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Ethical Leadership: A New Frontier for Design

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SharIN'House. Shaping interactions within IoT ecosystem through tangible interfaces

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ABSTRACT | Emerging forms of interaction and interfaces transcend traditional social constructs, shaping and being shaped by cultural and technological shifts. As everyday life patterns evolve, interest in co-living solutions is growing, driven by the need for flexibility and rising housing costs. These dynamics rely on interconnected product ecosystems, where tangible interfaces convert quantitative data into qualitative insights, shaping user behaviour. While the Internet of Things (IoT) enables this exchange through connected devices, design guides interactions by offering explicit feedback that fosters engagement. This research explores the intersection of IoT ecosystems and product development through a laboratory setting, where international designers investigate the behavioural effects of emerging technologies. The study unfolds in two phases: a qualitative field study using ethnographic methods and surveys to analyse interactions in shared spaces, followed by a speculative design approach embedding sensors to collect user-environment data. Actuators then convert this data into adaptive product configurations, transforming quantitative insights into qualitative feedback. Through an analysis of outcomes, this study establishes a framework for impact-share design, mapping behavioural effects in human-technology interactions. The dual cause-effect approach shows how IoT data transforms into qualitative insights, enhancing design for behavioural change. The research underscores how interconnected products shape shared environments, guiding future interactive design.

KEYWORDS | SOCIAL RELATIONS, BEHAVIOUR, QUALITATIVE ANALYSIS, COLIVING

1. Introduction

> "When everything is connected to everything else, for better or for worse, everything matters" (Mau & Leonard, 2004, p. 128)

Since the 'age of uncertainty' (Bauman, 2007), new interactions and interfaces have transcended traditional social constructs, shaping and being shaped by cultural and technological landscapes (Scolari, 2021). This shift demands adaptation to evolving work and leisure patterns, rekindling interest in co-living arrangements as responses to dynamic and flexible lifestyles (Ehrenberg & Keinonen, 2022). These transformations not only affect interpersonal relationships but also reshape the connections between individuals and their living and working environments (Piardi et al., 2012).

Co-living spaces, defined by the cohabitation of unrelated individuals sharing communal areas, offer an example of this evolving dynamic (Medar & Ćurčić, 2021). Residents of such spaces operate under specific codes and agreements that can influence individual behaviour (Meltzer, 2005), potentially leading to tensions. The type of interaction within co-housing environments is shaped by a variety of factors (Clitheroe et al., 1998), including personal traits, informal social dynamics, and formal structures such as house rules. Together, these elements contribute to the overall quality of the co-living experience. Conversely, artifacts within these spaces play a pivotal role in balancing the need for community-building with the preservation of individual privacy.

The interaction between interior space, artifacts, and social formats such as co-living highlights contemporary societal challenges, presenting design with opportunities to address new living conditions (Scullica et al., 2022). Future technologies - context-aware, networked, and proactive (Perera et al., 2014) - promise to dynamically adapt to individual needs, shaping spatial and social interactions. Research in interaction design (IxD) emphasises that engagement with technology emerges from the interplay between physical, cultural, and social elements. Understanding engagement with space should not only consider static configurations but also view it as an evolving interaction involving people, cultural practices, objects, and the surrounding environment (Anzani et al., 2022). Studies have identified key elements of engagement relevant to both technology and space, including cultural practices, physical conditions, and social interactions. Our physical presence in space influences our experience even before conscious sense-making, which is the foundation of an affective engagement (Fritsch, 2009). Sense-making is often supported by physical actions, emphasising the role of materiality in interactions with environments (Dalsgaard et al., 2011). In this context, IoT holds potential to provide valuable insights into behaviour by integrating physical devices within complex systems, thereby offering enriched, real-time data. Design can influence user behaviour (Fogg, 2009) by leveraging explicit feedback mechanisms, which facilitate new interaction models. While Fogg's concept of Persuasive Design lays the foundation for understanding how digital systems can shape behaviour, our approach diverges by focusing on how real-time, contextual feedback in IoT environments enable not only persuasion but also reflection and agency. Rather than purely steering behaviour, the design strategies explored here aim to support users in making informed decisions within dynamic, data-rich settings.

This study establishes a framework for impact-share design, mapping behavioural effects of human-technology interactions. By analysing laboratory outcomes, it illustrates how advanced, interconnected product systems drive behavioural change. A dual cause-effect approach translates quantitative sensor data into qualitative insights,

enhancing understanding of how IoT technologies facilitate new data exchange models and inform design practices that encourage behavioural shifts. As co-living expands as a living model, designers must balance "living and respect," ensuring social harmony. While conflicts may arise, understanding resident behaviours can guide design strategies that promote well-being, improve social bonds, and enhance overall co-living experience.

2. Critical interaction design

To shed further light on the design methodology deployed for this study, an in-depth analysis of Design Thinking and Critical Thinking is needed, to better tackle the role of empathy involvement and bring reflection on its implication in the design development. Moreover, the interplay between Design Thinking and Critical Thinking will be elaborated, to describe how those influenced the production of the results of the study.

The human-centred design approach is the backbone of Design Thinking (Verganti et al., 2021). Gathering user feedback is the starting point of this process that ends with the design and development of tailored solutions that fit customer needs. Building deep empathy through observation and ethnography with the recipients of the design aims at solving problems from their perspective (Brown, 2009).

At the same time as technologies become increasingly sophisticated and integrated into everyday life, making these technological advancements accessible and user-friendly become paramount. A salient example of this phenomenon is digitalisation; as Information Technology (IT) applications transition from business services to direct consumer use, the demand for design - particularly in the realms of User Experience (UX) and User Interface (UI) design - has surged.

Design Thinking drives the innovation process, UX Design examines the quality of the user experience, and Interaction Design shapes the dialogue between people and artefacts; together, these three perspectives guide the study and development of a product.

a. Empathic Design for User Experience

Empathy and active listening help designers understand user needs, desires, and motivations. In design thinking, this understanding is iteratively incorporated into solutions that address real user problems. Additionally, user interfaces can represent user behaviour data, subtly encouraging more socially acceptable actions.

User-centred design places user experience at its core while designers envisage empathic bridges to immerse themselves in users' lives - whether hypothetical, potential, or future - to ensure that products and services align with their needs (Koskinen et al., 2003). Gasparini (2015) defines that empathy can be either emotional - an instinctive, affective, shared, and mirrored experience - or cognitive, involving the ability to understand another's perspective (New & Kimbell, 2013; Spencer, 1881). According to this, an empathic approach becomes a crucial component in the design process that enables designers to connect with users on a deeper level for successful design outcomes (Kouprie & Sleeswijk Visser, 2009).

To foster this connection, tools and techniques adopted by designers include direct contact with users, supporting the first research part of a design process, effective communication of research findings, and ideation methods that leverage designers' own experiences. These approaches not only lead to a nuanced understanding of user needs

but also enable the creation of meaningful user-centred design solutions. As empathy can be conceptualised as a tool to design with, requiring the transformation of feelings into actionable attributes (Koskinen et al., 2003), designers can leverage empathy to gain valuable insights into users' needs, which subsequently informs the design process (Brown, 2009). For instance, in a Design Thinking framework, it is essential for all participants in a design team to empathise with the users for whom they are designing. This collective empathic engagement is crucial for generating relevant and effective solutions.

By these premises, using an emotional approach toward cognitive empathy bridge, designers apply different methods to build up that competence and insight, enabling them to prioritise the needs of the users and make the results of the process more desirable (Brown, 2008; Holloway, 2009; Ward et al., 2009). Communication of user study results could support both possibilities to immerse in the user's world and to reflect on it with the designer's own experiences. Communication tools should convey the expectations of the user's world, as well as an understanding of it. By using tools which combine raw data (e.g. video fragments, quotes) and suggestive leads towards interpretations, designers are supported in the act of designing. Data represented in stories, storyboards or in personas serves very well in allowing designers to step into and walk around in the user's world and connect with the user (Pruitt & Adlin, 2006).

b. Critical Thinking of Design interaction

Critical thinking complements design thinking by providing a framework for evaluating information, questioning assumptions, and analysing the implications of design decisions (Shelley, 2009). It encourages designers to reflect on their processes and outcomes, ensuring that the solutions developed are not only innovative but also ethically sound and socially responsible (Lilley & Wilson, 2013). For instance, the integration of critical thinking into the design process allows designers to assess the potential impacts of their work on user behaviour and societal norms, thereby promoting sustainable practices (Lilley, 2009). This refers to prompting individuals to consistently maintain positive behaviours over the long term and to do that it is essential to implement a strategy focused on behavioural sustainability. This approach strategically emphasises continuous engagement and reinforcement, helping people to adopt and sustain good practices over time. By creating lasting habits and fostering a culture of accountability, the strategy supports ongoing commitment to sustainable living behaviours, even as circumstances and dynamics evolve.

Reflective design practices challenge designers to critically examine their assumptions, encouraging them to reflect on the societal and ethical dimensions of their work. This approach ensures solutions are not only functional but also inclusive and socially responsive. These practices promote an iterative approach to uncovering and addressing biases, ensuring designs resonate with diverse user needs and contexts. Critical design, on the other hand, invites designers to interrogate societal norms, question dominant narratives, and propose alternative futures through speculative prototypes and thought-provoking scenario.

