Towards Design of Interaction Systems for Constrained Spaces

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

The completed studies presented in the subsequent chapters are the result of collaborative work between me and my research colleagues. The following notes provide some indication for the amount of their involvement:

1. For the fieldwork presented in Chapter 3, I designed and conducted the study in its entirety. Arden Song assisted by running four of the participant sessions. I carried out all remaining data collection, analysis, and writing for the study, and was the lead author on the paper that resulted from this work.

2. For the fieldwork presented in Chapter 4, I planned the study in collaboration with graduate student Kateryna Morayko. She went with me for two of the three meetups, and was present for most of the interviews. She was also present in 4 out of the 5 public spaces, and interviewed two people for the study. Arden and she assisted me in the thematic analysis we conducted for this study. I was the lead author on the paper that came out of this analysis.

3. For the work on Proteus presented in Chapter 5, I led the design and development of the card system, including all three prototypes (hardware and software). I planned the study, conducted pilot tests, ran the full user study, and performed the analysis. Arden Song assisted in system optimization, contributed documentation to the study materials, ran an independent pilot study, and supported testing logistics. She also presented our poster introducing the Proteus Card Deck at CHI PLAY 2024. I was the lead author on the paper based on this work, which is planned for submission to CHI 2026.

Additionally, this thesis includes first-authored peer-reviewed material that has appeared in conference and journal proceedings published by the by the Association for Computing Machinery (ACM). The ACM's policy on reuse of published materials in a dissertation is for Computing Machinery, n.d.:

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The following list serves as a declaration of the Versions of Record for works included in this dissertation:

Chapter 3

Ali Haider Rizvi, Mark Hancock. (2023). Small Spaces, Many Places: A Phenomenological Analysis of Technology-Mediated Placemaking in Small Spaces. In Proceedings of the 2024 GI Graphics Interface (GI '24). Association for Computing Machinery, New York, NY, USA *(published paper)*

Chapter 4

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Chapter 5

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Abstract

The traditional definition of home is undergoing a number of changes, primarily driven by socioeconomic factors that make home affordability challenging. Other drivers of change include new technologies (such as online collaboration and work tools), the widespread availability of the internet in remote areas, and increased remote work opportunities. This shift has led to the emergence of small living spaces, such as co-living setups and tiny homes, where technology plays a crucial role in everyday activities. However, much of today's technology assumes larger living spaces, potentially compromising user experience in these spatially constrained environments.

My first chapter details a study that re-examines these implicit assumptions within human-computer interaction (HCI), focusing on how small spaces can still foster the creation of meaningful "places" through technology. By conducting phenomenological analysis and diary studies among inhabitants of small spaces, I identify key elements—boundaries, temporality, mastery, and future-thinking—that contribute to placemaking. Additionally, I found seven distinct types of places that emerge in these environments, such as leisure places and work places. These findings suggest that even in physically restricted spaces, individuals are capable of creating a rich multiplicity of places. Through this study, I demonstrated that small spaces, when augmented with technological interventions and personal agency, can support the creation of dynamic and versatile places.

My second chapter details a study where I investigated placemaking in small spaces "in the wild" by studying the non-traditional lifestyle of `#vanlife`. This lifestyle is gaining traction through social media and socio-economic factors noted before, and it is estimated that three million people live the vanlife in North America alone. Vanlife merges travel, home, and work, with individuals living full-time in modified cargo vans—an ideal community to further investigate placemaking in small, constrained spaces. This extended study, involving around 200 hours of fieldwork and interviews, offered a detailed portrait of vanlifers' current technology practices. A thematic analysis revealed unique intersections of technology with culture, design, homesteading, offline organization, and gaming. These findings yielded eleven provocations aimed at inspiring critical design and fostering informed inquiry into technological solutions tailored for vanlife. Through this study, I continued to uncover how technology not only adapts to but also enhances unconventional living arrangements.

Building on insights from the first two studies, I identified a design opportunity to create a research artifact that directly responded to the infrastructural constraints and placemaking practices observed in small, resource-limited environments. Through a Research

through Design (RtD) process, I developed the Proteus Card Deck: a centrally coordinated set of battery-less e-ink displays that function as a hybrid physical-digital deck. Its design reflects the practical limitations and socio-technical adaptations documented in both shared housing and vanlife settings, supporting flexible, low-power, and space-efficient interaction. By enabling tangible engagement for play, Proteus fosters the creation of distributed places for work, mastery, and social connection. The final system was evaluated through a within-subjects user study using validated instruments to assess usability, player experience, and social connection, alongside qualitative analysis of open-ended feedback. Results showed that Proteus effectively extended the placemaking strategies identified in the earlier studies, enhancing perceptions of social connection in remote contexts and offering a more engaging, tangible experience than conventional digital platforms.

The trajectory from field-informed design to iterative construction to targeted deployments in the field was foundational to my research, enabling the production of situated design knowledge grounded in empirical findings and materially responsive to the lived realities of small, technologically constrained spaces. My thesis highlights the need for HCI to consider diverse living conditions in technology design, offering a new perspective on enhancing user experience in non-traditional living arrangements. This research provides a foundation for designing technology that considers spatial constraint, while opening up new avenues for HCI research in understanding and facilitating interaction in small spaces.

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Dedication

To my mother for always encouraging me to dream big, my father for giving me the safety net to make it possible, and my sister for dealing with the process.

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Chapter 1

Introduction

My thesis explores technology and placemaking in small living spaces through three studies: the first re-examines assumptions in human-computer interaction (HCI) to show how technology can create meaningful places in small spaces; the second investigates the vanlife lifestyle, revealing how technology enhances unconventional living; and the third builds upon the first two by applying the findings to design and evaluate a new technology targeted at people living in small spaces.

1.1 Context and Background

The traditional definition of the "home" in North America is changing, driven largely by socio-economic factors that make housing less affordable. In Canada, the Real Residential Property Prices index (CPI-deflated) climbed from approximately 91 to 153 (2010 was the baseline at 100) between Q1 2010 and Q4 2024, marking a substantial rise in real house prices (Bank for International Settlements, 2024). In contrast, median household income grew at a much slower pace during the same period (Statistics Canada, 2024). Similarly, in the United States, inflation-adjusted median home prices rose by 121% nationwide since 1960, while real median household income increased by only 29% (Estate, 2019). By early 2019, Canada's house price-to-income ratio was among the highest across member nations of the Organization for Economic Co-operation and Development (OECD, 2016).

Other drivers of the changing definition of home include new technologies (such as online collaboration and work tools), the widespread availability of internet in remote areas, and

increased remote work opportunities—all factors that the COVID-19 pandemic hastened. Together, these factors are resulting in the growth of a number of alternate living situations, of which co-living and living in alternate residences (earth-ships, tiny homes, etc.) are some examples.

With these alternate residences, come alternate types of spaces. The space that technology is used in is fundamental to the experience of using it, but place—"a space which is *invested with understandings* of behavioural appropriateness, cultural expectations, and so forth" (Harrison & Dourish, 1996, p. 69)—is an important concept that can help identify how people appropriate meaning within these spaces (i.e., engage in placemaking). Dourish (2006) encourages researchers and designers to consider both space and place when studying human-environment interactions to create more meaningful and context-aware experiences and technologies. This past research has highlighted that a variety of spaces can lead to a multiplicity of places. However, this past work often relies on the assumption of the vastness of space. Often, multiple rooms or buildings are thought of as allowing for this multiplicity, and technological design decisions often rely on assumptions rooted in the traditional notion of a North American single-family home (Desjardins et al., 2019a). This focus on larger spaces with dedicated rooms or spots for specific technology creates a gap in technology design. Consider smart home technology, which assumes traditional wiring is in place and often relies on distant interaction; or virtual reality (VR) and gaming controllers like HTC Vive and Microsoft Kinect, which require a large space to function properly.

While design artifacts may not always consider the case for diverse spaces, previous work in HCI has investigated non-traditional homes, either as new areas for design (Desjardins et al., 2015, 2019b; Zafiroglu & Chang, 2007b) or to look at the motivations and implications of non-traditional homes or work practices (De Carvalho et al., 2017; Ferreira et al., 2019; Petersen et al., 2010; Rossitto & Eklundh, 2007; Thompson, 2018). The output of this prior work, however, does not provide either guidelines, implications, or other findings that could be applied to build technological solutions for people living in small spaces. This lack of relevant research was noted in a previous paper that investigated literature around one type of non-traditional living, nomadic culture (Rossitto et al., 2017), and noted a requirement for more diverse papers beyond non-traditional work setups (which remain the current focus of most papers in the field).

This thesis addresses this gap in literature by understanding how technology is used in spaces that are physically constrained; furthering that understanding by understanding technology use in physically-constrained, mobile spaces that do double duty as spaces for work and living; and finally building a technology artifact that conforms to the constraints and opportunities identified in the first two studies.

1.2 Research Questions

My research challenges assumptions about spatial requirements for effective technology usage and placemaking, expanding an understanding of how space and technology interact within small, constrained spaces. This is crucial for human-computer interaction (HCI) research, which often considers the context of technology use but may not fully account for the variability in spatial constraints faced by users. To contribute new design spaces, provocations, and artifacts to address challenges faced by people inhabiting small spaces, I ask the following research questions:

RQ1: How can technology mediate a sense of place for people living in small spaces? Small spaces, such as studio apartments, co-living environments, and van homes, are becoming increasingly prevalent due to rising housing costs, urbanization, and the popularity of minimalist lifestyles. These constrained environments present unique challenges for creating meaningful "places"—spaces imbued with emotional, cultural, and functional significance. However, the role of technology in enabling placemaking within these small spaces remains under explored.

Existing research in HCI has examined placemaking in larger, more traditional environments, but these studies often assume ample spatial resources and conventional layouts (Desjardins & Wakkary, 2016; Oogjes et al., 2018). For example, technologies such as smart home systems, voice assistants, and augmented reality tools are typically designed with the assumption of spacious, fixed living arrangements, limiting their applicability in compact or shared spaces (Crabtree, 2003; J.-K. Lee et al., 2023). This raises critical questions about how such technologies might need to adapt to smaller, shared, or multifunctional spaces to remain effective.

In smaller spaces, individuals must use technology creatively to establish boundaries, manage temporality, and foster a sense of mastery and future-thinking. For instance, studies show that spaces can transform through technology, such as using smart lighting to transition a small room between a workspace during the day and a place of leisure in the evening (Dourish, 2006; Harrison & Dourish, 1996). Similarly, shared spaces in co-living arrangements highlight the need for technologies that respect privacy while fostering community (Desjardins et al., 2019a).

Presently, there is a risk of neglecting the needs of a growing population living in such environments. This knowledge gap limits researchers and designers ability to design

technologies that enhance both the functional and emotional aspects of these spaces. For example, insights from the study of alternative living arrangements, such as van homes (Desjardins & Wakkary, 2016), emphasize the importance of designing technology to support multi-functionality and emotional resonance.

By addressing this question, I advance HCI research by broadening its focus beyond traditional spaces, ensuring that technological innovation is inclusive of diverse living conditions and capable of meeting the challenges posed by constrained environments.

RQ2: How is technology currently used by people living the vanlife? A specific type of small space is a cargo or small passenger van converted into a living space, often by the inhabitants themselves. Previous work has identified persons living in vans and recreational vehicles as non-traditional homes (Desjardins & Wakkary, 2016; Desjardins et al., 2019a; Gretzel & Hardy, 2019); but not considered the impact of this space also being a mobile workspace.

The nomadic nature of vanlife has required the expansion of how everyday technology is used, from jobs, to interactions with friends and family, to religious gatherings. Paradoxically, this technology is designed with expectations of traditional homes and workplaces—potentially leading to a sub-par user experience in non-traditional settings. This compromised experience is evident in the case of commonly used technology, such as smart home technology (which assumes a fixed location of objects), voice assistants (which usually assume constant connectivity and low background noise), and gaming consoles (which assume fixed and large living room spaces).

Previous work in HCI has investigated non-traditional homes, either as new areas of design (Desjardins et al., 2015, 2019b; Zafiroglu & Chang, 2007b) or to examine the motivations and implications of nomadic homes or work practices (De Carvalho et al., 2017; Ferreira et al., 2019; Petersen et al., 2010; Rossitto & Eklundh, 2007; Thompson, 2018). For example, Rossitto et al. (2017) investigated literature around nomadic cultures, and noted a requirement for more diverse papers beyond just nomadic work. In the only other work from the HCI community that exclusively considered people living in mobile homes, Rossitto and Eklundh (2007) looked at retired persons living in recreational vehicles and noted a domestication of the vehicle, making it a home. Thus, previous work has identified persons living in vans and recreational vehicles as non-traditional homes; however, the implications of that home also being a workplace and a means of establishing community remain unclear.

This question invites further exploration into how technology can be designed and adapted to better suit the unique needs of vanlife, where the intersection of living, working, and travelling creates distinct challenges and opportunities. Understanding the dual role of vans as both home and workspace highlights a critical gap in current HCI research. While prior studies have explored the domestication of mobile spaces (e.g., Rossitto & Eklundh, 2007) and the cultural practices of nomadic lifestyles (Petersen et al., 2010; Thompson, 2018), the specific technological adaptations required for multi-functionality in these constrained, mobile environments remains unexpolored.

Key challenges include ensuring reliable connectivity, enabling multifunctional use of limited physical spaces, and addressing the evolving needs of users who simultaneously navigate personal and professional spheres. Technologies like augmented reality, Internet of Things (IoT)-enabled devices, and portable power systems hold promise in addressing these challenges. However, these solutions must account for the mobility, spatial limitations, and diverse contexts inherent to vanlife.

By addressing this research question, I provide actionable insights for designing inclusive and adaptable technologies, ultimately enhancing the quality of life for individuals living in non-traditional, mobile environments.

RQ3: How can a tangible-digital system, grounded in the constraints of small and mobile living, be designed to support connection and flexible interaction across contexts? A recurring theme across both fixed spatially constrained, and vanlife contexts is the inadequacy of existing digital tools to support interaction that feels socially rich and physically grounded. While participants creatively adapted technologies to suit their constrained environments, these tools were rarely designed with their spatial, infrastructural, or social realities in mind. In chapter 3 (RQ1), I found that individuals living in compact apartments used digital systems to establish boundaries, build routines, and foster a sense of place. Yet they also described technology as isolating or impersonal—better suited to single-user consumption than shared activity. The physical limitations of their environments often meant foregoing large displays or dedicated surfaces, making it harder to engage in collaborative or playful experiences with others.

In chapter 4 (RQ2), the findings revealed similar challenges in the context of mobile living. Vanlifers stretched the functionality of mainstream technologies to accommodate work, community, and leisure while on the move. However, many digital tools assumed constant power, stable internet, and fixed usage contexts. Participants described the loss

of co-located rituals—playing games, brainstorming ideas, sharing media—as a side effect of going digital. These experiences point to a critical blind spot in HCI: a lack of systems that can flexibly adapt across spatial contexts while preserving the embodied and social qualities that make in-person interaction meaningful.

RQ3 emerges from the intersection of these two studies. It asks how interactive systems might be designed not just to "fit" into constrained spaces, but to restore forms of engagement that participants found lacking in current tools. It foregrounds a need for hybrid systems that support material expressiveness, digital flexibility, and social connectedness—especially for people living in homes that are shared, modular, mobile, or infrastructurally constrained. Concretely, this includes supporting shared attention, turn-taking, spatial negotiation, and interpersonal awareness across physical and digital boundaries.

By addressing this research question, I offer design insights for creating socially meaningful, spatially adaptable technologies that better support connection and collaboration in constrained or mobile living environments. To evaluate such systems in future work, I focus on four key dimensions surfaced by the earlier studies: whether users find the system usable in constrained settings, whether it offers a positive and engaging experience during interaction, whether it fosters a felt sense of closeness or inclusion, and whether it enables a robust sense of presence and awareness in hybrid or remote contexts. These measures reflect not only standard HCI concerns but also the specific breakdowns participants articulated—moments when digital systems functioned, but failed to feel human.

Putting it all together This thesis contributes to HCI by tracing how people make place under constraints of space, and by translating those insights into the design of technologies that better support spatial, social, and functional adaptability. From compact urban apartments to mobile homes, the studies uncover how users actively reshape mainstream digital tools to negotiate limited space, shifting routines, and shared presence. By culminating in the design and evaluation of a tangible-digital system grounded in these lived realities, the research bridges ethnographic inquiry with technological intervention. The implications extend beyond any single use case—offering design principles for emerging contexts such as urban micro-housing, post-disaster shelters, remote workspaces, and long-duration space habitats. Ultimately, this work repositions constrained living not as a deficit to be managed, but as a site of creativity, resilience, and opportunity for re-imagining the role of interactive systems.

1.3 Methodology

In this section, I describe the methodology used to address each research question.

RQ1: How can technology mediate a sense of place for people living in small spaces? To address this research question, I investigated placemaking in an environment where participants described their spaces as "small." This phenomenological study examines the technological practices individuals employ to create meaningful "places" within these small spaces. An illustrative example of this interactivity can be seen in kitchens, which often transform into multi-functional spaces as people arrange them based on specific contexts, incorporating both individuals and their belongings (Hand et al., 2007). In a manner analogous to Desjardins and Wakkary (2016) and consistent with the work done in chapter 4, this work uses the distinction, tension, and overall relationship between place, physical space, and technology. In this paper, technology refers to digital artifacts found in domestic settings, such as televisions, ovens, and gaming consoles. Participants defined "technology" based on their own interpretations, typically encompassing digital technology and electricity-powered appliances.

I employed interviews, self-drawings of participants' spaces, and a diary study to enable participants to express how technology influenced their daily experiences, ranging from mundane to celebratory, restless to restful. Data collection was followed by a phenomenological analysis (Casey, 1996) and a mind-mapping exercise to establish connections between technology, emotions, and common places I defined based on participant descriptions.

Following the data analysis, I describe four elements that characterize the creation of places in constrained environments: *boundaries*, *temporality*, *mastery*, and *future-thinking*, each contributing to the multiplicity of places within a single space. Additionally, I identify seven distinct types of places emerging in these settings, including places of leisure, shared places, and unfamiliar places, among others.

This study complicates the assumption that effective technology use requires expansive or fixed spaces. Instead, it shows how people actively negotiate their environments—transforming small, constrained settings into multifunctional places through boundary-setting, routines, and creative adaptations. These findings extend existing HCI discourse by illustrating that placemaking is not a luxury of space, but a practice of agency. For researchers and designers, this offers a shift in perspective: from designing for the ideal home to designing with the resourcefulness of real users in mind—whether they're in a studio apartment, a shared co-living space, or a van parked off-grid.

RQ2: How is technology currently used by people living the vanlife? To address this question, I conducted an extensive investigation into the technological practices, adaptations, and challenges faced by vanlifers, a nomadic community that blends living, working, and travel within mobile spaces. This study involved approximately 200 hours of immersive fieldwork, including semi-structured interviews with vanlifers, ethnographic participation where researchers lived in a converted van to directly experience the lifestyle, and detailed observations at vanlife meetups—temporary gatherings that serve as social and organizational hubs for this community. These meetups are consistent with the forms of community building described by Petersen et al. (2010) as "tactics for homing," where individuals create personalized, meaningful spaces even in transient environments. The methodology incorporated practices akin to those outlined by Creswell and Poth (2016), emphasizing the need for rich qualitative data to understand lived experiences.

