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RESEARCH ARTICLE

Buildings as macro-cognitive artefacts: Material engagement theory and the architecture of thinking-through-things—The case of Moriyama House

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Metaplasticity

Abstract This study redefines the ontological status of architecture through the framework of Lambros Malafouris's Material Engagement Theory (MET). Moving beyond paradigms that treat buildings as passive settings or symbolic forms, it argues that architecture operates as a macro-cognitive artifact—an active, constitutive participant in cognitive life. The investigation centers on Ryue Nishizawa's Moriyama House, a radically fragmented Tokyo residence that serves as an exemplary "theoretical probe" for tracing the dynamics of material engagement in situ.

The analysis is structured around five core MET processes that illuminate the archaeology of cognitive behavior—the layered, historical emergence of thought patterns through material forms: (1) Thinging, or thinking-through-materials; (2) Enactive Signification, where meaning (like "privacy" or "gathering") is not represented but performed through bodily engagement; (3) Participatory Agency, which co-constitutes action within human-nonhuman intra-actions (4) We-Intentionality, where shared goals materialize through triadic intra-actions among heterogeneous actors; and (5) Metaplasticity, the long-term, reciprocal reshaping of inhabitant habits and architectural wear.

Employing a hybrid methodology of architectural analysis and frame-by-frame deconstruction of the ethnographic film Moriyama-San, the research demonstrates how these processes coalesce to form a cognitive habitat.

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1. Introduction

The shift toward embodied, embedded, enactive, and ecological paradigms in cognitive science has relocated the mind from the isolated brain to the dynamic interplay of organism and environment. Consequently, architecture can no longer be theorized as a mere backdrop for human activity but must be understood as an active participant in cognitive and perceptual life. Recent scholarship at the intersection of cognitive science and architectural theory has begun to illuminate how built environments actively shape perception, action, and social dynamics. Pioneering work by Mallgrave (2010) established foundational connections between neuroscience and architectural design, arguing that spatial experiences are fundamentally embodied.

The material turn in cognitive science has further deepened these connections by foregrounding the entangled relationships between cognitive environments and human—non-human entities. Within this contemporary trajectory, MET, as developed by Lambros Malafouris, offers a transformative lens—building upon, yet moving beyond, the foundational insights of 4E cognition frameworks. MET's specific contributions to architectural research are explored in detail in the first section of this paper.

The author operationalizes MET through a case study of the Moriyama House by Ryue Nishizawa. Its radical fragmentation into ten discrete units on a Tokyo plot dismantles conventional domestic typologies. This design does not simply host activity; it acts as a "theoretical probe," making hyper-visible the everyday cognitive coupling between residents and their environment. It thus presents an ideal site to investigate architecture as a macro-cognitive artifact.

Drawing on recent theoretical and empirical advancements, the study aims to elucidate key concepts, position its findings within contemporary knowledge, and demonstrate how the built environment actively participates in cognitive processes rather than merely influences them. Specifically, it investigates the Moriyama House, designed by Ryue Nishizawa, as a case study to illustrate how architectural forms—through the blurring of interior-exterior boundaries, the abstraction of design or spatial divisions, and the flexible clustering of units—actively scaffold and co-constitute cognitive processes.

Accordingly, this study is guided by the following research questions:

Q1 How does the abstractness of architectural design modulate material engagement, and in what ways does it co-constitute human-material cognitive ecologies through acts of conceptual thinking?
Q2 What participatory agencies and affordances are enacted by the minimalist, scaled-clustered plan of the Moriyama House, and how do these affordances scaffold modes of individual and collective engagement?
Q3 In what ways does the Moriyama House function as a site of material engagement, where cognition is enacted through the dynamic intra-action of architectural forms, lived practices, and socio-material intra-actions?

1.1. Methodology

The research comprises two steps (Fig. 1). In the first step, the Moriyama House was analyzed in terms of its design principles, with particular attention to its clustered layout, spatial scale, design abstraction, and the interplay between interior and exterior spaces. This architectural analysis provided the foundational understanding of the house's physical and conceptual framework.

The second step utilizes an ethnographic film of Moriyama-San, recorded by Bêka and Lemoine. The use of ethnographic film addresses the challenges of directly observing life within these buildings due to the private, domestic nature of the residence. The ethnographic film, with its capacity to capture lived experiences in a nuanced and immersive manner, is an appropriate methodological tool to address this limitation. The deconstruction of the film began by takind agential cuts and identifying,categorizing key cinematic moments where the intra-action (Barad, 2003) between the body and its material environment is most pronounced. This entailed breaking the film into individual frames and sequences that exemplify embodied engagements with space, objects, and architectural structures, as illustrated in Fig. 1. The scenes isolated are those where humans and non-humans intra-act, such as brushing teeth in an open-air unit, drying laundry on trees, or transitioning between detached modules. Each of these moments served as a site for analysis, highlighting how the body navigates and reshapes material boundaries.

Key categorization metrics included:

- **Spatial Entanglements:** Exploring the enacted spatial dynamics that emerge from the relational intra-action between architectural elements, human bodies, and non-human agents.
- **Material Intra-Actions:** Analyzing the intra-active roles of diverse actors—such as glass, gravel, roof and vegetation—in shaping affordances, bodily recalibrations, and affective orientations.

Deconstructing a film to explore the relationship between body and matter necessitates a methodological approach that foregrounds the cinematic medium's material, spatial, and performative dimensions. Sarah Pink's Doing Visual Ethnography examines how visual materials, such as films, can serve as research tools for documenting and analyzing cultural practices (Pink, 2021). Ethnographic films often employ techniques such as long takes, observational camerawork, and natural soundscapes to provide an immersive account of architectural spaces as they are. Such films prove to be a suitable methodological tool for capturing and reflecting the realities of everyday life as they unfold, offering a rich visual and narrative documentation of human experiences. In this regard, film extends beyond storytelling as a critical tool for documenting the nuances of everyday practices within specific spatial and cultural contexts (Nichols, 2001). This capacity aligns with the broader role of visual media, including photography and cinema, in capturing and circulating architectural narratives and their associated social practices (Pink, 2006).

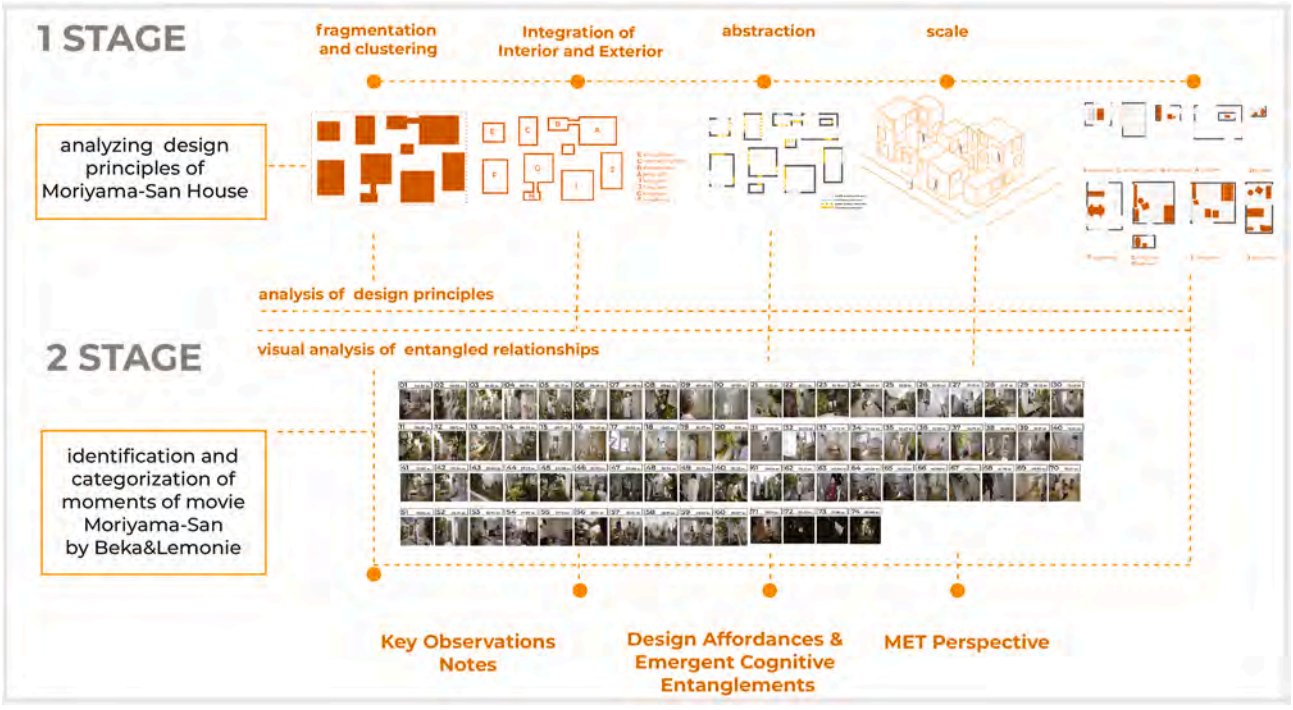

Fig. 1 Research methodology: architectural analysis and ethnographic film deconstruction.