This reflective practice over sustainable practices is crucial in a rapidly changing technological landscape, where user needs and behaviours are continuously evolving. In summary, the interplay between design thinking and critical thinking is essential for understanding and influencing user behaviour. Design Thinking provides a structured approach to empathising with users and developing solutions, while critical thinking

ensures that these solutions are rigorously evaluated and refined. Together, they create a robust framework for addressing complex design challenges and fostering meaningful user interactions.

The iterative nature of UX design allows for continuous feedback and improvement, which is essential for refining how information is communicated. By employing methods such as user testing and feedback loops, designers can identify areas where the information relay may be lacking and make necessary adjustments to enhance the user experience. This iterative process is crucial for ensuring that the information provided is not only accurate but also resonates with users on a practical level.

This approach not only facilitates the implementation of innovative technologies but also ensures that these solutions are sustainable and socially responsible, ultimately contributing to behavioural change for an increased quality of shared living environments.

3. Beyond Data collection: tangible interfaces for IoT products

Since its conceptualisation in 1999 by Kevin Ashton[1], the IoT has rapidly integrated into everyday life, with projections estimating 55.9 billion interconnected devices by 2025 (Chan & Caprio, 2024). IoT refers to any electronic object with embedded sensors capable of collecting data and transmitting it to other components in the network. The European Commission highlights the role of IoT innovation clusters in fostering technological advancements and knowledge transfer (European Commission et al., 2019). Furthermore, McKinsey estimates that IoT could generate a global economic value between $5.5 trillion and $12.6 trillion by 2030, with consumer-oriented applications such as smart homes driving much of this growth (Chui et al., 2021).

Building upon its rapid adoption and projected economic impact, the influence of IoT extends beyond mere data collection, influencing the way information is interpreted and acted upon. While quantitative data provides numerical insights (e.g., temperature, energy consumption, traffic flow), qualitative data is equally crucial in design-driven applications. In the context of design, qualitative data encompasses user perceptions, contextual interactions, and emotional engagement with technology. Unlike purely quantitative metrics, qualitative data offers a deeper understanding of how users experience and interpret information, allowing for more meaningful interactions. IoT, through embedded sensors and tangible interfaces, has the potential to bridge the gap between raw data and human-centred insights, transforming data collection into a process that is not only analytical but also experiential.

By integrating tangible interaction principles with IoT ecosystems, designers and technologists can create richer, more intuitive experiences that leverage both quantitative and qualitative data. This approach not only enhances usability but also ensures that technology aligns with human behaviours, preferences, and sensory interactions. In this light, IoT becomes more than just a network of connected devices - it evolves into an ecosystem where data gains meaning through interaction, interpretation, and design-driven insights.

a. Interaction layers of IoT ecosystem

Interactions with digital devices increasingly combine graphical displays with sensors

that detect location, touch-less gestures and environmental cues, effectively tethering screen-based interfaces to the physical world. Yet, because feedback remains predominantly visual and confined to a private surface, these interfaces can limit multi-user engagement and embodied exploration. This form of interaction can Interactions with digital devices occur through abstract, screen-based interfaces that are disconnected from the physical world, creating a sense of alienation for users, as their interactions often feel unnatural or detached. According to Angelini et al. (2018), this alienation is a consequence of the abstraction and complexity of current IoT systems, which fail to align with the innate human abilities to interact with the physical environment. In this regard, tangible interaction may bridge the gap between the digital and physical worlds as it relies on embodied interaction, physical manipulation, material representation of data, and integration into real space (Hornecker & Buur, 2006). Modern touchscreen-based interfaces lack tactile depth and physical interactivity, reducing the effectiveness and naturalness of human interaction with technological tools - as envisioned by Bret Victor in one of his report[2]. By reintroducing the physical interaction, tangible interfaces can reduce alienation leveraging users' natural sensory and motor skills, fostering a deeper connection with IoT devices. Tangible User Interfaces (TUIs) address this gap by externalising digital state into graspable artefacts, offering spatial persistence, rich haptic feedback and opportunities for shared manipulation, thus complementing—not replacing—the role of screens within IoT ecosystems. Moreover, TUIs allow users to engage with digital systems in ways that feel more natural and intuitive, activating learning mechanisms (Revelle et al., 2005)

Conversely, richer interaction paradigms within IoT systems, grounded in tangible interaction, could foster deeper user understanding and stronger emotional bonds with objects, leveraging human abilities such as touch, spatial reasoning, and physical manipulation to create meaningful, reflective, and context-driven interactions (Krestanova et al., 2021). Furthermore, tangible interaction can provide immediate and intuitive feedback while also encouraging users to reflect on the system and its functionality. Rather than offering quick or superficial interaction, these interfaces allow users to explore and engage deeply with IoT devices, supporting collaborative use, influencing social dynamics as users share access to connected devices and engage in joint decision-making (Hofstra et al., 2008).

Tangible interaction enhances users' spatial awareness and physical engagement with the system, making interactions more intuitive and immersive. Additionally, it employs expressive, material representations that facilitate cognitive processes, making complex systems easier to understand and navigate (Shaer & Hornecker, 2009). One of the key advantages of tangible interaction is its persistence, as digital information is embedded in physical elements rather than being limited to transient screen-based displays (Rowland et al., 2015). This ensures that data remains accessible even when a system is inactive or temporarily disconnected, making tangible interfaces particularly valuable in IoT environments (van den Hoven et al., 2013). By maintaining a visible and interactive presence, these interfaces enhance both usability and system transparency, especially in shared spaces.

This persistence raises important questions about how interactive IoT devices can help users make sense of data. How IoT devices can enhance user interaction, simplify data interpretation, and support collaborative data collection and analysis (Rittenbruch & Donovan, 2019). Thus, offering an opportunity to transform the way users interact with IoT systems.

In this regard, a laboratory has been developed to investigate how tangible interaction through enhanced artifacts can provide immediate and intuitive feedback that encourages users to reflect on their co-living experiences. Particularly, if these shared interfaces could allow users to explore and engage deeply with IoT devices, supporting collaborative use, influencing social dynamics, and engaging in joint decision-making.

4. Interaction Design Studio: the SharIN'House lab experiment

The laboratory convened a group of young international designers to explore the potential of technological solutions tailored for the complexities of shared living environments. The laboratory adopted the Design Thinking process to guide the stages of empathy, definition of the problem, and rapid prototyping. During evaluation, UX design criteria enabled the measurement of the prototypes' perceptual quality and their impact on the roommates' daily lives. Finally, the tangible implementation of the prototypes was approached according to Interaction Design principles, with particular attention to physical-digital feedback and interaction timing. The participants were challenged to investigate the intentions behind emerging designs, particularly those leveraging the IoT to create ecosystems of interconnected products. The primary goal was to develop innovative solutions that facilitated seamless interaction between people, objects, and spaces, ultimately enriching information exchange for enhanced shared experiences.

To ensure a comprehensive evaluation of shared living dynamics and behaviours, three key areas were identified as a starting point: needs (e.g., daily personal needs), responsibilities (e.g., household management), and leisure (e.g., recreational activities).

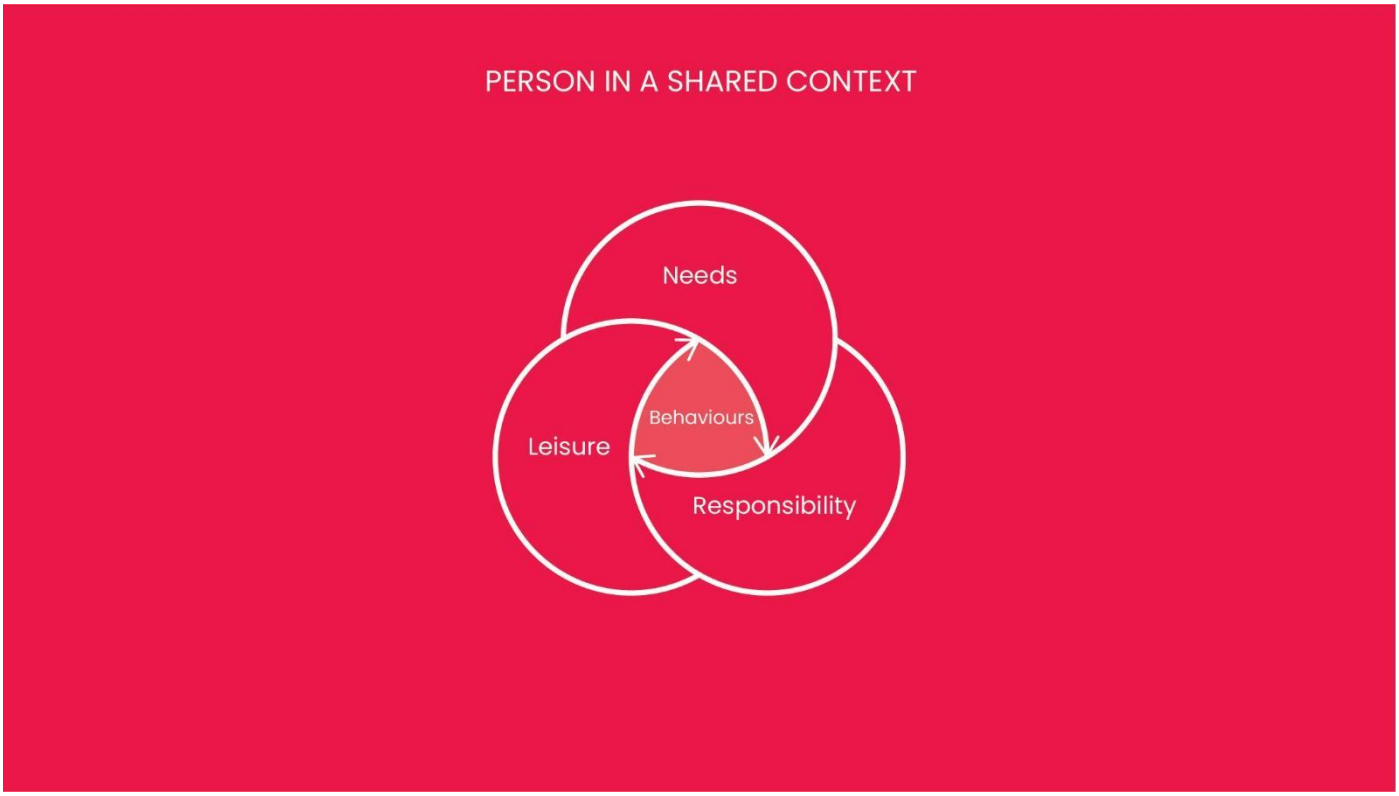


Figure 1. key areas identified by the laboratory as focus points.