The study employed thematic analysis to uncover vanlife's unique position as a techno-centric community. This aligns with findings by Dourish (2006) and Rossitto and Eklundh (2007), who emphasize the need to understand the interplay of space and place when designing for mobile and non-traditional environments. The research identified how vanlifers adapt and innovate to overcome challenges such as limited power, variable internet connectivity, and the spatial constraints of mobile living. These constraints highlight opportunities for designing technology that is modular, multi-functional, and resource-efficient, as echoed by prior studies on constrained domestic environments by Desjardins et al. (2019a) and Zafiroglu and Chang (2007b).

In addition to the analytical work, I developed a visual cultural portrait inspired by Creswell and Poth (2016), emphasizing how vanlifers express their identities and navigate their lifestyles through visual media. This representation resonates with the concept of mobility as a lifestyle explored by Cohen (2010) and Muller and Druin (2012), who noted that mobile communities often blend work, leisure, and identity through their use of technology and media. The portrayal also underscored the prominence of the `#vanlife` movement on social media platforms like Instagram, which fosters both individual expression and communal belonging.

The study culminated in eleven provocations aimed at guiding technological design and research in the human-computer interaction (HCI) domain. These provocations draw on ideas from critical design theory (Biggs et al., 2021) to address key needs such as improving environmental control, enhancing connectivity for dynamic communities, and enabling seamless transitions between work and leisure. For instance, the research identified parallels with work by Gabriel et al. (2020) on collective effervescence, suggesting ways technology can replicate the sense of togetherness vanlifers experience at in-person gatherings. Additionally,

it emphasized tools that support planning and reminiscing, consistent with findings by (van Gennip et al., 2015) on the role of memory in enhancing user experiences.

By synthesizing these findings, the research not only contributes to understanding vanlife as a cultural and technological phenomenon but also informs broader design considerations for mobile, resource-constrained, and non-traditional communities. This aligns with calls by Tellioglu et al. (2019) for HCI to engage with diverse and emerging solutions.

RQ3: How can a tangible-digital system, grounded in the constraints of small and mobile living, be designed to support connection and flexible interaction across contexts? To address RQ3, I adopted a Research through Design (RtD) approach, culminating in the development and evaluation of the *Proteus Card Deck*: a tangible electronic card system designed for use in small, hybrid, or remote environments. RtD was inherently aligned with the aims of this inquiry, enabling a design process that progressed through iterative cycles of ideation, prototyping, and contextual reflection. Grounded in empirical insights from prior studies (Chapters 3 and 4), the research artifact was developed through sustained engagement with material, conceptual, and contextual constraints. A final evaluation was conducted with participants living in spatially constrained environments, purposefully sampled across well-defined strata of low and high socio-economic status. This trajectory—from field-informed design to iterative construction to targeted deployment—represented the most direct and appropriate means of generating the situated design knowledge this thesis aimed to produce.

The design of Proteus was motivated by a specific interactional gap. Card decks—simple, flexible, and social—are widely used for gaming. However, they rely heavily on co-location: the feel of cards in hand, the visibility of shared piles, the pacing of turn-taking. Digital equivalents, from simulators to apps, often lose this interactional fidelity. Proteus aimed to bridge this divide by embedding low-power e-ink displays into a coordinated deck of physical cards, each controlled wirelessly from a central interface. This allowed the cards to dynamically update content (e.g., game states, scores, etc.) while preserving traditional gestures such as fanning, shuffling, and laying out cards in space.

Following this design process, I conducted a structured within-subjects evaluation ($N = 36$), comparing Proteus to both traditional physical cards and a digital tabletop simulator. Each participant engaged in gameplay under four conditions: (1) traditional cards, co-located; (2) digital simulator, remote; (3) Proteus, co-located; and (4) Proteus, remote. This 2×2 factorial design allowed me to test the effects of both modality and

location, while controlling for individual differences. To measure user experience, I employed a suite of validated instruments:

- **UMUX-LITE** to assess usability;
- **PXI (Player Experience Inventory)** to capture engagement and immersion;
- **IOS (Inclusion of Other in the Self)** to gauge perceived closeness between players;
- **Networked Minds** to evaluate dimensions of social presence.

I supplemented these measures with qualitative observations and post-session interviews to understand not just what users experienced, but why. Many participants described the Proteus cards as "feeling real," even in remote settings—a key signal that the design successfully reintroduced physicality without sacrificing flexibility.

Thus, the methodology for RQ3 was both evaluative and generative. It built directly on the theoretical and empirical foundations of chapters 3 and 4, translated those insights into a working system, and tested its impact through a mixed-methods approach that emphasized both interactional nuance and real-world relevance.

1.4 Research Context Within HCI

My research straddles two sub-domains within human-computer interaction. While these areas have overlaps and fuzzy boundaries, both offer distinct scholarship and methods on which I built my thesis:

1. **Placemaking in Space**: Placemaking and allied literature focus on the interaction of technology and space. This field could be considered a sub-field of computer-supported collaborative work (CSCW), and has a wide-ranging focus—from designing imagined futures for the home (Cho et al., 2024) to investigating placemaking in various contexts (Agrawaal et al., 2024; Neupart et al., 2024).

2. **Contested Values of the Home**: My research is concerned with technology for people living (and often working) in small spaces—at its very core, this is a different type of home than what is currently considered in technology design. While domestic research has many themes, I believe mine best falls into contested values of the home. One of the questions of research in this theme has been described by Desjardins et al. (2015) as:

> "How can we go beyond common assumptions about what the home is in a way that can tell us more about how to design interactive domestic technologies?" (Desjardins et al., 2015, p. 4)

The fields and their context within human-computer interaction are showcased in Figure 1.1.

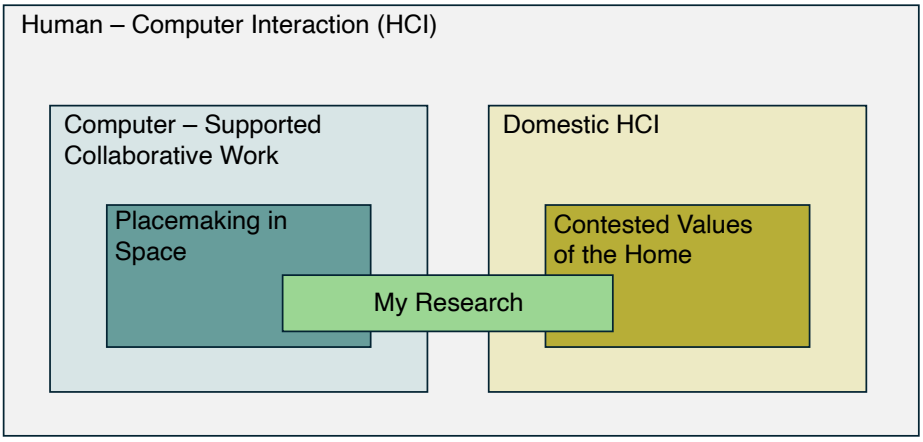


Figure 1.1: Context of this thesis within human-computer interaction

1.5 Contributions

The primary contributions of this thesis, along with their associated research questions, are noted below. RQ1: How can technology mediate a sense of place for people living in small spaces? (chapter 3)

1. **C1.1:** I provide a deeper theoretical understanding of technology-mediated placemaking in small domestic environments by identifying four core elements (boundaries,

temporality, mastery, and future-thinking) that enable the emergence of a multiplicity of places within a physically constrained space.

2. **C1.2:** I challenge assumptions in HCI that meaningful placemaking requires expansive environments, and instead demonstrate how users transform spatial limitations into opportunities for rich, layered place-experiences through creative and affective uses of everyday technology. This offers design guidance for technologies that better support co-located and remote life in compact, multi-use spaces.

RQ2: How is technology currently used by people living the vanlife? (chapter 4)

1. **C2.1:** I identify eleven design provocations that articulate how technology can be re-imagined to support the subjective well-being of vanlifers, offering the HCI community actionable directions for future critical and speculative design.

2. **C2.2:** I develop a situated understanding of the constraints and values that shape technology use in the vanlife community, including concerns around affordability, energy efficiency, modularity, and infrastructural independence.

RQ3: How can a tangible-digital system, grounded in the constraints of small and mobile living, be designed to support connection and flexible interaction across contexts? (chapter 5)

1. **C3.1:** I develop the Proteus Card Deck, a tangible-digital card system that directly designs for the spatial, infrastructural, and temporal constraints identified in earlier studies.

2. **C3.2:** Through a field-based evaluation, I show that Proteus enables comparable usability, connection, and coordination to traditional alternatives (physical cards and online games) in both remote and co-located settings.

3. **C3.3:** I provide a set of seven design strategies for hybrid systems (systems that can be used in co-located or remote settings) that operate under constraint.

1.6 Positionality Statement

I approach this thesis through a pragmatic lens, grounded in the belief that research should produce meaningful, actionable outcomes. My methodological stance is pluralistic—I draw on ethnographic, phenomenological, and design-based approaches, and engage both inductively and deductively depending on what the research demands (Creswell & Poth, 2016; Onwuegbuzie & Leech, 2005). I treat research not as a linear path, but as an iterative process of listening, building, testing, and refining. This reflects the methodological flexibility valued in HCI, and is also shaped by my background as a product manager.

Prior to academia, I spent years developing data-driven technologies for users I would rarely meet. That experience trained me to look beyond what users do, toward why they act as they do, and what gets in their way. It also made me wary of abstractions: how easily we turn people into personas or design for imagined edge cases. My turn to HCI, and this thesis in particular, was driven by a need to reconnect design with lived realities, especially those often excluded from dominant narratives of technological progress.

That said, I remain an outsider to many of the experiences I study. I have not lived long-term in vans co-living, or alternate home setups. My understanding comes through fieldwork: brief periods of immersion, careful observation, and long-form interviews. I've tried to meet this positional gap not by minimizing it, but by foregrounding it—approaching participants as experts in their own lives, and interpreting findings through a lens of situated, relational inquiry (England, 1994; Haraway, 2013).

This approach aligns with critical and feminist HCI traditions that emphasize reflexivity, power, and the co-construction of knowledge (Bardzell, 2010). My interpretations are shaped by my own position: as a product manager trained in industry, a researcher working within academia, and someone raised in more conventional domestic environments. This positionality shaped what I noticed, what I asked, and what I had to unlearn—particularly when engaging with contested notions of "home" (Desjardins et al., 2015; Mallett, 2004; Tuan, 1977).

This thesis is the result of that convergence: a blend of design and inquiry that aims to be both rigorous and grounded. The Proteus Card Deck and the provocations in this work were not just designed for small spaces—they emerged from a long process of learning what small spaces mean to the people who inhabit them. I see my role not as a neutral observer, but as a reflective, iterative practitioner—one who believes that good research is not only about understanding systems, but dwelling within them (Dourish, 2006; Suchman, 2007).

1.7 Thesis Structure

This thesis begins with the introduction, followed by a related work section covering the previous work upon which all three studies build. The following three chapters each include one study: Chapter 3 covers the study on the phenomenological analysis of technology-mediated placemaking in small spaces; Chapter 4 covers the study on placemaking in vanlife; and Chapter 5 covers the design and development process of the Proteus card deck using the learning from the first two chapters.

Each of these chapters contains an introduction to ground the study in the overall thesis, a detailed methods section specific to the study (and any associated related work), and a discussion of the results and conclusions.

Following the three studies, Chapter 6 synthesizes design implications and theoretical contributions across the studies. This chapter provides a cross-study integration of findings and presents a set of guidelines for designing interactive technologies in constrained environments. It also articulates the theoretical contributions of the work to HCI literature on placemaking, mobility, and hybrid systems.

Finally, Section 7.7 concludes the thesis. It reflects on the research contributions, examines cross-cutting tensions, and presents meta-reflections on the research approach. The chapter also outlines limitations and proposes directions for future work, positioning the contributions of this thesis within broader HCI discourse.

1.8 Note on Study Sequence and Access Limitations

While the vanlife study was conducted before the small space study, I present them in reverse order due to critical access challenges encountered during the COVID-19 pandemic. As a researcher affiliated with a government university, I faced resistance from vanlife communities who expressed concern that formal engagement might lead to surveillance or displacement—particularly given rising tensions with local authorities over informal parking and living arrangements. These concerns were valid and reflected broader issues of institutional mistrust and precarity that shaped the fieldwork itself.

In response, I shifted my focus to small space living in fixed urban settings, where participants were more receptive to in-depth engagement. This transition re-framed the

trajectory of the research. Presenting the small spaces study first allows the thesis to establish a stable analytic foundation: how people create place under constraint using digital tools in infrastructurally stable but spatially limited environments. This forms a conceptual base for the vanlife chapter, where similar themes unfold under greater mobility, resource scarcity, and infrastructural fragility.

The reordered presentation supports the intellectual arc of the thesis: from fixed to mobile, from constrained to precarious, and from observation to intervention. This sequence mirrors the design trajectory as well, culminating in chapter 5 with the Proteus system—an artifact that draws on findings across both studies to support hybrid, socially meaningful interaction in small or mobile spaces.

Chapter 2

Related Work

The exploration of technology for placemaking in small and mobile spaces draws on a rich intersection of disciplinary perspectives, including environmental psychology, cultural geography, architecture, and human-computer interaction (HCI). Each of these fields contributes distinct conceptual tools for understanding how people imbue space with meaning, navigate spatial constraints, and leverage material and technological artifacts to make a place their own. In the context of constrained living—whether due to size, mobility, or infrastructure—technological interventions become not only functional but expressive, adaptive, and affective.

This chapter reviews key literature across five domains relevant to this thesis: foundational theories of place and perception; technological adaptations in domestic and mobile environments; design strategies that foreground agency, identity, and constraint; hybrid tangible-digital systems for collaboration and play; and methodological frameworks that support studying these phenomena in-situ. My goal is twofold: to identify gaps in current discourse, and to position this thesis within a broader scholarly landscape that bridges theoretical abstraction with empirical, design-led inquiry.

To help orient the reader, Table 2.1 summarizes the main contributions of each section, maps them to the corresponding chapters of the thesis, and highlights representative literature foundational to each domain. Methodological details are further elaborated on in future chapters in the respective methods sections 3.2, 4.2 and 5.3.

Table 2.1: Summary of Related Work Structure and Chapter Linkages

Section	Key Sub-themes	Representative References	Chapter
2.1 Conceptual and Theoretical Foundations	Space vs. place; perception and boundedness; architectural affect	Casey (1996), Malpas (2012), Dourish (2006), Bachelard (1964), Cresswell (2014), Alavi et al. (2019) and Becerik-Gerber et al. (2022)	Chapters 3 and 4
2.2 Technology in Constrained Living Environments	Smart homes; mobile domesticity; van conversion; resource constraints	Desjardins and Wakkary (2016), Oogjes et al. (2018), Zafiroglu and Chang (2007b), Desjardins et al. (2015), Petersen et al. (2010)	Chapter 4
2.3 Design Strategies for Placemaking with Technology	Feminist/participatory design; boundary routines; speculation & provocations	Suchman (1987), Ferreira et al. (2019), Bardzell et al. (2012), Park et al. (2006)	Chapters 3–5
2.4 Bridging Physical and Digital: Tangible Systems	TUIs; remote co-play; distributed coordination	Kirshenbaum and Robertson (2018), Rogerson et al. (2016), Halskov and Dalsgård (2006), Kordaki and Gousiou (2017), Kohtake et al. (2005)	Chapter 5
2.5 Methodological Considerations	Phenomenology; reflexive thematic analysis; RtD methodology	Giorgi (2009), Zimmerman et al. (2007), Desjardins and Wakkary (2016), Tutia et al. (2019)	Chapters 3–5

2.1 Conceptual and Theoretical Foundations of Placemaking

Placemaking is a multi-dimensional process involving perceptual, affective, material, and technological components. In this thesis, I approach placemaking from a phenomenological perspective, attending to how constrained or mobile spaces become imbued with meaning, memory, and utility through interaction and adaptation. This orientation synthesizes work from environmental psychology, cultural geography, architecture, and human-computer interaction (HCI).

2.1.1 Phenomenology: Space and Place as Experienced

We begin with the foundational distinction between *space* and *place*. Casey (1996) contends that place is not merely a container for experience, but co-constituted by it—humans are not only *in* place, but *of* it. Perception, memory, and embodied movement form the constitutive fabric of place. In contrast, space is abstract and geometrical until inhabited and interpreted. Malpas (2012) deepens this ontological framing by defining place as a bounded, emergent structure shaped through the interplay of self, environment, and temporality. While Malpas offers a broad theoretical structure, this thesis adopts the more situated and affectively grounded interpretation advanced by Casey.

Historically, phenomenology offers a foundation for understanding space and place as lived rather than abstract. Heidegger's notion of *Being-in-the-World* situates human existence in a meaningful spatial context (Heidegger, 2010), while Merleau-Ponty emphasises the body as co-creating space through perception and movement (Merleau-Ponty et al., 2013). Later contributions from Bachelard's poetics of domestic space (Bachelard, 1964), Tuan's distinction between space as freedom and place as security (Tuan, 1977), and Seamon's concept of "place-ballets" (Seamon, 2015) illuminate how intimacy, attachment, and routine transform spaces into places. In the compact dwellings studied here, such processes are intensified: inhabitants continually adapt layouts, rituals, and thresholds to sustain a sense of place.

2.1.2 Architectural Perspectives: Inhabitation and Thresholds

Architectural discourse has long examined how abstract space becomes place. Le Corbusier's minimal dwellings, such as the 3.66 m × 3.66 m *Cabanon*, exemplified the modernist belief that spatial efficiency and functional integration could predetermine inhabitation. Yet even such rigorously authored micro-architectures recall the vernacular and improvised—the "primitive hut" reinterpreted for a new era. In spatially constrained dwellings, affordances emerge less from fixed plans than from occupation and ongoing adaptation (Bachelard, 1964; Pallasmaa, 2024).

Architectural theorists emphasize that the *genius loci* arises in dialogue between built form, cultural memory, and sensory engagement (Norberg-Schulz, 1980; Taverne, 1981). Thresholds—physical or symbolic—are key in this process. They mediate between interior and exterior, public and private, and in small spaces often hold heightened significance: the open rear doors of a van framing a landscape, or the porch of a tiny home hosting social life. Inhabitation, here, is not a static condition but an unfolding act, with thresholds continually renegotiated through daily use.

The small home and vanlife studies illustrate how residents act as co-designers. A narrow shelf becomes a combined shrine and storage; a curtain divides a single room into zones; a skylight substitutes for an attic. Such improvisations resonate with small-space creativity movements, from the Tiny House ethos of maximizing function per square metre (Thoreau, 1854) to the *Nomadic Furniture* designs, which advocated lightweight, knock-down furnishings for mobile living (Hennessey & Papanek, 1973). These traditions share a democratic stance on design, positioning inhabitants as active makers rather than passive occupants.

