 35 UK-based participants: 15 practising architects, 10 built-environment students and 10 participants without educational or professional experience in architecture, design, engineering or construction. Nine participants were aged 18–25, 22 were aged 26–35 and four were older than 35. Each participant experienced all 15 prototypes in a repeated-measures design, controlling for between-participant variability and supporting within-participant comparison [56,57].

Data collection took place between July and October 2025 in controlled settings at Manchester Metropolitan University and an architectural practice in London. Participants received study and consent information in advance and a standardised briefing on headset use, safe movement and the evaluation procedure. Individuals who reported a history of motion sickness or high susceptibility to cybersickness were excluded [58,59]. A Meta Quest 2 head-mounted display in standalone mode enabled untethered first-person exploration.

Sessions lasted approximately 90 min and comprised familiarisation, prototype exposure and post-exposure evaluation. All participants progressed through the dwelling-size strands in the same order: 15, 25 and 37 m^2. Within each dwelling-size strand, prototypes were presented in a fixed sequence comprising the static baseline, manual reconfiguration, the two bounded deterministic automated alternatives and automated building-scale sharing. The static baseline was presented first as a common non-adaptive reference, while repeating the sequence maintained a consistent comparison structure. Because the order was not counterbalanced, possible order, learning, novelty and fatigue effects cannot be excluded. Perceived spatial quality was assessed by asking 'How effectively did this strategy enhance spatial quality?', while perceived functionality was assessed through 'How well did the space meet your immediate needs in terms of functionality?'. Where a prototype included multiple functional states, participants could freely switch between them using an interactive menu embedded in the VR environment. Where state changes involved physical reconfiguration, selecting a state triggered the corresponding animated transition in real time, allowing participants to observe both the movement of the adaptive elements and the resulting spatial configuration. The in-VR menu provided a standardised experimental interface for accessing and comparing spatial states and did not reproduce the intended real-world control method of every strategy. In particular, participants were asked to consider that the manual-reconfiguration states would require manual operation in real use, although the VR interface did not reproduce the physical effort required to perform those changes. Accordingly, VR ratings of the manual prototypes are interpreted as evaluations of their spatial and functional outcomes rather than as direct measures of embodied reconfiguration effort.

The environments were developed in Unity 2022.3.17f1, with experimental structure, logging and data handling supported by the Unity Experiment Framework [60]. A five-participant pilot tested transition clarity, interaction legibility, headset comfort, task flow, question wording and technical robustness before formal data collection. Immersive VR allowed participants to explore alternative spatial states and observe the transitions at bodily scale under controlled and repeatable conditions. Static representations would communicate the experience of changing layout, enclosure, openness and movement less adequately [61–63].

Within each prototype, participants rated perceived spatial quality, perceived functionality and the adequacy of six domestic functions: living, sleeping, working, dining, open space and storage. The two headline measures used a five-point scale from 1 = Very much to 5 = Not at all; the six adequacy statements used five-point scales coded from 1 = more favourable to 5 = less favourable. The six function ratings were averaged to form the combined adequacy index, used as a transparent summary of functional adequacy rather than as a latent psychometric construct. These study-specific measures operationalised the constructs defined in Table 1, and their wording and interpretability were refined through the five-participant pilot. After completing the prototype sequence, participants responded to selected measures concerning psychological impact, comfort with self-adapting space, expected adjustment over time, perceived control, triggering, interface preference, visual organisation, movement speed and the perceived potential of adaptive elements at different dwelling sizes.

Prototype outcomes were summarised using means, standard deviations, medians and distributions. All participants evaluated the same 15 prototypes. Each of the three headline outcomes was therefore compared across prototypes using a Friedman test [64], with Kendall's W and its 95% confidence interval reported as the associated effect-size measure. Where pairwise follow-up comparisons were conducted, Wilcoxon signed-rank tests were used with Holm adjustment for multiple testing [65]. In the main text, pairwise differences are treated as descriptive unless an adjusted pairwise p value is explicitly reported. The Category 3 strategy-level means reported below are averages of the two prototype means within each dwelling-size condition and were not treated as pooled experimental conditions in the inferential tests. Exploratory participant-group comparisons used Kruskal–Wallis H tests followed, where appropriate, by Bonferroni-adjusted Dunn comparisons [66,67]. These subgroup analyses were treated as secondary because of the modest and unequal group sizes. The repeated post-exposure dwelling-size item was analysed separately using a Friedman test followed by Holm-adjusted Wilcoxon signed-rank comparisons.

For the composite prototype ranking, each participant's ratings for perceived spatial quality, perceived functionality and combined adequacy were averaged for each prototype to form an equally weighted three-outcome composite score. Equal weighting was used because the three headline outcomes were treated as complementary dimensions of prototype performance and no a priori hierarchy between them was specified. These composite scores were then ranked within participant across the 15 prototypes, with ties assigned average ranks. Mean composite ranks were calculated across participants. Top three selection rates were derived from the same within-participant composite scores; where ties occurred at the cut point, selections were allocated fractionally so that each participant contributed exactly three top-tier selections. Because the constituent measures are ordinal and conceptually related, the composite ranking was used as an integrative comparative summary rather than as a separate inferential outcome; inferential conclusions remained based on the individual repeated-measures outcome analyses.

3.6. Mixed-Methods Integration

Integration was undertaken at the level of adaptive strategy and shared construct. Survey, focus-group and VR findings were examined together for convergence, complementarity and divergence rather than combined into a single score. Quantitative patterns identified where support or performance differed, while qualitative evidence was used to interpret the practical and psychological mechanisms underlying those patterns. Where findings diverged, the difference was retained and used to qualify the interpretation rather than resolved by privileging one method.

Triangulation was treated as complementary evidence rather than direct replication, reflecting the different aspects of the framework addressed by the three empirical phases. The synthesis therefore distinguished between findings supported across methods and those evidenced within a single phase, allowing claims about effort, legibility, predictability, control and domestic acceptability to remain proportionate to the evidence available. A supplementary participant-validation follow-up was completed with seven participants from the original VR cohort. Participants reviewed a brief written synthesis of the principal VR interpretations and rated their agreement with five interpretive statements on five-point scales. The exercise served as a descriptive credibility check and was not treated as a separate inferential dataset.

4. Results

4.1. Overall Strategy Preferences and the Emerging Middle Ground

In the survey, bounded deterministic automated adaptation received the most favourable overall rating (M = 1.63, SD = 0.74), followed by manual reconfiguration (M = 1.98, SD = 0.60). Open-ended non-deterministic automated adaptation was rated less favourably (M = 2.53, SD = 0.82), while the fixed layout remained close to the scale midpoint (M = 3.02, SD = 0.66). Virtual extension received the least favourable mean rating (M = 3.99, SD = 0.78). Selected measures relevant to interpreting this pattern are reported in Table 2.

Table 2. Survey strategy comparison and selected explanatory measures.

Measure	*n*	*M*	*SD*
Fixed static layout [a]	460	3.02	0.66
Manual reconfiguration [a]	460	1.98	0.60
Bounded deterministic automated adaptation [a]	460	1.63	0.74
Open-ended non-deterministic automated adaptation [a]	460	2.53	0.82
Virtual extension [a]	460	3.99	0.78
Bounded automation is more beneficial than manual change [b]	459	2.16	0.59
Difficulty adjusting to automatic movement [b]	459	2.46	0.75
Manual time and effort as a barrier [c]	459	1.93	0.83
Importance of permanence and stability [d]	460	1.98	0.64

Note: Lower scores indicate a more favourable response or stronger agreement, depending on item wording. [a] 1 = Very good to 5 = Very poor; [b] 1 = Strongly agree to 5 = Strongly disagree; [c] 1 = Definitely to 5 = Definitely not; [d] 1 = Extremely important to 5 = Not important. Only measures reported in this paper are shown.

The accompanying measures indicate that support for adaptation was conditional. Respondents agreed that the time and effort required for manual reconfiguration could become a barrier (M = 1.93, SD = 0.83), while also placing high importance on permanence and stability (M = 1.98, SD = 0.64). Bounded automation was generally considered more beneficial than manual change (M = 2.16, SD = 0.59), although adjusting to automatic movement remained a moderate concern (M = 2.46, SD = 0.75).

The focus-group evidence broadly reinforced this pattern, with bounded deterministic automation attracting the strongest preference while manual effort and the less predictable behaviour of open-ended systems emerged as recurring reservations. The strategy-specific findings are examined in the following sections.

4.2. Results of Category 1: Static Flexibility and the Fixed Static Baseline

Category 1 static flexibility was not represented by an equivalent VR prototype. It was examined through the framework and precedents and evaluated through the survey and focus-group discussions. Participants recognised the value of multi-use rooms, integrated storage and plans capable of absorbing changing routines without requiring repeated transformation. Its advantage was that several activities could be accommodated without recurrent reconfiguration. Its limitation was the amount of spatial reserve available within the plan: very small dwellings could not always accommodate the required functions without direct competition between furniture, circulation and privacy.

The fixed baselines in the VR experiment provided the non-adaptive comparator rather than Category 1 prototypes. Their performance improved markedly as dwelling size increased. Perceived spatial quality changed from $M = 3.17$ at 15 m^2 to $M = 2.63$ at 25 m^2 and $M = 2.26$ at 37 m^2. Perceived functionality improved from $M = 3.31$ to $M = 2.69$ and $M = 1.89$, while combined adequacy improved from $M = 3.77$ to $M = 2.73$ and $M = 1.99$. The static condition was therefore weakest where spatial conflict was greatest and became competitive once the plan contained sufficient capacity (Figure 9).

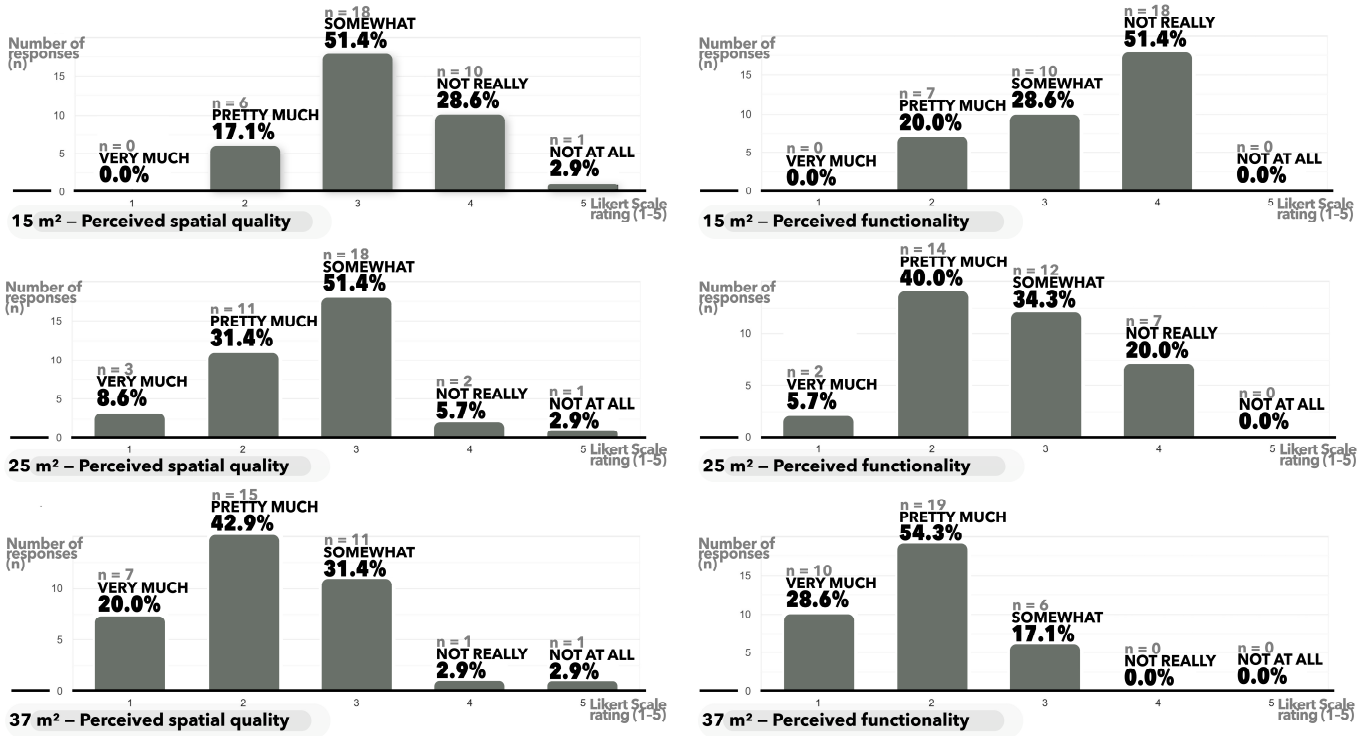

Figure 9. VR ratings of the fixed static baseline across dwelling sizes for perceived spatial quality and perceived functionality. Lower scores indicate more favourable evaluations.