The participants were organised into groups of three and assigned specific focus areas throughout the investigation and design process.

Through hands-on experimentation, designers were required to not only contribute to the development of products and services but also to consider the environmental contexts, cultural dynamics, technological possibilities that shape shared living while reflecting on the broader systemic implications of their interventions.

The lab was structured into two distinct phases: the first phase, which involved a qualitative field study to observe real-world interactions in shared housing environments; and a second phase, where designers integrated sensors and actuators into products, translating quantitative data into meaningful qualitative information.

a. First phase: co-living research

This phase is characterised by two iterative cycles comprising introductory interviews, design experiments, workshops, and follow-up interviews. Designers utilised a comprehensive analytical framework and an interdisciplinary approach to gather initial data from the ecosystem, including interactions within shared spaces and the use of everyday objects. The integration of design thinking and speculative design methodologies enriched this exploration, enabling a critical examination of contemporary shared living scenarios where housemates engage in diverse activities. To retrieve data around users and their experiences, qualitative methods such as ethnographic interviews (Fetterman, 2010), discovery templates, and 5Ws surveys (Su, 2014) were employed to elucidate key contextual aspects, namely: People, Spaces, Activities, Artifacts, and Behaviours which were collected through a grounded approach (Corbin & Strauss, 2008).

Structured prompts guided the investigation, focusing on:

1. Who: identifying users based on demographics, lifestyles, habits, routines, and specific needs.
2. What: mapping daily activities and tools to users' routines and the shared objects they interact with.
3. Why: exploring motivations and context to uncover reasons behind user actions and preferences.
4. When: analysing time allocation and routine patterns to determine activity frequencies and schedules.
5. Where: mapping spatial usage and interaction within shared environments.

To further contextualise the initial findings, designers employed a discovery sheet (figure 2) to develop a semi-structured, in-depth questionnaire. Interviews were then conducted with residents from distinct cohousing environments, selected for their contrasting spatial designs and social dynamics. This diversity allowed for a more comprehensive analysis of the potential influence of various factors, such as governance models, the organisation of shared activities, informal social structures, and individual attributes (Williams, 2005).

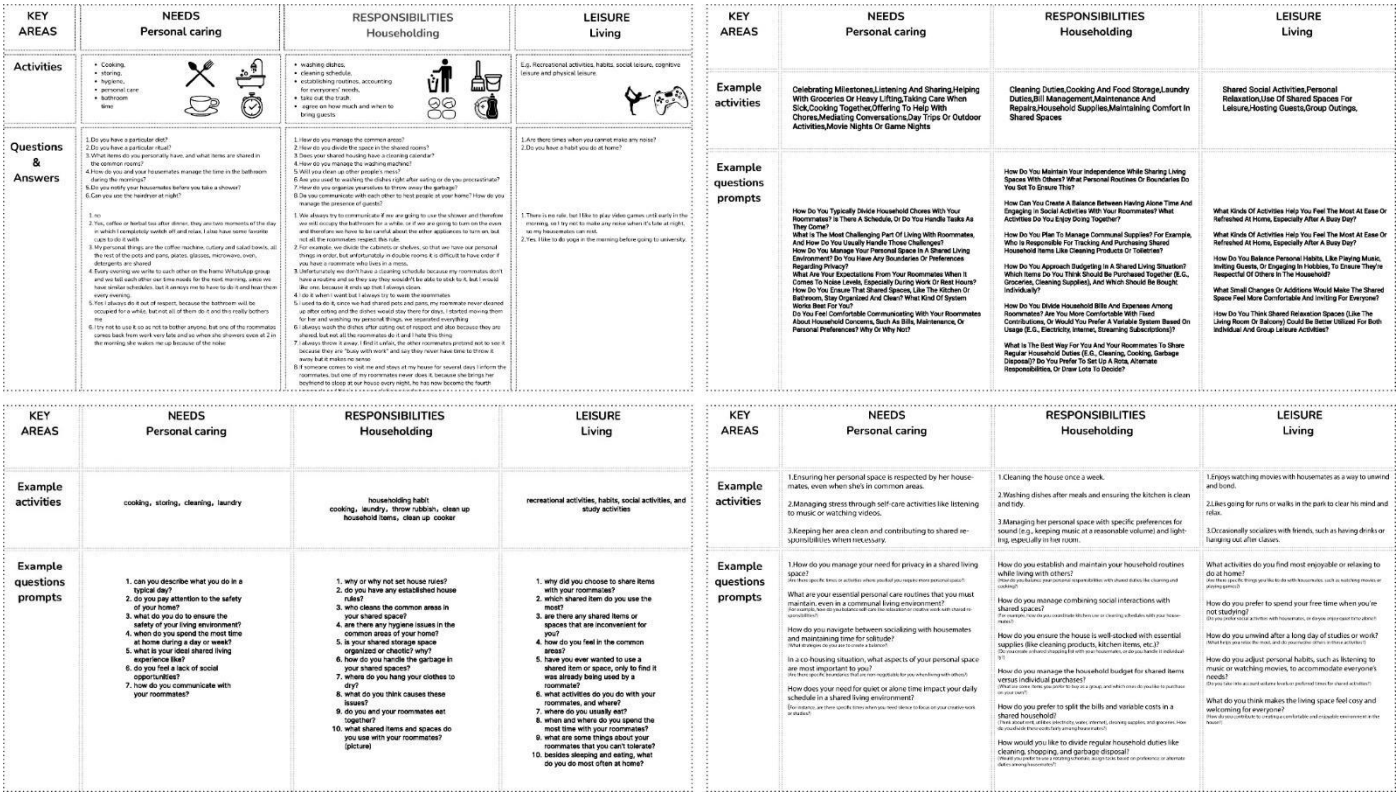


Figure 2. Filled Discovery Sheets examples.

The data collected provided valuable insights into the dynamics that govern housing, revealing user interaction pain points and areas of friction that could lead to tension among housemates. To further explore established routines, social norms, and opportunities for design in supporting sustainable practices in shared living, expert interventions in Design Thinking facilitated the design process through the implementation of a series of workshops.

b. Affinity clustering workshop

During the workshop's sessions, designers referred to the Double Diamond to generate actionable insights (Sanders, 2000). The process began with visual analysis, where participants used storytelling tools such as sketches and post-it to synthesise interview data (figure 3). Through affinity clustering, recurring responses were categorised, helping to uncover significant tendencies and representative behaviours. From these clusters, personas were developed, representing diverse profiles (e.g., introverted vs. extroverted, active vs. homebody), their behaviours, habits and interaction that influence how they interact with their environment, housemates, and resources (specific tools, devices, or spaces required for their tasks).

Figure 3. Visual data analysis and affinity clustering process.

Furthermore, detailed user journeys were created, revealing emotional responses including pains and gains. Through a comparison, critical points such as patterns of activity peaks (e.g., busiest times in the kitchen), their duration, and their impact on shared space usage were retrieved. Additionally, visual tools such as timelines and interaction flow/heat maps, clarified activity-space relationships, providing insight into spatial and functional design needs and the importance of shared norms in maintaining household rhythms.

Moreover, the workshops facilitated the designer to uncover the rationales for user actions (e.g., use of shared versus personal appliances) combined with their values, expectations (e.g., cleaning after use), and habits. Ultimately, it helped to identify opportunities for design intervention, acknowledging that successful co-living requires balancing individual behaviours and desires with effective governance, management, and the prevention of potential drawbacks. Thus, optimising the overall experience for residents.

c. Second phase: new scenarios

Initially, participants attended a workshop where they developed scenarios through collaborative design testing, simulations. These iterative processes allowed them to experiment with different rough prototypes (figure 4), configurations and systems, integrating sensors and actuators into products to generate real-time, quantitative data that enhanced understanding of user-environment interactions (figure 5).

Figure 4. Rough prototype iteration examples.