Christopher Frayling's distinction between *research for* and *research through* design (Frayling, 1994) is apt: the adaptations seen in vans and small homes are forms of *research-through-living*. Residents iteratively test configurations, learning what supports comfort, routine, and identity in minimal space. These practices reveal a productive interplay between formal architectural ideals and lived, vernacular making. Boundaries and thresholds are thus active sites where space becomes place through situated creativity.

2.1.3 Technological Mediation of Place in HCI

From an HCI standpoint, Dourish (2006) draws a distinction: space is the physical geometry of a setting, while place emerges through the interpretive practices and routines enacted

within it. Technologies, in this view, are constitutive of place—structuring rhythms, enabling activities, and embedding values into the lived environment (Harrison & Dourish, 1996). This aligns with experience-centred design, where meaning arises from situated use and ongoing engagement.

Empirical work shows how domestic and mobile technologies co-produce spatial identity and routine (Crabtree, 2003; Desjardins & Wakkary, 2016). In compact dwellings, such as those studied here, technological adaptations—from modular furniture to off-grid power systems—are central to sustaining place. Broader HCI studies echo this: Leshed et al. (2014) describe how farm households weave ICTs into seasonal work–home rhythms; Håkansson and Sengers (2013) show that simple-living eco-families integrate sustainability values holistically into daily routines; and Woodruff et al. (2008) find that environmentally committed households reconfigure space and behaviour in everyday life to align with ethical priorities.

Communal living contexts offer further examples. Jenkins (2021) examine how co-housing communities use shared technologies and IoT prototypes to support resource coordination and social interaction; and Wyche et al. (2018) analyze solar-powered lighting systems in off-grid Kenyan homes, showing how they extend domestic routines, reconfigure spaces, and reshape belonging.

In the context of this thesis, these dynamics are visible in the adaptive and often improvised technological practices observed in compact dwelling case studies. Participants described retrofitting van interiors with solar charging systems, re-purposing domestic appliances to fit cramped storage, and relying on mobile networks to sustain work and social life on the move. These practices mirror the broader literature: technology mediates place-building by transforming constraints into affordances, embedding personal and collective values into space, and fostering belonging—even in highly transient conditions.

2.1.4 Power, Belonging, and Feminist Spatial Critique

Building on these insights, this thesis treats placemaking as an interpretive and performative act materialized through adaptive use, negotiation, and affective engagement. Cresswell (2014) frames place as "space invested with meaning in the context of power," foregrounding both agency and constraint. Feminist and critical geographies elaborate this: Tieken (2010) shows how belonging is cultivated through community care and cultural labour, even in contexts of mobility or uncertainty; McDowell and Sundberg (2001) examines how gendered

divisions of labour, visibility, and marginality shape access to and control over space; and Sundberg (2004) reveals how race, gender, and power relations actively produce socio-spatial identities in ways that both enable and constrain agency.

These perspectives are essential for understanding mobile and small-space living, where agency often depends on informal adaptation and emotional investment rather than architectural authority or ownership. In such settings, spatial practices—like converting a van interior to allow shared meals, or establishing a temporary garden in a vacant lot—are both material and political acts. They are conditioned by access to resources, by cultural perceptions of legitimacy, and by the emotional labour of making constrained environments livable. This aligns with feminist geography's insistence that place is inseparable from the socio-political structures and everyday labours that sustain it.

Feminist HCI (Bardzell, 2010) provided a foundation for recognizing alternate and marginal forms of living as legitimate sites of design inquiry. By valuing lived experience, care practices, and situated agency, feminist HCI rejects the notion that design should focus only on normative or permanent homes. This theoretical stance shaped the research approach here: van conversions, micro-apartments, and other constrained dwellings were approached not as anomalies but as rich, knowledge-producing sites that reveal how care, improvisation, and negotiation build belonging under constraint.

Furthermore, these perspectives highlight that marginal contexts are not only shaped by limitation but also by creativity and resistance. Tieken (2010) underscores how communities facing resource scarcity still enact belonging through everyday practices of mutual aid. McDowell and Sundberg (2001) shows that even transient or insecure spatial arrangements—like seasonal housing—can be transformed into places of solidarity through shared routines and reciprocal care. Sundberg (2004) illustrates how marginalized groups contest and reshape spatial orders that exclude them, embedding alternative meanings into the land through cultural and ecological stewardship.

In the context of this thesis, such insights foreground that spatially constrained homes are socially and politically charged spaces where residents continually navigate questions of legitimacy, visibility, and identity. They point to the importance of examining how technologies and design interventions intersect with these dynamics—whether by reinforcing inequities or by enabling new forms of care and collective belonging. In this way, feminist and critical geographies do more than inform the analysis: they legitimize the study of constrained and mobile dwellings within HCI, and they challenge designers to consider how power, care, and marginality are woven into the very fabric of place.

2.1.5 Spatial Configuration and Human-Building Interaction

Finally, emerging work in Human-Building Interaction (HBI) articulates three interconnected aspects of spatial experience—physical-material, spatial-configurational, and socio-cultural (Alavi et al., 2019; Becerik-Gerber et al., 2022). This thesis engages most directly with the spatial-configurational dimension, exploring how technologies reconfigure spatial roles, boundaries, and behaviours in compact environments.

Placemaking in this context is not merely decorative or expressive—it is infrastructural, iterative, and mediated through tools, surfaces, and routines. Whether through the conversion of a van into a home and office, the use of hybrid card systems to coordinate remote collaboration, or the personalization of micro-dwellings, placemaking emerges as an ongoing negotiation between material constraint and imaginative reconfiguration.

Building on these conceptual foundations, the next section examines how these theoretical constructs manifest in practice—particularly through technological adaptations within domestic and mobile environments—drawing from research on homes, non-traditional dwellings, and the emergent design challenges they present.

2.2 Alternative Dwellings and Situated Design

While the previous section situated placemaking within conceptual and theoretical frames, this section reviews how these concepts manifest in non-traditional domestic environments. In particular, it draws attention to how individuals living in small, mobile, or otherwise alternative dwellings reconfigure both their spatial and technological conditions. These sites of domestic innovation often fall outside normative design considerations, yet they reveal situated tactics and material improvisations essential to understanding life in constrained or mobile contexts.

2.2.1 Reconfiguring Domestic Norms in Alternative Homes

Oogjes et al. (2018) foreground the speculative dimensions of "designing for an other home," articulating how home is not a fixed typology but a concept under continual renegotiation. In their work, technology is not seamlessly integrated but emerges through frictions and

contingencies—devices that are stowed, modified, and repurposed depending on context. These dynamics echo the vanlife community explored by Desjardins and Wakkary (2016), where self-built homes on wheels become deeply personalized spaces, adapted to afford sleep, work, intimacy, and recreation. Through living in a prototype, they showcase how form and function evolve iteratively, shaped as much by lifestyle as by technical constraint.

2.2.2 Improvisation, Labour, and the Unimagined in Mobile Contexts

Zafiroglu and Chang's study of digital homes on wheels underscores the improvised nature of mobile domesticity. They argue that many aspects of technological provisioning in such homes remain unanticipated by formal design paradigms, necessitating what they term "designing for the unimagined" (Zafiroglu & Chang, 2007a). Similarly, Dorn's storytelling analysis of vanlife highlights how aesthetic narratives on social media often obscure the labour of ongoing spatial negotiation, maintenance, and repair (Dorn, 2015). These perspectives foreground the gap between curated portrayals and the lived, often-precarious realities of mobile life.

2.2.3 Mobility, Connectivity, and Socio-Technical Adaptation

Importantly, these studies also unsettle dominant narratives of domestic stability and boundedness. As vanlifers traverse borders and infrastructures, they encounter novel limitations and affordances for place-making. Work by A. Lee, Toombs, Erickson, et al. (2019) and Ferreira et al. (2019) traces how digital nomads and itinerant workers reconfigure sociotechnical infrastructure in order to blend leisure, labour, and logistics. These practices illustrate how the spatial configuration of the home becomes inseparable from mobile work practices and digital connectivity.

Together, these works challenge HCI to reconsider the ontologies of home and inhabitation. They highlight the need for design approaches that centre uncertainty, partial infrastructure, and bodily improvisation. This aligns with the methodological commitments of this thesis: by attending closely to how people live in and adapt small or mobile spaces, I access design-relevant insights into routines, rhythms, and reconfigurations not captured in traditional housing contexts.

These diverse cases (summarized in Table 2.2) highlight how alternative dwellings serve as rich sites for uncovering design-relevant practices that challenge conventional assumptions about infrastructure, domesticity, and spatial adaptation.

Table 2.2: Design Insights from Studies on Alternative Dwellings

Study	**Focus and Key Insights**	**Design Implications**
Oogjes et al. (2018)	Explores speculative designs for "other homes" and uncovers fluid definitions of domesticity in atypical dwellings.	Design must accommodate shifting boundaries, partial infrastructures, and appropriated technologies.
Desjardins and Wakkary (2016)	Ethnographic account of converting and living in a van; examines adaptive design in mobile homes.	Highlights lived constraints, iterative repair, and the evolving entanglement of space and practice.
Zafiroglu and Chang (2007a)	Studies retirees living in recreational vehicles and their practices of integrating digital technology.	Argues for designing systems that accommodate unpredictability and user-driven infrastructural work.
Dorn (2015)	Analyzes vanlife as a narrative and cultural practice, focusing on the tension between aesthetic ideal and material effort.	Suggests designing with/in resistance to social media romanticization and acknowledging hidden labor.
Ferreira et al. (2019)	Explores nomadic cyclists' use of mobile tech for coordination and social connection.	Emphasizes community-driven tooling and the logistical layering of leisure and digital planning.

2.3 Design Strategies for Placemaking with Technology

Placemaking is not simply a theoretical or spatial transformation, but a design challenge that requires situated responses to constraints, identities, and lived experience. This section

surveys three interconnected design strategies evident across this thesis: how people actively configure their environments through material and digital means, how design provocations can guide reflection and action, and how situated speculation can feed into iterative system-building through Research through Design (RtD).

2.3.1 Home-Making, Mobile-Making, and Hybrid-Making

HCI research has long engaged with the home as a site of technology integration and personal meaning-making. Scholars such as Bardzell (2010) have foregrounded feminist perspectives on the home, emphasizing care, identity, and contested values as central to the design of technologies. These perspectives illuminate the often-invisible labour involved in making spaces feel livable and coherent, particularly for those navigating constrained or shared environments.

In small or mobile settings, these practices become more overt and adaptive. For example, in section 4.2, vanlifers creatively re-purpose household technologies and digital devices to define routines, negotiate shared boundaries, and reinforce affective anchors. These home-making strategies blend physical layout with rhythms of use, revealing how hybrid practices emerge—what might be called *mobile-making* or *hybrid-making*—when stability and infrastructure are partial or provisional. As discussed in section 3.2, participants in small spaces perform similar acts of spatial negotiation using furniture, light, and digital tools to demarcate zones and establish temporal routines.

2.3.2 Provocations for Technology Design

Designing for constrained living requires not only descriptive analysis but also critical reflection. In section 4.2, the vanlife study yields a set of eleven provocations that capture unmet needs and design directions. These provocations serve as both method and output: they encapsulate user values, frame systemic gaps, and invite alternative possibilities. This aligns with earlier uses of critical design within HCI, where designers aim not to solve problems but to re-frame them, often in speculative or politically charged ways (Gaver, 2012).

These provocations do not remain abstract—they inform the concrete design of Proteus. For example, the need for flexible, expressive tools that enable remote coordination and

preserve physical interaction (Provocations 1, 3, 5, 9) directly inspired the development of the Proteus card deck (chapter 5). This illustrates how speculative insights, grounded in lived realities, can be translated into design material.

2.3.3 Situated Speculation and Research through Design

The third axis of this strategy draws from traditions in Research through Design (RtD), particularly the formulation by Gaver (2012) and Zimmerman et al. (2007), which treat artifacts as epistemic vehicles. RtD emphasizes generativity, iteration, and contextual evaluation, making it well-suited for work situated in everyday and often-precarious settings. The Proteus system exemplifies this process. Built on themes from the small spaces and vanlife studies, it embodies speculative commitments across modularity, expressivity, remoteness; while undergoing empirical validation through deployment and a structured study.

By embedding these themes into a research artifact and iteratively refining it, the Proteus project bridges interpretive fieldwork with system-building. This layered methodology—spanning provocation, design, and evaluation—demonstrates how speculative and empirical commitments can coalesce to address real constraints, while preserving the exploratory spirit of RtD.

2.4 Bridging Physical and Digital: Tangible Systems for Hybrid Contexts

Digital systems increasingly mediate human collaboration, play, and learning—yet their physical embodiments are often overlooked. In contexts where co-location is disrupted or unavailable, hybrid systems that combine tangible artifacts with digital coordination offer a compelling approach to preserving interactional richness. This section reviews how remote tangible play informs the design of Proteus.

2.4.1 Hybrid Systems for Placemaking in Constrained Environments

Hybrid systems in constrained environments are socio-technical configurations that interweave digital and material modalities to transform impersonal "space" into meaningful "place" for users in mobile, shared, or spatially limited contexts (Harrison & Dourish, 1996). These systems exemplify socio-material entanglements, where technology is inseparable from the physical routines and artifacts that support placemaking, coordination, and connection (Orlikowski & Scott, 2016).

Prior HCI and CSCW research has investigated how domestic IoT devices and tangible or ambient interfaces enrich constrained living settings. For instance, slow technologies such as the *Photobox*, which sporadically prints personal images, support reflection and meaning-making in the home (W. T. Odom et al., 2014). Tangible interfaces like *Tangible Bits* similarly show how digital information can be embedded in physical objects to support peripheral awareness and embodied interaction (Ishii & Ullmer, 1997).

Concurrent research on spatial constraints reveals how mobility, density, and uncertainty shape domestic life. Studies of nomadic homemaking describe how individuals create affective boundaries and temporal routines across transient or shared dwellings (Petersen et al., 2010), while work on co-living communities highlights how users co-construct identity, belonging, and infrastructure on the move (A. Lee, Toombs, Erickson, et al., 2019; Liegl, 2014). Contemporary "vanlife" exemplifies this hybridity: van dwellers employ consumer technologies—power banks, media devices, modular furniture—to convert vehicles into highly personalized mobile homes (Desjardins & Ball, 2018; Zafiroglu & Chang, 2007a).

Reflective and speculative design approaches have further emphasized constrained hybrid living. Researchers have lived within prototype apartments to test IoT interventions in-situ (Desjardins & Wakkary, 2016), or challenged domestic technology assumptions through fiction-based design that reimagines alternative homes (Oogjes et al., 2018).

Lastly, tangible hybrid systems such as digitally enhanced card decks have emerged as flexible artifacts that combine material tactility with digital responsiveness. These systems extend gameplay into remote or space-constrained contexts (Roy & Warren, 2019; Tørresdal et al., 2021).

This thesis builds upon and extends these trajectories by presenting three situated studies: one on placemaking in small urban homes through ambient and shared media; one

on technological homesteading in mobile vans; and one on the design and deployment of the Proteus Card Deck, a hybrid tangible interface for co-present and remote interaction in constrained spaces.

2.4.2 Remote Collaboration and Tangible Interfaces

Several systems have sought to maintain the benefits of physical play across distance. Early examples like *The Eye of Judgment* (Studio, 2007) and the Augmented Trading Card Game by Sakamoto et al. (2014) used vision-based tracking and projection to simulate card-based gameplay in hybrid formats. These projects foreground the expressive potential of tangible-digital integration but rely heavily on proprietary hardware and fixed-location setups.

More flexible approaches emerged in systems like the PEPA Deck by Kirshenbaum and Robertson (2018), which utilized paper-like interfaces with embedded sensors and e-paper displays to enable tangible interaction. However, PEPA's one-to-one mapping between card and logic introduced scalability limitations for multiplayer use. Proteus builds on these insights by implementing a many-to-one orchestration model that supports distributed gameplay across remote users using BLE-enabled e-ink cards and a centralized logic controller.

2.4.3 Systems Architecture and Orchestration

Hybrid tangible systems require not only physical interaction components but robust orchestration architectures that enable synchronized coordination of content, state, and interaction logic across distributed environments. As tangible computing moves into hybrid and mobile contexts, these systems must support real-time responsiveness, dynamic configuration, and infrastructural flexibility—particularly in environments characterized by power limitations, intermittent connectivity, and spatial constraints (Desjardins & Wakkary, 2016; A. Lee, Toombs, & Erickson, 2019; Zafiroglu & Chang, 2007a).

Prior work in ubiquitous and pervasive computing has proposed various architectural strategies to address such challenges. Kohtake et al. proposed the Coordinated Display Pattern framework for spatially and temporally synchronized content presentation across multiple surfaces, supporting dynamic multi-display environments (Kohtake et al., 2005).

Omicini and Zambonelli outlined middleware-based orchestration layers that manage interaction across ensembles of connected artifacts, enabling adaptive and decentralized control in ubiquitous computing settings (Omicini & Zambonelli, 2016a). Tolmie et al. introduced lightweight toolkits for mobile collaboration that emphasize infrastructural pragmatism and loosely coupled interaction, aligning with the needs of highly mobile or ad-hoc user groups (Tolmie et al., 2010).

In addition to coordination and distribution, orchestration architectures must support temporal fluidity and embodied interaction. For example, previous studies have argued that effective orchestration in hybrid systems should accommodate slow interaction rhythms and peripheral awareness to avoid over-determining user experience (W. T. Odom et al., 2014). Similarly, research on tangible interfaces has shown that orchestration is not only technical but socio-material—requiring support for emerging, situated routines in which artifacts must flexibly respond to human activity (Ishii & Ullmer, 1997; Orlikowski & Scott, 2016).

In constrained environments like vans, off-grid dwellings, or mobile classrooms, orchestration systems must be power-efficient, latency-tolerant, and capable of graceful degradation. The Proteus Card Deck responds to these challenges by employing a centralized orchestration layer that coordinates state across a set of BLE-enabled, battery-less e-ink displays. This architecture supports asynchronous update cycles, persistent visual states, and minimal infrastructure overhead—building on insights from hybrid system deployments in constrained domestic settings (Desjardins et al., 2019a; A. Lee, Toombs, & Erickson, 2019; Zafiroglu & Chang, 2007a).

Future orchestration layers may further leverage edge computing, offline-first protocols, and mesh architectures to support remote play, co-creation, and instruction in bandwidth-limited environments. As tangible systems become increasingly decentralized and context-aware, orchestration must evolve from static configuration to adaptive choreography—balancing responsiveness with interpretability, and modularity with embodied cohesion (Desjardins & Wakkary, 2016; A. Lee, Toombs, Erickson, et al., 2019).

2.4.4 Coordinated Display Systems and Hardware

Proteus relies on low-power e-ink screens to maintain responsiveness without sacrificing mobility. E-ink technology (Henzen et al., 2004) has been used in prior HCI systems (Kirshenbaum & Robertson, 2018; Klamka & Dachselt, 2021) for its energy efficiency and persistent display properties. Coordination across displays remains a challenge; prior work

in ubiquitous computing (Kohtake et al., 2005; Omicini & Zambonelli, 2016b; Tolmie et al., 2010) has focused on home-based installations and smart environments, with limited exploration of mobile, modular setups.