Within the tested size range, the fixed baseline provides a practical reference for interpreting adaptive benefit.

4.3. Results of Category 2: Manual Reconfiguration and the Friction of Effort

Manual reconfiguration was the second most favourably rated overarching strategy. Participants valued its directness and the absence of dependence on complex automated systems. Focus-group participants also associated manual elements with affordability, repairability and tactile engagement. One described manual systems as 'a more affordable opportunity for smaller square footage' (FG1-P5), while another valued being 'physically connected to your home. . . a more personal relationship' (FG4-P2).

The same evidence revealed the strategy's limit. Twenty-one coded excerpts addressed manual effort, of which 16 were critical. Participants anticipated that slow or demanding changes would be abandoned: 'if it took too long. . . you probably would end up not bothering' (FG1-P7). Large elements raised questions of physical capacity, particularly where beds, storage or partitions had to be moved repeatedly: 'I don't think I would want to move a wardrobe every day. . . That's when the machine comes in' (FG3-P3). Manual reconfiguration could therefore turn adaptability into a recurring domestic task. Its potential versatility was unlikely to be realised fully in everyday use where each spatial gain depended on repeated labour.

The VR prototypes reflected this mixed position. At 15 m^2, the manual prototype was rated more favourably than the fixed baseline for perceived functionality (M = 2.94 versus 3.31) and combined adequacy (M = 3.45 versus 3.77), while perceived spatial quality was similar (M = 3.03 versus 3.17). At 25 m^2, the manual prototype again had somewhat more favourable means for functionality (M = 2.43 versus 2.69) and adequacy (M = 2.59 versus 2.73), with little difference in spatial quality (M = 2.57 versus 2.63). At 37 m^2, its means were less favourable than the fixed baseline across all three outcomes: spatial quality (M = 2.31 versus 2.26), functionality (M = 2.37 versus 1.89) and combined adequacy (M = 2.10 versus 1.99) (Figure 10).

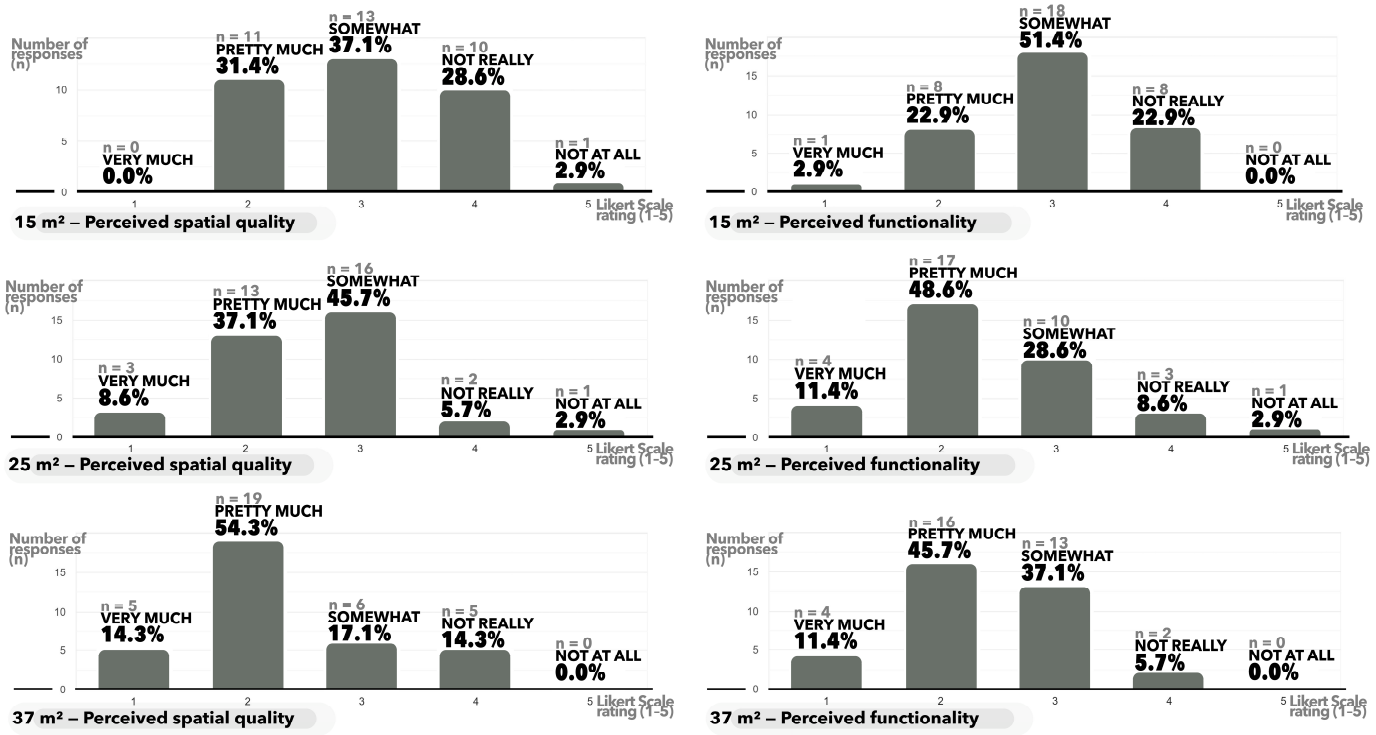

Figure 10. VR ratings of manual reconfiguration across dwelling sizes for perceived spatial quality and perceived functionality. Lower scores indicate more favourable evaluations.

Manual reconfiguration was therefore most credible where actions were simple, occasional and proportionate to the gain; in the VR comparison, it showed modest gains over the fixed baseline at 15 and 25 m^2, but not at 37 m^2. These VR ratings describe the resulting spatial and functional conditions rather than the physical effort of manual transformation; the operational-effort interpretation comes primarily from the survey and focus groups.

4.4. Results of Category 3: Bounded Deterministic Automated Adaptation

Bounded deterministic automated adaptation was the most consistently endorsed strategy across the survey and focus groups. Respondents generally agreed that bounded automated changes were more beneficial than manual alternatives (M = 2.16, SD = 0.59). At the element level, support clustered around recognisable large components such as beds and storage rather than around numerous small or swarm-like elements. The focus groups explained this preference primarily through convenience and reduced recurrent effort. Participants described automated change as 'easy to get around, easy to use and easy to access' (FG1-P7) and linked its value to everyday fatigue: 'We don't have the energy or time to manage everything' (FG3-P4). For some, the attraction was that 'the whole space... can change directly from function to function' (FG4-P5), making automation useful as a means of moving efficiently between recognisable domestic states rather than as technological novelty.

This benefit was closely tied to spatial need and frequency of use. Participants saw automation as particularly credible in 'super small areas where you don't have the space to move around... so you just press a button' (FG1-P5). Repeated transformations also strengthened the case for automation: 'If it happens a lot per day... maybe it is worth it' (FG3-P5). The same logic imposed limits. Predefined layouts could reduce decision-making and make outcomes easier to anticipate, but some participants regarded repetition as restrictive, describing the prospect of 'always doing the same thing again and again' (FG2-P1). Transformation speed was another practical condition: 'If you do it every day... it shouldn't take even two minutes' (FG5-P4). Cost, reliability and simultaneous demands from different household members further qualified support. Category 3 was therefore valued where automation reduced recurrent reconfiguration work while the number, purpose and timing of spatial states remained proportionate to everyday need.

The VR experiment provided the strongest comparative evidence. At 15 m^2, both Category 3 prototypes had more favourable means than the fixed and manual conditions across perceived spatial quality, perceived functionality and combined adequacy. At 25 m^2, P8 recorded the most favourable mean in the full prototype set for each of the three headline outcomes, whereas P9 remained much closer to the fixed and manual conditions. At 37 m^2, both Category 3 prototypes were rated favourably for spatial quality, but the fixed baseline already received the most favourable functionality mean within that size condition (Figure 11).

The contrasting performance of P8 and P9, despite their shared 25 m^2 dwelling size and bounded deterministic strategy, highlights the importance of architectural implementation. Plausible explanations include the positioning of movable furniture, the release of contiguous usable floor area, and the maintenance of circulation, storage access and privacy across task-ready states. As these characteristics were not varied independently, their relative contributions to the observed difference cannot be established.

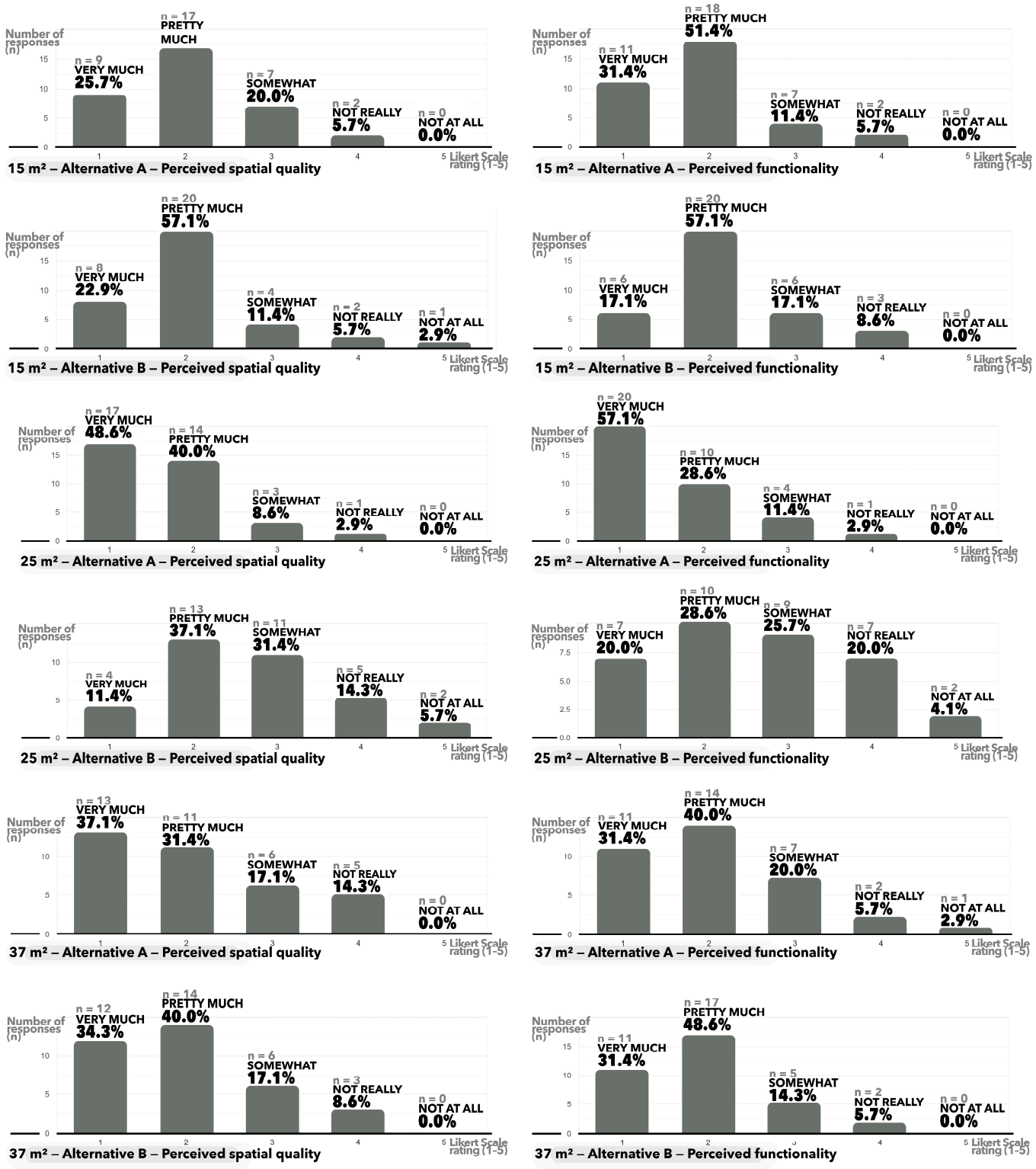

Figure 11. VR ratings of bounded deterministic automated adaptation across dwelling sizes for perceived spatial quality and perceived functionality. Alternative A and Alternative B denote the two Category 3 prototype implementations tested at each dwelling size. Lower scores indicate more favourable evaluations.