Bêka and Lemoine's Moriyama-San exemplifies this ethnographic approach to filmmaking, where life within the architectural structure becomes the focal point of exploration (Bêka and Lemoine, 2023). Ila Bêka emphasizes that the essence of their films lies in documenting the ordinary rhythms of life within buildings, shedding light on the lived experience of architectural spaces rather than their abstract formal qualities (Bêka and Lemoine, 2017). This approach bridges architecture and filmmaking, inviting a deeper understanding of how daily intra-actions inhabit, perceive, and transform spaces. Using MET as the analytical framework, the paper analyzes the film as a record of material engagement, enabling a close examination of how bodies and materialities intra-act and co-constitute emergent properties within the spatial and temporal boundaries of the film. By combining these two steps, the research bridges the house's tangible and intangible design aspects with the emergent cognitive processes shaped by its lived experience.

It is important to note that within the framework of MET, the methodological outcomes of this study are understood as situated rather than universal. Since cognition is enacted through culturally and materially specific engagements, the findings derived from the Moriyama House are inseparable from the socio-material context of Tokyo in which they unfold. Even if the same architectural configuration were transposed to a different cultural and environmental setting—such as Türkiye—the resulting patterns of material engagement, affordance perception, and enactive signification would differ. This divergence stems from MET's emphasis on metaplasticity—the reciprocal adaptation between material forms and the embodied, culturally sedimented practices of their users. In this sense, the methodology recognizes architecture not as an isolated variable but as a dynamic participant in a broader cognitive ecology, whose manifestations depend on local habits, sensory expectations, and social codes of intra-action. The study, therefore, approaches the Moriyama House as an empirically bounded yet theoretically generative case through which the situatedness of material cognition can be examined and compared across typologies and cultures.

2. Material engagement and the enactive constitution of space: architecture as cognitive intra-action

Contemporary cognitive science has increasingly shifted from brain-centric models toward ecological and embodied frameworks, viewing the mind, body, and environment as an integrated system. Within this perspective of cognitive ecology, human thought and perception unfold not in isolation but through continuous intra-actions with physical surroundings (Heras-Escribano, 2021). Early post-cognitivist approaches—such as embodied, embedded, enactive, and extended cognition—laid the groundwork by demonstrating that cognition is relational and distributed across the brain, body, and world. While the 4E frameworks emphasize the distributed coupling of mind and environment, MET extends this paradigm by foregrounding the constitutive role of materiality itself. It departs from representational models by proposing that meaning and intentionality are enactively generated through material transactions rather than mentally represented. For instance, ecological psychology's theory of affordances (Gibson, 1979) emphasizes that organisms perceive actionable possibilities within the environment. These affordances are not fixed properties of objects but emergent relations—where a staircase invites climbing, and a window affords looking through—that exist

only through intra-action between an organism and its environment (Heras-Escribano, 2021).

Positioning MET within contemporary cognitive and architectural theory clarifies its distinct contribution. While phenomenological approaches (e.g., Pallasmaa, 2012) share MET's commitment to embodied, lived experience, MET provides a process-based account of how materiality constitutively shapes cognition through mechanisms like metaplasticity (Malafouris, 2013). Similarly, MET builds upon but extends Gibsonian affordance theory (Gibson, 1979): where affordances are typically seen as perceived possibilities for action, MET emphasizes their enactive signification—how a feature like a windowsill becomes a seat through the very act of sitting, a meaning co-constituted in real-time engagement (Malafouris, 2013, 2019). Crucially, MET also advances debates within 4E cognition itself. Where the Extended Mind hypothesis (Clark and Chalmers, 1998) argues that external artefacts can serve the function of mental states (e.g., a notebook serving as memory), MET posits a more radical, constitutive entanglement: cognition does not simply extend into the world; it emerges from the dynamic, reciprocal engagement between the brain, body, and material environment (Malafouris, 2013, 2021). This focus on constitutive material agency is what allows us to analyze a building not merely as a setting for cognition, but as a macro-cognitive artifact and a cognitive agent in its own right.

Such insights position buildings and designed spaces as integral to cognitive activity rather than passive backdrops. The built environment functions as part of our cognitive apparatus—a scaffold shaping memory, attention, and behavior (Overmann, 2023). Studies of material culture further suggest that even abstract cognitive domains (like mathematics) arise through engagement with material media, underscoring that thinking itself is inseparable from "thinging," or thinking through things (Malafouris, 2020; Overmann, 2023). Architecture, therefore, becomes a key node in our distributed mind: a structured cognitive ecology that hosts and participates in mental processes (Aston, 2022; Malafouris et al., 2024).

Here, MET provides a robust framework for articulating this intertwining of architecture and cognition. Developed by Malafouris and Renfrew, MET reconceptualizes cognition as a dynamic entanglement of brain, body, and material world (Malafouris, 2013; Malafouris et al., 2024; Alessandroni and Malafouris, 2023; Renfrew, 2004; Malafouris and Renfrew, 2010). This view challenges the conventional inner/outer divide by asserting that materiality is an active constituent of the mind, not merely its context or output. Cognitive processes thus become transactions crossing the skin barrier—thinking happens with and through environmental materials (Alessandroni et al., 2024). In MET's terms, a building is not just a container for cognitive agents; it is itself a cognitive artifact that augments and reconfigures agency and intentionality. As minds extend into architectural forms, people adopt built structures to support remembering, problem-solving, and sense-making. Consequently, agency is redefined as participatory—distributed across persons and the things they engage with (Malafouris, 2014; Overmann, 2023).

Other MET concepts underscore this dynamism: metaplasticity and enactive signification. Metaplasticity denotes the recursive co-adaptation between the brain's plasticity and material culture's malleability. Human cognition evolves through historically sedimented engagement with material things, which shape and are shaped by neural structures (Malafouris, 2013, 2014). Architecturally, metaplasticity explains how repetitive engagement with built forms—thresholds, staircases, walls, windows—reshapes bodily postures, action possibilities, and perceptual expectations over time.

Enactive signification, meanwhile, challenges representational views of meaning by proposing that meaning does not preexist signs but emerges through embodied material engagement. For MET, signified and signifier co-emerge: meaning is enacted through doing, not referenced from mental symbols (Malafouris, 2013; Iliopoulos, 2019). A doorway does not merely symbolize passage; it becomes meaningful through acts of crossing, hesitation, or bodily alignment. Architecture, therefore, enacts meaning through spatial practices rather than illustrating it.

Experimental research supports this participatory, dynamic view. A longitudinal study (Franchak and Adolph, 2013) tracked how a pregnant woman's affordance thresholds for passing through doorways changed weekly during pregnancy and postpartum. While her body dimensions increased, raising the threshold for successful passage, her performance variability remained stable. This suggests that despite bodily mutability, individuals perceptually co-constitute action boundaries through continuous material engagement—a process Iliopoulos (2019) terms "enactive discovery." Here, new cognitive contents emerge from recursive, embodied recalibration with materials and affordances, not preexisting mental representations. Notably, affordance thresholds were consistently lower than torso size, indicating active bodily compression and dynamic environmental adjustment. Such findings confirm that affordances arise from context-sensitive body-architecture intra-actions, exemplifying MET's premise of cognition enacted through material engagement.

Moreover, intentions are not solely private mental states but situated activities emerging from organism-environment coupling. Malafouris et al. (2024) describe human intentionality as fundamentally ecological and participatory: we form intentions with things, not merely about them. For example, a wall can "hold" an intention—offering privacy or support—that materializes only through human engagement. This is not to endow the wall with a mind, but to recognize that its material properties (its height, opacity, and solidity) are non-negotiable participants in the enactment of human intentions. Architecture thus contributes to "we-intentionality," where people and material settings jointly enact goals (Malafouris et al., 2024). Even developmental research supports this distributed view: infants understand others' actions by coordinating with adults and objects in triadic intra-actions, not mind-reading in a vacuum (Vietri et al., 2023). Intentionality is therefore an emergent property of intra-active systems, co-constituted through human-thing entanglement.

Within architectural design, this implies materials and spaces possess agency in cognitive ecosystems. Buildings continuously "act back" on occupants, cueing behaviours, constraining actions, and creating possibilities for thought and social intra-actions (Heras-Escribano, 2021; Alessandroni et al., 2024). A staircase, for instance, does more than

connect floors—it organizes movement and attention, teaching rhythms of ascent/descent while shaping social encounters on landings. Similarly, wall texture or window transparency guides touch and gaze, steering experiential flow. MET frames these effects as emergent cognitive properties: building and user form a hybrid system producing qualities (wayfinding ease, ambience, intimacy) neither could achieve alone.

Phenomenological approaches (e.g., Pallasmaa, 2012) emphasize architecture's multisensory role in structuring lived experience, aligning with enactive cognition. Kirsh's (2013) studies of workspace design reveal spatial configurations as external cognitive artefacts, complementing Hutchins' (1995, 2010) distributed cognition theory. Recent studies quantify these relationships: Zhang et al. (2023) showed ceiling heights modulate perceived autonomy, while Harries (2020) investigates the affective and atmospheric materiality of therapeutic spaces. Whereas Rietveld and Kiverstein's (2014) ecological-enactive approach treats architecture as affordance networks, MET uniquely positions materials as co-constitutive of cognition. This distinction remains underdeveloped, even in material assemblage analyses (De Landa, 2015; Tylén and McGraw, 2014), which lack MET's focus on metaplastic cognitive emergence. Recent MET advances clarify dynamics further: Alessandroni et al. (2024) reconceptualize conceptual thinking as ecologically emergent, while Malafouris et al. (2024) reframe shared intentionality as human-material-environment intra-action—resonating with Overmann's (2023) historical analysis of material-scaffolded numerical cognition.