In contrast, Proteus emphasizes portability (DC9) and centrally coordinated logic (DC2), enabling its deployment in classrooms, homes, and low-infrastructure settings. The orchestration model builds on work by Karrer et al. Kohtake et al., 2005, adapting it to mobile, card-based form factors that can be flexibly assigned and reconfigured across contexts.

This thesis integrates multiple methodological approaches—descriptive phenomenology, design provocations, and Research through Design (RtD)—to study the lived realities of constrained and mobile spaces. Each method supports a different aspect of the overall inquiry: understanding meaning, identifying gaps, and building working alternatives.

2.5 Methods

This thesis employs a mixed-methods approach that integrates descriptive phenomenology, reflexive ethnography, research through design (RtD), and design provocations. These methods are deployed across three interlinked studies, each situated in constrained or mobile contexts. My approach is fundamentally iterative and exploratory, drawing on HCI traditions of qualitative inquiry, speculative design, and empirical deployment. Table 2.3 maps each study to its methodological choices and corresponding contributions, following Wobbrock et al.'s taxonomy (Wobbrock, 2012). A summary of the methods employed across the three studies—including their analytic goals, data types, and contribution categories—is presented in Table 2.3.

2.5.1 Descriptive Phenomenological Analysis

To access lived experiences of placemaking in small spaces, I draw on descriptive phenomenology following Giorgi (2009), as elaborated in section 3.2. This method centres on bracketing assumptions to represent participants' worlds through structural synthesis, seeking the invariant structures of experience.

While phenomenological methods are gaining traction in HCI (Gunkel, 2018; Harrison et al., 2007; Svanæs, 2001), descriptive phenomenology is chosen here over cognitive or behavioural models because it centres the *felt* life of place. Where other approaches might catalogue behaviours or model mental representations, this method attends to first-person accounts, revealing subtle meanings—comfort in a personalised corner, unease at a transient threshold—critical for understanding small-space placemaking.

2.5.2 Diary Studies

Diary studies were a core part of the data collection for the small spaces study (section 3.2). Participants were asked to submit one image or video per day for a week, accompanied by a short narrative describing their use of space and technology. This method enabled us to capture temporal rhythms, spatial reconfigurations, and everyday improvisations in-situ—insights that are difficult to elicit through one-time interviews alone.

By combining these entries with sketch-based elicitation and phenomenological interviews, I obtained a rich, contextual dataset that illuminated the role of digital devices in participants' evolving sense of place. These diary submissions became particularly useful during phenomenological reduction, as they preserved the immediacy of lived experience and provided reflective anchors for analysis.

This approach aligns with prior HCI research employing diary studies to examine dynamic, real-world technology use (W. T. Odom et al., 2014; Palen & Salzman, 2002). This study design added emphasis on affective resonance, spatial agency, and narrative coherence, all of which are central concerns in the examination of placemaking under spatial constraint.

2.5.3 Reflexive Thematic Analysis

In the vanlife chapter 4 and Proteus chapter 5 studies, qualitative data were analyzed using reflexive thematic analysis (RTA) as outlined by Braun and Clarke (Braun & Clarke, 2006). This method provides a systematic way to identify and interpret patterns (themes) across a dataset while explicitly incorporating the researcher's active, reflexive role in the analytic process.

RTA treats the researcher's subjectivity and insight as a valuable analytic resource rather than a bias to be eliminated (Braun & Clarke, 2021). Please note that this article came out after I used Reflexive thematic analysis in the vanlife study (chapter 5), however the lessons remain valid. Unlike more positivist approaches, RTA treats the researcher's subjectivity and insight as a valuable analytic resource rather than a bias to be eliminated (Braun & Clarke, 2021). While this articulation was published after the completion of the vanlife study (chapter 5), its principles remain consistent with the analytic stance I adopted. Adopting RTA enabled a rigorous yet flexible analysis that integrated multiple forms of qualitative data—interview transcripts, 360-degree video observations, and field notes, all within one cohesive framework (Guest et al., 2011). By engaging deeply with these diverse data sources and continually reflecting on my own interpretive influence, I aimed to generate solid, defensible insights that are transparently grounded in both the participants' perspectives and the researcher's analytical lens (Nowell et al., 2017). Additional details on the use of RTA for the study noted in chapter 4 is presented in section 4.2.

2.5.4 Ethnographic Approaches: Digital, Auto, and Public

To capture the multifaceted nature of the vanlife experience, I adopted a multi-modal ethnographic methodology, integrating *digital ethnography*, *auto-ethnography*, and *public-space participant observation*. This combined approach extends conventional ethnographic practice in HCI by embracing multiple contexts of engagement, from online platforms to immersive personal experience and community gatherings. Such an approach aligns with calls in CSCW for studying technology use across diverse sites of interaction (Dourish, 2006; Harrison & Dourish, 1996; Rossitto & Eklundh, 2007). By triangulating insights from digital, personal, and communal domains, I gained a richer and more robust understanding of how vanlifers integrate technology into their daily lives.

Digital ethnography involved sustained immersion in online vanlife communities (e.g., Facebook groups, Instagram hashtags and feeds). Given that the `#vanlife` movement is largely mediated through social media, these digital spaces served as important field sites for observing identity construction, community norms, and the sharing of technical know-how. I monitored discussions, posts, and shared images to see how vanlifers negotiate their lifestyle in the digital realm. This allowed us to witness the public narrative of vanlife as it unfolds online — how van dwellers portray daily routines, troubleshoot challenges, and celebrate milestones in a highly visible way. My use of digital ethnography follows the approach used to study in Gretzel and Hardy (2019). This analysis of the `#vanlife` phenomenon highlights how social media acts as a gathering space for this "traveling neo-tribe," fuelled

by digital storytelling and peer exchange (Gretzel & Hardy, 2019). In the vanlife study, the prevalence of online content (millions of posts tagged `#vanlife`) indicated that much of the community's collective knowledge and identity is co-created digitally. By observing these virtual interactions, I captured phenomena that might not surface in interviews or short field visits — for instance, the curation of idealized vanlife imagery and the crowd-sourced advice on issues like solar power, mobile internet, and minimalism. Digital ethnography thus complemented physical fieldwork by highlighting broad socio-technical narratives and helping us identify salient topics and vernacular used by vanlifers themselves.

In parallel, I incorporated an auto-ethnographic element through direct participation in the vanlife lifestyle. One of the researchers (first author) temporarily lived in a converted van during a major vanlife gathering, blending the role of observer and participant. This immersive field engagement provided first-hand experiential insight into the quotidian realities of van dwelling — from managing limited resources to experiencing the social dynamics of campground life. Such an approach is akin to researcher self-embedding in the field (in the spirit of autobiographical or "live-in" research methods recognized in HCI) (Desjardins & Wakkary, 2016; Neustaedter & Sengers, 2012). By living the experience, the researcher could reflexively note the everyday challenges and workarounds that define vanlife (e.g., improvisations for privacy in shared campsites, or creative configurations of devices in a confined space). Embracing this auto-ethnographic stance meant treating the researcher's own lived experience as a source of data and insight, consistent with interpretist methodologies in HCI which view researcher subjectivity as a valuable analytic resource rather than a bias to eliminate (Boehner et al., 2007). This reflexive immersion helped anchor the analysis in lived reality, lending credibility and empathy to the interpretations. It also facilitated rapport with participants — by sharing in aspects of vanlife, I engaged in more authentic conversations with vanlifers, who often responded positively knowing that I had "walked a mile in their shoes." Notably, prior HCI work has successfully employed similar *live-with* approaches (for instance, researchers inhabiting prototype smart homes to understand new domestic technologies (Desjardins & Wakkary, 2016)) to uncover tacit and embodied dimensions of technology use that might escape more detached forms of inquiry. In this case, the auto-ethnographic experience of vanlife provided exactly this kind of insider perspective, revealing subtle insights (like the emotional ebb-and-flow of constant mobility, or the ingenious micro-optimizations vanlifers make to feel "at home" on the road) that would have been hard to grasp through interviews alone.

Finally, I carried out public-space participant observations at vanlife meetups and community gatherings. These field observations took place in communal areas — for instance, around campfires, at group DIY workshops, and in other informal social hubs that

naturally emerged at meetup sites. In these settings, I assumed an overt participant-observer role, openly identifying myself as a researcher while primarily listening, observing, and jotting down field notes on group interactions. By observing vanlifers in shared public spaces, I captured collective practices and cultural expressions that extend beyond any single individual's perspective. For example, I noted how knowledge is collaboratively constructed on the fly: at one meetup, a casual conversation at a campfire evolved into an impromptu tutorial on solar panel wiring, as multiple attendees chimed in with tips and personal experiences. Witnessing such interactions in situ allowed me to document how community norms and support networks take shape in real time. This lens is critical because certain social dynamics — such as the emergence of mentorship relationships, group problem-solving rituals, or norms around sharing tools and resources — only become evident through direct observation of the group in context. The public-space ethnography used in this study thus illuminated the communal and performative dimensions of vanlife culture, complementing the more curated view from social media and the individual accounts from interviews. Prior studies in HCI have emphasized the importance of studying technology "in the wild" to grasp its full social and situated impact (Paulos & Goodman, 2004a). Likewise, research on highly mobile or nomadic populations underscores that the meaning of *place* and the tactics for creating a sense of home on the move can only be understood by examining people's interactions across multiple locales and social contexts (Petersen et al., 2010; Rossitto & Eklundh, 2007). Guided by these insights, meetup observations allowed us to see how vanlifers co-create a sense of place and community despite constant mobility — for instance, by establishing temporary "neighbourhoods" of parked vans, or by collectively maintaining shared camp infrastructures — and how technology is woven into these practices (from coordinating meetups via Facebook to using off-grid power systems as communal assets).

In summary, the fusion of digital, auto-ethnographic, and public observational methods provided a comprehensive methodological framework for the vanlife study. Each approach offered a distinct vantage point: the online engagements revealed broad patterns and discourse; the auto-ethnography yielded intimate, embodied understanding; and the in-person observations captured group dynamics and context. Importantly, these strands of inquiry informed one another iteratively. Insights from the digital ethnography (e.g., popular topics or concerns surfaced online) helped focus during field observations and interviews. Conversely, personal experiences from the auto-ethnography sensitized us to subtle issues (such as the fatigue of moving between campsites or the ingenuity required to stay connected off-grid) that I later probed in online forums and participant conversations. By converging evidence from these different modes, I strengthened the trustworthiness of the findings through methodological triangulation. Observations that consistently recurred across online,

first-person, and communal contexts showed that the themes identified were robust and not artifacts of a single method or site. In effect, this ethnographic strategy was a deliberate effort to "meet the community where they are"—be it on social media, on the road, or around a campfire—yielding a deeply contextualized understanding of vanlifers' interactions with technology.

2.5.5 Research Through Design

Research through Design (RtD) frames design practice as a mode of inquiry, wherein artifacts serve as epistemic instruments for generating knowledge through iterative making (Zimmerman et al., 2007). Rather than validating hypotheses through controlled experimentation, RtD embraces the generative potential of design itself to surface new concepts, questions, and framings. Zimmerman *et al.* formalized this approach in HCI, emphasizing that design artifacts can embody theoretical constructs and crystallize research insights. Gaver (2012) extends this view, proposing that RtD produces distinctive forms of knowledge—including conceptual contributions, annotated portfolios, and intermediate-level theory—arising directly from the process of iterative making and situated reflection.

RtD in HCI encompasses a wide methodological spectrum, ranging from short-term iterative cycles to long-term ethnographically embedded deployments. At one end of this range are sustained RtD efforts such as those led by Odom, which deploy a single research product into domestic settings over several weeks or months. These approaches prioritize temporal depth and contextual richness, exploring how people integrate and interpret artifacts over time (W. T. Odom et al., 2014). At the other end are shorter-term iterative studies that emphasize rapid prototyping, refinement, and structured reflection through multiple design-build-evaluate loops (Frauenberger et al., 2016; Márquez Segura et al., 2018). While these approaches differ in execution and depth of contextual engagement, both share a commitment to epistemic inquiry through artifact construction.

This thesis aligns with the iterative, short-term tradition in RtD. The Proteus Card Deck was developed as a research artifact through multiple build–reflect–redeploy cycles, each informed by empirical provocations from two earlier studies of small homes and vanlife. In line with Zimmerman *et al.*'s framing, Proteus was not conceived as a final solution but as an epistemic object that instantiated and interrogated design hypotheses around hybrid tangible interaction, digital augmentation, and spatial constraint.

The research artifact was used to surface insights through both its performance and through its design evolution—what was built, why it was changed, and how it engaged

core theoretical concerns. Such short-term RtD approaches are well-established in HCI, particularly when they foreground reflective iteration and the integration of prior fieldwork into artifact design (Frauenberger et al., 2016; Márquez Segura et al., 2018; Yang et al., 2019).

In summary, the design and deployment of the Proteus Card Deck represent the instantiation of the knowledge created through the first two studies. Through iterative making grounded in prior empirical work, this thesis contributes to ongoing discourse about hybrid systems and placemaking in constrained environments, while advancing a design-led mode of knowledge production through the research artifact itself.

2.5.6 Conclusion

Together, these methodologies support a layered, pluralistic investigation into the affective, spatial, and technological dimensions of constrained living. Rather than committing to a single methodological stance, I adopted a pragmatically grounded approach—selecting methods that aligned with the phenomena under study and the situated contexts in which they occurred. This strategy enabled the production of multiple types of contributions while remaining attentive to participants' lived experiences. Table 2.3 summarizes each study's methods and maps them to Wobbrock et al.'s typology of HCI contribution types (Wobbrock, 2012), highlighting the range of insights generated across the thesis.

Together, these methods enable a layered investigation of how people inhabit, adapt, and re-imagine small or mobile spaces. They support a praxis-oriented HCI that moves between interpretation, critique, and empirical deployment.

Across these domains, there is an iterative progression: from the affective anchoring of small spaces, to the speculative re-imagining of mobile domesticity, to the material instantiation of hybrid systems. This literature scaffold reflects a methodological deepening that supports the trajectory of this thesis.

Table 2.3: Methods and HCI Contribution Types by Study

Study / Chapter	**Method(s)**	**Outcome**	**HCI Contribution Type**
Chapter 3 (Small Spaces Phenomenology)	Descriptive Phenomenology	Understanding of embodied placemaking practices in constrained settings	Empirical
Chapter 4 (Vanlife + Provocations)	Ethnography, Reflexive Thematic Analysis, Design Provocations	Design-relevant insights and speculative prompts based on mobile lifestyles	Empirical
Chapter 5 (Proteus)	Research through Design (RtD), System Prototyping	Functional system bridging tangible and digital play in hybrid contexts	Artifact

Chapter 3

Small Spaces, Many Places

A Phenomenological Analysis of Technology-Mediated Placemaking in Small Spaces

3.1 Introduction

As urbanization accelerates and housing prices continue to rise in cities around the world, small spaces—studio apartments, micro-units, shared flats, and co-living arrangements—have become a common reality for many. These small spaces, driven by urban density, economic constraints, and increasingly minimalist lifestyles, present unique challenges and opportunities for creating meaningful places. While some residents choose small spaces to align with values of sustainability and intentional living, others are constrained by affordability or temporary life transitions. In either case, these environments call for a rethinking of how space, identity, and technology intersect in everyday life.

This chapter explores how people make place—emotionally, socially, and functionally—within homes that are not only small, but often shared, transitional, or multifunctional. Placemaking in this context is not about decoration or permanence, but about creating a sense of control, familiarity, and self-expression in constrained circumstances. While HCI has long acknowledged the importance of "context" in design, it has often overlooked the

practical and emotional complexities of small or shared living environments. Technologies designed for the home frequently assume spaciousness, stability, and consistent infrastructure. The lived experiences of those in compact, improvised, or fragmented domestic spaces push against these assumptions.

To investigate these experiences, this chapter draws on a phenomenological study involving interviews, diary entries, and participant-generated sketches from individuals living in a range of small space contexts. The goal is to understand not only what people do in these spaces, but how they feel about them—and how technologies become entangled in the process of transforming "space" into "place." This approach aligns with the larger goals of the thesis: to center lived experience, foreground constraint as a design condition, and generate grounded insights that can inform technology design in meaningful ways.

This chapter is organized around two major contributions. First, it introduces four cross-cutting themes that shape placemaking in small spaces: boundary-setting, temporality, mastery, and future orientation. These themes reflect how individuals create psychological and functional distinctions within limited square footage—building routines, managing interruptions, and constructing mental architectures of control. Second, the chapter presents a typology of seven place types that emerge even within constrained spatial contexts. These include places that range from places of leisure and work to shared and unfamiliar places.

Together, these findings reveal that placemaking in small spaces hinges less on physical dimensions and more on narrative, rhythm, and adaptation. Technology plays a central (but not always harmonious) role in this process: not simply as a solution, but as something to be negotiated, appropriated, or occasionally resisted. By attending to the creative, often contradictory ways people configure meaning within spatial constraints, this chapter broadens the conversation in domestic HCI to include forms of dwelling that are fluid, improvisational, and deeply personal. It also sets the stage for the next chapter, which shifts from fixed dwellings to mobile ones—examining how the dynamics of placemaking evolve when small spaces are not only constrained, but constantly on the move.

3.2 Method

This section outlines this studies approach to data collection, analysis, and reporting. To capture the essence of placemaking in small, constrained spaces, I adopted a descriptive phenomenological (DP) approach as outlined by Giorgi (Giorgi, 2009). This choice was

aimed at accessing the core experiences of individuals living in small spaces. Unlike other qualitative methods commonly employed in human-computer interaction (HCI) research, such as reflexive thematic analysis (RTA), which focuses on identifying themes, or grounded theory, which seeks to construct a theory from data, descriptive phenomenology is uniquely suited to this study's goals to help describe a lived experience.

DP concentrates on describing the lived experiences of participants without presuppositions. This method allows us to delve into how participants experience their space and the role of technology within it, aiming to articulate the "essence" of these experiences. Such an approach is invaluable in studies like this one in HCI, where understanding the deep, subjective interaction between humans and their technological environments can lead to more empathetic and effective design solutions.

While phenomenological methods are gaining traction within HCI (Gunkel, 2018; Harrison et al., 2007; Svanæs, 2001), the specific application of DP offers a direct route to comprehend the foundational aspects of human-building interactions. This methodological choice ensures that the findings illuminate the intrinsic characteristics of placemaking in small spaces, providing insights that might be overlooked by more theory-driven or thematic approaches. This focus is crucial for developing technologies and spaces that genuinely resonate with the lived realities of users in compact living conditions.