4.5. Results of Category 4: Open-Ended Non-Deterministic Automated Adaptation

Open-ended adaptation offered greater configurational freedom but attracted weaker support than manual and bounded deterministic adaptation in the survey. The focus groups nevertheless revealed considerable imaginative interest. Participants envisaged

'a house made from boxes' (FG1-P3), an empty space where 'all of the interior is made up of tiny robots' (FG2-P5), and transformable objects for which 'today I need a bench. . . tomorrow I need three little stools' (FG4-P2). Others valued the broader principle because 'the way we live is always changing' (FG1-P12). Category 4 therefore appealed through the possibility of a continuously reconfigurable interior rather than a fixed repertoire of predefined states.

Moving from possibility to everyday occupation exposed practical limits. Participants questioned whether highly dynamic systems could be affordable, maintainable and materially convincing, while domestic clutter created a more immediate constraint. Idealised reconfiguration assumes that surfaces and movement paths remain available, whereas everyday occupation produces 'papers everywhere. My laptop here, book here, my lunch there' (FG2-P3); as another participant observed, 'in reality, you wouldn't always have the empty table when you're using it' (FG3-P5). Greater configurational freedom therefore depended on sufficient physical clearance for possessions, people and moving elements.

Psychological responses were similarly divided. Some participants welcomed recurrent change, while others found the proposition difficult to imagine as an ordinary domestic condition. One described it as 'too advanced to imagine' (FG2-P1), and participants cautioned that 'you don't want something new every day. . . surprised that things are moving around' (FG4-P3). The underlying requirement was expressed directly by another participant: 'I wouldn't like my home to be completely chaotic. I want it to be stable and safe' (FG5-P4).

The concern was therefore not advanced technology in itself, but the domestic consequences of a larger and less predictable behavioural repertoire. More open-ended systems increase the number of possible elements, movements and states that residents may need to interpret and monitor. Category 4 was not tested through equivalent VR prototypes, so these findings concern anticipated credibility rather than embodied comparative performance. Even so, the survey and focus groups identify an important boundary: greater configurational freedom does not necessarily produce greater domestic value when behaviour becomes difficult to anticipate, accommodate or govern.

4.6. Results of Category 5: Automated Building-Scale Sharing or Redistribution

Automated building-scale sharing extended adaptive capacity beyond the private dwelling by making some functions dependent on access to shared or redistributed space. In the immersive VR experiment, these prototypes generally performed less favourably than bounded within-unit adaptation. At 15 m^2, automated building-scale sharing received mean ratings of 3.09 for perceived spatial quality and 2.91 for perceived functionality. Performance weakened at 25 m^2, where the prototype received the least favourable ratings within its size group for both spatial quality (M = 3.63) and functionality (M = 3.43). At 37 m^2, ratings improved to M = 3.00 and M = 2.57, respectively, but remained less favourable than the strongest within-unit conditions (Figure 12).

The focus groups indicated that this limitation was not simply a question of spatial provision. Once domestic capacity was distributed beyond the dwelling, access, privacy and coordination became part of its usability. Shared provision was considered more credible for occasional functions that could tolerate delayed or scheduled access, but less suitable where activities required immediacy, privacy or reliable everyday availability. Participants consequently raised concerns around proximity, booking and entitlement, hygiene, management and dependence on other residents. Automated building-scale sharing or redistribution could therefore increase the range of spaces available to a household, but at the cost of introducing additional operational and social dependencies.

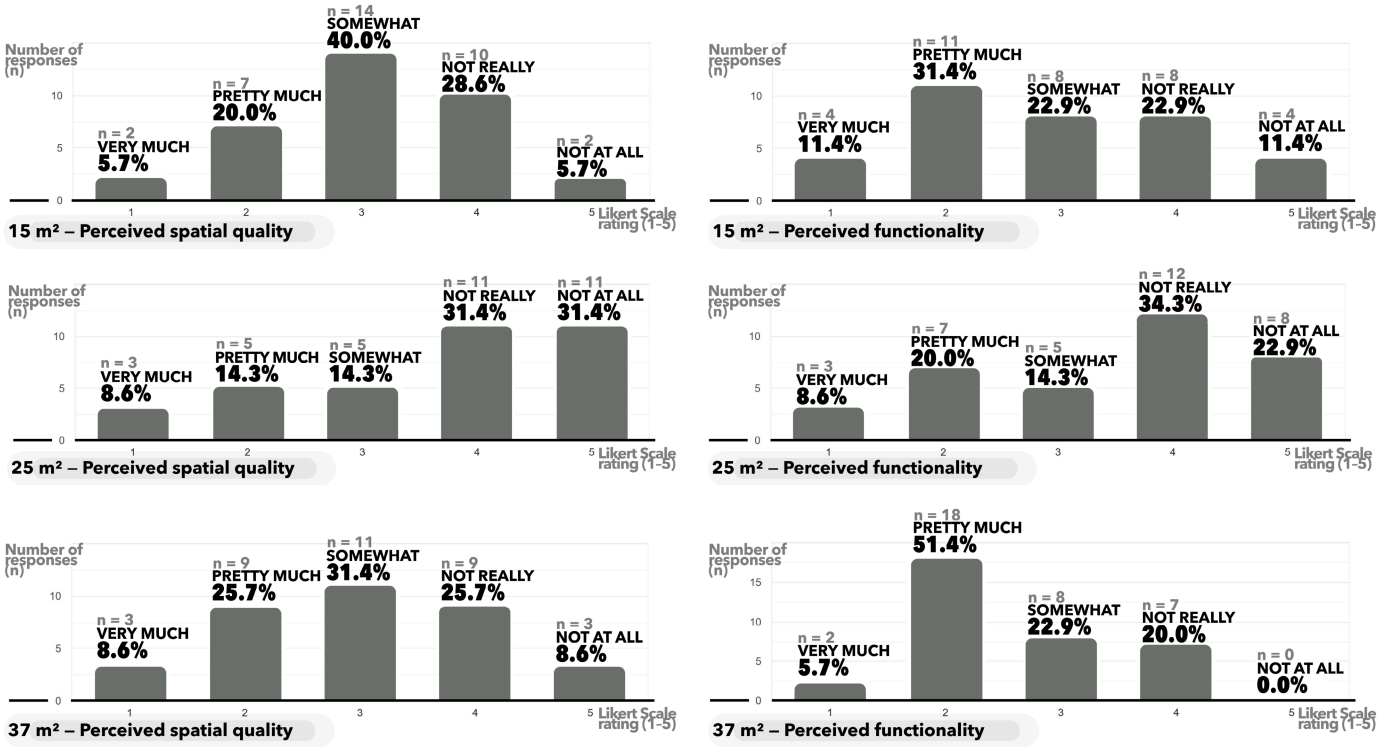

Figure 12. VR ratings of Category 5 automated building-scale sharing or redistribution across dwelling sizes for perceived spatial quality and perceived functionality. Lower scores indicate more favourable evaluations.

4.7. Results of Virtual Extension

Virtual extension occupied a distinct position because it altered the perceptual and experiential qualities of the dwelling without materially reallocating its physical space. It received the least favourable overall survey rating among the strategies examined (M = 3.99, SD = 0.78), indicating comparatively weak support for virtual extension as a response to spatial constraint.

Survey and focus-group evidence nevertheless suggested a more specific potential role. Digital layers could contribute to outlook, atmosphere, entertainment or mediated social connection, but participants did not regard these benefits as substitutes for the physical requirements of everyday domestic activities. Storage, sleeping, dining, movement and spatial separation continued to depend on material capacity.

Virtual extension was therefore evaluated through the survey and qualitative phases rather than represented by an equivalent prototype in the immersive VR comparison. The findings position it most convincingly as an adjacent perceptual layer that can supplement physical adaptation, rather than as an alternative to the spatial capacity provided by reconfiguration or redistribution.

4.8. Comparative Strategy-Level Performance Across Dwelling Sizes

Table 3 provides a comparative strategy-level summary of the fixed baseline, manual reconfiguration, bounded deterministic automated adaptation and automated building-scale sharing or redistribution within each dwelling-size strand. For Category 3, the two prototype means within each size are averaged to show the overall cross-size pattern; these averages were not entered as pooled conditions in the inferential analysis. Lower values indicate more favourable ratings.

At the prototype level, the repeated-measures analyses showed differences across the 15 conditions for perceived spatial quality: Friedman $\chi^2(14) = 149.12$, $p < 0.001$,

Kendall's $W = 0.304$, 95% CI [0.245, 0.419]. Perceived functionality also differed: Friedman $\chi^2(14) = 145.72$, $p < 0.001$, Kendall's $W = 0.297$, 95% CI [0.249, 0.395]. These tests establish overall heterogeneity among the tested prototypes. The strategy-level means in Table 3 provide comparative summaries of how performance varies across dwelling sizes, but no formal dwelling-size × strategy interaction was estimated because the VR conditions did not form a balanced factorial design across strategy categories. Cross-size strategy patterns are therefore interpreted as comparative and exploratory rather than as evidence of a statistically established interaction.

Table 3. Comparative strategy-level mean ratings across dwelling sizes in the immersive VR experiment.

Size	Outcome	Fixed Baseline (Comparator)	Category 2: Manual Reconfiguration	Category 3: Bounded Deterministic Automated Adaptation	Category 5: AUTOMATED Building-Scale Sharing
15 m^2	Spatial quality	3.17	3.03	2.07	3.09
15 m^2	Functionality	3.31	2.94	2.04	2.91
15 m^2	Combined adequacy	3.77	3.45	2.34	2.83
25 m^2	Spatial quality	2.63	2.57	2.16	3.63
25 m^2	Functionality	2.69	2.43	2.11	3.43
25 m^2	Combined adequacy	2.73	2.59	2.03	2.95
37 m^2	Spatial quality	2.26	2.31	2.04	3.00
37 m^2	Functionality	1.89	2.37	2.01	2.57
37 m^2	Combined adequacy	1.99	2.10	2.04	2.17

Category 3 values are means of the two bounded deterministic automated prototypes within each size strand. Lower values indicate more favourable ratings.

Across the tested size strands, the comparative advantage of Category 3 narrowed as dwelling size increased. Relative to the fixed baseline, its mean spatial-quality advantage decreased from 1.10 scale points at 15 m^2 to 0.47 at 25 m^2 and 0.22 at 37 m^2 (Figure 13).

The cross-size convergence was more pronounced for functionality and combined adequacy. Category 3 was more favourable than the fixed baseline at 15 and 25 m^2, but at 37 m^2 the fixed baseline was slightly more favourable for functionality and almost identical on combined adequacy. The comparative pattern therefore extended beyond perceived spatial quality to the functional outcomes, showing that the Category 3 advantage was not consistent across the three tested dwelling sizes (Figure 14).

Within the tested prototypes, bounded deterministic automated adaptation therefore showed its largest comparative advantage at 15 and 25 m^2. At 37 m^2, this advantage narrowed substantially: Category 3 remained slightly more favourable for perceived spatial quality, while the fixed baseline was slightly more favourable for functionality and closely matched Category 3 on combined adequacy. The comparative pattern therefore indicates that adaptive benefit was not constant across the tested dwelling sizes.