Critically, these emergent properties feedback into human cognition—influencing mood, memory, decision-making, and creativity. As Aston (2022) illustrates archaeologically, a marble figure's aesthetic experience arises through material-maker dialogue. Likewise, architectural design "speaks" to users via affordances and resistances, actively shaping thought and action. Far from neutral, the built environment saturates daily life with cognitive invitations: benches afford rest, plazas encourage gathering, labyrinthine layouts encourage exploration. These cues exemplify MET's "material agency" (Malafouris, 2013, 2019, 2021; Overmann, 2023)—not implying buildings have minds, but that through design, they participate in directing attention, action, and social coordination. Architecture thus becomes an enactive cognitive partner, co-creating thought and behavior.

It might be countered from a traditional cognitivist perspective that the brain remains the irreducible locus of cognition, with the environment serving as mere input. MET responds by reframing the brain not as a sole cause but as a crucial component in a larger cognitive system (Malafouris, 2013). The empirical evidence of dynamic affordance calibration (Franchak and Adolph, 2013) demonstrates that cognitive boundaries are not pre-computed but emerge through ongoing organism-environment intra-action.

Recent scholarship applying MET to architecture increasingly highlights the built environment's role in co-constituting human cognition. For instance, Mulder (2022) frames the Rietveld Schröder House as a cognitive partner for its inhabitant, demonstrating through decades of spatial reconfiguration how buildings function as evolving cognitive artefacts. In design practice, Bardt (2022) emphasizes the critical role of material resistance and sensory feedback, arguing for a material-based design theory that recaptures meaning. From a MET perspective, she questions the long-term impact of digital tools on creativity, warning of a potential disconnection from the embodied, materially responsive nature of architectural thinking.

This perspective is extended into digital realms by Poulsgaard and Malafouris (2023), who conceptualize "digital materiality" to illustrate how computational design tools serve as cognitive media that mediate enactive perception and situated imagination. At the urban scale, Weissenborn (2022) proposes that MET can be applied beyond architecture to urban morphology. His synthesis bridges MET with Space Syntax theory and Synergetic Inter-Representation Networks, modeling urban form as an artifact of distributed, nonlinear processes involving both human and non-human agencies. Further enriching this discourse, craft research reveals the nature of "hand intelligence," suggesting that when designers use materials like clay, the enactive nature of material engagement directly influences the design outcome. This process reflects the material's attributes and affordances, enabling embodied cognition and leveraging the powerful know-how of tacit experience (Groth and Mäkelä, 2016). Notably, changing materials and encountering their limits are fundamental aspects of material engagement that can themselves trigger design transformation.

Building on these foundations, this study positions the Moriyama House as a paradigmatic site for exploring architecture as a cognitive habitat. It advances the discourse by examining how the house's fragmented spatial configurations and minimalist material cues dynamically scaffold human cognition through lived, material engagement.

Reconceptualizing buildings as entangled in cognition carries significant implications. Architecture should be studied and designed not just for form/function, but as integral to thought, experience, and development. Architectural environments are cognitive habitats, affording specific mental states and skills while discouraging others, thereby shaping cognitive abilities over time (Vietri et al., 2023). For example, a school's spatial layout scaffolds childhood learning and social intra-actions, much as objects scaffold infant concept formation (Alessandroni et al., 2024; Vietri et al., 2023). Ultimately, well-designed spaces engaging participatory agency can amplify creativity, collaboration, and well-being—aligning with MET's call for ecological-enactive design: recognizing buildings not as static shells, but as ongoing material dialogues with occupants (Malafouris et al., 2024).

3. Design principles: the case of Moriyama House

The Moriyama House, designed by Ryue Nishizawa, features a fragmented design of ten cubic units arranged as individual clusters. Each unit is designated for specific functions, such as living, sleeping, or dining, forming a modular and flexible layout. These clusters are dispersed across the site and interspersed with private gardens, which blur the boundaries between indoor and outdoor spaces. The design emphasizes visual permeability and spatial continuity

through the integration of gardens (Bêka and Lemoine, 2023; Kotsioris, 2019).

3.1. Fragmentation, clustering and thresholds

The house is composed of ten independent cubic units scattered across the site. Each unit functions as a self-contained "mini-house", as illustrated through the designated distributed functions mapped in Fig. 2. Unlike traditional zoning principles, where circulation areas and functional units are stacked or arranged in enclosed spaces, the distribution of units in this design adopts a more decentralized approach (Fig. 3). The building units cluster within the site boundaries, fostering a permeable relationship with the street. These units are situated within a garden, with spaces of varying degrees of privacy, such as bathrooms and living areas, dispersed independently across the garden (Figs. 2 and 3). This arrangement blurs the boundaries between interior and exterior spaces, creating a dynamic interplay between privacy and publicness while enhancing the connection between the built environment and its natural surroundings.

3.1.1. Integration of interior and exterior

The design of the Moriyama House radically redefines the relationship between exterior and interior spaces, dissolving the conventional boundaries that typically separate these realms in residential architecture (Fig. 3). By distributing the dwelling into multiple detached units organized around a shared garden, the layout eliminates the clear distinction between "inside" and "outside" conditions. Instead, it cultivates a fluid and dynamic spatial dialogue in which interior environments continuously bleed into the exterior landscape.

Large operable windows and translucent wall panels amplify this porosity by allowing natural light, ventilation, and visual access to greenery to permeate the interiors (Fig. 4). When opened, these apertures maximize spatial functionality, extending domestic practices outdoors and enabling a multiplicity of interior—exterior combinations. Conversely, when closed, each unit transforms into an autonomous, self-contained entity, forming a cluster of discrete yet interconnected structures along the narrow street.

The use of diverse materials—transparent, semi-transparent, and mobile architectural components—further enhances embodied and cognitive engagement by encouraging residents to negotiate spatial thresholds through movement, visibility, and the manipulation of light. These affordances support a continuously dynamic coupling of spatial experience that aligns with the enactive and ecological dimensions of cognition.

3.1.2. Scale

The Moriyama House is characterized by its exceptionally minimal scale, with each unit conceived as a compact, self-contained architectural entity. The precise dimensions of these units reflect an intentional reductionism aimed at maximizing efficiency within limited space.

- Building A: 22.4 m^2 (5.6 m $\times$ 4.0 m)
- Building B: 5.22 m^2 (2.9 m $\times$ 1.8 m)

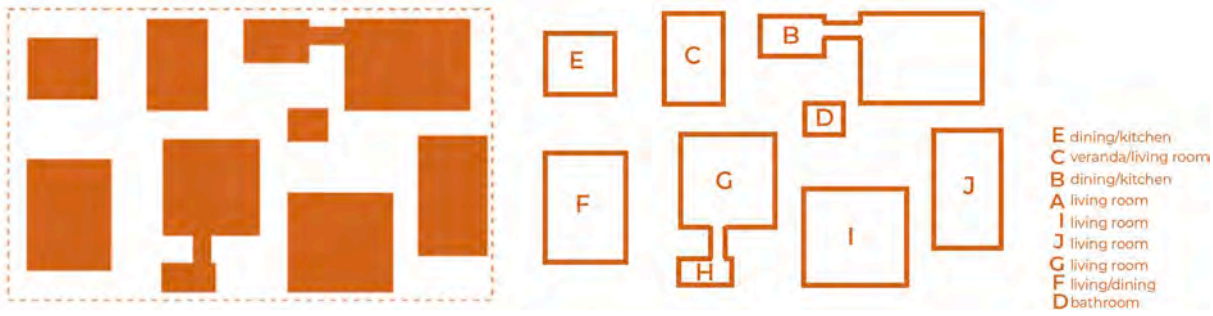

Fig. 2 Clustered design and functions distributed among the ten units in Moriyama House.

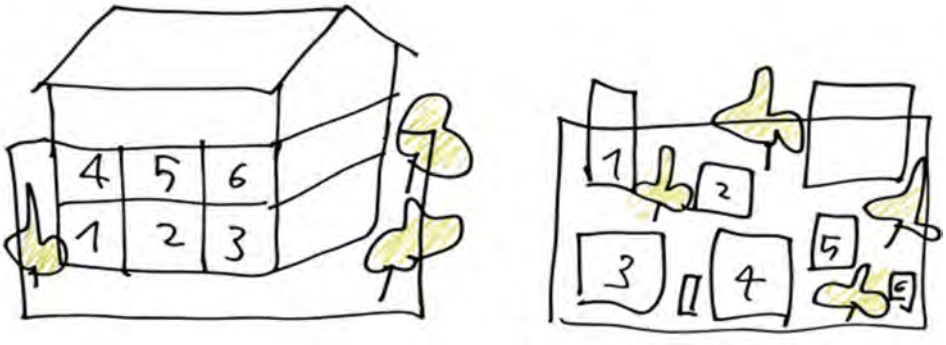

Fig. 3 Conventional housing cluster versus Moriyama House arrangement (Kotsioris, 2019).