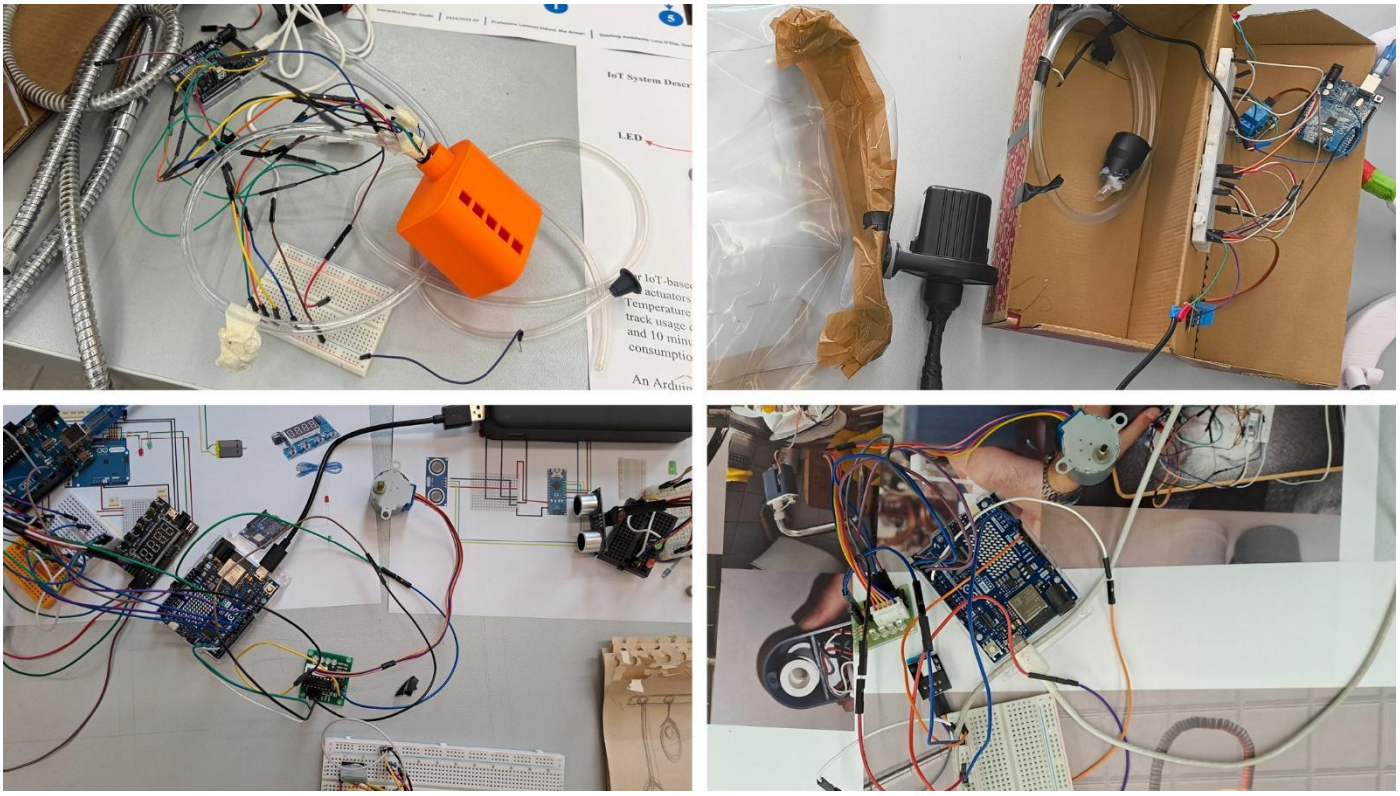


Figure 5. IoT system ideation and testing examples.

During the final phase, designers synthesised observations from the previous stages to design an interactive product system focusing on the quality of user interactions with their environment (figure 6). This phase emphasised translating quantitative data into qualitative information, creating systems that encourage reflection on shared responsibilities, daily habits, and collective values.

Figure 6. IoT system context application examples.

By processing data, designers reimagined the shared living ecosystem through interactive product systems that used data to inform decisions. These systems leveraged everyday activities and redefined the way shared spaces and artifacts are used, enabling communication exchange between housemates.

5. Interactive products

At the end of the design process, each group successfully developed products that effectively integrated a range of inputs and responded to the needs of shared living. From the analyses conducted, it emerged that the systems were capable of automatically filtering and prioritising the most relevant information, helping housemates manage their environment more effectively. In particular, it became clear that the success of co-living largely depends on three core factors: 1) Governance Structure, the effective implementation of organisational structures and rules to manage shared spaces ; 2) Qualitative Data Communication, the ability to convey complex information through communication physical artifacts; and 3) Behavioural Sustainability, the presence of a long-term engagement and reinforcement strategy, that creates lasting habits and supports ongoing commitment to sustainable living behaviours, even as dynamics evolve. These factors are critical for designing solutions that address specific behaviours and challenges, foster a sense of community and social interaction, reduce conflicts, and facilitate information sharing. All the factors and tools discussed thus far have been applied accordingly in the design process of the following projects.

a. KNOCKER X AIR SOFA

The *Knocker X Air Sofa* (figure 7) uses a connected knocker and modular sofa unit to promote fairer space-sharing behaviour. The sofa features an inflatable cushion that deflates when a user's emotional state - measured by the knock sensor - reaches a certain threshold. This creates an uncomfortable seating experience, encouraging users to leave the sofa thereby addressing any underlying tension.

1. Governance Structure: time limits on individual sofa use are defined by the system, regulating independent space.

2. Qualitative Data Communication: the inflation/deflation of the cushion visually and physically communicates the user's emotional state.

3. Behavioural Sustainability: the discomfort created by the deflation encourages users to leave the sofa, addressing conflict resolution and promoting healthy space-sharing behaviours.

Figure 7. Display of the final prototype and initial drafts of the *Knocker X Air Sofa* design, created by M. Ghods, K. Umitvar, T. Solakoglu.

b. RUG 'N' RACK SYSTEM

The *Rug 'n' Rack System* (figure 8) is designed to respond to spatial requirements and organisation while encouraging shared responsibility. By incorporating sensors to a combination of personal sanitary items such as a rug and individual holders, the system reminds users to return their belongings after use, using light, sound, and vibration cues.

1. Governance Structure: space limit on individual shower use is defined by the system, monitoring the presence of unwanted items.

2. Qualitative Data Communication: sensory feedback (light, sound, vibration) prompt users to return their belongings.

3. Behavioural Sustainability: automated reminders help users maintain communal routines and reduce friction.

Figure 8. Display of the final prototype and initial drafts of the *Rug 'n' Rack System* design, created by G. Tarantino, E. Zannetti, A. Aleksandrova.

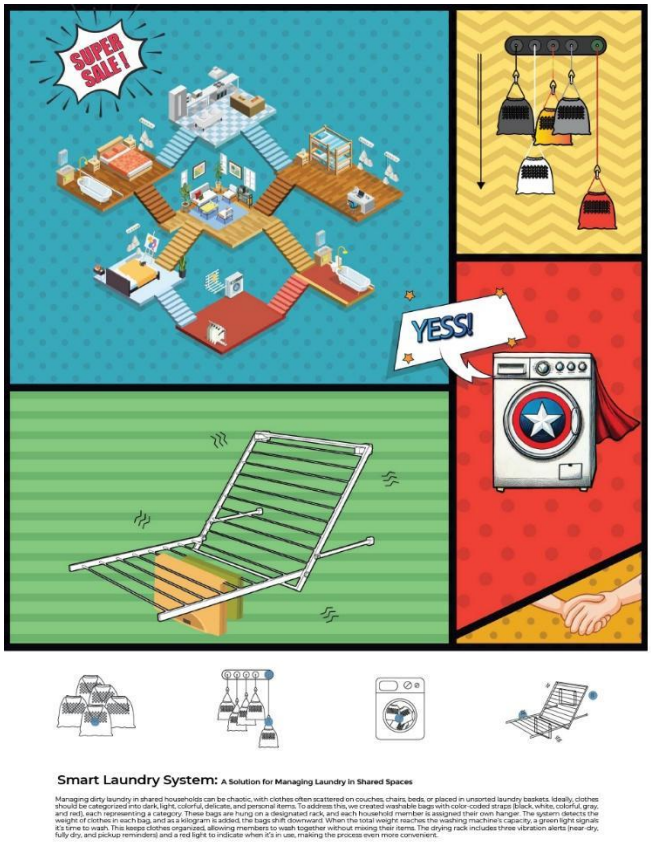
c. SMART LAUNDRY SYSTEM

The *Smart Laundry System* (figure 9) addresses the challenges of managing laundry in shared spaces while enhancing cooperation among housemates. The system uses wall-mounted hangers with different weight-sensing bags, to notify users when the collective amount of laundry is ready to be washed. The system features a smart drying rack that signals when clothes are dry, optimising laundry schedules and reducing conflicts.

1. Governance Structure: the system organises laundry schedules based on shared capacity and automated notifications.

2. Qualitative Data Communication: visual signals (green/red lights) and vibrations communicate laundry status to users. The rack vibrates at varying intensities to indicate drying progress.