A separate post-exposure item asked participants to rate the perceived potential of adaptive elements at 15, 25, 37 and more than 50 m^2. Ratings differed across dwelling sizes: Friedman $\chi^2(3) = 43.95$, $p < 0.001$, Kendall's $W = 0.42$. The 15 m^2 ($M = 1.66$, $Md = 1$) and 25 m^2 conditions ($M = 1.66$, $Md = 2$) were rated more favourably than the 37 m^2 ($M = 2.66$, $Md = 3$) and >50 m^2 conditions ($M = 2.97$, $Md = 3$). All four smaller-versus-larger contrasts remained significant after Holm adjustment (all adjusted $p < 0.001$). The 15 and 25 m^2 conditions did not differ, while the 37 and >50 m^2 comparison did not remain

significant after correction (adjusted $p = 0.075$). This separate measure provides additional evidence that participants perceived adaptive elements as more useful under greater spatial constraint, while not constituting a direct test of the dwelling-size × strategy interaction in the prototype experiment.

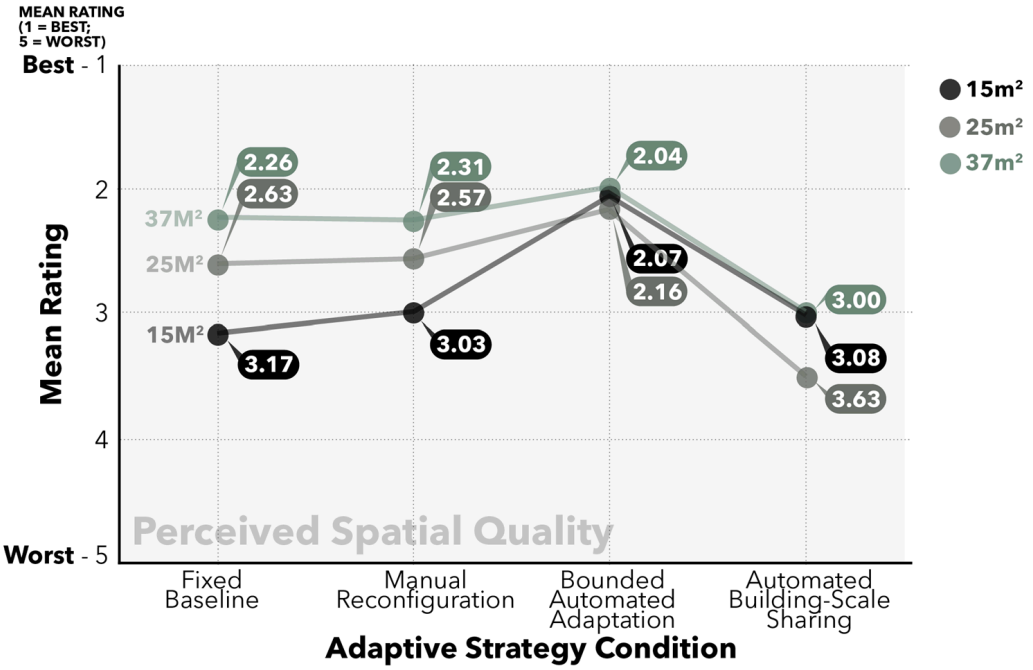

Figure 13. Mean VR ratings of perceived spatial quality across dwelling sizes and strategy conditions. Lower scores are more favourable; Category 3 values are descriptive means of the two bounded deterministic automated prototypes.

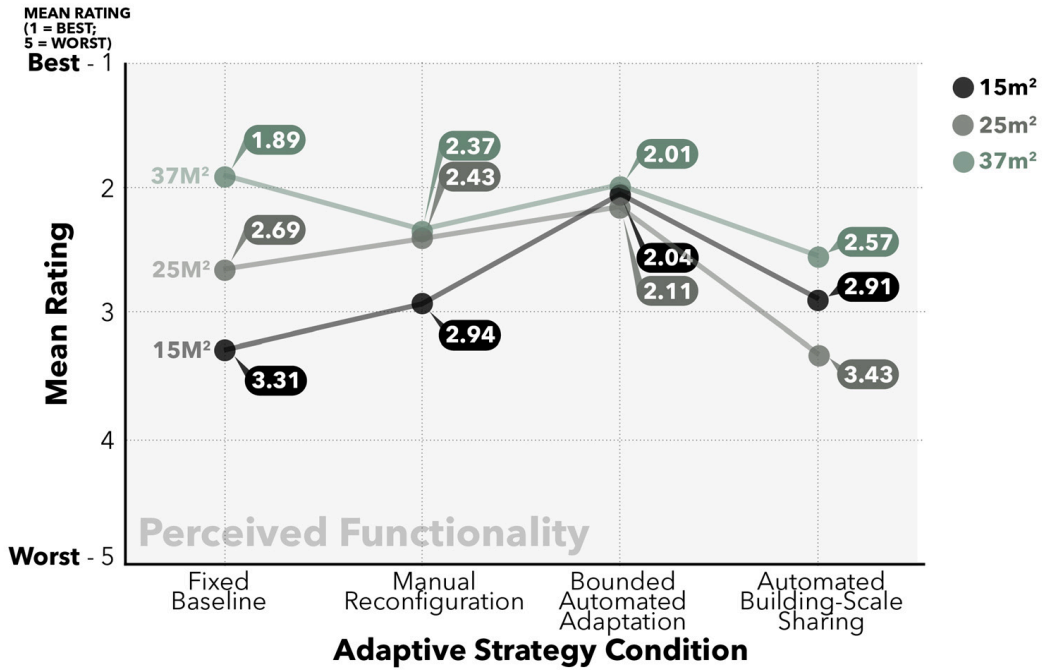

Figure 14. Mean VR ratings of perceived functionality across dwelling sizes and strategy conditions. Lower scores are more favourable; Category 3 values are descriptive means of the two bounded deterministic automated prototypes.

Table 4 consolidates the three headline outcomes for all 15 prototypes. It also records the composite rank reported in Section 4.10. The full comparison is retained in this paper because the variation between prototypes is central to the strategy argument.

Table 4. Consolidated prototype results from the immersive VR experiment.

Size	Strategy	Spatial Quality *M* (*SD*)	Functionality *M* (*SD*)	Combined Adequacy *M* (*SD*)	Rank
15 m^2	Fixed static baseline	3.17 (0.75)	3.31 (0.80)	3.77 (0.56)	15
15 m^2	Manual reconfiguration	3.03 (0.86)	2.94 (0.77)	3.45 (0.59)	13
15 m^2	Bounded deterministic automated adapt. A	2.06 (0.84)	1.91 (0.82)	2.50 (0.75)	6
15 m^2	Bounded deterministic automated adapt. B	2.09 (0.92)	2.17 (0.82)	2.18 (0.53)	5
15 m^2	Automated building-scale sharing	3.09 (0.98)	2.91 (1.22)	2.83 (0.74)	12
25 m^2	Fixed static baseline	2.63 (0.84)	2.69 (0.87)	2.73 (0.78)	11
25 m^2	Manual reconfiguration	2.57 (0.85)	2.43 (0.92)	2.59 (0.62)	8
25 m^2	Bounded deterministic automated adapt. A	1.66 (0.77)	1.60 (0.81)	1.56 (0.47)	1
25 m^2	Bounded deterministic automated adapt. B	2.66 (1.06)	2.63 (1.19)	2.50 (0.71)	9
25 m^2	Automated building-scale sharing	3.63 (1.31)	3.43 (1.29)	2.95 (0.80)	14
37 m^2	Fixed static baseline	2.26 (0.92)	1.89 (0.68)	1.99 (0.64)	4
37 m^2	Manual reconfiguration	2.31 (0.90)	2.37 (0.77)	2.10 (0.57)	7
37 m^2	Bounded deterministic automated adapt. A	2.09 (1.07)	2.09 (1.01)	1.92 (0.59)	3
37 m^2	Bounded deterministic automated adapt. B	2.00 (0.94)	1.94 (0.84)	2.15 (0.77)	2
37 m^2	Automated building-scale sharing	3.00 (1.11)	2.57 (0.88)	2.17 (0.61)	10

4.9. Combined Adequacy Across Six Domestic Functions

Combined adequacy also differed across the 15 prototypes: Friedman $\chi^2(14) = 223.12$, $p < 0.001$, Kendall's $W = 0.455$, 95% CI [0.396, 0.549]. Kendall's W was larger for combined adequacy than for perceived spatial quality ($W = 0.304$) or perceived functionality ($W = 0.297$), indicating the strongest overall differentiation of the three headline outcomes. P8, the 25 m^2 bounded deterministic automated prototype, had the most favourable mean combined-adequacy rating ($M = 1.56$), while P1, the 15 m^2 fixed baseline, had the least favourable mean ($M = 3.77$).

The pattern varied substantially with dwelling size. At 15 m^2, both bounded deterministic automated prototypes were more favourable than the fixed and manual conditions; at 25 m^2, P8 was the strongest condition, while P9 and the manual prototype were more closely matched. At 37 m^2, the means converged, with P13 ($M = 1.92$) and the fixed baseline P11 ($M = 1.99$) closely matched and the remaining conditions occupying a comparatively narrow range (Figure 15).

The combined index showed the same comparative cross-size pattern. Category 3 had its largest advantage over the fixed baseline at 15 and 25 m^2, while at 37 m^2, the two were closely matched. The contrast between P8 and P9 also shows that prototypes sharing the same adaptive strategy could perform very differently, reinforcing the importance of prototype-specific architectural resolution alongside strategy type.

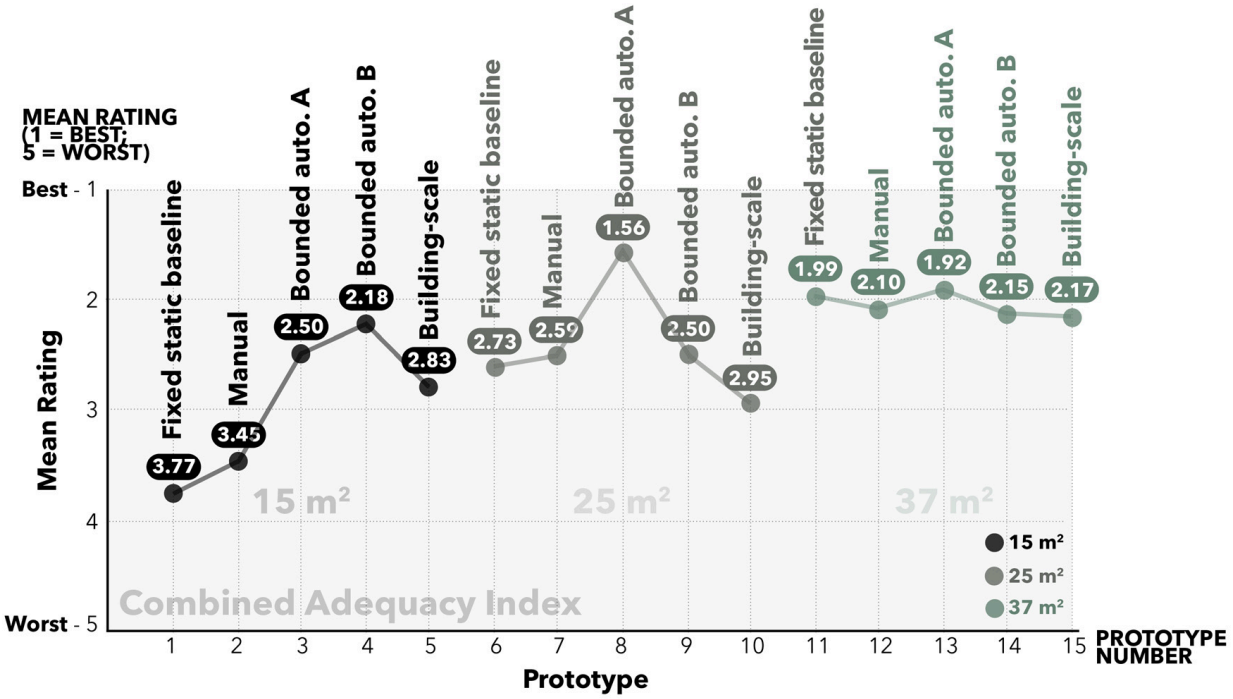

Figure 15. Mean combined adequacy index across living, sleeping, working, dining, open space and storage for the 15 individually tested prototypes. Lower scores indicate more favourable ratings. "Bounded auto. A" and "Bounded auto. B" denote the two Category 3 bounded deterministic automated prototype implementations within each dwelling-size condition; "Building-scale" denotes the Category 5 automated building-scale sharing condition.