3.2.1 Participants & Recruitment Strategy

Following approval from a university ethics committee, recruitment began using on-campus posters (for a short period when the campus was open during the COVID pandemic) and mailing lists. I stopped recruitment based on prior knowledge of drop-offs (anticipating a 50% drop-off rate), with the aim to get between six to twelve participants. This was based on previous research that noted that "the most profound insights with in-depth reflections [are discovered with] ... about six to 12 cases as 'windows' to, and illustrations of, a phenomenon. There is danger in choosing a sample that is too large." (Todres & Holloway, 2004, p. 79)

Fourteen participants were recruited, of which eight participants signed the consent form, attended the interview, and submitted at least one diary study artifact. After the initial interview was completed, the participants were compensated with $10 in their local currency for their time. Every time participants provided pictures or media (for the diary study), they were given tickets to a draw for a $500 Amazon gift card. Table 3.1 provides

a breakdown of participant demographics. Interviews were conducted by me (n=4), and Arden Song (n=4)

	Pseudonym	**Reported Occupation**	**Income Level**	**House Size**	**Recruitment Method**	**Comments**
P1	Jack	Software Industry	30,000 USD	$65\,m^2$	Previous Study Participant	Lives with Amy
P2	Amy	Administration Professional	30,000 USD	$65\,m^2$	Previous Study Participant	Lives with Jack
P3	Anya	Online Marketing	40,000 USD	$37\,m^2$	On-campus mailer	
P4	Hudson	Student	15,000 USD	$28\,m^2$	Previous Study Participant	$28\,m^2$ in a shared space
P5	Faith	Consultant	N/A	$56\,m^2$	On-campus mailer	$56\,m^2$ in a shared space
P6	Milo	Student	N/A	$46\,m^2$	On-campus mailer	
P7	Morgan	Student	20,000 USD	$46\,m^2$	On-campus mailer	
P8	Jaime	Software Developer	N/A	$37\,m^2$	On-campus mailer	

Table 3.1: List of participants (with pseudonyms for each) in the study.

3.2.2 Interview and Diary Study

Participants were invited to take part in one-on-one, semi-structured interviews over Zoom for around an hour each. At the start of the call, the interviewer confirmed that the participants still lived in "small" spaces. We did not explain or define what "small" could mean. We then obtained informed consent for the study. We then asked participants to sketch their spaces, using the following prompt:

> *Draw your living space—in any way you would like. It could be a floor plan, impressionist, in the style of Monet, or whatever you feel like. Don't worry about the quality of your drawings, just draw what you feel.*

To spark creativity and encourage diverse representations of space, we used the words "floor plan," "impressionist," and "in the style of Monet", and the order was varied with each interview. One participant drew a 3D sketch, and all others drew a floor plan. Participants were given uninterrupted, unlimited time to complete their sketches. A few sketches are presented in Figure 3.1.

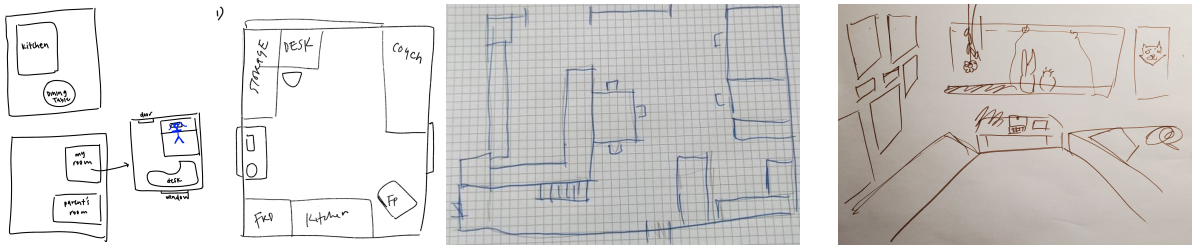
Once participants completed their sketches, we continued with the semi-structured interview. As a part of this interview, participants often referred to their sketches, either by asking the interviewers to view it in email, or by holding it up to their camera and pointing. The interview was designed to elicit three components of the participants' lived experience: a deeper understanding of any technological adaptations to their space, emotions that their spaces and technology would occupy, and any external elements that impacted their use of the space. Once the interview was complete, demographic information was collected. A sample of the initial (structured) questions that prompted deeper conversations include:

- "Where would you relax? or work?"
- "Do you reconfigure your space as technology changes?"
- "What spaces are your happy places?"

Most of these were followed up by a question around specific situations they mentioned, and the technology use or adaptation. For example, the question about "happy places" was followed up by a deep dive on how the space and technology worked together to create that place. This was unstructured, but for three participants the follow-up questions were as follows:

- "What are you doing when you are in your happy place?"
- "Ok, so <device mentioned> seems to help you feel happy doing <activity>, is it always in <space>?"
- "Where else would <device> get you to feel the same way?"
- "Could you do <activity> on a different device and get to the same feeling?"

We did not explicitly ask about competence or familiarity with technology so as to not ground the participants' perception that this was of importance to the research team prior



(a) Faith **(b)** Anya **(c)** Amy **(d)** Jaime

Figure 3.1: Our participants' portrayals of their spaces. All followed a similar view of their spaces, sticking to a familiar top-down floor plan view. Each of the participants talked through their spaces, and described considerations for how they placemake within them.

to their diary study; however, we found that all participants had at-least one cell phone and one laptop, most participants ($n = 6$) discussed their tablets, and some ($n = 4$) discussed either their own or shared televisions. Only one participant mentioned a shared gaming console (a Nintendo Switch).

After the interview, we requested the participants send one picture or video of their space and technology usage every day for a week, along with a narrative describing the media. Four participants provided seven or more images, three participants provided five, and one provided four. None sent videos.

3.2.3 A Note on Data Preparation and Visual Artifacts

In addition to textual interview transcripts, participants provided hand-drawn floorplans and daily diary entries that included images and written captions. These artifacts were integrated into the phenomenological analysis by grounding them in participants' verbal accounts. During meaning unit extraction section 3.2.4, each visual element was considered only insofar as it was described or reflected upon by the participant in the associated narrative. For example, spatial annotations in a floorplan became analytically relevant when accompanied by participant commentary that revealed lived relationships to the marked areas. Similarly, images from the diary study were analyzed through the lens of participants' captions and interview elaborations, allowing their meaning to emerge phenomenologically rather than being inferred visually. This approach ensured that all data contributed to the eidetic reduction without violating the descriptive orientation of the method.

3.2.4 Analysis Procedure

Our approach, descriptive phenomenology, is described as: "an inductive qualitative research approach that is rooted in the philosophical proposition that researchers can gain valuable insight into the structure of how people understand their experiences" (Bliss, 2016, p. 14). Furthermore, Frauenberger et al. (2010) state that "phenomenology provides the designer with a framework for studying user experience by affording an intrinsically contextual view of the way we interact with things around us." (p. 187)

Specifically, Giorgi (2009) describes the steps of DP as follows (enumeration added): "For the scientific level of analysis, ..."

1. "one first obtains descriptions of experiences from others [p. 67—72], ..."
2. "then one enters into a scientific phenomenological reduction while simultaneously adopting a psychological perspective [p. 73—80], ..."
3. "then one analyzes the raw data to come up with the essential structure of the experience [p. 80—90], ..."
4. "which is then carefully described at a level other than that of the original description [p. 90 onwards]."

The first step has been described earlier (subsection 3.2.2), and I describe the remaining steps in the following sections.

Phenomenological reduction

This step involves setting aside presuppositions and assumptions about the world, including scientific, psychological, and philosophical theories, in order to focus solely on the phenomenon of placemaking in small spaces. This process allowed us to approach this phenomenon with a sense of openness and curiosity, free from the constraints of preconceived ideas or beliefs.

As a researcher with prior experience in HCI and familiarity with placemaking literature, I approached this study with a clear awareness of the need for bracketing. Following Giorgi's descriptive phenomenological method, I engaged in systematic self-reflection to suspend

pre-existing theoretical and experiential commitments. Prior to analysis, I documented key assumptions (such as the presumed centrality of digital technology in placemaking) and set them aside through reflexive memoing. During the extraction and transformation of meaning units, I maintained fidelity to participants' descriptions, ensuring that the analytic process remained grounded in their language and framing. This allowed meaning units to reflect the participants' lived experience rather than my preconceptions. Concepts such as anti-homing and distributed boundaries thus emerged inductively from the structure of participants' accounts.

By suspending judgment and adopting a stance of phenomenological neutrality, my goal was to explore the essential structures and meanings of lived experiences of placemaking. Through this step, my primary aim was to access the pure, unmediated experience of the placemaking phenomenon in small spaces, uncovering its essential features, and the underlying structures that give rise to them. In this step, I analyzed the three textual data sets: interview data, captions of images provided, and researcher notes, as well as visual data from the floor plans and the images provided by the participants.

The Essential Structure of Placemaking in Small Spaces

Through the process of phenomenological reduction (or "bracketing"), the data revealed two interrelated layers of meaning. The first concerned the constitutive features of the placemaking experience—those experiential structures through which participants actively gave meaning to space. These included practices such as establishing boundaries, asserting control, and negotiating presence, often mediated through technological and material means. The second layer involved the intentional objects of these acts: the specific places participants described living through, such as zones of comfort, work, leisure, or social connection. These were not treated as fixed spatial categories but as *lived places*, constituted through participants' embodied routines, situated concerns, and directed consciousness. Together, these layers reflect the essential structure of placemaking in small spaces: the interplay between the processes by which meaning is constituted and the phenomena that are constituted as meaningful.

To uncover this structure, I analyzed participants' accounts by identifying meaning units, which are discernible shifts in psychological meaning that indicated changes in how lived space was experienced or interpreted. As Giorgi (2009, p. 7) explains, "the interrogation of each meaning unit was to express, in a more satisfactory way, the implications of the life-world descriptions given by the participants." While meaning units in Descriptive

Phenomenology are distinct from themes in Reflexive Thematic Analysis, they similarly provide a lens for articulating how experience is structured. The outcomes of this analysis are presented in the two sections that follow.

Meaning units, as used in this study, refer to segments of the transcript in which a single psychological meaning related to placemaking is expressed. For example, a participant's account of arranging technology to delineate work from leisure within a confined space was treated as one such unit. Each meaning unit was then subjected to transformation such that its everyday description was reformulated to reveal the implicit structure of experience it conveyed. This involved clarifying the participant's intentional relationship to space—how meaning was constituted, while setting aside redundant or incidental content. Through this process, the meaning units served as the basis for articulating the essential features of placemaking in small spaces.

Structure

The essential meanings derived from the individual units are integrated into a description of the lived experiences of the participants. This synthesis aims to reveal the underlying structures of the experience, such as spatial boundaries, temporality, and the role of technology, as identified in the study. I then grouped the meaning units into themes, which are grouped into two sections: in section 3.3, I talk through the elements that contribute to placemaking in small spaces (themes in sections 3.3.1 to 3.3.4); in section 3.4, I discuss the places created by the participants (themes in sections 3.4.1 to 3.4.7). The places reflected affectations or meaningfulness that the participant derived from their spaces. I have edited participant quotes for clarity, including modifications, where appropriate, to ensure that space and place are represented accurately.

3.3 Elements of Placemaking in Small Spaces

This section details the elements that facilitate placemaking in small, constrained spaces; as identified through phenomenological analysis. The interplay between physical limitations and the creative utilization of technology emerges as a central theme in defining and enhancing the functionality and affective resonance of these spaces. Through an analysis of participant experiences, I identified four elements in the transformation of spaces into places. These elements provide a framework for understanding the nature of placemaking in small

spaces. Each plays a distinct role in how the participants used technology to alter how they perceived and interacted with their environment, impacting their ability to create places that not only fulfilled practical needs but also supported their emotional and psychological well-being. These elements consider both the individual's interaction with their physical and technological environments and the broader cultural and social implications of their placemaking strategies. This exploration not only highlights the adaptability and resilience of individuals living in small spaces but also offers insights into the potential for technology to facilitate meaningful spatial experiences in any living arrangement.

3.3.1 Boundaries

A distinction between "my space" and shared spaces was well-defined for participants living in shared spaces, while those living in small spaces of their own still have some sense of such boundaries. For example, Jack and Amy live in the same space, but Jack considers the entire small space to be both Jack and Amy's, while Amy only considers part of the space to be belonging to them (Amy). The connection between various spaces and a sense of belonging has been shown in previous studies from social spaces (Glover, 2017) to women-only swimming pools (Lenneis et al., 2020). I found that the distinction between shared spaces and one's own space doesn't take away from a sense of belonging. Participants are finding ways of homing (as defined by Lynggaard (2012)) within shared spaces.

Our participants usually drew spaces that they felt connected to, even if they lived in a larger space. Most of their personal technology use (laptops, phones, tablets) was confined to these spaces. Three participants lived in either multi-generation households or shared living spaces, and only identified a part of the space as their 'own'. For example, Faith drew only part of their house (Figure 3.1a):

> *"The places I drew out, like the different rooms, or the different places in my house that are the most, I guess, prominent for me."*

Interestingly, their space wasn't confined to a continuous area:

> *"Sometimes I would go to my grandparents room just to talk to them and make conversation... sometimes I would go to my garage because our oven is in the garage like we have a smaller oven because we don't want to stink up the place when we cook stuff."*



Figure 3.2: Milo's image shows how their technology works with time to transform their space into a place of connection.

Participants would also engage in "anti-homing," where those with agency over spaces would make them friendly to co-occupants to provide them with a greater sense of belonging. Faith, for example, would leave only shared food on tables in common spaces. If she wanted to signal that she was either preparing or consuming the food item, she would often leave her phone with a YouTube video next to the container. As in this instance, the intrinsic connection between space and belonging opens up a number of avenues for places of belonging to be created through technology.

3.3.2 Temporality

Place is temporal, and technology can mediate temporality in any space. Feelings of place being temporal was repeated across the participant pool, with everyone connecting a feeling of time with particular aspects of the places they make. This theme showcases the importance of temporality in making a place out of a space, and is reflected in shared activities that invoke a feeling of a specific time, or a specific time to carry out an activity. W. T. Odom et al. (2018) brought together researchers to discuss research and design initiatives related to temporality, looking at time and the speed of temporality, and showcasing how design could enable placemaking for subjective experiences of time. Similarly, Rahm-Skågeby and Rahm (2021) explored the design space of HCI within deep time design thinking. The concept of place provides a sense of grounding for people (whether or not they have agency in the space) to understand time and temporality. As noted by Irvine (2020) there are interactions between humans, technologies, and geological temporalities—the concept of place brings them together in one construct.

One of the participants, Milo, would convert their space into a place of social connection every Saturday. They connected this feeling of temporality to their screen (as shown in Figure 3.2, an image they shared of a computer screen with a pair of dice).

> *"Typically one of the bigger highlights of the week, Saturday is marked by the Dungeons and Dragons session that marks the later half of my afternoon and evening. Even though we only play for around 5-6 hours a week, I think about the game throughout the week, running through scenarios, trying to solve problems, fiddling around with mechanics, or writing and developing characters. We've been playing for around three or four years. I can fall into some hermit lifestyle habits, and this day is usually where I get my socialization quota, unwind after a workweek, and catch up with friends."*

Overall, temporality in space allows the creation of places that tie in time with the specific space to the user, teleporting them to different worlds (which Milo may appreciate as a power in their D&D game). Placemaking can thus enable effective anticipation for a new shared future (for example through shared calendars (Forghani et al., 2018)) or while reminiscing about the past.



Figure 3.3: Hudson's image of a clean, almost empty room reflects their sense of imperfection if there was any 'stuff' scattered around. This space, while imperfect in their own eyes, also allowed Hudson to develop a stronger sense of autonomy and agency within their space.

3.3.3 Mastery

Mastery is achieved through the cultivation of both autonomy and competence within a space. Although these constructs are interrelated, they are presented separately here to enhance conceptual clarity and analytical precision. Autonomy and competence are presented in the following sub-sections:

Autonomy

Spatial autonomy is often inter-related with concepts of independence, self-governance, accomplishment and well-being (Lan, 2018; Song, 2010). This is reflected in the participants' viewpoints, where autonomy and space are interrelated. In a similar vein, Murray et al. (2014) found that "how learners imagine a space to be, perceive it, define it, and articulate their understandings transforms a space into a place, determines what they do there, and influences their autonomy."

While describing their space (Figure 3.3), Hudson said that:

> *"Like mine won't look that great. And I will tell you right now, I'm a perfectionist. So I will probably hate it."*

In the same discussion, they provided more context around their space:

> "*Having blocked off the side of the room with my study table, being a bit of a perfectionist, feeling a bit overwhelmed due to the amount of things I need to do, and having another table, which is currently available for me to use with larger window and directly facing greenery in this space, are all factors which led me to believe that I do not need to rush myself with the cleaning process, and figuring out where everything should go. I have also surprisingly found myself open to the idea of re-arranging things after I decide to put them in one place. This is surprising for me personally as I was not a fan of moving things around as much in the past. The way I used to see it, things had one place where they would go, they didn't need to move around so much, (or at all really), once they had their place.*"

The juxtaposition of a lack of competence, thus, did not translate into a lack of mastery in the same space. The space that created a sense of imperfection also allowed Hudson to develop a stronger sense of autonomy, thereby creating mastery within their space. This tension is usually resolved through creative use of technology—from phones to stand mixers.



Figure 3.4: Amy and Jack's Space. For Jack, this space reflected a sense of mastery through their electronic appliances. For Amy, this was a place of utility and creativity in their food.

Competence

Technology has the ability to create feelings of competence in their users. A lot of the time, this feeling is directly related to the task being performed, as shown when Jack talked about their small kitchen appliances (Figure 3.4):

> *"The idea is that I can feel comfortable when trying to make more elaborate meals. Because I have this tool, which makes it easier for me, instead of something that technically could do it. But it would take a lot of time. And the result wouldn't be as good as if I had done it with this sort of more professional specific tool."*

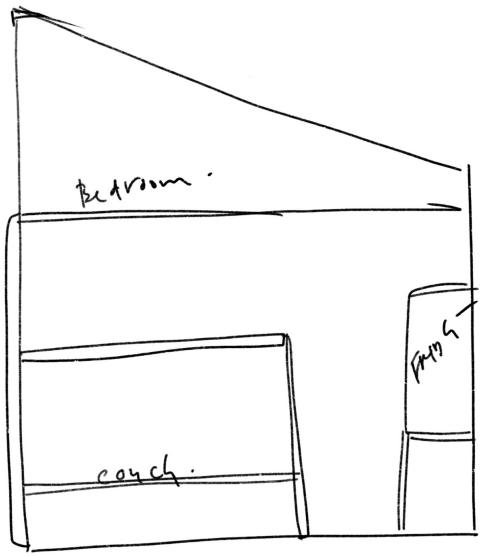


Figure 3.5: Anya's image of the profile view of their space, showing a couch where they would spend time with a future partner.

Keeping smart, application-focused appliances in a space has the effect of creating a sense of competence for Jack. A few of the other participants ($n = 4$) had similar feelings about their kitchens in general, and appliances in particular. It is interesting to note that everyone who built a place of competence through kitchen appliances liked cooking. There is a demonstrated link between perceived competence and enjoyment (Carroll & Loumidis, 2001). Creating places of competence would, through an improvement in perceived competence, create enjoyment. Thus, there are ways to mediate spaces to create places of perceived competence.