3. Behavioural Sustainability: automated alerts reduce scheduling conflicts and promote cooperative laundry management.



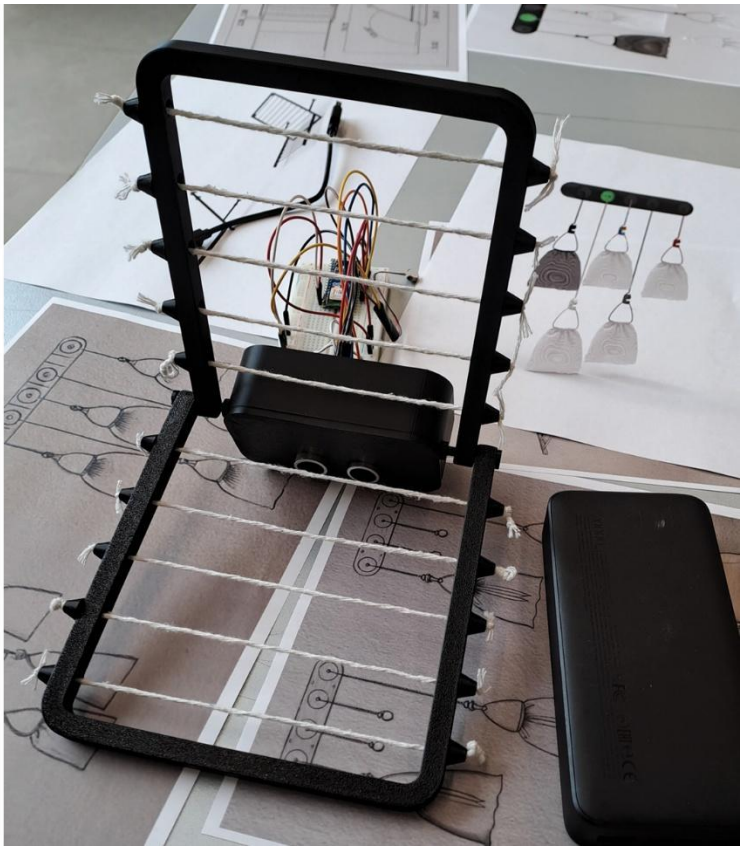


Figure 9. Display of the final prototype and initial drafts of the *Smart Laundry System* design, created by F. Esmaeilpour Amirikiasar, A. Mohebbi.

d. LEAFLINK

The *Leaflink* (figure 10) facilitates communication and social interaction in shared spaces through a central device (*Leaflink* Main) and individual devices (*Leaflink* Keyholder). It uses plant-themed devices to signal moods and availability, promoting social cohesion without disrupting personal privacy.

1. Governance Structure: the system allows housemates to communicate their moods or availability without direct confrontation.

2. Qualitative Data Communication: by blowing on the personal *Leaflink* device, mood and availability are signalled through light colours and plant movements on the central *Leaflink* main device.

3. Behavioural Sustainability: the system encourages a balance between social interaction and solitude, allowing for flexible communication and respect for privacy.

Figure 10. Display of the final prototype and initial drafts of the *Laflink* design, created by Y. Elkayam, G. Pan, L. Barberis.

e. SMART SHARING HOME WATER MANAGEMENT SYSTEM

The Smart Sharing Home Water Management System (figure 11) is designed to promote cooperation among users by regulating water flow in shared spaces during peak usage times. Thanks to devices specifically designed for the sinks and showers taps, the project ensures that hot water and water pressure is available to all housemates by limiting flow based on usage patterns.

1. Governance Structure: limits water usage per person, ensuring fairness during shared use.

2. Qualitative Data Communication: water usage is regulated and communicated through system cues, such as changes in water pressure.

3. Behavioural Sustainability: encourages mindful water usage while ensuring equitable access to shared resources.

Figure 11. Display of the final prototype and initial drafts of the *Smart Sharing Home Water Management System* design, created by S. Elyasi, F. M'Haimah Romero, D. Voskanian.

f. CLESSHYDRA

Clesshydra (figure 12) is a system designed to foster accountability among housemates by reducing conflicts over bathroom resources access. The project features a showerhead that measures water usage and a clepsydra (water clock) that visually displays consumption.

1. Governance Structure: regulates time and water usage, ensuring fair distribution and reducing overuse.

2. Qualitative Data Communication: water usage is displayed visually through the clepsydra, making data tangible.

3. Behavioural Sustainability: by promoting mindful usage, the system encourages water conservation and fosters shared responsibility.

Figure 12. Display of the final prototype and initial drafts of the *Clesshydra* design, created by E. Ricci, M. De Cagna, C. N. Putri.

g. LIVING VOID

The *Living Void* (figure 13) addresses waste management in shared living spaces, ensuring liability and proper waste disposal through automated alerts. The system features a bin and connects personal devices that notify users when the bin reaches its full capacity.

1. Governance Structure: the system regulates responsibility-sharing by ensuring each housemate takes turns managing the garbage.

2. Qualitative Data Communication: the system triggers visual and sensory responses (e.g., smoke or light) to indicate when it's time to take out the trash.

3. Behavioural Sustainability: automated alerts and reminders help users stay accountable for waste management, ensuring a clean and healthy living space over time.

Figure 13. Display of the final prototype and initial drafts of the *Living Void* design, created by L. Arena, Y. Zhang, A. Ponzi.

h. AURA

The Aura system (figure 14) is designed to foster social interaction among housemates. It consists of three objects: a carpet, a light cube, and an outer lamp. The carpet detects when someone is alone in the room and shifts to a "sad" mode. Tapping on it triggers signals to invite other housemates. Once they join, the carpet recognises the type of activity - whether it's socialising, calm socialising, or partying - and communicates with the light cube. The light cube adjusts accordingly, creating a relaxing atmosphere during calm socialising or emitting colourful lights during parties to encourage dancing.

1. Governance Structure: encourages social interaction by prompting users to connect when alone, fostering a shared experience in the living space.

2. Qualitative Data Communication: the carpet's change in mood and the light cube's responsive lighting visually communicate the activity type and emotional atmosphere.

3. Behavioural Sustainability: the system promotes increased social interaction, reducing loneliness and enhancing positive engagement within shared living spaces.

Figure 14. Display of the final prototype and initial drafts of the *Aura* design, created by O. Özder, S. S. Tok, C. Del Palacio.

i. GHOST HOUSE

The Ghost House (figure 15) is an ecosystem of products designed to monitor and manage noise levels in shared living spaces, particularly in the dining room. When the noise exceeds a predefined threshold, the ceiling lamp begins to swing like a pendulum. If the noise persists, the standing lamp dims its light, and if the noise level remains too high, the radio emits intermittent sounds to alert the housemates until the noise level is reduced.

1. Governance Structure: Regulates noise levels by encouraging quieter behaviour in shared spaces.

2. Qualitative Data Communication: The system uses visual cues (pendulum motion, dimming light) and auditory signals (radio noise) to indicate excessive noise, prompting users to reduce their sound levels.

3. Behavioural Sustainability: By encouraging quieter behaviour through intrusive alerts, the system reduces conflicts and fosters a respectful shared environment.

Figure 15. Display of the final prototype and initial drafts of the *Ghost House* design, created by A. Scardigno, M. Ladhiri, L. D. Guijosa Perez.

6. Interactive Design lab's findings

From the analysis and the consideration stated so far, it is possible to retrieve a first picture of a potential tendency of design outcomes when dealing with friction points and areas of tension that commonly arise in shared living environments. The insight gained throughout the design process has highlighted the same design paths when designers are exposed to specific key areas, namely needs, responsibility and leisure.

Table 1. Key areas of intervention for design, namely needs, responsibility, leisure and result.

Need	Responsibility	Leisure	Aim
Regulating independent space usage	Monitor shared space usage	Promote social interaction	Promote fairer space-sharing behaviour

It is evident that the design process has inevitably overlapped these areas to put into system the intricate interplay between individual physical, personal, and social factors influencing behaviour in shared living environments.