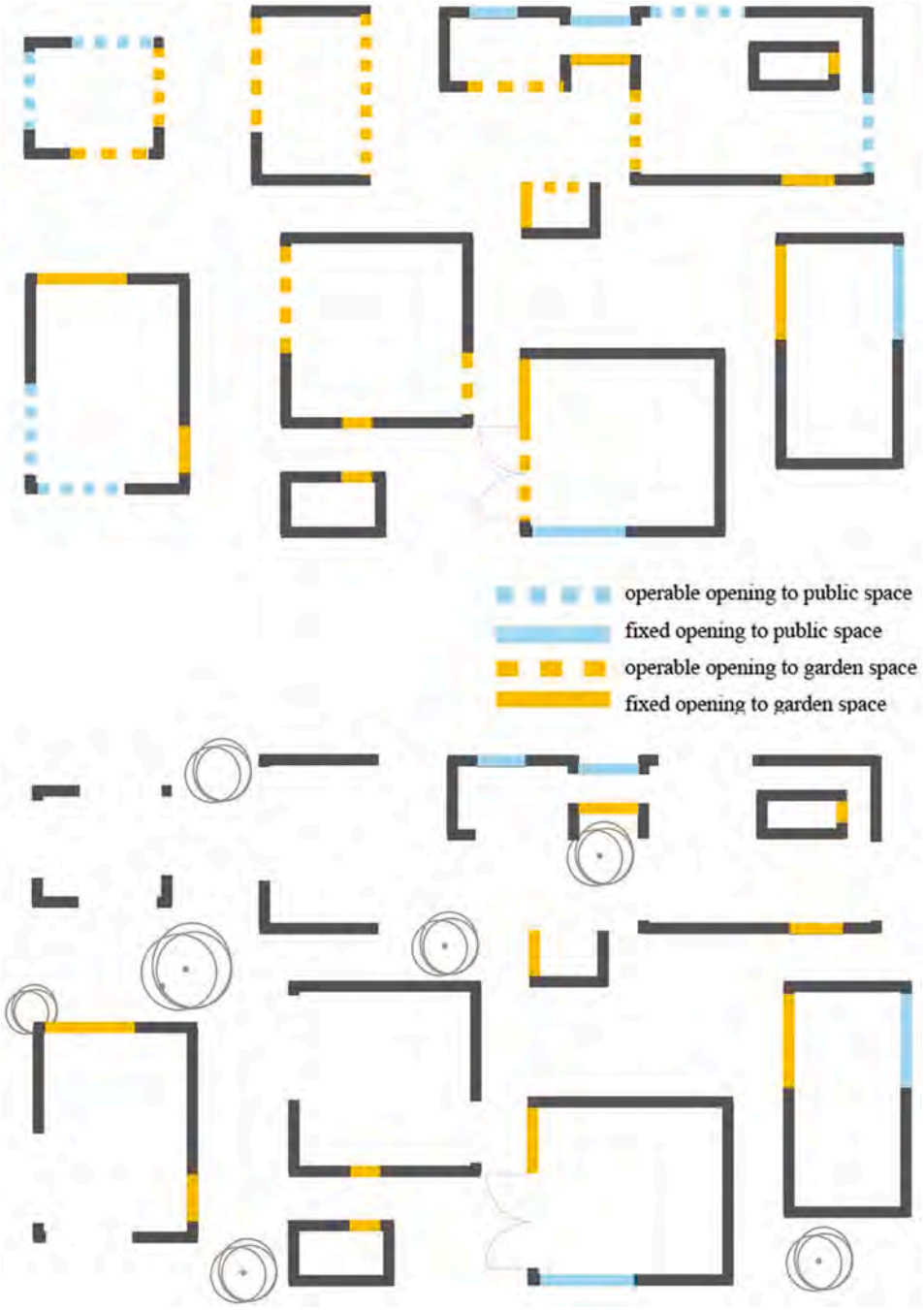

Fig. 4 Diagrams illustrating different possibilities of interiority and exteriority. Merging spaces with the garden through windows and doors creates infinite array of possibilities for combinations and novel interior and exterior scenarios, fostering hybridizations and new configurations.

- Building C: 10.8 m^2 (2.7 m × 4.0 m)
- Building D: 2.16 m^2 (1.8 m × 1.2 m)
- Building F: 9.99 m^2 (3.7 m × 2.7 m)
- Building G: 19.36 m^2 (4.4 m × 4.4 m)
- Building H: 2.99 m^2 (2.3 m × 1.3 m)
- Building I: 19.74 m^2 (4.7 m × 4.2 m)
- Building J: 14.84 m^2 (5.3 m × 2.8 m)

This radical minimalism is not limited to spatial volume but extends to interior furnishings. Most units lack fixed furniture altogether, except for essential elements like kitchen counters. Instead, residents engage with adaptable furnishings, allowing flexible and situated uses of space. As Figs. 5 and 6 illustrate, this functional essentialism fosters embodied spatial practices and material

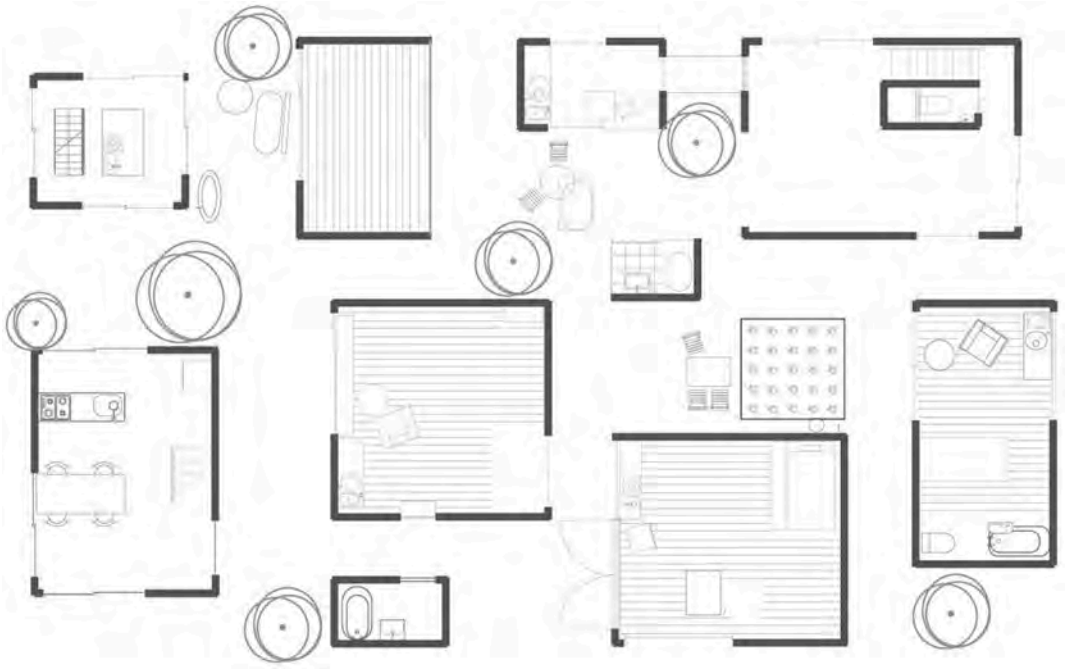

Fig. 5 The scale of Moriyama House and interior furnishings.

Fig. 6 The adaptable interior furnishings of different units in Moriyama House.

improvisation—key aspects of the enactive and ecological dimensions of cognition.

4. Research findings: ethnography of the entanglement of human-non-human intra-actions in the film Moriyama San

When Moriyama-San is deconstructed through its filmic scenes (Fig. 7), the entangled relationships between body and material environments reveal the emergent cognitive capacities embedded within these intra-actions. Each identified and categorized frame illustrates how architectural thresholds, adaptable configurations, and fluid interior—exterior transitions actively contribute to the co-constitution of cognitive experience (Fig. 6). From the perspective of MET, spatial—material arrangements do not merely represent thought—they enact it, participating constitutively in the very process of thinking-through-things. Cognition, in this view, is not extended into the material world but emerges within it, through the dynamic coupling of cognition between human—material engagement.

In this context, the film becomes not just a representational medium but a methodological tool, enabling the analysis of embodied engagements within the house. It presents the Moriyama House as both a spatial structure and a cognitive landscape in which bodily practices and material affordances dynamically negotiate. The analysis of the film, particularly its architectural settings and human and non-human entanglements, reveals four interrelated themes that emerge from the spatial logic of the house: (1) adaptable interiors shaped by minimalist scale, (2) thresholds and blurred boundaries, (3) the fluid interface between interiority and exteriority, and (4) thresholds as sites of community intra-action and collective engagement.

4.1. Adaptable spaces and scale

The design of Moriyama House's spaces, characterized by minimalism, modularity, and an absence of fixed furniture, disrupts conventional notions of architecture, resulting in new material intra-actions. The analyzed scenes from the movie, focusing on the adaptable interiors, are detailed in Table 1.

Fig. 7 Scenes from the film Moriyama-San by Bêka and Lemoine (2017).

- **Floors and Stairs as Sites of Thinging**

Within the Moriyama House, horizontal and sloping planes are primary sites for thinging—the process of thinking through the material world. The film reveals how the minimalist design, which eschews fixed furniture, transforms the floor and stairs from inert surfaces into active cognitive partners.