4.10. Composite Prototype Rankings

For each participant, perceived spatial quality, perceived functionality and combined adequacy were averaged for each prototype to form an equally weighted three-outcome composite score. These scores were then ranked within participant across the 15 prototypes, with ties assigned average ranks. Mean composite ranks provide a descriptive overall ordering of the prototypes, while top-three selection rates indicate how frequently each prototype entered a participant's three highest-ranked conditions. These measures summarise performance across the three outcome families and are not treated as an additional independent significance test. Table 5 reports both measures.

P8 had the most favourable composite mean rank (2.84) and a top-three selection rate of 71.0% after fractional allocation of ties. P14 and P13, the two 37 m^2 bounded deterministic automated prototypes, ranked second and third, followed closely by the 37 m^2 fixed baseline. The two 15 m^2 bounded deterministic automated prototypes ranked fifth and sixth.

Variation within the bounded deterministic strategy was nevertheless substantial. P8 ranked first, whereas P9, the alternative implementation at the same 25 m^2 dwelling size, ranked ninth. The result reinforces the distinction between strategy and prototype: bounded deterministic adaptation created favourable conditions for performance but did not remove the influence of plan organisation and architectural resolution.

At the lower end of the ranking, the 15 m^2 manual prototype P2 ranked thirteenth, the 25 m^2 automated building-scale sharing prototype P10 fourteenth and the 15 m^2 fixed baseline P1 last. Taken together, the rankings did not resolve into a simple preference for greater dwelling size or greater adaptiveness. The highest-ranked positions instead clustered around prototypes that combined favourable spatial and functional evaluations

while avoiding the recurrent labour associated with manual reconfiguration and the access and management constraints of building-scale redistribution.

Table 5. Composite prototype rankings and top-three selection rates.

Rank	Prototype	Size and Strategy	Composite Mean Rank	Top-Three Rate
1	P8	25 m^2, Bounded Deterministic Automated Adaptation	2.84	71.0%
2	P14	37 m^2, Bounded Deterministic Automated Adaptation	4.60	46.0%
3	P13	37 m^2, Bounded Deterministic Automated Adaptation	5.47	36.0%
4	P11	37 m^2, Fixed Static Baseline	5.59	35.3%
5	P4	15 m^2, Bounded Deterministic Automated Adaptation	6.06	23.6%
6	P3	15 m^2, Bounded Deterministic Automated Adaptation	6.37	20.0%
7	P12	37 m^2, Manual Reconfiguration	6.87	17.9%
8	P7	25 m^2, Manual Reconfiguration	8.11	13.1%
9	P9	25 m^2, Bounded Deterministic Automated Adaptation	8.61	14.3%
10	P15	37 m^2, Automated Building-Scale Sharing	8.74	5.7%
11	P6	25 m^2, Fixed Static Baseline	9.31	8.6%
12	P5	15 m^2, Automated Building-Scale Sharing	10.49	8.6%
13	P2	15 m^2, Manual Reconfiguration	11.77	0.0%
14	P10	25 m^2, Automated Building-Scale Sharing	12.46	0.0%
15	P1	15 m^2, Fixed Static Baseline	12.70	0.0%

Lower mean ranks indicate stronger performance. Ties at the top-three cut point were allocated fractionally so that each participant contributed exactly three selections. Underlying fractional allocations sum to 300%; displayed percentages may differ slightly because of rounding.

4.11. Psychological, Operational and User-Related Conditions of Domestic Acceptability

4.11.1. Movement, Permanence and Habituation

Survey respondents placed substantial importance on permanence and stability (M = 1.98, SD = 0.64), despite their broader support for spatial adaptation. Responses to the multiple-response item on anticipated psychological effects were correspondingly mixed: 40.0% selected 'curious and excited', 30.1% were unsure how they would feel and 26.2% selected 'flexible and open-minded'. By contrast, 12.0% selected 'uncertain and anxious' and 5.5% 'stressed and uncomfortable'. Interest in adaptive space therefore coexisted with uncertainty about the experience of recurrent change.

The post-exposure VR measures showed a similarly conditional response. These items used different question-specific anchors, so their means are interpreted within each item rather than compared directly with one another. Participants expected automatic movement to have a psychological effect (M = 2.34, 95% CI [2.02, 2.66]) and reported moderate comfort with self-adapting space (M = 2.49, 95% CI [2.12, 2.85]). Responses were more favourable to the proposition that residents could become accustomed to adaptation over time (M = 1.91, 95% CI [1.61, 2.22]).

These responses are consistent with habituation as a plausible longer-term process, but they do not demonstrate it. Participants experienced the prototypes within controlled sessions rather than through sustained occupation, so longer-term acclimatisation, irritation or changes in trust were not measured.

4.11.2. Control, Triggering and Transition Legibility

Perceived control following immersive exposure was favourable overall (M = 2.20, 95% CI [1.89, 2.51]), but trigger preferences did not favour complete autonomy. Assisted triggering was selected by 14 of 35 participants (40.0%), hybrid or shared triggering by 10 (28.6%), manual triggering by eight (22.9%) and fully automatic triggering by three (8.6%). Assisted and hybrid arrangements therefore accounted for 24 of 35 participants (68.6%).

Interface preferences reinforced this pattern. In a multiple-response item, a mobile application was selected by 29 of 35 participants (82.9%), physical buttons or switches by 28 (80.0%) and voice control by 23 (65.7%). Artificial-intelligence prediction without a visible interface was selected by four participants (11.4%). Multiple responses were permitted, so these percentages do not sum to 100%. Participants thus favoured automation that reduced the work of reconfiguration while retaining an explicit means of interaction. The same preference also appeared in the focus groups: 'There needs to be… an override function… to… turn it off' (FG4-P1).

Transition speed and visual organisation also contributed to legibility. Survey respondents most often selected one minute, 30 s or 10 s as acceptable transformation times, with a median and mode of one minute. Following immersive exposure, 24 of 35 participants (68.6%) rated the demonstrated movement speed at the midpoint 'just right'. Together with the focus-group evidence, these results indicate that the acceptability of movement depended on a clear relationship between purpose, transition, destination state and resident control rather than on speed alone.

Safety, reliability and maintenance formed a further operational condition across the survey and focus groups. Participants raised concerns about dependence on systems that might fail, require specialist maintenance or affect essential domestic functions. One participant recalled a real experience in which 'my bed was stuck… my bed was up for a few hours… it just wouldn't go down' (FG1-P4). Such concerns were not tested longitudinally in the VR experiment, but they identify operational confidence as part of domestic acceptability alongside immediate control and transition legibility.

4.11.3. Household, Life Stage and Socioeconomic Conditions

User-related differences were more qualified than the strategy-level findings. For the survey item assessing adaptive systems as a potential solution for very small homes (M = 1.70, SD = 0.75), ratings varied by age: $H(6) = 51.43$, $p < 0.001$, $\varepsilon^2 = 0.10$. They also varied by occupation: $H(5) = 34.97$, $p < 0.001$, $\varepsilon^2 = 0.07$. Ratings also became less favourable with increasing age ($\rho = 0.30$, 95% CI [0.22, 0.38], $p < 0.001$). These associations should be interpreted cautiously because older respondents were underrepresented and age or occupation may partly reflect differences in life stage, housing need, technological familiarity or willingness to become accustomed to automated spatial change.

After correction for multiple comparisons, the VR subgroup analysis provided no evidence of a professional or educational group difference. For the Category 3 prototypes, students gave somewhat more favourable means for perceived spatial quality (M = 1.95) than architects (M = 2.17) or participants without a built-environment background (M = 2.13). The same direction appeared for perceived functionality (students M = 1.98; architects M = 2.11; other participants M = 2.05). However, no study-group difference remained statistically significant following Bonferroni-adjusted Dunn comparisons. These patterns are therefore treated as exploratory descriptive tendencies rather than evidence of distinct group responses.

Household composition emerged more consistently in the focus groups. Single occupancy was the most frequently coded user-related theme, with 11 excerpts. It was considered to reduce coordination conflict because one resident could determine when a

room changed state. In shared households, simultaneous activities introduced additional demands, for example where 'one of you wants to work and the other one wants to sleep' (FG3-P3). Adaptation could address sequential competition for space but not eliminate simultaneous demand between occupants.

Participants also identified automated movement as potentially useful where repeated manual reconfiguration would be physically demanding. This suggests a possible accessibility benefit, but physical ability and accessibility were not directly evaluated experimentally and require dedicated testing.

Affordability was likewise identified as a condition of viability, particularly in relation to the purchase, servicing and maintenance of automated systems. The study did not evaluate lifecycle costs or delivery models, so socioeconomic suitability should be understood as an implementation condition rather than a measured performance effect. Taken together, the evidence identifies relevant user and contextual tendencies rather than a fixed classification of for whom adaptive housing is suitable.

4.11.4. Acceptability Framework

The mixed-methods synthesis organised the recurring findings into six interrelated conditions of domestic acceptability: sufficient usefulness, domestic stability, architectural resolution, visual and material integration, cognitive legibility, and resident control and operational reliability (Figure 16). These conditions emerged from convergence and complementarity across the survey, focus-group and VR evidence rather than from a separate scale or predictive model.

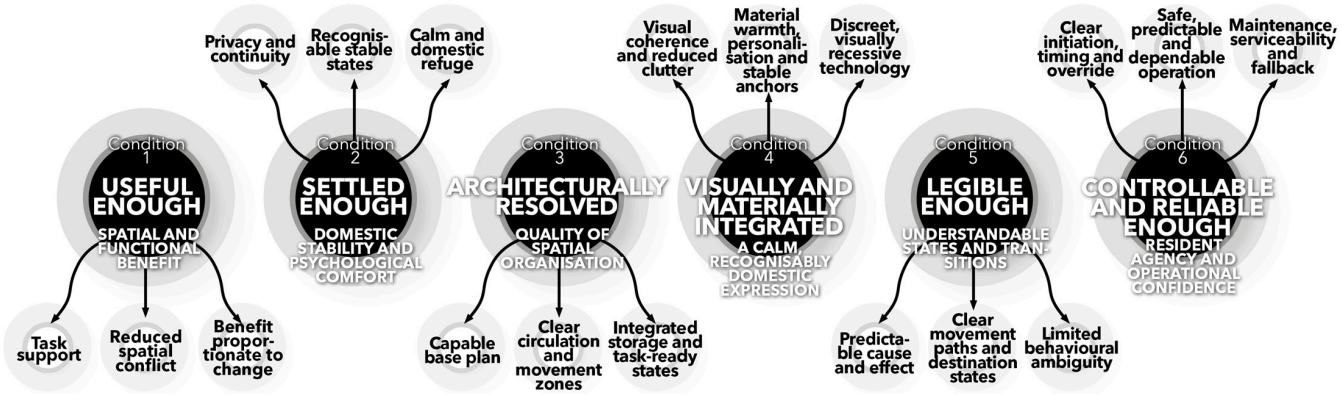

Figure 16. Acceptability framework for adaptive compact housing. Six interrelated conditions link spatial and functional benefit to domestic stability, architectural resolution, visual and material integration, cognitive legibility, and resident control and operational reliability. Contextual conditions qualify the balance between adaptive benefit and burden.

Sufficient usefulness concerned whether spatial and functional gains justified the effort and infrastructure required to produce them. Evidence from manual reconfiguration, the dwelling-size comparisons and the post-exposure size assessment showed that adaptive benefit was strongest where spatial conflict remained substantial. Domestic stability reflected the parallel requirement for continuity: respondents valued permanence and stability even while expressing interest in adaptive space, and the VR findings suggested that habituation may shape responses to recurrent change over time.