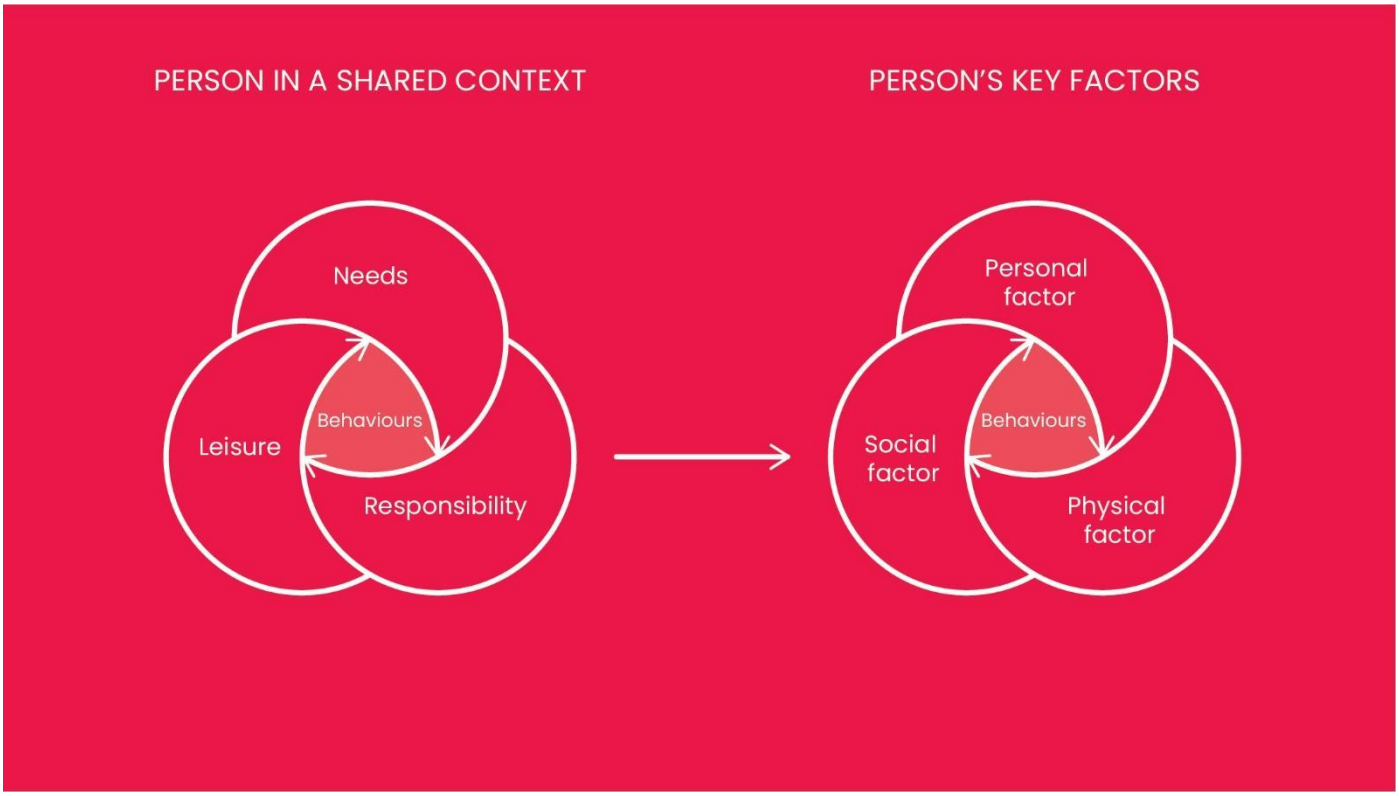


Figure 16. The interaction between physical, personal and social factors and impact on behaviour. Source: Adapted from Williams (2005).

It is possible to see a change in behaviour resulting in frictions as soon as people are put in shared environments, where the organisation of the physical space and the social context are significantly shaped. In such a scenario, the intervention of Design and the integration of advanced IoT technologies have shown the potential to escalate these challenges while enhancing new behaviours. By actively connect physical objects, new value-added information and functionalities for users are provided. Devices, information, users, and applications are integrated to create an IoT ecosystem in which new solution and products are developed in an organic way, mediating possible drawbacks.

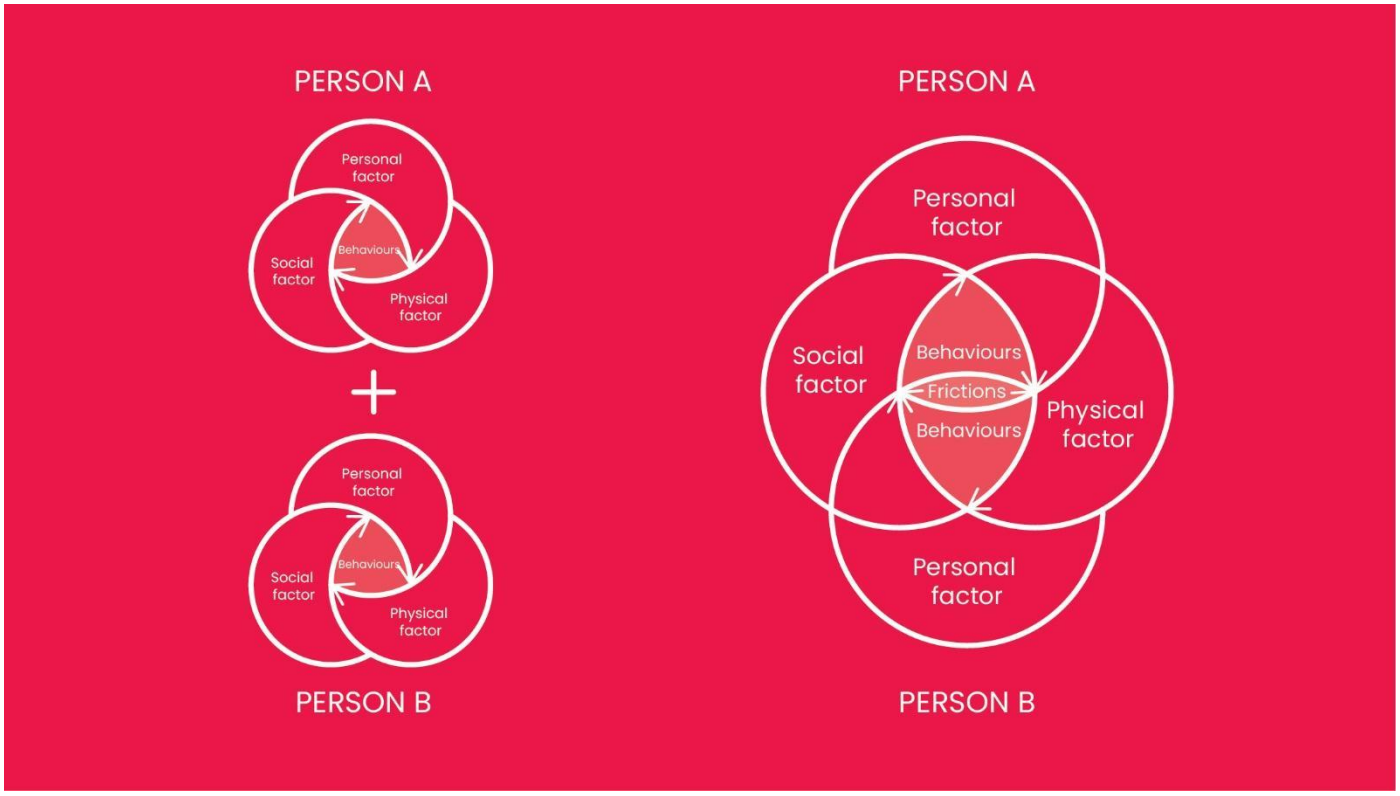


Figure 17. Interaction between more people in the same context causing frictions.

The findings suggest that through critical thinking approach, products not only become emphatic and tailored to the user needs but are capable of promptly picture, manage and reduce future tensions.

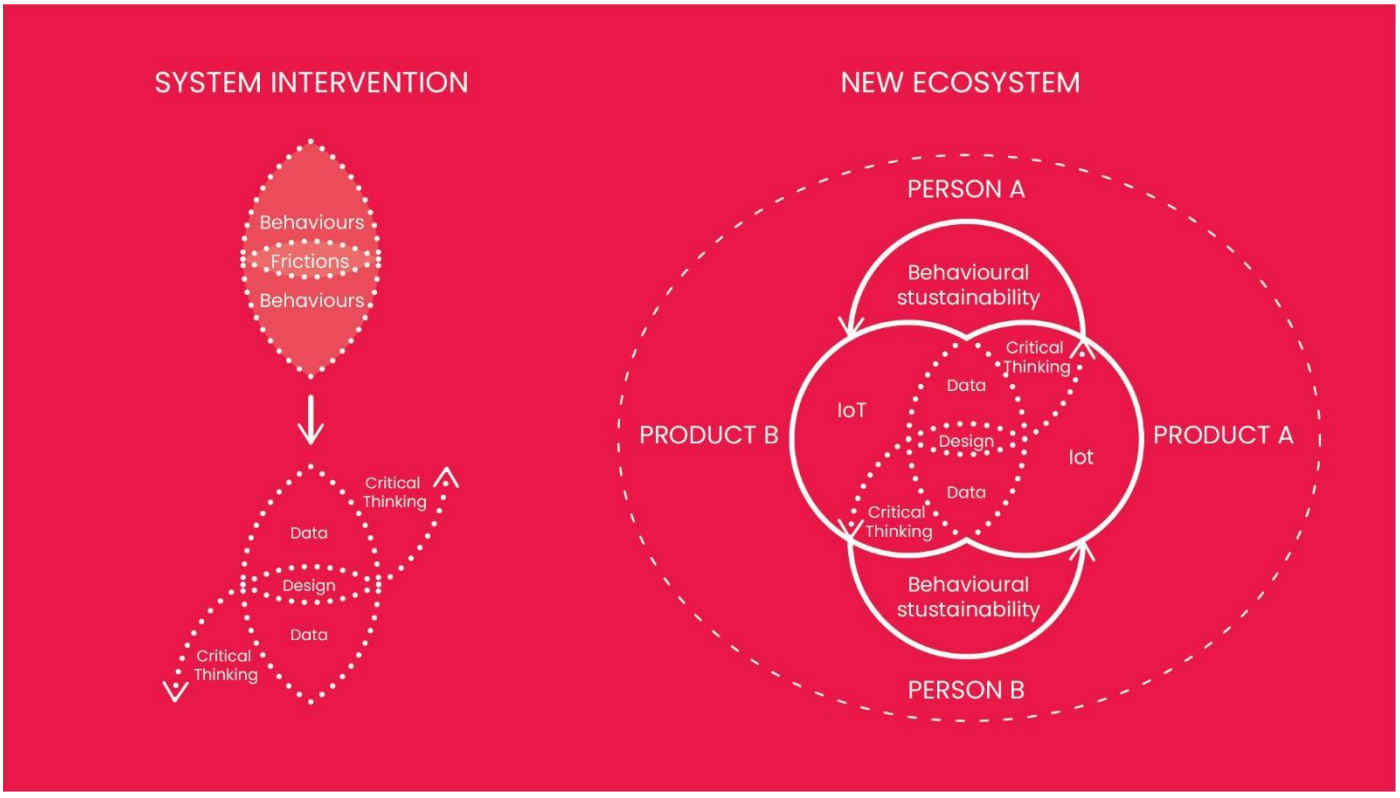


Figure 18. Design – System intervention and resulting new ecosystem.