3.3.4 Future-Thinking

There is a distinct connection between a current place and longing for a future state. Participants were always placemaking for the future. Whether it be for a future partner, a future move, or a future work opportunity, the participants have made place for it. There has been prior work on reminiscing in HCI which uses space as a cue (van Gennip et al., 2015). Another line of inquiry has been work in history museums that connect the past to the museum space, to people through technology (Ciolfi & McLoughlin, 2012).

While temporality and space are intertwined in how they are imagined, most of these experiences reflect placemaking through prior experiences. For participants, spatial design was focused on imagined futures (represting technology from laptops to televisions). In one instance, Anya positioned their couch on the basis of a forward-thinking thought:

> *"I placed my couch here so that I could have it to the side. And, um, I use the table to watch Netflix on my laptop, and I wanted the couch to feel accessible not just to me, but to a future partner as well. I placed it here so that he and I could watch movies and cuddle. If we felt tired, we could just go right up to the bedroom."*

To emphasize their point, Anya drew another image of their space, this time a floor plan in profile shown in Figure 3.5.

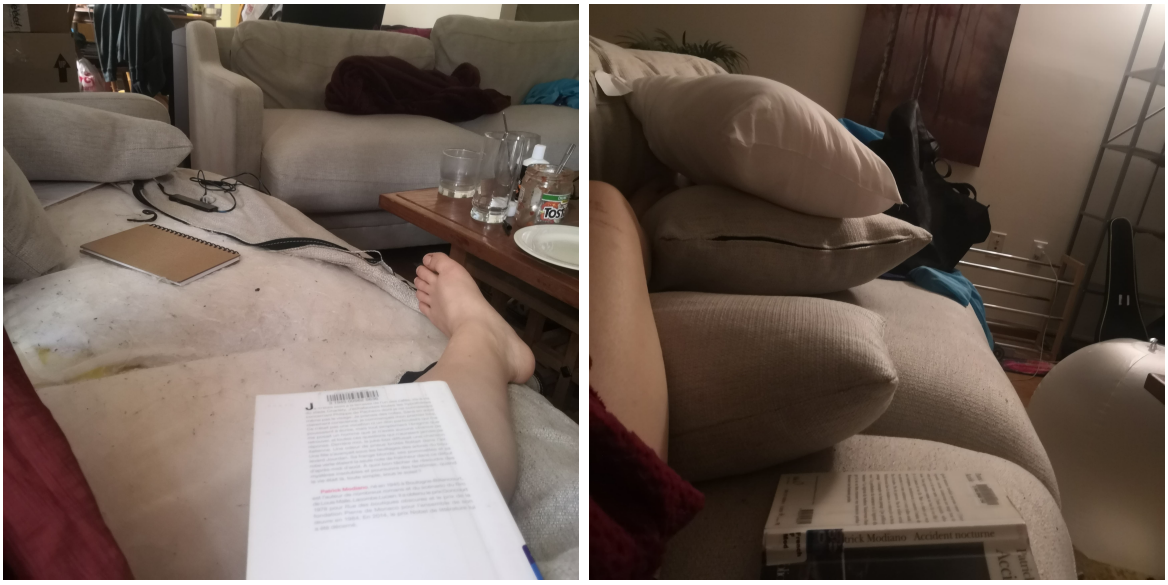
In conclusion, these findings show how participants leverage their physical confines and technological resources while sense-making and creating places. The four elements each contribute to the enhancement of functional and affective aspects of these spaces. *Boundaries*, for instance, help delineate personal space and manage privacy, while *temporality* underscores the transient and evolving nature of space. *Mastery* reflects the competence and autonomy in managing one's environment, and *future-thinking* provides a lens for imagining potential futures.

3.4 Places Created in Small Spaces

In exploring the concept of placemaking within small, constrained spaces, this study identifies seven distinct types of places that participants consistently described as emerging within their limited spatial settings. These places, each independent of a specific type of space within their homes or immediate environments, illustrate the versatile and dynamic nature of placemaking, even under spatial constraints. This section elaborates on each of these places, revealing the unique ways in which individuals utilize and transform these spaces into meaningful places that serve multiple purposes and evoke diverse experiences.

3.4.1 Places for Leisure

These are the places at the centre of participants' "down time." Primarily, three devices form these places: cell phones, tablets, and televisions. Henderson and Frelke (2000) have



(a) **(b)**

Figure 3.6: Jaime's pictures of their Places for Leisure.

previously explored the relationship between space and the creation of place related to the theorized meanings of leisure for individuals and groups, and found that placemaking affects the overall quality of people's leisure experiences. Participants used their phones or televisions to get to this place, showing that technologies for leisure create a sense of home, discovery, and belonging. The primary emotions are togetherness, relaxation, reminiscing, and desire for the future.

One participant, Jamie, described their leisure place (Figure 3.6) in their diary notes on multiple occasions:

> Day 3: *dying at midnight on the same sofa. Taking a very long pause from reading to watch YouTube videos on the sofa. Dying because it's very hot (30 °C). Can't go upstairs because upstairs is even hotter. Won't go to the basement because there's nowhere to sit there so I'm stuck on this sofa periodically changing the cushions I'm propped against to get the 'cool sides'. This continues for many hours until the house and I finally get cool enough to fall asleep.*

> Day 4: *drinking and eating snacks while watching a classic shojo anime with my*

roommate (still on the same sofa LMFAO I literally don't move). Not pictured is a large bag of tortilla chips on the sofa that I'm snacking from.

3.4.2 Places for Work

Our participants had a place for work at the centre of their professional and social lives. Seven out of eight participants were working from home (as opposed to a strictly work-oriented space), but for all eight, these places also became the centre of their social lives. Thus, places for work morphed into places of connection, work, productivity, and togetherness—showing that transforming space to places of work enables collaboration of all types. This finding also supports the theory by Harrison and Dourish (1996), that the distinction between place and space could be successfully applied to collaborative work. While this phenomenon has been noted before as a blurring of boundaries (Olson-Buchanan & Boswell, 2006), I argue that it is a *removal* of boundaries. This place affords designers immense freedom in creating technologies to make work more social (thereby reducing subjective stress (Ganster et al., 1986)), or to create moments of social engagement between moments of work. Participants primarily used laptops and cellphones to mediate these places. Anya used their place for work in multiple ways:

As their "happy" place in their house:

> *"So I like that I can leave all my things out. And that my chair is comfortable. And then I like that I can get work done here. So I'm usually happy in this space."*

To talk to friends:

> *"I usually tend to either be sitting at the desk because I have thoughts that I know I can rest my phone ... if I'm doing a video chat with a friend"*

To start their day:

> *"I think it's because the desk is a good height and the chairs are comfortable, but I do I start my day"*

For another participant (Jack), the app *Slack* mediated a sense of a place for work wherever they were. Designers can design technologies that afford a sense of place for work in office places, autonomous cars, or even outdoors. Some examples could be virtual spaces for connection that can be combined into places for work once activated (like Slack, or Discord), or even forward-looking technologies like holographic telepresence systems (Blanche et al., 2010).

3.4.3 Places for Proficiency

Our participants created places for proficiency through utility. No matter the activity, this place helped the participants feel more competent. For some, it was manifested through being able to practice self care, for others, through the creativity in the food they made. While it is known that space design can lead to increased feelings of mastery (Hoff et al., 2004; Vaatstra & De Vries, 2007), for participants these places fit into daily rituals in a way that other places cannot. These places were mediated through small appliances, laptop computers, games, and gaming consoles.

Putting users in such places will enable easier completion of goal-based tasks in environments such as education, research, and unboxing experiences. For example, creating proficiency through small known tasks in new input technology could help users overcome learning curves. Similar applications in education may lend themselves to digital high performance simulator training in fields where skills build upon each other, like skilled trades, driving, or even flying planes.

3.4.4 Places for Comfort

Places for comfort are usually the most personal of places in multi-function spaces, and hold the most tension of all the places identified. They are do-nothing or do-everything places—enabling positive inaction, rather than the negative themes usually associated with inaction (Sandefur, 2007). This, in turn, helps reduce negative feelings in cases of negative outcomes (Landman, 1987). These places are mediated through either a lack of technology or an abundance—two participants included two or more screens (tablet, cell phone or television). Interestingly, while Jack and Amy were interviewed separately, neither put their places for comfort into their drawings. Jack stated:

> *"Generally because ... the most interesting part of our apartment was just this main room. Because again, it's a combined sort of living room, office space and dining room. And the <place for comfort> is literally just that guy."*

For Milo, their place for comfort held more meaning:

> *"It's pretty much just like a comfort sort of, like coping place for me. Like, if I'm tired, I go to bed. If I'm sad, I go to bed. And if I'm like, feeling like okay, I have nothing else to do. I just lie in bed."*

Creating places for comfort through technology can help reduce anxiety and regret in cases where there could be perceived negative news or consequences, and could help assist with meaningfulness and meditation. Use cases of abundance of technology to reduce anxiety promise to be an exciting area for further study.

3.4.5 Shared places

These places allow multi-generational families, co-habitating friends, or couples to interact face-to-face and accrue memories. All shared places had a sense of familiar community, which usually led to tech-free zones or connection zones where technology was used as an augmentation. Shared places appear in HCI literature as spaces with tabletop (or similar horizontal) displays for collaboration and reminiscing in HCI literature as well with everything from multi-modal decision making (Rogers et al., 2004) to rich personal storytelling (Shen et al., 2003). Three examples of shared places are:

> Milo: *"Okay, so this is the dining table. So initially, this is a seafood one day. So like I was putting all my work and stuff here, but one day I found a bunch of food on my work and I was like, bro, who?... So some people like some things just are convenient to have on that table."*

> Anya: *"So does it move the chair in but I do um, if I wanted to have people over I would take my desk out and use it as a table probably in the middle of the room."*

> Faith: *"[My parents] always bring the food out onto the dining table, they never put it back in the fridge. Just because that they don't want my grandparents to, you know, fumble through the fridge and stuff. So putting it out there in the open, like tells them that there's food and they can eat from it."*

Shared places are versatile, and there is something unexpected every time you encounter one. This feeling of mystery and wonder makes them a place for familiar community, hanging out, relaxation, or implicit communication. Technologies that create shared places would enable the next generation of digitally mediated social interaction—one that doesn't feel mediated, but blends into the background, like a table under a feast. These places could be built through collaborative tabletop games (like the Infinity Arcade table[1]), audio games using voice agents; or interactive, asynchronous notes to exchange information.

3.4.6 Familiar places without a sense of belonging

Our participants constructed familiar places where they had no sense of ownership or agency, were very perceptive to changes, and found both beauty and disgust. Some participants ($n = 2$) sent in images of bugs instead of technology use, and attached affective responses to the pictures. While creatures (animals or insects) are not technology, these images reflect a reverse anthropomorphization— these living creatures are placed in the same category as digital tools as modes of companionship. Participants had a number of familiar spaces close to their homes, as seen in Figure 3.7.

One of the common themes in this space was a sense of experimentation and growth based on the tensions between familiarity and a sense of lack of control. Paulos and Goodman (2004b) used a concept similar to familiar places to study interpersonal interactions. They used such spaces with 'familiar strangers', and built technologies to enhance interactions with strangers. Finally, familiar spaces could act as living laboratories for technology in motion, for example, using mobile-phone based exergames for anxiety reduction (Viana & de Lira, 2020) within a space that becomes a familiar place over time, or applying geo-location based technology to augment spaces to create familiar places.

[1] https://infinitygametable.com/



(a)



(b)

Figure 3.7: Our participants had a number of familiar spaces close to their homes. Quotes reproduced from the captions provided with the media. (a) Milo said *"Walking to work and there are [sic] a COPIOUS amount of dead cicadas on the ground (all the black dots). They're hanging off plant stems and walls as well. I even found one squirming on my doormat as i [sic] stepped out in the morning. It was gross gross gross."* (b) Jaime said *"Since quarantine, my siblings and I have found more time to take more walks around the neighbourhood. It helps combat the sedentary habits we've developed, and it's [sic] also tends to help scratch the itch to pet something furry, since we sometimes encounter a few of the neighbour's animals or strays."*

3.4.7 Unfamiliar places

Unfamiliar places are new and dynamic places that manifest themselves as places for problem-solving when participants solved otherwise mundane problems in them, or as places for cautious discovery when they learn something within such places. These findings add a new dimension to previous studies that have considered nature and the outdoors as a space for recreation (Jones et al., 2018), or in the context of elder adults and their anxieties around such places (Phillips, 2013; Phillips et al., 2013). One participant (Hudson), for instance, felt a sense of accomplishment when they were able find their way in a new city:

> *"I actually have been using Google Maps to find the grocery stores that I need to go to or like the nearest one. And I've been using my phone like I had to get my roommate to call an Uber for me the other day just because I had too much stuff that I bought at the store."*

An unfamiliar place helped Milo catch up on his media:

> *"I actually quite like commuting, and it can be one of my more relaxing parts of the day. Because the pandemic had drastically cut my travel, a combination of distrust and the sad fact of having nowhere to be, I've found myself too restless sometimes to sit down and just listen to the podcasts and new playlists, or read the e-books that I typically use to fill up the time I'm transiting. Now that I'm working again, and therefore commuting, it's been a chance for me to catch up on media I've been falling behind on"*

Unfamiliar places allow for cautious discovery, media consumption, and problem solving. Putting children, for example, in unfamiliar places while in a familiar space (classroom) may promote learning and discovery. Such tools could build on prior work (Simamora, Saragih, et al., 2019) that has looked at building self-guided discovery models for education. Where leisure places are safe places for consumption and discovery, unfamiliar places act as places for either consumption of known content or cautious discovery of new content. Mediating these two places through technology can assist in changing engagement patterns—for example, for social media or media streaming sites. Finally, creating wonder and accomplishment through technology like smartphone applications in an otherwise unfamiliar space holds a lot of promise for improving the well being of older adults.

To summarize, this section provides insight into how small, constrained spaces do not necessarily hinder the creation of meaningful and multipurpose places, but rather, show that technology can enhance the creativity and utility of such spaces.

3.5 Discussion

In this section, I discuss the implications of this study's findings for both theoretical frameworks and practical applications in design and technology.

3.5.1 Revisiting the Concept of Space and Place

Our study challenges the traditional assumptions that diverse placemaking needs big spaces. I demonstrate that even in constrained spaces, individuals can effectively create multi-functional and meaningful places. The emergent places identified—ranging from places of leisure to places for proficiency—showcase the versatility of small spaces when complemented by thoughtful technological integration and personal adaptation. This supports the assertion by Dourish (2006) that understanding the interplay between space and place can lead to better-designed human-building interactions.

3.5.2 Design Implications

Technology plays a pivotal role in transforming mere spaces into vibrant places. The use of digital and electronic devices not only facilitates various functionalities but also helps in defining the emotional and behavioural contours of a place. For instance, the transformation of a kitchen countertop into a mastery place emphasizes the role of appliances in enhancing personal competence and autonomy. Similarly, the temporality aspect highlighted by participants—where a single space serves multiple purposes at different times—underscores the dynamic nature of placemaking facilitated by technology. Recognizing that small spaces do not hinder placemaking but rather modify its expression, designers and architects can innovate more effectively within the constraints of modern urban living. Additionally, technology designers can consider how devices and interfaces can be optimized to support multipurpose use and emotional richness, enhancing the sense of place within limited areas.

3.5.3 Future Research Directions

While this study provides a foundational understanding, it also opens several avenues for further research. Future studies could explore the role of sensory experiences (e.g., sound

and lighting) in placemaking, particularly in small spaces. Moreover, the impact of emerging technologies such as virtual reality (VR) and the Internet of Things (IoT) on the perception and utilization of space warrants closer examination. These technologies could potentially redefine the boundaries of place and alter the landscape of placemaking in profound ways.

Examples of research directions include:

- **Placemaking Deep Dives:** I have presented seven places that participants created while placemaking. Each place, however, could span an entire body of research. As an example, the place for leisure would benefit from additional research around technology that helps people create these places. Each paper builds on both this work, and previous work in HCI around placemaking (Alavi et al., 2019; Becerik-Gerber et al., 2022).
- **Changing Places:** In this study, I focused understanding the elements that enable placemaking in small spaces. As such, the results showed that there are active changes between places in the same space, expanding on previous work that considered physical configurations of space (Oogjes et al., 2018). Changing place through technology using a combination of the elements from section 3.3 holds promise in further understanding placemaking as a whole.
- **Fictional Futures:** Placemaking lends itself well to the concept and practice of fictional design (Lindley & Coulton, 2016). Each place or situated constraint can be further explored through a series of fictional design studies, which would then point to a fictional future. These studies would be revealing within situations including human-robot interaction and intelligent agents, among others.
- **Negotiating Boundaries and Ownership**: This study did not consider ownership of either place or space. Kuzminykh and Cauchard (2020) have laid a foundation for HCI research around ownership, and understanding how occupants of a space negotiate ownership of place would be an exciting new avenue to understand complex ownership issues in both— the digital and the physical realms.

3.5.4 The Role of Technology in Placemaking

The primary insight from this study advances the discourse on Human Building Interaction (Alavi et al., 2019; Becerik-Gerber et al., 2022) and Ambient Intelligence (Cook et al., 2009),

suggesting that effective placemaking is less about the physical size of a space and more about how technology can be leveraged to maximize the space's potential. For instance, consider a single small room with a table and chair (similar to a part of Hudson's space). This room can morph from a place for work to a place for leisure through a combination of a laptop and temporal factors, like the time at which work usually ends. The same space can then be transformed into a place for proficiency by removing digital technology and adding baking appliances and ingredients. In this study, the participants formed most places through a combination of smartphones and laptop computers. In addition to phones and computers, participants used appliances when forming places for proficiency. There were two counter-intuitive findings that merit further investigation: places for comfort were formed either through an abundance of technology, or a complete absence of it; and, tablet computers were only discussed in the context of places for leisure or comfort despite six out of eight participants discussing having one. Overall, this paper illustrates how digital technologies and appliances can redefine space, enabling multi-functionality and adaptability even in the most constrained settings.

3.6 Chapter Summary

This chapter has developed a conceptual understanding of placemaking in small spaces, grounded in a review of existing literature and synthesized through a descriptive phenomenological lens. It argued that even in spatially constrained environments, individuals construct richly meaningful places through affective, technological, and embodied practices. By focusing on the lived experience of spatial transformation, the chapter challenges assumptions within HCI that implicitly associate meaningful placemaking with larger spaces.

This chapter addresses **RQ1: How can technology mediate a sense of place for people living in small spaces?** (chapter 3)

1. **C1.1:** I provide a deeper theoretical understanding of technology-mediated placemaking in small domestic environments by identifying four core elements—*boundaries*, *temporality*, *mastery*, and *future-thinking*—that enable the emergence of a multiplicity of places within a physically constrained space.

2. **C1.2:** I challenge assumptions in HCI that meaningful placemaking requires expansive environments, and instead demonstrate how users transform spatial limitations into

opportunities for rich, layered place-experiences through creative and affective uses of everyday technology. This offers design guidance for technologies that better support co-located and remote life in compact, multi-use spaces.