Architectural resolution and visual and material integration concerned how adaptation was incorporated into the dwelling. The contrast between P8 and P9 showed that the same adaptive strategy could produce markedly different outcomes under comparable envelope conditions, while the focus groups associated acceptable adaptive interiors with

personalisation, visual restraint, familiar materials, reduced clutter and technology that did not dominate the domestic setting.

Cognitive legibility concerned whether residents could understand the purpose, path and outcome of spatial change. Resident control and operational reliability concerned how that change was initiated and governed, together with anticipated requirements for safety, maintenance and failure recovery. Preferences for assisted or hybrid triggering and explicit interfaces indicated that participants favoured automation that reduced labour while retaining resident involvement.

The relevance of these six conditions varied with dwelling size, household composition and user context, while physical ability, affordability and management arrangements emerged as further implementation considerations. The framework therefore summarises the conditions that qualified adaptive benefit across the three study phases. It is interpretive rather than predictive and does not prescribe universal thresholds of acceptability. The supplementary participant-validation follow-up was consistent with these broader interpretations. Across all five statements, none of the seven returning participants disagreed, and all seven strongly agreed that automation was most acceptable when it remained predictable and controllable. The remaining statements concerning the relative value of adaptation across the tested dwelling sizes also received predominantly positive responses. Given the small, self-selecting follow-up sample, these findings are treated as a descriptive credibility check rather than confirmatory evidence.

5. Discussion

5.1. Comparative Performance and the Right Level of Adaptiveness

Two levels of inference need to be distinguished. At the strategy level, the mixed-methods evidence does not support a progression in which increasing automation or configurational freedom necessarily produces a better home. At the prototype level, however, the VR results show substantial variation within the same strategy category, demonstrating that strategy alone did not determine performance. Plan organisation, circulation, storage integration, privacy, clear-floor release and the usefulness of each task-ready state remained important to the observed performance. The strategies instead involved different forms of benefit and burden. Static space required no recurrent spatial reconfiguration but offered limited reserve capacity under severe constraint. Manual reconfiguration transferred the work of transformation to the resident. Open-ended automation expanded the range of possible states while increasing interpretive demands. Building-scale redistribution introduced dependencies on access and management. Prototype-level comparisons showed the strongest differentiation for combined adequacy, indicating that differences between proposals became particularly apparent when the six domestic functions were considered together.

This synthesis extends the flexibility literature by connecting spatial capacity to the effort, control and intelligibility involved in producing it. Hertzberger [68], Kronenburg [7], De Paris and Lopes [8], Askar, Bragança and Gervásio [69], and Femenias and Geromel [9] each show that adaptability is not a single property. It can be latent in the plan, enacted by residents or embedded in technical systems. The present study shows that these strategies impose different operational and cognitive demands.

The relative value of transformation also varied across the tested dwelling sizes. At 15 and 25 m^2, Category 3 showed a clear comparative advantage over the fixed baseline, whereas at 37 m^2, this advantage narrowed or disappeared across the three headline outcomes. Together with the separate post-exposure size assessment, this supports the interpretation that adaptation offers greater benefit where static spatial capacity is more constrained. Because no formal dwelling-size × strategy interaction was estimated, 37 m^2

is interpreted as a boundary observed within the tested prototypes and sample rather than as a generally applicable threshold for compact housing. The value of additional transformation therefore varied with what the underlying plan could already provide, the activities being supported and the quality of the adaptive intervention.

The ranking data reinforce this conclusion. P8 did not succeed merely because it was automated. P9 shared the same strategy category and dwelling size but ranked much lower. P11, the 37 m^2 fixed baseline, ranked above several adaptive proposals. Category 3 created favourable conditions for performance, but it did not replace architectural judgement. The location of moving elements, storage integration, circulation, privacy, clear-floor release and the usefulness of each state remained decisive.

5.2. Why Bounded Deterministic Automated Adaptation Provided the Most Consistent Balance

The findings suggest several mechanisms that may help account for the relative strength of Category 3. Automatic movement can reduce the resident's physical work of reconfiguration. Predefined task-ready states could reduce decision-making and make the purpose of each configuration easier to understand, while a finite repertoire supported anticipation of likely outcomes. Integrated moving storage could also release floor area and reduce visual clutter. The observed advantage therefore appears to arise from the combination of reduced effort, legible state changes and useful spatial outcomes rather than from automation alone.

CityHome and Ori Living illustrate a similar operational logic. Their significance lies less in the claim that a small home can become literally larger than in the sequencing of functions through a compact set of known transformations [18,19]. Radha [6] and Radha, Tayib and Mohammed [21] likewise associate large-element automation with functional flexibility, while Rodriguez and Feng [70] show how users can evaluate and customise robotic-furniture arrangements in an immersive environment. The present findings add comparative user evidence to literature that has often focused on feasibility and demonstration. Within the tested prototypes, bounded automated adaptation often received more favourable spatial and functional ratings than fixed, manual and building-scale alternatives, although the magnitude and consistency of this advantage varied with dwelling size and architectural resolution. This does not constitute a like-for-like experimental ranking of all framework categories, as Category 1, Category 4 and virtual extension were evaluated primarily through the survey and focus groups rather than equivalent VR prototypes.

One plausible advantage of boundedness is that it supports a more stable mental model of system behaviour. Dragan, Lee and Srinivasa [31] distinguish movement that reveals its goal from movement that conforms to expectations. Adaptive furniture must do both: residents need to understand what is changing and anticipate the resulting spatial condition. Nguyen, Han and Vande Moere [36] similarly show that autonomous architectural movement should respond to place and activity without becoming disruptive, while Nguyen and Vande Moere [28] demonstrate the value of advisory, shared and reversible control. Participants' preference for assisted and hybrid triggering and visible controls, together with low support for full autonomy, is consistent with that work.

Yet the internal Category 3 variation precludes an overly simple explanation. Boundedness can make safety, prediction and control more tractable, but a poor task repertoire can still produce weak outcomes. A moving wall that creates awkward circulation, a bed that releases little useful floor area or storage that remains visually dominant cannot be rescued by deterministic control. The most consistent balance emerged where bounded behaviour was combined with useful task-ready states, low recurrent effort for the user and a well-resolved architectural base plan.

5.3. Time-Dependent Functional Capacity Across Dwelling Sizes

The results are consistent with time-based spatial allocation as one explanation for the observed adaptive benefit. The dwelling does not gain area. Instead, furniture can retract or reposition so that competing functions no longer occupy the same footprint simultaneously, temporarily releasing floor area and circulation for the activity in use. The benefit therefore concerns how existing area becomes available across time rather than an increase in geometric size. Spatial experience may depend not only on visual depth or enclosure but also on the amount of usable space available for the activity at hand.

Research on interior perception supports the distinction between geometric size and spatial experience. Architectural evaluations are shaped by enclosure, coherence, visual organisation and individual differences rather than by area alone [71,72]. Tural and Tural [34] similarly show that spaciousness can be assessed through immersive and screen-based settings as an experiential judgement. The present study adds a functional layer: participants evaluated not only how open a prototype felt but how well it supported living, sleeping, working, dining, open space and storage.

The three outcome families should therefore be interpreted separately, even when they are summarised descriptively in the composite ranking. At 37 m^2, the Category 3 mean remained slightly more favourable for perceived spatial quality, while the fixed baseline was slightly more favourable for perceived functionality and approximately matched Category 3 on combined adequacy. An interior can still feel more open when furniture moves, yet the transformation becomes less necessary once the static plan already supports the required functions. As static capacity increases, the case for adaptation shifts from functional necessity towards convenience or amenity.

This cross-size pattern matters for the wider claims surrounding adaptive housing. Manufacturer and research narratives have suggested that robotic interiors can allow compact dwellings to 'act bigger' by increasing the functional capacity of a fixed footprint [6,18,19,21]. For example, Ori founder Hasier Larrea described the aim of the system as using robotics to make small spaces 'act like they were two or three times bigger' [73]. The present paper does not quantify area equivalence; rather, it tests whether favourable spatial and functional outcomes persist as baseline dwelling size increases. Size compensation is credible only where the strategy produces measurable spatial and functional gains and where those gains remain domestically acceptable. In the tested prototypes, the strongest comparative benefits occurred at 15 and 25 m^2 and converged towards the fixed baseline at 37 m^2, while the separate post-exposure assessment also favoured the smaller dwelling-size conditions. Adaptability should therefore not be treated as providing a constant level of size compensation irrespective of baseline spatial capacity.

5.4. From Manual Effort to Open-Ended Opacity

Category 2 and Category 4 reveal contrasting forms of friction. Manual reconfiguration remains directly legible to the resident but can turn spatial capacity into recurring work. Open-ended automation removes some physical work and expands the range of possible arrangements but can make system behaviour harder to interpret.

Social practice theory shifts attention from isolated user behaviour to the recurring practices through which domestic life is organised. These practices depend on relations among materials, competences and meanings [74]. An adaptive bed, table or storage wall becomes part of how residents sleep, work, dine or store possessions rather than simply a device they choose to operate. Where reconfiguration fits established routines and reduces effort, it may become embedded in everyday practice; where it repeatedly interrupts or adds work, flexibility becomes a routine obligation. Femenias and Geromel [9] similarly

show that available adaptability does not guarantee continued use. The focus-group evidence therefore suggests that manual systems remain valuable only while the required transformations can be absorbed into ordinary domestic routines rather than continually performed as additional work.

Open-ended systems create a different burden. Roombots, RoomShift and related robotic systems demonstrate how many small elements can support dynamically composed furniture or room-scale behaviour [17,37,38]. Architecturally, they extend the cybernetic idea of environments that can reorganise themselves in response to changing use. Their domestic translation, however, introduces more states, trajectories and potential failures than a bounded system. Residents may need to keep watching, interpreting and evaluating what the environment is doing.

One plausible psychological burden is the need for continued monitoring. Lee and See [35] argue that trust in automation depends on appropriate reliance rather than either blind confidence or wholesale rejection. In a home, the demand for vigilance conflicts with the expectation that technology can recede from attention. Weiser and Brown's [75] concept of calm technology is relevant here: systems should move between the centre and periphery of attention rather than demanding continuous engagement. More open-ended spatial behaviour risks doing the opposite. What remains compelling as a speculative architecture may therefore be harder to reconcile with a settled domestic routine.

The weaker support for Category 4 should not be read as resistance to innovation. Participants accepted advanced automation where its benefit and behaviour were clear. They were cautious about systems composed of many smaller moving parts or less predictable behaviours because these systems increased cognitive demand, reduced perceived control and made outcomes harder to anticipate. The issue was not novelty. It was behavioural opacity.

5.5. Domestic Acceptability: Legibility, Control and Stability in Motion

The home is both a spatial arrangement and a psychological setting. Altman [23], Després [24], Sixsmith [25], Proshansky, Fabian and Kaminoff [26] describe privacy, identity, attachment, refuge and control as central dimensions of domestic experience. These qualities do not require the physical environment to remain unchanged. They require enough continuity for residents to orient themselves, establish routine and regulate interaction.

The findings suggest that adaptive movement is more likely to remain acceptable in everyday domestic use when it is legible, bounded and aligned with resident intention. Residents need to understand the cause, sequence and outcome of change. They need access to initiation, confirmation, pause or override where movement affects privacy, safety or essential functions. They also need stable reference points: fixed circulation, retained personal space, recognisable resting states and continuity in how possessions are stored. Stability in motion is not the absence of transformation. It is a condition in which transformation remains governable enough for the home to feel settled.

Smart-home research identifies comparable concerns through a different technological domain. Gram-Hanssen and Darby [15] argue that smart-home research often underestimates the meaning and practices of home. Marikyan, Papagiannidis and Alamanos [16], Cannizzaro et al. [76], Schomakers, Biermann and Ziefle [77], Aggarwal and Singh [78], and Fakhr Hosseini et al. [79] identify trust, privacy, control and intelligibility as recurring conditions of acceptance. Physical adaptation intensifies those concerns because system behaviour changes bodily access and the arrangement of domestic life, not only energy settings or information displays.

The preference for assisted and hybrid triggering helps specify the form of control participants preferred: reduced reconfiguration labour without relinquishing resident

authority. This relationship helps explain why Category 3 provided the most consistent balance across the mixed-methods evidence. It combined assistance with a limited, recognisable repertoire; open-ended systems weakened that repertoire, while manual systems preserved authority at the cost of repeated work.