The wooden floor is repeatedly engaged as a site for rest and work (Scenes 01, 02, 30, 35, 37, 70 in Fig. 8). The postures Moriyama adopts—lying fully extended, sitting cross-legged, or leaning back onto his hands—are not arbitrary but are direct, embodied negotiations with the floor's affordances. This is not a passive use of a platform but an active thinking-through-the-floor; the solution for comfort and support is found in the dynamic coupling of body and material, not in a pre-planned arrangement.

Similarly, the stairs (Scenes 16, 32 in Fig. 8) transcend their nominal function as circulation tools, becoming modular platforms for work, sitting, or storage. These are not their canonical functions but are enactive significations that emerge through bodily engagement with the specific geometry of stairs.

- **Objects as Active Participants in Enactive Spatial Organisation**

Across the scenes (19, 40, 69, 70 in Fig. 8 and Table 1), the arrangement of furniture and objects demonstrates how spatial functions are not predetermined but co-emerge through iterative material engagement. The book stacks, chairs, media equipment, and the open floor surface participate in a continuous reconfiguration of domestic practices. Rather than operating as fixed functional units—"a chair for sitting," "a shelf for storing"—these elements form flexible constellations that acquire meaning through use. In Scene 19, for example, books are piled to save space or opened to create a library; function becomes a flexible emergent property through time, space, and need.

Similarly, in Scene 60 (Fig. 8), the floor, speakers, and stacks of books together constitute a listening environment. Without relying on formal programmatic prescriptions. In this sense, furniture and function are not separate categories but are mutually constituted through processes, emerging through the situated, material—semiotic encounters that structure everyday life in the Moriyama House.

This process of enactive signification extends beyond the interior. Scenes 60 and 61 show laundry hung on tree branches, a vivid instance of thinging where the resident thinks through the arboreal affordances. The branch is not a symbol of nature but a co-participant in the domestic chore, its rigidity and height collaborating with the body to enact a drying line. This triadic coupling of human, tree, and cloth dissolves the boundary between the natural environment and the cognitive system of the home.

In this cognitive habitat, furniture and function are not separate categories but are mutually constituted through metaplastic engagement. The house's design provides a field of potentialities, but the specific cognitive and domestic

Table 1 Key observations on adaptive materiality in ınterior and exterior spatial configurations.

Scenes from Fig. 7, interiors	Key observations	Met concept	Met-driven ınsight	Emergent cognitive property
1, 2, 16, 20, 22, 26, 29, 30, 32, 35, 37, 70	Minimalist floors and stairs facilitate direct bodily engagement (sitting, lying)	Thinging	Residents "think through" the floor's materiality to redefine their sitting and resting practices.	Emergence of enactive affordances: Floors are not inert surfaces but active partners in grounding perception (Malafouris, 2013, 2018).
1,2,22,35,37,40,61,69	The absence of fixed furniture forces dynamic object rearrangement	Participatory agency	Spatial functions emerge from the participatory intra-action of users and objects: a Ground becomes a table, a branch becomes a drying rack. Agency is not located in either but distributed across the network of human and material actants.	Distributed intentionality: Intentions (e.g., "I need a workspace") emerge through negotiation with material constraints (Malafouris et al., 2024).
20, 26	Open windows mediate street intra-actions	Enactive signification	Windows do not merely delineate boundaries; they enact privacy and publicness through situated engagement—leaning on the sill, opening the pane, or peering outward becomes a way of thinking and relating through matter.	Fluid thresholds: Privacy is not a fixed property but a cognitive accomplishment co-constituted by glass, posture, and urban context (Alessandroni et al., 2024).
23, 24, 41,42, 44, 45, 48, 60, 66, 72, 73	Modular units reconfigured for varying uses	Metaplasticity	The house's fragmented layout enables metaplastic engagement: Cognitive habits and spatial configurations are co-constituted through material engagement; pathfinding, for instance, emerges from the dynamic resident-space system.	Cognitive mutualism: Residents and materials co-constitutively rewire spatial cognition over time (Malafouris, 2020; Malafouris and Koukouti 2022).

Fig. 8 Material engagement and situational metaplasticity in Moriyama House: everyday objects and architectural elements dynamically reconfigure their roles through enactive use. Scenes from Moriyama-San (Bêka and Lemoine, 2017).

Fig. 9 Blurred interior—exterior thresholds fostering participatory and enactive engagement in Moriyama House. Scenes from Moriyama-San (Bêka and Lemoine, 2017).

practices—the "what it is" and "what it is for"—are continuously brought forth through situated, material intra-actions.

- **Modularity and Cognitive Mutualism**

The fragmented, adaptable layout of the Moriyama House generates cognitive mutualism by distributing agency across its modular units and surfaces. The constrained scale of individual units actively pushes domestic functions outward, forcing a continuous re-appropriation of non-canonical surfaces. Scenes 4, 5, 8, 9, and 13 demonstrate how gardens, transitional zones, and exterior walls become enactive thresholds—sites where activities like planting, resting, or storing are co-constituted through bodily engagement with gravel, vegetation, and built edges.

This functional distribution is further evidenced in Scenes 19 and 31 in Fig. 8. The minimal interior of unit (Scene 19) necessitates that the portable library operates as a cognitive scaffold for organization, while the stairs (Scene 31) enactively signify as hybrid platforms for sitting and pausing. Similarly, the rooftop (Scene 46 in Fig. 8) and garden (Scenes 50, in Fig. 8) become participatory agents in social and domestic life, where modular furniture and tree branches materially mediate gatherings and chores.

Furthermore, this intra-activity of adaptable spaces between user and building is not unique to Moriyama House. Hugo Mulder shows that the Rietveld Schröder House (1924) similarly allows shared agency: its movable partitions create a highly adaptable plan that occupants continuously reconfigure.

4.2. Thresholds and blurred boundaries

In the Moriyama House, thresholds are reconceptualized through MET as active cognitive artefacts that dissolve the conventional divide between mind and materiality. Rather than serving as passive transitions, these liminal spaces exemplify participatory agency, metaplasticity, and enactive signification, illustrating how architectural boundaries dynamically co-constitute perception, sociality, and embodied cognition (see Table 2).

- **Thresholds as Enactive Signifiers of Hybrid Ecologies**

Scenes 03, 04, and 05 in Fig. 9 demonstrate thresholds operating as enactive signifiers where spatial categories dissolve through direct material engagement. The semi-outdoor garden zones do not merely blur the lines between nature and culture; they enact ecological entanglement through situated practices, such as gardening in transitional areas. The visual documentation shows residents moving through garden zones not as transitions between domains, but as participants in continuous ecological entanglement. In Scenes 08 and 13, gardening practices and petcare in these transitional areas reveal how soil, tools, and vegetation co-constitute the very meaning of "garden" through situated action. For instance, a resident tending plants in a blurred garden-living zone (Scene 08, 28 in Fig. 9) does not simply "cross" a boundary but performs it into being through tactile intra-actions with soil, tools, and vegetation.

Scenes 14 and 28 in Fig. 9 capture how these thresholds function as cognitive hybrids - surfaces that simultaneously afford circulation, rest, and social observation. The material continuity between gravel paths, interior floors, and built edges creates what MET would frame as fluid cognitive ecologies, where perceptual boundaries emerge through bodily negotiation rather than architectural delineation.

- **Participatory Agency and Enactive Signifiers of Thresholds**

The house's windows (Scenes 27, 41, 42 in Table 2 and Fig. 9) do not simply mediate indoor-outdoor transitions;

Table 2 Key Observations on threshold scenes and their materiality in ınteriority/exteriority.

Scenes from Fig. 7, on thresholds	Key observations/notes	Met concept	Met-driven ınsight	Emergent cognitive property
3, 4,5,8,9, 10,11,12,14, 23, 29	Semi-outdoor spaces blur the boundaries between gardens and living spaces, merging natural and human-made environments.	Enactive signification	Thresholds do not represent nature-culture divides; they enact hybridity through situated use (e.g., gardening in transitional zones).	Fluid habitats: Nature and architecture co-constitute meaning via material engagement.
2, 14, 22, 26, 29, 73	Thresholds enable seamless transitions between private and public zones.	Participatory agency	The agency is distributed across bodies and thresholds: Door height and width invite specific postures (bowing, leaning).	Distributed intentionality: Movement patterns emerge from the negotiation of body thresholds.
60, 61	Trees are used for drying clothes blending functional and organic elements.	Metaplasticity	Trees and users reciprocally adapt: Branches become tool extensions, while use reshapes the growth of trees over time.	Cognitive mutualism: Human-tree collaboration fosters the development of new domestic practices.
8, 11, 13, 44	Gardens integrate ecosystems into functional and experiential design.	We-intentionality	Shared goals (e.g., fostering biodiversity) emerge from human-nature coordination (watering, planting).	Ecological co-agency: Intentions materialize through collaborative care of plants/soil.
20, 22, 26, 29	Windows act as transitional spaces, blurring the boundaries between indoor and outdoor areas.	Thinging	Residents think through window ledges: Hardness/texture informs sitting habits, redefining "furniture."	Embodied affordances: Ledges become cognitive tools for rest and work through tactile engagement.
14, 26, 27, 29, 41,42	Thresholds serve as liminal, multifunctional zones (e.g., window seating).	Metaplasticity	Thresholds adapt to user needs (e.g., seating becomes a workspace), while users adapt to threshold constraints.	Cognitive plasticity: Thresholds and users co-evolve, rewiring spatial habits.

they enact conditions of privacy and publicness through their situated use.