The four core elements identified—*boundaries*, *temporality*, *mastery*, and *future-thinking*—together offer a conceptual framework for understanding how users negotiate spatial constraint through spatial, temporal, and technological improvisation. These elements are analytically distinct yet deeply interwoven: boundaries shape the delineation of functional zones; temporality reflects the rhythms of transformation over time; mastery highlights the deepening competence with which users reconfigure their space; and future-thinking captures the aspirational, projective qualities of space-making even in materially limited environments. Collectively, these dimensions reposition placemaking as a dynamic and situated process, sensitive to both material conditions and technological mediation. This re-framing is particularly urgent for HCI, where spatial assumptions often underlie design norms but remain unexamined.

This chapter lays the groundwork for the studies that follow. Its contributions shape both the analytical lens and the design vocabulary used in subsequent chapters. In Chapter 4, this model is extended into mobile contexts, where the act of placemaking must contend not only with spatial constraint but also with continual movement, infrastructural variability, and socio-technical improvisation. The van becomes a site of ongoing reconfiguration, and the boundaries, rhythms, and aspirations of place must be negotiated afresh at each stop. This nomadic condition provides a rich counterpoint to the domestic fixity explored here, further deepening the thesis's exploration of constraint, flexibility, and place. In Chapter 5, the framework informs the design and evaluation of hybrid interactive systems that support flexible transitions between place types in both co-located and remote scenarios.

Finally, the chapter raises new questions that guide the rest of the thesis: How do ideas like mastery and future-thinking operate when home is on the move? What kinds of technologies best support changing uses of space when infrastructure is temporary or inconsistent? And how can interaction design better account for the emotional and symbolic aspects of boundaries in compact environments? By laying this foundation, the chapter sets the stage for a thesis-wide engagement with constraint as a meaningful and generative condition for design.

Chapter 4

Constrained but Connected

Technology Use in Vanlife

4.1 Introduction

The previous chapter examined how people create meaningful places within fixed small spaces such as studio apartments and shared flats. However, those environments are typically stationary and supported by stable infrastructure. In contrast, this chapter explores placemaking under a different set of constraints: mobility, infrastructural variability, and continuous spatial reconfiguration. By focusing on individuals living the vanlife—people who reside full-time in converted vehicles—this study extends this thesis' investigation from fixed to mobile constrained spaces. It examines how technology use, spatial adaptation, and community formation occur when space is not only small but also constantly in flux.

The rise of *vanlife* represents a confluence of economic constraint, cultural aspiration, and technological adaptation. What began as a niche or counter-cultural housing alternative has evolved into a globally visible lifestyle, amplified by social media and increasingly embraced by people across demographics. Today, an estimated three million people in North America live part-time or full-time in vans, buses, or trailers converted into mobile homes. Their motivations range from financial necessity to a desire for mobility, minimalism, self-sufficiency, or a deeper connection with nature.

At its core, vanlife is not simply about alternative housing; it is an intentional reconfiguration of how space, time, and technology interact in daily life. These mobile dwellings collapse the conventional boundaries between home, workplace, and vehicle, creating an environment where conventional design assumptions about infrastructure—stable power, fixed spatial layouts, and always-on internet—no longer hold. And yet, vanlifers live rich, connected, and productive lives in these spaces, using technology in creative, non-prescribed ways to sustain work, leisure, and community.

Human-computer interaction (HCI) has long studied domestic technologies (Crabtree, 2003; Desjardins & Wakkary, 2016; Desjardins et al., 2019a; Oogjes et al., 2018), but much of this work remains grounded in a normative model of the home: a fixed, spacious, often suburban dwelling with reliable infrastructure. Technologies such as smart thermostats, voice assistants, or gaming systems are typically designed for such environments, assuming ample space, stable connectivity, and distinct zones for different activities. Even research on mobile work tends to focus on temporary or transitional spaces like airports, co-working hubs, or hotel rooms, not permanent mobile homes. The vanlife community, with its unique blend of domesticity, mobility, and technological improvisation, thus remains largely under-examined in HCI.

In this chapter, I present findings from over 200 hours of immersive fieldwork, including in-depth interviews, participation in vanlife meetups, and ethnographic observation. I examine how vanlifers use, adapt, and often subvert mainstream technologies in service of placemaking—the process of transforming space into a meaningful and inhabitable place. Vanlife technologies are often modular, low-power, and multifunctional. They are also deeply expressive. One participant explained:

> *Everything I use in this van has to earn its place. It's not about minimalism for aesthetics—it's survival. If my fridge dies, it's not an inconvenience, it's a crisis.* (P7)

Technology in vanlife is not neutral. It is interwoven with identity, agency, and affect. For example, gaming consoles, which are often seen as leisure accessories in traditional homes, take on a different resonance when space is limited and community is remote:

> *This tiny screen is how I hang out with my friends. We play online every weekend—even if I'm in the middle of nowhere. It's how I feel human.* (P9)

These stories reflect a broader truth: vanlife is a dynamic negotiation between constraint and creativity, instability, and agency. Through a thematic analysis of participant data, I identify eleven design provocations—design-oriented insights that challenge conventional assumptions about domesticity, infrastructure, and interaction. These provocations highlight the ways technology can be re-imagined for small, mobile, and often marginalized domestic contexts.

While answering the call for more diverse research in nomadic culture (Rossitto et al., 2017), in this chapter, I also:

1. Present the HCI community with eleven provocations to inspire both critical design and further research to enhance the subjective well-being of vanlifers, and
2. Present the cultural and societal norms that drive technology use in the vanlife community.

I conclude with a discussion on the implications of potential new technologies, not just for vanlifers, but also for other communities that could be mobile, have small living spaces, or variable internet connectivity.

4.2 Method

This study began with a literature review of vanlife across disciplines by searching for prior literature using multiple keywords (digital nomads, vanlife, recreational vehicles, travel HCI, nomadic work, remote work, etc.) across multiple libraries (ACM DL, Google Scholar, Scopus).

For this study, I had one co-researcher (Katerina Morayko) who accompanied me in the field. None of us had previous experience with vanlife and we found limited research that considered vanlife. To cover this gap, we familiarized ourselves with the verbiage used in vanlife through blog posts, social media postings, and YouTube videos. We noted that the community gathered through two primary modes, and we planned the study around these modes:

1. Online gathering through Facebook groups.

2. Physical gathering through vanlife meetups: vanlifers meet at locations that are either scenic, have a pleasant climate, or are convenient for a large number of people in the community. These meetups were primarily organized through Facebook groups.

For this study, we planned on attending physical vanlife meetups. We wanted to collect video and photographs of the vans and their surroundings, conduct interviews, and rent a van to live in for one of the meetups.

The approach was realized through field work at three meetups. We collected data from nine interviews, over 12GB of digital data, and numerous researcher notes. We distilled themes from these data sources and presented them as provocations.

4.2.1 Location & Meetup Selection

The selection criteria for the meetups was geographical proximity to us, date of the meetup (November 2019), and the expected number of attendees. Following university ethics approval, we selected four meetups: two smaller social meetups, both expecting between 10 to 30 attendees, and two larger ones focused on building and renovating vans with 500 to 1000 expected attendees. We identified the gatekeeper for each of these meetups, then requested permission to recruit and conduct research in these areas. To identify the gatekeeper we messaged the person setting up the event on Facebook, the administrator of the group, and the moderator of the group to ask them about the person from whom to request permission. We were pointed in the direction of the organizers of the large event. For the smaller event, the administrator of the group was also the organizer. I heard back from the gatekeepers of only three meetups, who allowed me to conduct research there (Table 4.1).

Vanlifers from across the province attended these social meetups. Most vanlifers at these gatherings knew each other either from previous meetups or from the Facebook group. In contrast, the larger meetup was an organized event for individuals to work on their own van, or volunteer to work on others' vans. We rented and lived in a van while in attendance at this meetup.

4.2.2 Interviews

We conducted interviews with participants using an interview guide for the semi-structured interview. The interview guide covered topics including technology use, barriers to technology,

ID	Meetup Location	# Vans	# Attendees	Time Spent (hrs)	Gatekeeper
M1	Ontario, Canada	3	5	9	Facebook group moderator
M2	Arizona, USA	300	~600	192	Meetup organizer
M3	Ontario, Canada	9	20	5	Facebook group moderator

Table 4.1: List of Meetups Attended

living conditions, and ended with general demographic questions. Participants were recruited verbally at two vanlife meetups (M1,M2) in the common areas. Participants who expressed interest were asked to read an information and consent letter. Those who agreed were interviewed, and the interviews were recorded. Most participants immediately (eight out of nine) offered van tours, where they gave us a tour of their home. For the person who did not provide the tour, the interview was conducted outside their van in their living room space (the outdoor living room space is discussed in subsection 4.4.4). Demographics are noted in Table 4.2. Participants were then debriefed, thanked for their time, and paid $10 (US Dollars or Canadian Dollars, depending on the location of the meetup). The interviews were conducted by two researchers who both attended the meetups (M1 and M2). No interviews were conducted at M3.

4.2.3 Public Spaces

Public spaces reflect gathering areas in the meetups that were not otherwise claimed by neighbourhoods (Table 4.3, also see subsection 4.5.1). These pop-up spaces were used by vanlifers to socialize and exchange ideas, and provided a rich tapestry of thoughts that we recorded in hand-written journals. All public spaces, except one, were attended by two researchers. The final public space (PS5) was attended by only one researcher. On entering a public space, we identified ourselves as researchers, and listened to the conversation. In one public space (PS1), we asked a few questions which may have changed the direction of the conversation. In the following meetups, we did not interject to allow the conversations to run their natural course. We then independently took notes on our recollections and reflections of the conversations, which we then compared for accuracy. We noted a difference in our reflections that could be attributed to our backgrounds (one researcher has a background

ID	Meetup	Age	Gender	Time Vanlifing	Profession	Annual Income (USD)
P1	M1	30–40	M	2 years	Web Marketing	Variable
P2	M1	30–40	F	2 years	Web Marketing	Variable
P3	M1	50–60	M	6 months	Project Manager	>100,000
P4	M1	40–50	F	1 year	Customer Support	25,000
P5	M2	30–40	M	6 months	Online Professor	50,000
P6	M2	30–40	F	6 months	Therapist and Life Coach	35,000
P7	M2	30–40	M	2 years	Customer Service	25,000
P8	M2	60–70	M	2 years	Retired	40,000
P9	M2	20–30	M	1 year	Technical Writer	40,000

Table 4.2: Demographics of interviewed participants. P1 and P2 were living in the van together, as were P5 and P6. While all of the participants lived on the road full time, P3 owned a house they no longer lived in.

in management engineering, while the other has a psychology background).

ID	Meetup ID	Number of People	Time at the Space	Description of Space
PS1	M1	5	2 hours	An area formed by three vans parked around it
PS2	M2	15	5 hours	Public space in the desert near the meetup organizers' vans
PS3	M2	30	2 hours	A space formed for making furniture for the vans
PS4	M2	10	3 hours	A space formed for helping vans with solar issues
PS5	M3	20	5 hours	Vanlifers standing and sitting around a campfire

Table 4.3: Public spaces documented at the three meetups

4.2.4 Data Collection

We used documentary tools to collect data at the three meetups: voice recorders, pen and paper, a drone, and a 360° camera (Figure 4.1). For the visual portraits, we used a drone (with appropriate licenses and flight permissions). For the interviews and van tours, we used 360° cameras to more accurately capture the environment and context of the interview

and the tours. We selected these tools as they are commonly used to document vanlife on social media.



Figure 4.1: Our tools—pens and notebooks for journaling, drones, and 360 degree cameras as documentary tools, and voice recorders to aid in memorializing voice interviews

Drones

We used a drone (DJI Mavic Mini) to document the spatial setup and van setups for one of the meetups (M2). We took several pictures and recorded about 6 hours of video using the drone. The pictures of the large areas were annotated (e.g., Figure 4.7), and the pictures of vans were used to understand homesteading. I have stylized one picture to show the interior, and presented it as a view into the living area of one vanlifer in Figure 4.6.

360° Cameras

We used two GoPro Fusion cameras to document the van tours and interviews with participants who consented to video recording in their vans in 3D (5 participants). The use of 360° video and traditional field video in this study was grounded in an embodied ethnographic orientation. Rather than treating video as a neutral recording device, I adopted what Dourish (2001) and Pink (2015) refer to as a situated and embodied analytic stance. This stance views technological encounters as emergent from lived bodily routines. Specifically, I positioned the camera to follow the participant's point of view in the van, enabling analysis of how technologies were accessed, engaged with, and embedded in spatial routines. This perspective allowed me to capture how placemaking practices unfolded through movement, reachability, and gesture. Analytically, I treated video clips as a way to ground codes in spatial and material practices, supporting visual cross-reference with diary entries and interview transcripts. By maintaining an interpretive focus on action-in-space, rather than on static artifacts or predefined scripts, the video data served as a crucial layer for unpacking the embodied enactment of technological place.

At the time of analysis, we were not aware of any tools that supported coding or thematic analysis of 360° video data. To address this, we manually analyzed a 22-minute segment and identified three analytic strategies:

1. Using raw footage: This had the richest data due to the depth of information present in each frame. The analysis of this video took close to twenty times the length of each video.

2. Follow the interviewer: This method relied on watching one part of each frame. To do this, we tried to follow either the gestures or the language used by the interviewer, but it returned inconsistent results, often missing key points on video. The advantage of this approach is that if researchers knew they needed to convert the video to a different frame of vision, they could draw attention to points in space without needing to disturb their camera setup. For this method, areas of the video were selected in a narrower field of view on a continuous timeline, and then rendered into a new video. It took around seven times the length of the video to transform, and around twelve times the length of the video to analyze.

3. Follow the participant: As in the previous method, this relied on watching one part of each frame. For this method, we followed either the gestures or the language used by the participant. This method took approximately four times the length of the video to transform, and around twelve times the length of the video to analyze.

For the test video, we found that method 1 and 3 provided the richest data granularity. Both had an 85 percent overlap in themes identified. Based on the time taken and the richness of information output, we decided to use method 3 (follow the participant) for the remainder of the videos. The videos were edited using the GoPro Studio software [1], and themes were analyzed using ELAN video annotation software [2]. The time taken to edit does not include the time taken to render a final video once areas in specific frames were selected.



Figure 4.2: Image from the 3D camera, zoomed out and cropped for clarity

4.2.5 Data Analysis

We analyzed the dataset—including interviews, van tours, public space observations, and researcher reflections—using reflexive thematic analysis (RTA) (Braun & Clarke, 2006, 2021). RTA treats researcher interpretation as a strength rather than a bias, and supports a flexible, iterative, and situated approach to analysis. This aligns with emerging HCI approaches to understanding complex lived experience in technology-rich but infrastructurally constrained contexts (Gunkel, 2018).

[1]Available at https://gopro.com/en/nl/shop/softwareandapp/gopro-studio/GoPro-Studio.html
[2]Available at https://archive.mpi.nl/tla/elan

Coding and Memos

We conducted multiple readings of the transcripts and generated inductive codes capturing both surface-level and latent meanings. These codes were iteratively refined through memo writing and analytic discussion (Nowell et al., 2017). Early memos included interpretations such as "technology as shelter," "improvised ritual," and "domestic mobility," which helped link specific practices to broader conceptual frames.

Van Tour Analysis

We analyzed van tour footage using ELAN software [3], attending to gesture, spatial cues, and verbal framing. Gestures such as pointing to a solar panel while calling it a "lifeline" were coded as expressions of both material reliance and symbolic place-making. These embodied acts extended prior work on situated infrastructure and routine (Tolmie et al., 2010).

Material Sensemaking

We interpreted spatial arrangements and everyday artifacts not just as functional adaptations but as active elements in participants' meaning systems. Shade cloths, modular seating, rugs, and storage bins were all deployed to create privacy, comfort, and order. These interpretations were grounded in the interplay of observed materiality and participant descriptions.

Cross-Modal Triangulation

To develop a coherent analytic account from the diverse strands of digital, auto, and public ethnography, I used a convergent integration approach during reflexive thematic analysis. While initial coding was performed within each modality, all codes were subsequently pooled into a shared analytic corpus. This allowed for recursive comparison and contrast across modalities, identifying where patterns converged or diverged. For example, notions of territoriality emerged both in visual observations of spatial arrangements at public events

[3]Available at https://archive.mpi.nl/tla/elan

and in textual accounts from digital forums. Similarly, codes relating to infrastructure improvisation were developed through the interplay of personal experiences documented in auto-ethnographic memos and corroborated by visual behaviours observed in public settings. This cross-modality triangulation enabled the generation of meaningfully situated codes and themes, while preserving the contextual specificity of each data source. All interpretations were grounded in the epistemological orientation of reflexive thematic analysis, which privileges analytic subjectivity and iterative reflexivity. This approach aligns with established practices in applied thematic analysis (Guest et al., 2011).

Theme Development

We refined the thematic structure over multiple rounds of analytic discussion. Thirteen final themes were identified and grouped into three analytic domains: van-space interaction, mobile life practices, and community belonging. Ten of these themes were translated into design provocations, while the remaining three were retained as interpretive insights. Our analytic orientation emphasized contextual richness and interpretive transparency throughout (Braun & Clarke, 2021; Nowell et al., 2017).

This layered process illuminated how vanlifers transform constrained, mobile environments into meaningful places. It foregrounds spatial improvisation, infrastructural negotiation, and symbolic framing as central to technology-mediated placemaking.

4.2.6 Converting Themes to Provocations

Provocations have previously been used to stimulate discussions and critical thought among the HCI community, usually for large groups who historically have been overlooked by their community (Adamu, 2020; Menking et al., 2019; Park et al., 2006; Tutia et al., 2019). Previous research using provocations includes a study articulating social relations and transnational engagements through an African standpoint in HCI (Adamu, 2020), "unuseless" playful and provocative suggestions to enhance digital TV (Park et al., 2006), and the design of future intimate technologies for women during menopause (Tutia et al., 2019).

Bardzell et al. (2012) describe three categories of provocations: *conceptual*—a provocation that concerns an idea, belief, or concept tto challenge or critique through a design; *functional*—a provocation that deals with how far a design is from the norm of the way it works or

operates; and *aesthetic*—a provocation that deals with how far a design is from the mainstream in its visual look and materials used for crafting it. In addition to their utility in provoking critical thought, provocations have been used to create prototypes (e.g., Tutia et al., 2019)—futuristic concepts or speculations on technology that could answer the call posed by the provocation.

For the ten themes showcased the need for technological interventions, these are presented in a manner that added context while allowing practitioners to reflect and critically think about them. In order to do that, each theme was presented with representative quotes and findings from public spaces (with IDs noted next to the quotes). Some quotes were edited to remove identifying information or for clarity. This resulted in ten provocations. The final provocation (subsection 4.5.5) was based on our observations while we were recruiting for the study. The remaining three themes were presented as "Other Insights".