Moreover, the study was able to establish a framework for impact-share design that traces behavioural effects of human-technology interactions. The findings suggest that richer interaction within IoT systems, grounded in physical products, could foster deeper user understanding of their behaviours with their surroundings, creating meaningful, reflective, and context-driven interactions. The dual cause-effect approach facilitates the transformation of quantitative sensor data into qualitative insights, enhancing our understanding of how IoT technologies can enable new forms of qualitative data exchange, ultimately informing new practices that promote continuous sustainable behavioural changes.

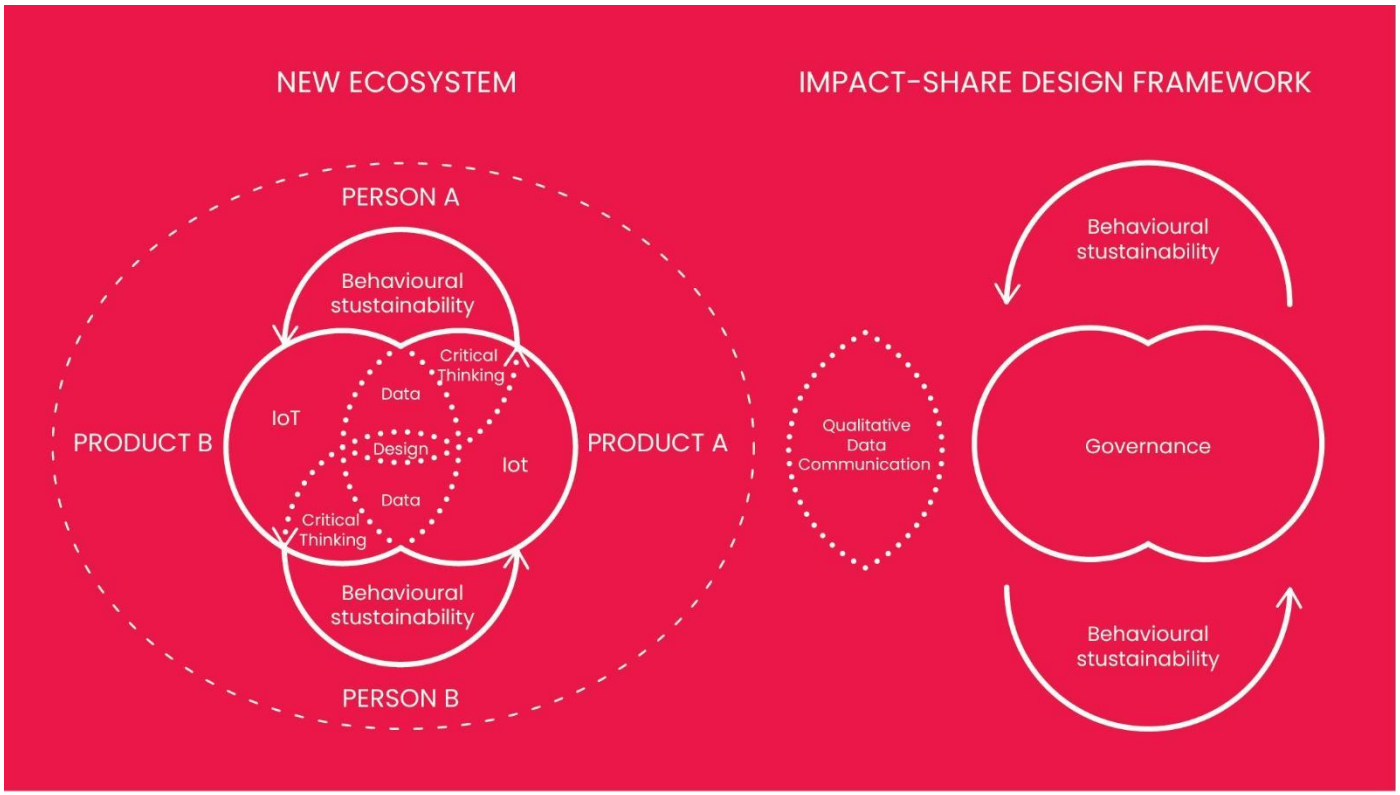


Figure 19. Impact-share design framework.

The dual cause-effect approach describes the bidirectional influence between IoT system implementations and user behavior in co-living situations. This approach recognizes that technological solutions shape social interactions while simultaneously being influenced by user feedback.
The approach emphasizes the interplay between causation initiated by design (e.g., IoT features prompting user interaction) and causation emerging from user behavior (e.g., feedback loops shaping future design iterations).
For this paper, the dual cause-effect approach was applied through iterative design sprints, user testing, and scenario-based evaluations. Each phase focused on capturing both designer-intended outcomes and emergent user behaviors.
Drawing on an example the IoT-enabled Shared Kitchen had as intent from the designer to reduce food waste by monitoring inventory and suggesting recipes. The emergent behavior was that users developed communal meal preparation routines, enhancing social cohesion.
To operationalize the dual cause-effect approach, designers should:

1. Identify bidirectional influences during the ideation phase.
2. Incorporate iterative feedback loops throughout development.
3. Leverage user insights to refine and evolve the designs.

7. Discussions

The findings of this study emphasise the critical role of design in addressing the inherent tensions and friction points that arise in shared living environments. When individuals engage in co-living arrangements, their behaviours inevitably shift in response to new social dynamics and spatial constraints. These behavioural changes can generate tensions, particularly in key areas such as personal needs, shared responsibilities, and leisure activities. Design, therefore, emerges as a fundamental mediator, capable of shaping interactions, fostering balance, and enhancing the overall co-living experience.

A central insight from this research is the potential of integrating IoT technologies into shared domestic spaces. By embedding sensors and actuators into physical objects, IoT facilitates the seamless exchange of information, allowing occupants to make more informed decisions about their communal environment. This technological integration enables products to act as intermediaries that encourage responsible behaviour, optimise shared resource management, and support more meaningful social interactions. Through real-time feedback mechanisms, IoT solutions enhance user awareness of their interactions with both their surroundings and cohabitants, ultimately promoting more conscious and pleasant living practices.

However, effective design solutions extend beyond the physical environment to include strategies for fostering fairness and cooperation among residents. Interfaces that encourage knowledge sharing, structured decision-making, and communal engagement can significantly contribute to reducing conflict and reinforcing a sense of collective responsibility. These design-driven interventions ensure that co-living spaces remain adaptable and supportive, accommodating the evolving needs of residents while maintaining a stable and cooperative atmosphere. In fact, beyond technological integration, the study highlights that the establishment of clear governance structures, and the enhancement of sustainable behaviour are enhanced through communication mechanisms within co-living settings.

Moreover, the transformation of sensor-generated quantitative data into qualitative insights is a key factor in understanding and enhancing co-living experiences. By analysing behavioural patterns and engagement levels, designers can refine interactions within shared environments, creating systems that actively shape and sustain positive behaviours. The research introduces a framework for "impact-share design," which traces the behavioural effects of human-technology interactions, offering a structured approach to designing solutions that reinforce shared responsibilities and collective values.

This approach strategically emphasises continuous engagement and reinforcement, helping individuals adopt and sustain positive behaviours over the long term. By creating lasting habits and fostering a culture of accountability, the strategy supports ongoing commitment to sustainable living behaviours, even as circumstances and dynamics evolve.

8. Conclusions

This study underscores the transformative potential of design in shaping in-house co-dwelling experiences. By integrating technology, behavioural insights, and effective governance strategies, design can mitigate tensions, foster meaningful interactions, and

create sustainable frameworks for shared living. Through a holistic approach that considers both social and spatial dynamics, the findings contribute to a deeper understanding of how tangible interaction through technological artifacts can enhance the quality of communication, ultimately ensuring that information exchange remain functional, inclusive, and enriching for all residents.

While IoT technologies offer considerable opportunities for translating sensor-generated quantitative data into qualitative insights - being context-aware, networked, and proactive - design must balance innovation with ethical considerations allowing users to explore, engage and reflect deeply with IoT devices, supporting collaborative use, influencing social dynamics, and engaging in joint decision-making.

Notes

1. On June 22, 2009, Kevin Ashton shared a definition on the RFID Journal website, recalling how the term "Internet of Things" was accidentally coined as the title of a presentation he gave at Procter & Gamble in 1999. The phrase was then used in a scientific publication for the first time a decade later. That 'Internet of Things' thing. RFID Journal. Retrieved on January 20th, 2025, from https://web.archive.org/web/20130415194522/http://www.rfidjournal.com/articles/view?4986

2. Victor, B. (2011). A brief rant on the future of interaction design. Retrieved on February 5th, 2025, from https://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/

References

Angelini, L., Mugellini, E., Abou Khaled, O., & Couture, N. (2018). Internet of Tangible Things (IoTT): Challenges and Opportunities for Tangible Interaction with IoT. *Informatics*, *5*(1), Articolo 1. https://doi.org/10.3390/informatics5010007

Anzani, A., Lonardo, E., & Schinco, M. (2022). *Reusing the built space: Atmosphere and human experience*. ITA. https://re.public.polimi.it/handle/11311/1220667

Bauman, Z. (2007). *Liquid Times: Living in an Age of Uncertainty*. Polity Pr.