The windows in the Moriyama House function as enactive thresholds where material agency is paramount. Their specific geometry and location co-constitute novel functional practices: sill dimensions afford sitting and leaning, enactively signifying each window as a hybrid platform (Scenes 14, 22, 26 in Fig. 9). Crucially, their adaptable nature—often featuring closable curtains—allows them to be reconfigured into screened or opaque surfaces, actively transforming the space into a private, enclosed environment. This network of mutable openings forms a distributed cognitive ecosystem for navigating social space. A street-facing window (Scene 27 in Fig. 9) scaffolds public engagement through participatory agency, while a garden-oriented one (Scenes 29, 41 in Fig. 9, detailed explanation in Table 2) supports seclusion. Thus, these thresholds are not static boundaries but active, adaptable zones where the very definitions of "inside/outside" and "private/public" are perpetually negotiated and materially enacted through metaplastic coupling.

Scenes 27, 31, 32 and 37 in Fig. 9 illustrate participatory agency at doorways and windows. Threshold dimensions (e.g., height, width, framing) and material properties (e.g., texture, transparency) do not passively allow movement—they invite specific bodily negotiations. Leaning on a windowsill (Scene 27 in Fig. 9) enacts we-intentionality, where privacy and publicness emerge from the interplay of glass opacity, posture, and street activity. MET thus reframes thresholds as co-authors of social practices, challenging notions of human-centric control.

- **Metaplastic Coupling with Arboreal Affordances and Gardens as We-Intentional Sites**

The ethnographic film reveals that tree branches are not merely background elements but are actively enlisted into the cognitive assembly of domestic tasks. In Scenes 60, and 61 in Fig. 9, residents engage with the specific affordances of branches—their horizontal rigidity, height, and fibrous texture—to perform the work of drying clothes. This is not a one-sided use of a passive object, but a dynamic coupling of emerging solutions to specific functional problems that demonstrates participatory agency.

Scenes 3, 8, 13, and 44 position the garden as a site of we-intentionality, where shared ecological goals (e.g., fostering biodiversity) emerge through triadic coordination between humans, plants, and soil. Watering plants or composting (Scene 13) is not an individual task but a collaborative achievement that involves tools, microorganisms, and seasonal rhythms. These participatory networks dissolve the human/nature dichotomy and exemplify ecological co-agency.

4.3. Interiority/exteriority

The selected scenes deconstruct the interplay between interior and exterior spaces, revealing their fluid boundaries and the emergent cognitive affordances shaped through material engagement. The visual analysis of these scenes, interpreted through the lens of MET, is presented in Table 3.

- **Windows as Enactive Signifiers of Hybrid Cognition**

Scenes 03, 29, 37, and 41 in Fig. 10 show windows and doors enactively signifying a hybrid interior-exterior ecology. These transparent surfaces do not symbolize a connection but materially constitute it, dissolving the cognitive boundary between nature and built block through embodied engagement. In scenes 03, 29, 37, and 41 in Fig. 10, the interior and exterior blend into each other through the openings of windows/doors. Transparent surfaces do not merely symbolize the connection between inside and outside; instead, they enact ecological entanglement of nature and built blocks. When residents dine in the garden (Scene 66 in Fig. 10), the practice emerges from this continuous cognitive habitat, not a crossing between separate domains. From a MET perspective, this exemplifies cognition-in-action: sensory engagement with soil, plants, and airflow dissolves conventional distinctions between the interior and exterior, generating situated knowledge that is irreducible to brain-bound representation.

- **Street-Facing Windows as Participatory Agents**

Scenes 26, 27, and 41 in Fig. 10 demonstrate participatory agency at street-facing interfaces. The operable windows' specific geometry (aperture size, sill height) invites bodily negotiations—leaning, crouching—that co-constitute conditions of social visibility. A resident's torso extending through the frame (Scene 27 in Fig. 10) enacts we-intentionality, where privacy is a cognitive achievement of the human-window-street system.

- **Garden as Metaplastic Cognitive Habitat**

Scenes 44, 47, 48, and 66 in Fig. 10 reveal the garden's metaplasticity. Its transformation into a gathering space, a

Table 3 Material engagement in ınteriority/exteriority scenes: observations, met concepts, and cognitive ımplications.

Scenes from Fig. 7, on interiority/exteriority	Key observations/notes	Met concept	Met-driven ınsight	Emergent cognitive property
23, 24, 25, 28	Garden and transparent windows mediate indoor/outdoor boundaries, fostering multisensory intra-action	Enactive signification	Windows and gardens do not symbolize nature-culture connections; they enact a hybrid spatial logic through daily use	Fluid cognitive habitats: Cognitive categories (indoor/outdoor) dissolve via material engagement.
26, 27, 29	Large openable windows connect the interior to the street.	Participatory agency	Window size and operability redistribute agency: Users and windows co-author social exposure	Distributed intentionality: Privacy becomes a negotiation between body posture and aperture.
44, 63, 66	The garden transforms into a graveyard, garage, or dining area.	Metaplasticity	The garden functions as a metaplastic partner in ritual practices, where burial and memorialization or dining emerge through enactive signification with soil, plants, and tools.	Cognitive mutualism: Mourning rituals co-evolve with the garden's material affordances.
09, 10, 73	Translucent glass balances privacy/publicness.	Thinging	Residents think through translucency's gradient opacity to negotiate visibility (e.g., adjusting proximity to glass to modulate exposure).	Embodied affordances: Privacy emerges from dynamic sensorimotor coupling.
13, 44, 45	The shared garden becomes a habitat for pets and ecosystems.	We-intentionality	Care practices (feeding pets, watering plants) materialize shared goals between humans, animals, and soil.	Ecological co-agency: Intentions distribute across species and materials.
8,11, 12, 60, 61	The garden functions as a transitional space for chores (drying clothes) and socializing.	Participatory agency	Tools (hose, clothesline) and users co-perform tasks: Hanging laundry becomes a human-tool-plant collaboration.	Social metaplasticity: Labor practices emerge from the triadic coupling of humans, objects, and environments.
3, 20, 23, 26, 27, 37 46, 47	Blurred indoor-outdoor transitions enhance sensory connectivity.	Metaplasticity	Repeated transitions rewire both user navigation habits and spatial perception (e.g., paths worn into garden soil guide movement).	Cognitive plasticity: Movement patterns co-evolve with threshold wear.

Fig. 10 Interiority—exteriority relations enacted through threshold intra-actions, where users and material configurations co-constitute spatial meaning in Moriyama House. Scenes from Moriyama-San (Bêka and Lemoine, 2017).

burial site, or a circulation path shows its role as a co-constitutive agent in the emergence of new functions and meanings. The soil, vegetation, and pathways actively participate in shaping rituals and social practices. Thus the garden operates not as a passive backdrop but as a co-constitutive agent in the enactive signification of function and meaning.

- **Translucency as Embodied Thinging**

Scenes 09, 10, and 73 in Fig. 10 illustrate residents thinking-through translucent glass. By sensorimotorly engaging with its opacity gradients—adjusting proximity to modulate visibility—they enactively signify degrees of privacy. The glass is not a predefined barrier but an enactive partner in a continuous negotiation.

- **Multispecies Care as Ecological Co-Agency**

Scenes 8, 11 and 13 in Fig. 10 position the garden as a cognitive habitat that enables the enactment of care practices. This ecology comprises a participatory network of more-than-human agents—the human caregiver, the animal, the water, the soil, and the tools.

- **Laundry as Triadic Cognitive Labor**

Scenes 11, 12, 44, and 60 in Fig. 10 illustrate laundry as a chore enacted through triadic we-intentionality. The activity emerges as a cognitive assembly where the resident's actions continuously coordinate with the participatory agency of non-human elements: the tree branch's rigidity affords hanging. This configuration demonstrates thinging—the resident thinks through the entire assembly rather than merely executing a predetermined plan. What appears as a simple chore is actually an enactive signification process where drying clothes becomes a shared accomplishment of the enacted cognitive system.

- **Worn Paths as Cognitive Metaplasticity**

Scenes 3 and 43 (in Fig. 10) illustrate metaplasticity in movement. Footpaths etched into the garden soil physically inscribe navigation habits, which, over time, shape and guide future movement patterns. This form of cognitive metaplasticity exemplifies a core premise of MET: that users and their environments co-constitute spatial cognition through sustained material engagement.

4.4. Clustered living in minimalistic scale and community engagement

The scenes described focus on the architectural and social affordances of the Moriyama House, particularly how its design fosters community engagement and collective living, as illustrated in Table 4 below.

- **Shared Gardens as We-Intentional Hubs**

Scenes 46, 47, 48, 50, 71, and 72 in Fig. 11 demonstrate how the fragmented layout generates social metaplasticity. The clustered arrangement and varying heights of the white

Table 4 Co-constituted community engagement: MET analysis of the Moriyama House.