5.6. User, Household and Socioeconomic Boundaries

The study identifies user-related patterns, but it does not support a fixed taxonomy of suitable users. Younger survey respondents rated the survey item on adaptive systems as a potential solution for very small homes more favourably, while students gave slightly more favourable ratings in the VR experiment. No VR subgroup comparison remained significant after adjustment for multiple comparisons. Older adults were underrepresented, and chronological age is unlikely to operate independently. Life stage, perceived housing need, technological familiarity and previous exposure to adaptive concepts may all contribute. These differences are therefore better understood as possible indicators of differing domestic routines, needs and relationships with technology than as stable individual traits.

Social practice theory sharpens this interpretation by shifting attention from individual behaviour to the recurring, often shared practices through which domestic life is organised [74]. The relevant question is not only whether a resident accepts adaptation but whether changing spatial states fit the timing and coordination of sleeping, working, dining, storage, privacy and social interaction. Household composition matters because these practices may be sequenced by a single resident but become simultaneous or competing in shared homes. Category 3 may reduce conflict between sequential uses, but it cannot eliminate situations in which one person's activity depends on a spatial state that conflicts with another's. Category 5 extends this coordination problem beyond the household through shared access, scheduling and dependence on other residents.

Physical ability is another condition shaping how domestic practices can be performed. Automated movement can reduce the labour of lifting, folding or sliding heavy elements and may therefore support residents for whom manual reconfiguration is difficult. That possibility emerged qualitatively but was not tested through a dedicated accessibility study. Safety, control reach, movement speed and failure recovery would require targeted evaluation before stronger claims could be made.

Affordability creates further structural tension. Residents under the greatest spatial pressure may have the strongest functional need for adaptive furniture while being least able to pay for advanced systems, maintenance or replacement. Higher-income households may be better able to afford the technology but also have greater access to larger conventional homes. Suitability therefore depends not simply on individual characteristics but on the fit between the spatial system, everyday routines, shared household practices and the material resources available to sustain them. The present framework identifies these as interacting boundary conditions rather than a classification of ideal users and does not establish which delivery models could make such systems affordable or equitable.

5.7. Contribution to BioCognitive Architectural Design

For adaptive interiors, architectural performance includes not only the quality of a static configuration but also the sequence of spatial states and transitions experienced during occupation. These transitions affect bodily access, functional use, anticipation and perceived control while taking place within recurring and shared domestic practices. This places adaptive interiors within BioCognitive Architectural Design by extending evaluation from static spatial form to environments whose organisation changes through use.

The mixed-methods evidence also shows why adaptive performance cannot be reduced to either technological sophistication or static spatial quality. Survey and focus-group

evidence revealed the practical and psychological conditions attached to spatial change, while immersive evaluation allowed participants to compare both task-ready spatial states and the transitions between them at bodily scale. A fixed plan could remain competitive where sufficient spatial capacity was already available, while bounded automated adaptation was most advantageous where spatial conflict was greater and the resulting states were well resolved. Methodologically, adaptive interiors should be evaluated not only as layouts but as sequences of spatial states, transitions and control relationships experienced during occupation.

5.8. Limitations and Future Research

Several limitations qualify the findings. Survey and focus-group responses partly reflected anticipated rather than lived experience. Participants evaluated descriptions, images and examples but had not lived with the systems. The VR experiment provided immersive exposure at bodily scale under controlled conditions, yet it could not reproduce long-term habituation, breakdown, maintenance, acoustic effects, domestic clutter or the accumulation of possessions. Both dwelling-size and prototype order were fixed: participants progressed from 15 to 25 to 37 m^2, with the static baseline presented first within each strand. This provided a common reference and consistent comparison structure, but order, anchoring, learning, novelty and fatigue effects cannot be excluded. Future studies should use counterbalancing or randomisation where the experimental design permits. The VR interface also standardised access to the spatial states and therefore did not reproduce the physical effort of manual reconfiguration or the full operational complexity of real-world automated systems.

The framework received non-equivalent empirical coverage because the strategies differed in scale and suitability for immersive testing. Category 1, Category 4 and virtual extension were not represented by equivalent VR prototypes, while Category 5 operated at a different spatial and governance scale from the unit-level strategies. Strategy-level interpretation therefore draws on triangulation where evidence is available across the survey, focus groups and VR, rather than assuming equivalent experimental testing of every category.

The survey used purposive online recruitment and is not nationally representative. The VR sample was modest, predominantly younger, and included substantial student and architect representation. The repeated-measures design strengthened within-participant comparison, but subgroup findings remain exploratory. The study also evaluated unbuilt propositions. It cannot establish real-world adoption, reliability or long-term satisfaction.

Prototype-specific variation limits category-wide inference. P8 and P9 illustrate that bounded deterministic operation can support both strong and less favourable outcomes. Future research should test occupied prototypes longitudinally, recruit more diverse households and age groups, examine maintenance and failure, compare interaction policies and evaluate concurrent use in multi-person homes. These studies are needed before the present findings can be translated into robust guidance for occupied housing.

6. Conclusions

Three principal findings emerge from the mixed-methods evaluation. First, adaptive interiors offered their greatest comparative benefit under severe spatial constraint: Category 3 performed more favourably than the fixed baseline across the three headline VR outcomes at 15 and 25 m^2, while this advantage narrowed or disappeared at 37 m^2. Second, bounded deterministic automated adaptation provided the most consistent balance among the approaches examined, combining reduced anticipated reconfiguration effort with a limited repertoire of recognisable, task-ready states. Third, architectural resolution

remained decisive, as demonstrated by the contrasting performance of P8 and P9, despite their shared operational strategy. These findings are specific to the tested prototypes and participants and do not establish a universal dwelling-size threshold or formal size × strategy interaction.

The study consequently frames the right level of adaptiveness as a conditional relationship rather than a technological endpoint. Adaptive capacity is most credible when spatial and functional gains remain proportionate to resident effort and to the reliance placed on mechanisms, controls, maintenance and reliable operation. Longitudinal testing in occupied homes is needed to establish how this balance changes with habituation, maintenance, failure, multi-person use and everyday domestic routines. The implication is not to maximise spatial change but to introduce only as much adaptation as the dwelling and household require.

Author Contributions: Conceptualisation, T.G. and Y.K.; methodology, T.G., Y.K. and A.C.; software, T.G.; formal analysis, T.G.; investigation, T.G.; data curation, T.G.; visualisation, T.G.; writing—original draft preparation, T.G.; writing—review and editing, T.G., Y.K. and A.C.; supervision, Y.K. and A.C.; project administration, T.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study received favourable ethical opinion from the Arts and Humanities Research Ethics and Governance Committee of Manchester Metropolitan University on 23 March 2023 (EthOS Reference Number: 48537).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: The datasets presented in this article are not readily available because they form part of an ongoing doctoral research project and are subject to participant consent, institutional ethical approval and applicable data-protection requirements. Requests to access the datasets should be directed to the corresponding author and will be considered in accordance with these restrictions.

Acknowledgments: The authors thank all participants who contributed to the survey, focus groups and immersive VR study, and Manchester Metropolitan University for supporting the doctoral research. During manuscript preparation, the authors used ChatGPT 5.6 (OpenAI) for organisational review and language refinement. Generative AI was not used for study design, data collection, data analysis or interpretation.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. RIBA. *Housing Survey 2013*; Ipsos MORI: London, UK, 2013.
2. Hubbard, P. Small Is Beautiful? Making Sense of 'Shrinking' Homes. *Urban Stud.* **2025**, *62*, 187–203. [CrossRef]
3. Hubbard, P. Enforcing the Nationally Described Space Standard: The Regulation of "Sub-Standard" English Housing. *J. Prop. Plan. Environ. Law* **2023**, *15*, 152–169. [CrossRef]
4. Morgan, M.; Cruickshank, H. Quantifying the Extent of Space Shortages: English Dwellings. *Build. Res. Inf.* **2014**, *42*, 710–724. [CrossRef]
5. Jaskiewicz, T. Towards a Methodology for Complex Adaptive Interactive Architecture. Ph.D. Thesis, Delft University of Technology, Delft, The Netherlands, 2013.
6. Radha, R.K. Flexible Smart Home Design: Case Study to Design Future Smart Home Prototypes. *Ain Shams Eng. J.* **2022**, *13*, 101513. [CrossRef]
7. Kronenburg, R. *Flexible: Architecture That Responds to Change*; Laurence King Publishing: London, UK, 2007.
8. De Paris, S.R.; Lopes, C.N.L. Housing Flexibility Problem: Review of Recent Limitations and Solutions. *Front. Archit. Res.* **2018**, *7*, 80–91. [CrossRef]

9. Femenias, P.; Geromel, F. Adaptable Housing? A Quantitative Study of Contemporary Apartment Layouts That Have Been Rearranged by End-Users. *J. Hous. Built Environ.* **2020**, *35*, 481–505. [CrossRef]
10. Archigram Group. Living 1990. *Archit. Des.* **1967**, *37*, 146–147. Available online: https://www.usmodernist.org/ADUK/ADUK-1967-03.pdf (accessed on 19 October 2026).
11. Friedman, Y. About the Flatwriter. In *Pro Domo*; Actar: Barcelona, Spain, 2006; pp. 137–139.
12. Friedman, Y.; Obrist, H.-U. *Yona Friedman*; Walther König: Cologne, Germany, 2007; Volume 7.
13. Pask, G. The Architectural Relevance of Cybernetics. *Archit. Des.* **1969**, *39*, 494–496.
14. Frazer, H.J. The Cybernetics of Architecture: A Tribute to the Contribution of Gordon Pask. *Kybernetes* **2001**, *30*, 641–651. [CrossRef]
15. Gram-Hanssen, K.; Darby, S.J. "Home Is Where the Smart Is"? Evaluating Smart Home Research and Approaches against the Concept of Home. *Energy Res. Soc. Sci.* **2018**, *37*, 94–101. [CrossRef]
16. Marikyan, D.; Papagiannidis, S.; Alamanos, E. A Systematic Review of the Smart Home Literature: A User Perspective. *Technol. Forecast. Soc. Change* **2019**, *138*, 139–154. [CrossRef]
17. Spröwitz, A.; Pouya, S.; Bonardi, S.; van den Kieboom, J.; Möckel, R.; Billard, A.; Dillenbourg, P.; Ijspeert, A.J. Roombots: Reconfigurable Robots for Adaptive Furniture. *Comput. Intell. Mag. IEEE* **2010**, *5*, 20–32. [CrossRef]
18. MIT Media Lab CityHome. Available online: https://www.media.mit.edu/projects/OLD_cityhome2/overview/ (accessed on 17 June 2026).
19. Ori Living. Ori Expandable Apartments. Available online: https://www.oriliving.com/ (accessed on 19 October 2026).
20. Bumblebee Spaces. Available online: https://bumblebeespaces.com/ (accessed on 3 May 2026).
21. Radha, R.K.; Tayib, A.; Mohammed, I. Comparative Study to Analyze the Impact of Smart Technology on Functional Flexibility and Space Occupancy. *J. Build. Pathol. Rehabil.* **2021**, *6*, 9. [CrossRef]
22. Dunne, A.; Raby, F. *Speculative Everything: Design, Fiction, and Social Dreaming*; MIT Press: Cambridge, UK, 2013.
23. Altman, I. *The Environment and Social Behavior: Privacy, Personal Space, Territory, Crowding*; Brooks/Cole Publishing Company: Monterey, CA, USA, 1975.
24. Després, C. The Meaning of Home: Literature Review and Directions for Future Research and Theoretical Development. *J. Archit. Plan. Res.* **1991**, *8*, 96–115.
25. Sixsmith, J. The Meaning of Home: An Exploratory Study of Environmental Experience. *J. Environ. Psychol.* **1986**, *6*, 281–298. [CrossRef]
26. Proshansky, H.M.; Fabian, A.K.; Kaminoff, R. Place-Identity: Physical World Socialization of the Self. *J. Environ. Psychol.* **1983**, *3*, 57–83. [CrossRef]
27. Alavi, H.S.; Churchill, E.F.; Wiberg, M.; Lalanne, D.; Dalsgaard, P.; Fatah Gen Schieck, A.; Rogers, Y. Introduction to Human-Building Interaction (HBI): Interfacing HCI with Architecture and Urban Design. *ACM Trans. Comput.-Hum. Interact.* **2019**, *26*, 1–10. [CrossRef]
28. Nguyen, B.V.D.; Vande Moere, A. The Adaptive Architectural Layout: How the Control of a Semi-Autonomous Mobile Robotic Partition Was Shared to Mediate the Environmental Demands and Resources of an Open-Plan Office. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*; ACM: Honolulu, HI, USA, 2024; pp. 1–20.
29. Guo, S.G.; Cañete, R.; Yu, J.J.; Leshed, G.; Walker, I.; Green, K.E. Reconfiguring the Home: Co-Designing the Future of Adaptive Domestic Environments. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems*; ACM: New York, NY, USA, 2026; pp. 1–22.
30. Taherkhani, R.; Aziminezhad, M. Human-Building Interaction: A Bibliometric Review. *Build. Environ.* **2023**, *242*, 110493. [CrossRef]
31. Dragan, A.D.; Lee, K.C.T.; Srinivasa, S.S. Legibility and Predictability of Robot Motion. In *Proceedings of the 2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*; IEEE: Tokyo, Japan, 2013; pp. 301–308.
32. Nguyen, A.B.V.D.; Christoforou, R.; Pigliautile, I.; Martins Gnecco, V.; Pogladič, A.; Arko, S.; Pisello, A.L.; Schaumann, D.; Schweiker, M.; Vande Moere, A. ARAM: A Threshold Model for Understanding Occupant Acceptance of Architectural Robot Adaptations. *Front. Comput. Sci.* **2026**, *8*, 1896307. [CrossRef]
33. Goessler, T.; Kaluarachchi, Y. Smart Adaptive Homes and Their Potential to Improve Space Efficiency and Personalisation. *Buildings* **2023**, *13*, 1132. [CrossRef]
34. Tural, A.; Tural, E. Exploring Sense of Spaciousness in Interior Settings: Screen-Based Assessments with Eye Tracking, and Virtual Reality Evaluations. *Front. Psychol.* **2024**, *15*, 1473520. [CrossRef] [PubMed]
35. Lee, J.D.; See, K.A. Trust in Automation: Designing for Appropriate Reliance. *Hum. Factors J. Hum. Factors Ergon. Soc.* **2004**, *46*, 50–80. [CrossRef] [PubMed]
36. Nguyen, B.V.D.; Han, J.; Vande Moere, A. Towards Responsive Architecture That Mediates Place: Recommendations on How and When an Autonomously Moving Robotic Wall Should Adapt a Spatial Layout. *Proc. ACM Hum.-Comput. Interact.* **2022**, *6*, 1–27. [CrossRef]