Brown, T. (2008, June 1st). Design Thinking. *Harvard Business Review*. https://hbr.org/2008/06/design-thinking

Brown, T. (2009). *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation* (1° edition). HarperCollins e-books.

Chan, B., & Caprio, D. (2024). *Internet of Things (IoT) Advisory Board (IoTAB) Report*. https://www.nist.gov/system/files/documents/2024/10/21/The%20IoT%20of%20Things%20Oct%202024%20508%20FINAL_1.pdf

Chui, M., Collins, M., & Patel, M. (2021). *Where and how to capture accelerating IoT value | McKinsey*. McKinsey. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/iot-value-set-to-accelerate-through-2030-where-and-how-to-capture-it

Clitheroe, H. C., Stokols, D., & Zmuidzinas, M. (1998). CONCEPTUALIZING THE CONTEXT OF ENVIRONMENT AND BEHAVIOR. *Journal of Environmental Psychology*, *18*(1), 103–112.

https://doi.org/10.1006/jevp.1998.0091

Corbin, J. M., & Strauss, A. L. (2008). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (3º edition). Sage Pubns.

Dalsgaard, P., Dindler, C., & Halskov, K. (2011). Understanding the Dynamics of Engaging Interaction in Public Spaces. In P. Campos, N. Graham, J. Jorge, N. Nunes, P. Palanque, & M. Winckler (Edited by), *Human-Computer Interaction – INTERACT 2011* (Vol. 6947, pp. 212–229). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-23771-3_17

Ehrenberg, N., & Keinonen, T. (2022). Co-Living as a Rental Home Experience: Smart Home Technologies and Autonomy. *Interaction Design and Architecture(s)*. https://doi.org/10.55612/s-5002-050-005

European Commission, The Joint Institute for Innovation Policy (JIIP)., Joanneum Research Forschungsgesellschaft., Fundación TECNALIA RESEARCH & INNOVATION., VTT., & KPMG. (2019). *Study on mapping Internet of Things innovation clusters in Europe.* Publications Office. https://data.europa.eu/doi/10.2759/91028

Fogg, B. (2009). A behavior model for persuasive design. *Proceedings of the 4th International Conference on Persuasive Technology*, 1–7. https://doi.org/10.1145/1541948.1541999

Fritsch, J. (2009). UNDERSTANDING AFFECTIVE ENGAGEMENT AS A RESOURCE IN INTERACTION DESIGN. *Nordes*, *3*, Articolo 3. https://archive.nordes.org/index.php/n13/article/view/57

Gasparini, A. (2015, febbraio). *Perspective and Use of Empathy in Design Thinking*.

Hofstra, H., Scholten, H., Zlatanova, S., & Scotta, A. (2008). Multi-user tangible interfaces for effective decision-making in disaster management. In S. Nayak & S. Zlatanova (Edited by), *Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters* (pp. 243–266). Springer. https://doi.org/10.1007/978-3-540-79259-8_14

Holloway, M. (2009). How Tangible Is Your Strategy? How Design Thinking Can Turn Your Strategy into Reality. *Journal of Business Strategy*, *30*, 50–56. https://doi.org/10.1108/02756660910942463

Hornecker, E., & Buur, J. (2006). Getting a grip on tangible interaction: A framework on physical space and social interaction. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 437–446. https://doi.org/10.1145/1124772.1124838

Koskinen, I., Mattelmäki, T., & Battarbee, K. (2003). *Empathic Design*.

Kouprie, M., & Sleeswijk Visser, F. (2009). A framework for empathy in design: Stepping into and out of the user's life. *Journal of Engineering Design - J ENGINEERING DESIGN*, *20*, 437–448. https://doi.org/10.1080/09544820902875033

Krestanova, A., Cerny, M., & Augustynek, M. (2021). Review: Development and Technical Design of Tangible User Interfaces in Wide-Field Areas of Application. *Sensors*, *21*(13), Articolo 13. https://doi.org/10.3390/s21134258

Lilley, D. (2009). Design for sustainable behaviour: Strategies and perceptions. *Design Studies*, *30*(6), 704–720. https://doi.org/10.1016/j.destud.2009.05.001

Lilley, D., & Wilson, G. T. (2013). Integrating ethics into design for sustainable behaviour. *J. of Design Research*, *11*(3), 278. https://doi.org/10.1504/JDR.2013.056593

Mau, B., & Leonard, J. (2004). *Massive change. Ediz. illustrata: A Manifesto for the Future of Global Design* (Illustrated edition). Phaidon.

Medar, K., & Ćurĉić, A. (2021). Cohousing and coliving—Comparative analysis of two alternative housing typologies by reviewing contemporary trends. *Facta universitatis - series: Architecture and Civil Engineering*, *19*, 81–92. https://doi.org/10.2298/FUACE210329007M

Meltzer, P. G. (2005). *Sustainable Community: Learning from the Cohousing Model*. Trafford Publishing.

New, S., & Kimbell, L. (2013). Chimps, Designers, Consultants and Empathy: A "Theory of Mind" for Service Design. *2nd CAMBRIDGE ACADEMIC DESIGN MANAGEMENT CONFERENCE*, 14. http://www.lucykimbell.com/stuff/New_Kimbell_Empathy_2013.pdf

Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context Aware Computing for The Internet of Things: A Survey. *IEEE Communications Surveys & Tutorials*, *16*(1), 414–454. IEEE Communications Surveys & Tutorials. https://doi.org/10.1109/SURV.2013.042313.00197

Piardi, S., Tieghi, S., & Natile, V. (2012). *Office design. Smart organization & layout: Dall'analisi al progetto* (1A edition). Franco Angeli.

Pruitt, J., & Adlin, T. (2006). The Persona Lifecycle. *The Persona Lifecycle*. https://doi.org/10.1016/B978-0-12-566251-2.X5000-X

Revelle, G., Zuckerman, O., Druin, A., & Bolas, M. (2005). Tangible user interfaces for children. *CHI '05 Extended Abstracts on Human Factors in Computing Systems*, 2051–2052. https://doi.org/10.1145/1056808.1057095

Rittenbruch, M., & Donovan, J. (2019). Direct End-User Interaction with and Through IoT Devices: Technology, Communications and Computing. In *Internet of Things* (pp. 143–165). https://doi.org/10.1007/978-3-319-94659-7_8

Rowland, C., Goodman, E., & Charlier, M. (2015). *Designing Connected Products: UX for the Consumer Internet of Things* (1st edition). O'Reilly Media.

Sanders, E. B.-N. (2000). Generative Tools for Co-designing. In S. A. R. Scrivener, L. J. Ball, & A. Woodcock (Edited by), *Collaborative Design* (pp. 3–12). Springer. https://doi.org/10.1007/978-1-4471-0779-8_1

Scolari, C. A. (2021). *Las Leyes De La Interfaz*. GEDISA.

Scullica, F., Borella, M. A., Postell, J. C., & Veronese, G. (2022). *Engaging Spaces: How to increase social awareness and human wellbeing through experience design* (B. Camocini & A. Dominoni, Edited by). FrancoAngeli.

Shaer, O., & Hornecker, E. (2009). Tangible User Interfaces: Past, Present, and Future Directions. *Foundations and Trends in Human-Computer Interaction*, *3*, 1–137.

https://doi.org/10.1561/1100000026

Shelley, A. E. (2009). *Beyond Buzz Words and Skill Sets: The Role of Critical Thinking in Information Literacy*. https://doi.org/10.17077/igb4-u44l

Spencer, H. (1881). *The principles of psychology [electronic resource]* (King's College London). London : Williams and Norgate. http://archive.org/details/b21292929_0002

Su, X. (2014). The Application of "5W1H" in Industrial Design. *Advanced Materials Research*, *1028*, 346–349. https://doi.org/10.4028/www.scientific.net/AMR.1028.346

van den Hoven, E., Van de Garde-Perik, E., Offermans, S., Boerdonk, K., & Lenssen, K.-M. (2013). Moving Tangible Interaction Systems to the Next Level. *Computer*, *46*, 70–76. https://doi.org/10.1109/MC.2012.360

Verganti, R., Dell'Era, C., & Swan, K. S. (2021). Design thinking: Critical analysis and future evolution. *Journal of Product Innovation Management*, *38*(6), 603–622. https://doi.org/10.1111/jpim.12610

Ward, A., Runcie, E., & Morris, L. (2009). Embedding Innovation: Design Thinking for Small Enterprises. *Journal of Business Strategy*, *30*, 78–84. https://doi.org/10.1108/02756660910942490

Williams, J. (2005). Designing Neighbourhoods for Social Interaction: The Case of Cohousing. *Williams, J. (2005) Designing neighbourhoods for social interaction: the case of cohousing. Journal of Urban Design, 10 (2). pp. 195-227. ISSN 13574809*, *10*. https://doi.org/10.1080/13574800500086998

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