Scenes from Fig. 7, on community engagement	Key observations/notes	Met concept	Met-driven ınsight	Emergent cognitive property
46, 47, 48, 51, 71, 72	The shared garden acts as a social hub, with modular units seamlessly integrating into the urban fabric.	We-intentionality	Collective goals (e.g., hosting film screenings) emerge from the coordination of human and material elements (e.g., chairs, sightlines, projector placement).	Social metaplasticity: Group cognition co-evolves with spatial and material configurations.
46, 47,48, 51, 60, 66	Rooftops and gardens extend living space into communal domains.	Participatory agency	Rooftop edges and furniture redistribute agency: Low walls invite sitting, while modular tables enable group negotiation	Distributed intentionality: Social practices emerge from human-object collaboration.
46, 51, 72	Open rooftops with modular furniture adapt to gatherings (e.g., concerts, meetings).	Metaplasticity	Furniture modularity enables mutual reshaping: Users reconfigure seating, which in turn reshapes social dynamics (e.g., from circular to linear arrangements).	Cognitive mutualism: Spatial habits and social patterns co-adapt.
09, 47, 51,60, 63	Shared gardens blend private and communal activities (e.g., gardening, laundry).	Thinging	Residents think through garden tools (hoses, clotheslines) to hybridize labor/leisure (e.g., watering plants while socializing).	Embodied affordances: Tools become cognitive mediators of sociality.
23, 41, 72, 73	The minimalist design blurs the boundaries between private and communal spaces.	Enactive signification	Boundaries do not represent privacy but rather enact it through situated use (e.g., folding screens modulate visibility dynamically).	Fluid social ecologies: Privacy emerges as a collaborative achievement.

Fig. 11 We-intentionality and social metaplasticity enacted through communal spatial arrangements and material affordances in Moriyama House.

cubic units create a series of discrete planar surfaces—flat roofs and blank walls. These pristine planes enactively signify as potential screens and stages through their very geometry and positioning. A film screening (Scene 46, Fig. 11) thus emerges from a triadic coordination: the minimal unit's flat roof serves as a platform, its white wall acts as a projection surface, and modular furniture assembles a collective viewing arrangement. This exemplifies how the clustered minimalism's specific morphology—the arrangement and scale of its parts—co-constitutes group cognition by providing material scaffolds that afford public gathering and shared focus.

This investigation into the architectural configuration of the Moriyama House introduces a novel conceptual articulation: social metaplasticity. This term encompasses the co-emergence and mutual transformation of collective cognitive patterns, rituals, and intentions through sustained engagement with architectural and cultural environments. Social metaplasticity refers to how spatial arrangements and group practices recursively co-emerge through enactive signification, generating participatory forms of cognition enacted through things.

- **Participatory Agency in Scalar Negotiation**

The agency of the clustered units materializes in rooftop social practices across Scenes 46, 51, and 72 in Fig. 11, where flat roofs and blank walls enactively signify as screening surfaces and gathering platforms. This material agency extends to gardens (Scenes 60, 66 in Fig. 11) where trees and transitional spaces co-constitute domestic routines. Through this material engagement, the architecture functions as a metaplastic scaffold where social patterns continuously emerge from resident-space intra-actions.

- **Cognitive Mutualism Through The Clusters**

Scenes 60 and 66 in Fig. 11 reveal how the minimal interior scale distributes domestic functions across the cluster through processes of enactive signification. Laundry (Scene 60, Fig. 11) does not simply "move" to the garden but is enacted as an outdoor practice through the affordances of trees as drying racks. Similarly, emergent function (Scene 71, Fig. 11) emerges not in predetermined quiet zones but through situated engagement with transitional spaces. Hence, the tension between minimal private units and the affordances of the communal areas co-constitutes social and functional patterns through an ongoing material dialogue with residents.

5. Findings of the research: ecological-enactive account of cognition through material engagement theory of Moriyama building

The design of the Moriyama House, including fragmentation and clustering, as well as its interior and exterior design, abstractness, and scale, has certain effects on the entanglement of mind and body and the emergence of an ecological enactive account of cognition. The findings of the research are as follows:

- **Q1: Abstractness as Cognitive Catalyst**

The house's radical abstraction—clean geometries, non-representational forms, and erased boundaries—functions not as aesthetic reduction but as a cognitive infrastructure that enables thinging. By eliminating conventional symbolic cues (e.g., "living room" typologies), the design prompts continuous enactive signification:

- Floors are frequently used as work surfaces.
- Windowsills are used as informal seating and sites of intra-action.
- Garden areas are appropriated as workspaces, garage, dining room, sometimes bathroom.

This abstractness dissolves predefined spatial categories, cultivating fluid habitats in which cognition emerges through sensorimotor negotiation with material properties such as hardness, transparency, and translucency. In this case study, abstraction is not conceived as emptiness but rather as an invitation to co-creation—a scaffold for conceptual thinking wherein meaning materializes through use, aligning with the principles of MET.

- **Q2: Participatory Agency in the Clustered Plan**

The minimalist clustered plan of Moriyama House fosters participatory agency by redistributing cognitive processes across humans, objects, and spatial thresholds:

- **Individual Engagement:** Compact units demand embodied thinging. For instance, the 5.22 m^2 unit necessitates continuous bodily negotiation with walls and floors, transforming residents into spatial bricoleurs who cognitively offload tasks onto material affordances—such as using ledges as improvised desks.
- **Collective Engagement:** Shared gardens embody we-intentionality, where modular furniture not only supports social gatherings but also co-authors them. Its reconfigurability reshapes social dynamics, as circular stool arrangements foster egalitarian dialogue and cognitive alignment among participants.

In this context, scalarity becomes a cognitive device—small spatial dimensions heighten the role of material agency in distributing and reshaping intentionality. At the same time, the very spatial features that enable these forms of material engagement—such as extreme minimalism, the reduction of interior functions, and the externalization of everyday routines—may also generate ambivalent experiences for some residents. While these configurations foster intensified bodily-material intra-actions, they can equally produce discomfort, exposure, or cognitive overload, depending on users' cultural habits, sensory expectations, and personal rhythms. This analysis therefore avoids normative judgments and instead traces how both enabling and constraining effects are enacted materially, without assuming that these outcomes are universally beneficial or desirable.

- **Q3: Architecture as Cognitive Ecosystem**
  The Moriyama House operates as a metaplastic cognitive ecosystem wherein material configurations actively participate in the emergence of thought:

- **Spatial Transitions Enact Cognition**: Thresholds act as sites for the metaplasticity. For example, leaning through a window enacts street engagement through the coordinated agency of glass, body posture, and social context.
- **Materials Encode Memory**: The physical wear on materials serves as a durable record of habitual engagement. Worn paths in the garden gravel (inferred from common use patterns in such designs) physically trace the most frequent navigational routes taken by residents. These paths are not symbolic encodings but are literal, material inscriptions of collective movement. They subsequently function as cognitive scaffolds, guiding future movement and reinforcing the very habits that created them.
- **Multispecies Cognition**: Pet-care practices redistribute intentionality across humans, animals, and tools, framing cognition as a trans-species, materially mediated process.

MET thereby rejects the passive model of buildings as static backdrops, recasting the Moriyama House as a thinking environment—a dynamic agent that evolves in concert with its inhabitants. At the same time, the fragmented configuration that supports flexible patterns of social intra-action may also be experienced as disjointed or alienating by users whose cultural expectations favor continuity, enclosure, or stable domestic boundaries. The same spatial openness that facilitates distributed cognition can equally impose demands related to privacy, coordination, and spatial coherence. For this reason, the analysis treats Moriyama House as a situated cognitive habitat rather than a universally applicable model, acknowledging that its effects are shaped by users' socio-cultural backgrounds and embodied habits.

6. Conclusion

The Moriyama House stands as a seminal case for architectural theory, not merely for its formal innovation but for its profound demonstration of Material Engagement Theory (MET) in practice. This analysis moves beyond describing its aesthetic or phenomenological qualities to reveal its operational logic as a macro-cognitive artifact.

6.1. Synthesis of findings: the house as a cognitive habitat

The investigation confirms that the house functions as a cognitive habitat—a designed environment where cognition is continuously co-constituted through resident-material intra-action. This is achieved through the interconnected dynamics of:

- **Thinging and Enactive Signification:** The radical abstraction and minimalism of the house strip away pre-assigned functions, compelling residents into a continuous process of "thinking-through-materials." Floors become desks, windowsills become seats, and gardens become rooms not by design dictate but through situated, embodied discovery.
- **Participatory Agency and We-Intentionality:** Agency does not reside in individuals alone but emerges from the intra-active network. The clustered plan distributes action potential across bodies, furniture, thresholds, and vegetation. Social events, like film screenings on rooftops, materialize through triadic negotiations (people-chairs-space), exemplifying how shared intentions are co-enacted with the material world.
- **Metaplasticity in Process:** The house is not a finished product but a metaplastic partner. The mutual reshaping is evident in how worn garden paths physically encode collective navigation habits, which in turn guide future movement. This long-term, reciprocal adaptation between inhabitant practices and architectural wear is the hallmark of a living cognitive system.