37. Hauser, S.; Mutlu, M.; Léziart, P.-A.; Khodr, H.; Bernardino, A.; Ijspeert, A.J. Roombots Extended: Challenges in the next Generation of Self-Reconfigurable Modular Robots and Their Application in Adaptive and Assistive Furniture. *Robot. Auton. Syst.* **2020**, *127*, 103467. [CrossRef]
38. Suzuki, R.; Hedayati, H.; Zheng, C.; Bohn, J.; Szafir, D.; Do, E.Y.-L.; Gross, M.; Leithinger, D. RoomShift: Room-Scale Dynamic Haptics for VR with Furniture-Moving Swarm Robots. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*; ACM: New York, NY, USA, 2020; pp. 1–11.
39. Basu, T.; Bannova, O.; Camba, J.D. Mixed Reality Architecture in Space Habitats. *Acta Astronaut.* **2021**, *178*, 548–555. [CrossRef]
40. Lawrence, J.; Goldman, D.; Achar, S.; Blascovich, G.M.; Desloge, J.G.; Fortes, T.; Gomez, E.M.; Häberling, S.; Hoppe, H.; Huibers, A.; et al. Project Starline: A High-Fidelity Telepresence System. *ACM Trans. Graph.* **2021**, *40*, 1–16. [CrossRef]
41. Creswell, J.W.; Creswell, J.D. *Research Design*, 5th ed.; SAGE: Los Angeles, CA, USA, 2018.
42. Ivankova, N.V.; Creswell, J.W.; Stick, S.L. Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods* **2006**, *18*, 3–20. [CrossRef]
43. Groat, L.; Wang, D. *Architectural Research Methods*, 2nd ed.; Wiley: Hoboken, NJ, USA, 2013.
44. Chaudhuri, A.; Stenger, H. *Survey Sampling*, 2nd ed.; Statistics: A Series of Textbooks and Monographs; CRC Press: Boca Raton, FL, USA, 2020; Volume 181.
45. Holm, S. A Simple Sequentially Rejective Multiple Test Procedure. *Scand. J. Stat.* **1979**, *6*, 65–70.
46. Amrhein, V.; Greenland, S.; McShane, B. Scientists Rise up against Statistical Significance. *Nature* **2019**, *567*, 305–307. [CrossRef] [PubMed]
47. Wasserstein, R.L.; Lazar, N.A. The ASA Statement on P-Values: Context, Process, and Purpose. *Am. Stat.* **2016**, *70*, 129–133. [CrossRef]
48. Bethlehem, J. Selection Bias in Web Surveys. *Int. Stat. Rev.* **2010**, *78*, 161–188. [CrossRef]
49. Nyumba, T.; Wilson, K.; Derrick, C.J.; Mukherjee, N. The Use of Focus Group Discussion Methodology: Insights from Two Decades of Application in Conservation. *Methods Ecol. Evol.* **2018**, *9*, 20–32. [CrossRef]
50. Hsieh, H.-F.; Shannon, S.E. Three Approaches to Qualitative Content Analysis. *Qual. Health Res.* **2005**, *15*, 1277–1288. [CrossRef] [PubMed]
51. Fereday, J.; Muir-Cochrane, E. Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *Int. J. Qual. Methods* **2006**, *5*, 80–92. [CrossRef]
52. Bengtsson, M. How to Plan and Perform a Qualitative Study Using Content Analysis. *NursingPlus Open* **2016**, *2*, 8–14. [CrossRef]
53. Krippendorff, K. *Content Analysis: An Introduction to Its Methodology*, 4th ed.; SAGE Publications: Thousand Oaks, CA, USA, 2019.
54. Sandelowski, M. Real Qualitative Researchers Do Not Count: The Use of Numbers in Qualitative Research. *Res. Nurs. Health* **2001**, *24*, 230–240. [CrossRef] [PubMed]
55. Maxwell, J.A. Using Numbers in Qualitative Research. *Qual. Inq.* **2010**, *16*, 475–482. [CrossRef]
56. Guo, Y.; Logan, H.L.; Glueck, D.H.; Muller, K.E. Selecting a Sample Size for Studies with Repeated Measures. *BMC Med. Res. Methodol.* **2013**, *13*, 100. [CrossRef] [PubMed]
57. Lakens, D. Sample Size Justification. *Collabra Psychol.* **2022**, *8*, 33267. [CrossRef]
58. Rebenitsch, L.; Owen, C. Review on Cybersickness in Applications and Visual Displays. *Virtual Real.* **2016**, *20*, 101–125. [CrossRef]
59. Farmani, Y.; Teather, R.J. Evaluating Discrete Viewpoint Control to Reduce Cybersickness in Virtual Reality. *Virtual Real.* **2020**, *24*, 645–664. [CrossRef]
60. Brookes, J.; Warburton, M.; Alghadier, M.; Mon-Williams, M.; Mushtaq, F. Studying Human Behavior with Virtual Reality: The Unity Experiment Framework. *Behav. Res.* **2020**, *52*, 455–463. [CrossRef] [PubMed]
61. Slater, M. Place Illusion and Plausibility Can Lead to Realistic Behaviour in Immersive Virtual Environments. *Phil. Trans. R. Soc. B* **2009**, *364*, 3549–3557. [CrossRef] [PubMed]
62. Kuliga, S.F.; Thrash, T.; Dalton, R.C.; Hölscher, C. Virtual Reality as an Empirical Research Tool—Exploring User Experience in a Real Building and a Corresponding Virtual Model. *Comput. Environ. Urban Syst.* **2015**, *54*, 363–375. [CrossRef]
63. Lyu, K.; Brambilla, A.; Globa, A.; De Dear, R. An Immersive Multisensory Virtual Reality Approach to the Study of Human-Built Environment Interactions. *Autom. Constr.* **2023**, *150*, 104836. [CrossRef]
64. Friedman, M. The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. *J. Am. Stat. Assoc.* **1937**, *32*, 675–701. [CrossRef]
65. Wilcoxon, F. Individual Comparisons by Ranking Methods. *Biom. Bull.* **1945**, *1*, 80–83. [CrossRef]
66. Kruskal, W.H.; Wallis, W.A. Use of Ranks in One-Criterion Variance Analysis. *J. Am. Stat. Assoc.* **1952**, *47*, 583–621. [CrossRef]
67. Dunn, O.J. Multiple Comparisons Using Rank Sums. *Technometrics* **1964**, *6*, 241–252. [CrossRef]
68. Hertzberger, H. *Lessons for Students in Architecture*; 010 Publishers: Rotterdam, The Netherlands, 1991.
69. Askar, R.; Bragança, L.; Gervásio, H. Adaptability of Buildings: A Critical Review on the Concept Evolution. *Appl. Sci.* **2021**, *11*, 4483. [CrossRef]

70. Rodriguez, J.D.S.; Feng, C.-W. Developing a User-Centered VR Platform for Applying Robotic Furniture. In *Extended Reality*; De Paolis, L.T., Arpaia, P., Sacco, M., Eds.; Lecture Notes in Computer Science; Springer Nature: Cham, Switzerland, 2024; Volume 15027, pp. 3–21.
71. Coburn, A.; Vartanian, O.; Kenett, Y.N.; Nadal, M.; Hartung, F.; Hayn-Leichsenring, G.; Navarrete, G.; González-Mora, J.L.; Chatterjee, A. Psychological and Neural Responses to Architectural Interiors. *Cortex* **2020**, *126*, 217–241. [CrossRef] [PubMed]
72. Vartanian, O.; Navarrete, G.; Palumbo, L.; Chatterjee, A. Individual Differences in Preference for Architectural Interiors. *J. Environ. Psychol.* **2021**, *77*, 101668. [CrossRef]
73. Matheson, R. Robotic Interiors: Smart Furniture Transforms Spaces in Tiny Apartments into Bedrooms, Work Spaces, or Closets. Available online: https://news.mit.edu/2018/startup-ori-robotic-furniture-0131 (accessed on 14 August 2026).
74. Shove, E.; Watson, M.; Hand, M.; Ingram, J. *The Design of Everyday Life*, 1st ed.; Cultures of consumption series; Berg: Oxford, UK, 2007.
75. Weiser, M.; Brown, S. The Coming Age of Calm Technology. In *Beyond Calculation: The Next Fifty Years of Computing*; Denning, P.J., Metcalfe, R.M., Eds.; Springer: New York, NY, USA, 1997; pp. 75–85.
76. Cannizzaro, S.; Procter, R.; Ma, S.; Maple, C. Trust in the Smart Home: Findings from a Nationally Representative Survey in the UK. *PLoS ONE* **2020**, *15*, e0231615. [CrossRef] [PubMed]
77. Schomakers, E.-M.; Biermann, H.; Ziefle, M. Users' Preferences for Smart Home Automation–Investigating Aspects of Privacy and Trust. *Telemat. Inform.* **2021**, *64*, 101689. [CrossRef]
78. Aggarwal, N.; Singh, S. Embracing the Future by Unlocking the Door to Smart Living: A Systematic Review of Consumers Adoption and Acceptance of Smart Home Devices. *NMIMS Manag. Rev.* **2024**, *32*, 231–244. [CrossRef]
79. Fakhr Hosseini, S.; Lee, C.; Lee, S.-H.; Coughlin, J. A Taxonomy of Home Automation: Expert Perspectives on the Future of Smarter Homes. *Inf. Syst. Front.* **2025**, *27*, 449–466. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.