6.2. Theoretical and practical implications

This reconceptualization carries decisive implications of theory and practical implications:

From the perspective of MET, the Moriyama House offers a productive site to examine how spatial and material configurations enact particular forms of cognitive habitat. However, it is essential to clarify that the forms of enactive signification and affordance relations identified in this case are not uniformly reproducible across all architectural settings. The specific patterns of attention, movement, and intra-action observed—such as the fluid negotiation between public and private thresholds or the distributed use of built elements as scaffolds for habitation—emerge from situated features like volumetric fragmentation, the central positioning of the garden, and the porous circulation between detached units. These features co-constitute a specific socio-material ecology that invites certain forms of embodied engagement while constraining others. Thus, while the analysis substantiates MET's broader claims about the constitutive role of material agency in shaping we-intentionality, further comparative investigations across architectural typologies are necessary. Such inquiry would help illuminate how different built environments—whether compact urban dwellings, introverted courtyard structures, or open-plan configurations— participate in the formation of distinct cognitive habitats and patterns of metaplastic cognitive becoming. Future research should expand this MET-driven framework to track how cognitive habits evolve through decades of resident-material engagement, mapping feedback loops between spatial wear and behavioral adaptation. Contrasting Moriyama's metaplasticity with other clustered designs can make it possible to identify cultural variables in material engagement.

This research demonstrates that applying MET to architecture fundamentally redefines core principles of contemporary design. For example, sustainability is recast not as a static technical achievement, but as a dynamic, relational process of metaplasticity—the capacity of a

human-material system to adapt and flourish over time, preventing obsolescence through continuous co-evolution. Simultaneously, the distribution of agency across people and things challenges the human-centric basis of traditional participatory design. Participation is no longer a preliminary consultation phase but an ongoing, material dialogue where the environment itself actively demands and scaffolds resident engagement through thinging and enactive signification. Consequently, we need to rethink both paradigms: sustainability becomes a shared relational achievement with the more-than-human world, while participatory design evolves into creating unfinished cognitive partnerships that empower inhabitants as perpetual co-authors of their spatial reality.

The methodological coupling of the study foregrounds the enactive, multimodal, and processual dimensions of architectural cognition, emphasizing that cognition unfolds through metaplastic transactions between bodies, materials, and environments rather than representational modeling. Future research could extend this MET-informed methodology by integrating observatory and participatory approaches, embodied mapping, and cross-typological comparisons—for instance, examining how different spatial typologies (courtyard houses, dense urban dwellings, or open-plan collectives) recalibrate affordances, distributed intentionality, and cognitive extension. Such expansions would enable researchers to trace how material—cognitive couplings evolve across scales and temporalities, fostering a shared methodological language between architecture, cognitive science, and design anthropology that situates cognition as materially enacted and architecturally constituted.

From MET perspective, architecture constitutes a situated and metaplastic cognitive ecosystem, emerging from the dynamic co-constitution of material configurations, embodied practices, and local socio-environmental conditions. Thinking-through-things and enactive signification are not universal procedures but context-bound processes that unfold within specific material ecologies. A building's capacity to mediate cognition and shared intentionality depends on its affordances for engagement—its material composition, climatic responsiveness, spatial porosity, and the socio-cultural rhythms it hosts. Consequently, the cognitive ecology of a fragmented Tokyo dwelling will diverge fundamentally from that of an Istanbul courtyard house. Acknowledging this situated metaplasticity allows designers to understand how spatial configurations participate in particular trajectories of enactive signification; design thus becomes an intervention in an already active field of material engagement where forms, gestures, and habits recursively shape one another.

Furthermore, different typologies generate distinct cognitive habitats. A hospital, a museum, and a home scaffold different cognitive trajectories because their organizational logics, temporal rhythms, and functional demands vary dramatically. These demands entail different participatory agencies and tolerances for variability: hospital infrastructures often aim to canalize sensorimotor routines and constrain unpredictable improvisation to ensure safety and precision, whereas dwellings and public spaces afford broader exploration, allowing cognition to emerge through open-ended material engagement. In MET terms, these functional distinctions specify the participatory potential of the environment, delimiting which metaplastic transformations are enabled or inhibited within each ecology.

Recognizing these differentiated ecologies equips designers to anticipate how configurations cultivate attention, empathy, and collective orientation. Scaled to the urban level, this perspective enables a distributed cognitive approach to urbanism: infrastructures and public spaces function as macro-cognitive artefacts, where enactive signification and we-intentionality are co-constituted at a collective scale. Architecture and urban design are thus reconceived not as static containers but as dynamic, dialogical partners in an ongoing process of thinking, meaning-making, and metaplastic becoming.

The Moriyama House epitomizes architecture as a cognitive habitat— a living system where walls, windows, and soil function as co-constituting elements within a cognitive ecosystem, their material properties actively shaping—or "scaffolding"—the emergent patterns of perception, attention, and social intention. By dissolving Cartesian boundaries between brain, body, and world, it reveals cognition as a situated, transactional process co-authored with materials. This demands a radical shift in design philosophy: from creating spaces for thought to crafting environments that think with us. As Nishizawa's "Village in the Forest" suggests, architectural practice need not focus solely on formal mastery, but can also be understood as the orchestration of material dialogues in which humans, things, and ecologies become interdependent components within materially distributed cognitive processes. While such a configuration may enable forms of thinking-with between bodies and material environments, the emergence of these effects—and whether they are experienced positively or negatively—depends on the cultural tendencies, habits, and broader contextual conditions of different user groups.

6.3. Addressing limitations and situating the case and counter arguments

A primary counterargument is that the Moriyama House, as a radical architectural experiment, is too singular to support broader conclusions about architecture and cognition. We concede its uniqueness but posit that this is precisely its analytical value. The house functions not as a universal model to be replicated, but as a "theoretical probe" or a "cognitive magnifying glass." Its extreme fragmentation, abstraction, and minimalism render hyper-visible the subtle, often unconscious processes of material engagement that occur in all built environments. The ways in which its inhabitants are compelled to think through floors, windowsills, and tree branches are intensified versions of the cognitive couplings that occur whenever a person arranges a desk, navigates a kitchen, or finds a favorite spot in a library. Thus, the case's value lies in revealing fundamental mechanisms of cognitive ecology through an exaggerated lens, rather than in prescribing a specific architectural style.

Following from the above, our analysis intentionally traces the enactive potentials scaffolded by the design. However, it is crucial to frame these not as unequivocally

positive outcomes but as cognitive trade-offs. The same spatial features that foster creative adaptation—extreme minimalism, functional ambiguity, and distributed circulation—can equally generate experiences of exposure, instability, or excessive cognitive demand for individuals whose habits or cultural expectations favor enclosure, continuity, and clear functional zoning. The house does not create a universally beneficial "cognitive habitat" but a highly specific one that privileges flexibility, bodily negotiation, and environmental attunement, potentially at the cost of privacy, predictability, and restful passivity. Recognizing this ambivalence is critical; it positions the architect not as a creator of ideologically perfect environments, but as a careful orchestrator of cognitive partnerships who must consciously consider the spectrum between designing for open-ended engagement and designing for reliable, low-demand support.

Building on MET's core principles, this analysis of the Moriyama House leads to the proposal of the "cognitive habitat" as a synthesizing concept. A cognitive habitat is not merely a "cognitive ecology"—a system where thinking occurs—but a specific type of environmental niche that actively elicits, shapes, and sustains particular patterns of metaplastic cognitive becoming through its architectural organization. The Moriyama House constitutes such a habitat because its material configurations (fragmentation, minimal scale, porous thresholds) do not simply allow for flexibility; they demand and scaffold continuous enactive signification and participatory agency. This habitat fosters a specific cognitive style characterized by thinging, we-intentionality, and the emergent behaviours. The concept integrates MET's key mechanisms: metaplasticity, enactive signification, and we-intentionality. Future research can employ this framework to compare how different architectural typologies—from introverted courtyards to open-plan institutions—create distinct cognitive habitats that foster different modes of thinking, sociality, and embodied practice.

6.4. Towards an MET-informed design framework

These findings imply that architects can design for active engagement and adaptability. Movable elements or modular volumes let inhabitants co-create space, embedding cognition in the structure. In practice, this might mean using sliding walls, multi-sensory cues, or flexible layouts to scaffold users' mental processes and co-emerge cognitive habitats with humans and other beings. Designers must recognize that environments are not passive containers but active participants in cognition; they operate as metaplastic partners that co-constitute thinking through material engagement.

Future research could further refine this MET-informed perspective by undertaking systematic comparative studies across diverse architectural typologies and functional environments. Examining the metaplastic dynamics of the Moriyama House alongside those of a traditional courtyard dwelling, a co-housing community, or a high-security correctional facility, or a hospital would illuminate how different spatial organizations, material regimes, and programmatic demands enact distinct trajectories of material engagement. Such comparisons would not aim to identify an ideal or universal model of cognitive ecology; rather, they would chart how varying degrees of spatial openness, enclosure, control, and adaptability modulate the possibilities for enactive signification, participatory agency, and distributed intentionality. In doing so, these studies would clarify how the functional logics of different building types—domesticity, collective living, care, education, security—configure specific affordance landscapes that scaffold or constrain cognitive and socio-material practices. Ultimately, this comparative approach would advance a richer understanding of how heterogeneous material configurations participate in shaping the forms, limits, and potentials of human thought.

Declaration of competing interest

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

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