The provocations were drafted as statements that reflect technology as an agent for positive design (Desmet & Pohlmeyer, 2013) for technology in the lives of vanlifers. Further, the provocations were drafted with a goal of evoking a sense of temporal harmony directed at the future (Hermosa Perrino & Burmester, 2020), that is, we balanced the present-hedonistic and future time perspectives. For presentation in this chapter, I then segmented the provocations based on vanlifers' beliefs and expectations of what technology ought to afford them into two categories:

1. Vanlifers' relationship with their spaces—not just their vans, but also the physical environment in which their van is present.
2. Vanlifers' relationships with their communities—this includes vanlifers' communities outside their vans: other vanlifers, people living in brick and mortar homes, their schools, or their workplaces.

Through this analysis, we also identified four core pillars underlying all the provocations. These form the design space of vanlife. Adhering to this design space is critical to any technology developed or adapted for vanlifers.

4.3 The Design Space of Vanlife

We have identified the design space for technology in vanlife as consisting for four core pillars:

4.3.1 Limited Power

Unlike the functionally limitless capacity of the electrical grid found in conventional homes, vans use automobile (or marine) batteries. Furthermore, vehicle batteries are rated at 12 V, while most household technology is rated for 110 V in North America. While power converters and additional batteries can reduce these barriers, these solutions are often costly and take up space in an already small home. vanlifers who purchase power converters remain, at the time of this study, the minority in the community. With such a limited electrical budget, power consumption becomes a constant concern for many. When choosing technology to include in their van, vanlifers have to consider its impact on both persistent electricity consumption (e.g., fridge, lights) and peak consumption (e.g., laptop/phone charging, electric kitchen appliances). The electricity-consciousness of technology designers should match that of vanlifers. When working with a limited electrical budget, one could increase power production or decrease consumption. An example of the former strategy would be the installation of solar panels to charge batteries, while an example of the latter would be the use of non-electric appliances (e.g., gas-powered stoves and air/water heaters). The latter solution also eliminates the issue of power conversion, which is another concern that designers should consider when creating new technology.

4.3.2 Variable Internet Connectivity

Internet connectivity changes according to where a van is parked. Consequently, vanlifers try to park where "good" internet is available and avoid areas with poor connection, which sometimes defeats their desire to travel more with their vans. This forms a core concern all the way from building a van to renovating it. As noted in a number of provocations, people living the vanlife design their vans around the technology in it. Since much of modern technology is designed with the assumption that it will have constant access to the internet, vanlifers are limited when it comes to what they can include in their van. Designing technology to cope with changing connectivity—either by eliminating the constant connection requirement, or by including a "limited internet" mode—would increase the technological selection available to vanlifers and allow them to add more of what they may desire in their van.

4.3.3 Limited Space

Any technology (or combination of competing technologies) needs to fit within the small spaces of vans. For instance, six participants lived in less than 7.5 m^2 of space. When one considers the spatial requirements of sleeping arrangements, seating, storage, and food (among others), the available space for technology shrinks even further. Design concepts such as miniaturization and multi-functionality would provide vanlifers with more freedom when it comes to creating and arranging their living space. In addition to living in a relatively small space, vanlifers often rearrange the interior of their van when switching between aspects of their life (e.g., work, leisure, driving), only bringing things out when they are needed and stowing them away otherwise. To account for these regular changes, any non-stationary technology within the van should be fairly easy to disconnect, move, and reconnect.

4.3.4 Limited Disposable Income

While vanlife may appear to be a frugal lifestyle, vanlifers still have to spend to maintain their lifestyle. Expenses such as gas, repairs, renovations, and access to utilities, in addition to the limited career options for vanlifers, result in a financial situation with limited disposable income. Currently, vanlifers spend around 50% of their van build budget on technology (P1,P2,P3,P4,P5,P6,P9)—focused primarily on high quality batteries, solar panels, and fridges. Any additional technology, however, is generally considered superfluous, and would be thoroughly considered to determine whether it is "worth it". The consistent factor to determine worth among participants was how multi-functional the device is, how it operates in different environments, and the potential ability of the vanlifer to fix the technology in case it breaks down. It would be beneficial for technology designers to consider the impact of a device in comparison to its cost and how to increase its "impact-per-dollar" value.

4.4 #Vanlife - A Community at the Crossroads of Technology and Ingenuity

Our first set of provocations focuses on how vanlifers engage with and inhabit their mobile spaces. These themes highlight the ways in which vanlifers actively reconfigure their vans,

and the environments they temporarily occupy, to support daily routines, technological practices, and personal expression. In doing so, they transform constrained physical settings into lived places, embedding meaning and functionality into limited square footage. These provocations foreground the spatial negotiations and infrastructural adaptations that underlie vanlife, offering design insights for technologies that must operate in fluid, compact, and often resource-scarce contexts.

4.4.1 Provocation 1: Allow users to express themselves through physical technology.

One common theme that participants highlighted was the DIY nature of their van. A handshake was replaced with a van tour. Each of the 40 van tours presented to us during the course of the study(including those of the participants) was short, practised, and included some personal highlights of their inhabitants' conversion process. We report only on the van tours from those people who consented to be a part of the study. P5 and P6 had a memorable highlight:

> *We stripped out burgundy carpeting that was all around the van, helped by my 87 year old grandfather who is a jack of all trades—electrical, woodworking, plumbing. He had tools that we didn't even know the names of!* (P6)

P5 and P6's pride and emotion in their van-build ("build") is a theme repeated in all van tours. Some participants' D.I.Y. homes are shown in Figure 4.4. During these tours, the appliances and technology were often hidden, at times impacting their usability. Such technology currently includes (but is not limited to): refrigerators, AC-to-DC converters, battery packs and sockets, vent fans, and induction cook-tops.

> *The fridge is under there.* (P6, pointing, seen in Figure 4.3)

Technology was hidden in ingenious ways: fridges hidden in drawers, sockets concealed behind panels, even removable wall pieces to cover the vent fans (PS3). This phenomenon occurs because the technology takes away from expressing individuality and the sense of pride in craftsmanship (PS3, PS5), despite vanlifers spending a large percentage of their van build budget and time on domestic technology (PS1, PS3, PS4, PS5). Technology should add to people's individuality, not take away from it, especially in small spaces where every inch is a canvas for self-expression.



Figure 4.3: *Hide and Seek*. The fridge, tucked away between the front seats. Note how it doubles for use as a table in this case, necessitating the removal of everything on the table to open the fridge.



Figure 4.4: *Homemade homes, Hidden Technology.* Clockwise from upper left: P1 and P2 live in a self converted high roof, long wheelbase Dodge Sprinter Van, P3 lives in a converted passenger minivan, P8 lives in a trailer he used to share with his daughter as a two bedroom vehicle, but has now converted it to one bedroom, and P4 lives in a converted low roof, short wheelbase cargo van.

4.4.2 Provocation 2: Visualize and monitor data to control for root causes of temperature related issues.

P4 lives within 100 miles of a heavily urban area where winter temperatures can be as low as $-20\,^{\circ}\mathrm{C}$. His job requires him to take calls and have phone conversations from within the van without getting disturbed by traffic and other sounds. He built his home on wheels to be heavily insulated to withstand the cold in an old cargo van.

> *There's two layers of insulation here, and the diesel heater, which keeps it warm in the winter. I also have Refletix on the back windows. It sometimes gets too hot in the winter* (P4)

This insulation has a negative effect on the van as well. In response to a question on how technology could make their lives better,

> *If you can control condensation, man. I have to strip the van because of mould and condensation, and the condensation in the winter loosens the glue.* (P4)

Like P4, most vanlifers design their van around one primary concern: what temperature the van will be used in. Without technology to help them accurately control the internal environment, they are subject to the negative effects of temperature. Currently, there are no technologies to *actively* monitor temperature and humidity states in vans. There are thermostats available to control air conditioners, but these do not monitor or visualize internal environmental conditions.

> *I am stripping my trailer's insulation every time the season changes or I move to a place with different temperatures, my fans and thermostat can't help with the condensation. Condensation builds between the (outer metal) skin and the insulation, which creates (mould) spots.* (P8)

This is a problem that has been solved in conventional homes through smart thermostats. With much smaller spaces compared to the conventional home, it should be easier for vanlifers to monitor their internal environment. However, technology is not designed to fit in a home like a van. Technology should help visualize and monitor environmental variables, even in spaces with limited power and variable internet.

4.4.3 Provocation 3: Computing peripherals should be multi-functional and go beyond their intended use.

P1 and P2 work in web marketing, and they are also the admins for a local #vanlife Facebook group that they started—consequently using both their laptops extensively. As they designed their new home, they started with:

> *[. . .]everything has to kind of do multiple things[. . .]* (P1)

This multi-function layout is designed around the peripherals for their technology.

> *I have a laptop and I have a tablet and a bunch of notebooks and some external hard drives and we run everything ready (to) work through (in our space).* (P2)

Peripherals, specifically chargers and cords, also determined one piece of furniture that they thoughtfully installed and used in a variety of ways:

> *This is a marine table, and we pull it in to be a dining table or it can be inside and be [P1]'s workplace.* (P2)

The "inside" position reflects the length of a charging cord. This theme is repeated across other participants who design their vans around the peripherals for their technology. All participants used laptops and cellphones for their work. P2 noted using a tablet in addition to her laptop. Some participants (P7, P9) used external mice, and designed tables in their vans to allow them to easily place their laptops and mice (Figure 4.5).

> *The table is very large so it can fit my mouse when I need to work [. . .] I also try to work on the front seat and have (a little folding table) for the mouse.* (P7)

Another component of peripherals was that they often determine technology purchase choices, often leading to unintended negative consequences:



Figure 4.5: *Worse mouse traps?* P7 is working in his van, and P9 has set up a dedicated work space. In both cases, though, the table size is built to accommodate the laptop and a portable mouse.

> *I am not on iMessage so I'm removed from my family groups. I got an android because I already had a USB-C setup.* (P8)

Vanlifers are stuck using technology peripherals designed with a conventional homes and workplace in mind, thus forcing them to design around it. Technology design encompasses everything that makes the technology usable: whether it is a charger, caster wheels (e.g., Apple Mac Pro Wheels [4]), and mice among others. Designers should design peripherals that work in limited space, are multi-functional, and need limited power.

4.4.4 Provocation 4: Technology should enable dynamic homesteading.

A unique aspect of vanlife is the dynamic creation of homesteads. Homesteads are an extension of the van's space into nature. These can range from not homesteading ("stealth"

[4]Available at (https://www.apple.com/ca/shop/product/MX572ZM/A/apple-mac-pro-wheels-kit)



Figure 4.6: *Homesteading in the wild.* A stylized image of P7's van. They have been living in this van for over two years while carrying out a customer support job.

parking) in urban parking lots, to large rural homesteads. Although there is no official ownership of land, small areas around individual vehicles are considered as being a homestead or the vehicle owner's living area. One of the researchers, while walking through a space in M2, was told to: "keep off my backyard", as that space had been claimed by a vanlifer due to the proximity to their van. In Figure 4.6, the shrubs and clothesline form the bounds of the homestead, and the lifted tailgate forms the gate. In this configuration, the area behind the van (near the tailgate) is the living room, the backseats are the bedroom, and the left side of the van is the kitchen.

> *I park to get good internet [. . .] and some spots get better internet than others [. . .] My van always faces away from the sun so that there is no glare on my laptop.* (P9)

P7 sits in the front, despite building a dedicated work space in the back (which is for city

use only) because his displays cannot be seen in the light. There are other concerns as well:

> *I don't work, but I need power. My panels don't work when I put them on the ground in this way (points out a specific orientation).* (P8)

As the homesteads grow, they cause concerns. As they contract, they again cause concerns:

> *No vent fan because I live in a large city and take this van to work. I don't want them knowing I live in it, I use a USB fan when I'm travelling.* (P3)

Homesteading in vanlife today is a process of trial and error. In addition to its practical aspects, when vanlifers set up homesteads, technology artifacts aided the process of homing (Petersen et al., 2010). Technology should remove the error and allow vanlifers to move between different homesteads and homestead rapidly, based on their personal preferences.

4.4.5 Provocation 5: Exergames should expand/contract with the space/internet connectivity they inhabit.

P9 works remotely with an international team. He travels extensively to spaces with nature.

> *I like to follow people on either Facebook or Instagram. This summer I went to Pacific Northwest, so I hung on Oregon and Washington. Well, mostly in Oregon, Bend. I went to descend on Bend. I plan to spend a lot of time in BLM [Bureau of Land Management land, which is free of cost for camping] in Nevada and Arizona.* (P9)

However, he feels that he got a better workout while living in an apartment.

> *I had more equipment in my apartment [. . .] I would like to get a bike [. . .] I'm not sure like what but I like to go have a kayak. That'd be great.* (P9)

Vanlifers may seem like they are more active by virtue of being in nature or outdoors, but they feel like they work out less or are less fit after moving into a van. In a number of public spaces (PS1, PS2, PS5), vanlifers felt that this was because of limited access to indoor gym-like spaces.

We hike a little more, but don't get any other type of exercise. (P2) does some yoga here. We want to workout more inside the van. (P1)

Exergames could be a space efficient solution to this challenge. These have already been tried with drones on streets (Scheible et al., 2017). There is space to expand the concept to exergames both inside and outside a van. Currently, popular commercially available technologies, such as Microsoft Kinect, do not meet the power or space requirements of a van. Additionally, not all participants shared the opinion of being more unfit after moving into a van. P7 felt that he was more active on account of hiking, compared to before living in a van, when he did not go to the gym. Technology should be created to enrich the lives and health of people living in variable sized spaces, with variable internet bandwidth.

4.4.6 Provocation 6: We should be able to realize our yearnings for our incomplete spaces.

P8 had been living in his cargo trailer alone for six months. Before that, his daughter used to travel with him.

I had two bedrooms that we would enter through windows, and my daughter would have space to practice her Japanese. I've converted the trailer now to a single bedroom with the bathroom up front. (P8)

The trailer construction was complete. However, there was a sense that once the redesign was finished, there was something missing:

I wish the trailer was either a little larger [. . .] I may switch to a high top van next. (P8)

This sense of yearning is also reflected in other participants. All participants built their dream vans, and wanted their "next build" to be a little different regarding features, size, layout, or even colour scheme.

I would get a larger van next. (P9)

> *We are redoing our van next year—we will change the layout a little bit, but change the aesthetics.* (P1, P2)

Vanlifers are constantly looking at the next evolution of their space, but have no way to conceptualize this new space. While 3D home planning programs have helped in planning spaces, they do not allow for personal conceptualizing (through personal artifacts, or reflecting their DIY skill), or need extensive knowledge to make architectural renderings. An app has been developed to cater to the specific needs of vanlifers (Vanspace, 2020), however this app helps people plan van layouts and not conceptualize their spaces. Technology should be able to help novices conceptualize alternate realities of their small spaces without needing to know how to code.

4.5 Social Media and Connectivity Tools

This section explores how vanlifers construct and sustain social relationships within and across the mobile geographies they inhabit. Despite limited or unreliable internet connectivity at most meetup sites, vanlifers actively engage in placemaking through improvised and hybrid forms of social connection.

While digital platforms like Instagram and Facebook remain central to long-distance community formation, the ephemeral and infrastructurally sparse nature of meetup locations necessitates alternative, often offline, modes of social cohesion. These practices are deeply spatial: they not only shape the relational dynamics among vanlifers, but also contribute to the ongoing transformation of campsites, parking lots, and public lands into meaningful communal places. Each theme is presented in its own subsection, supported by illustrative quotations that reveal how technological adaptation, spatial negotiation, and social belonging coalesce in vanlife settings.

4.5.1 Provocation 7: Technology should create a sense of belonging whilst aiding in self-organization.

As vanlifers begin to gather and homestead at vanlife meetups, people in similar life situations (young professionals, affluent older adults, families with kids, etc.) gather in similar parts of

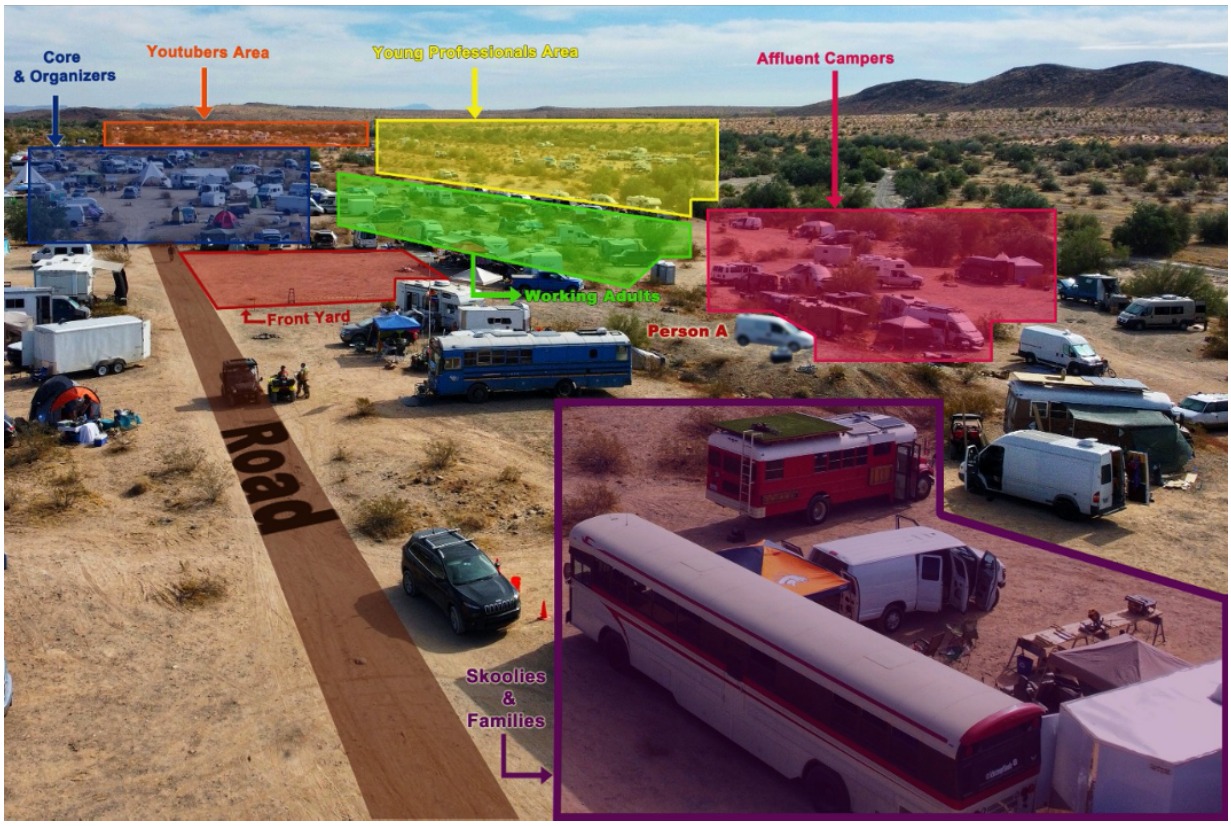


Figure 4.7: The newest subdivision: Distinct neighbourhoods formed on free government camping land at vanlife meetup M2.

the venue (M2). This can be seen in Figure 4.7, where distinct "neighborhoods" are formed by like-minded people. This phenomenon existed despite vanlifers arriving at the meetup at different times—sometimes early in the morning, at other times late in the night when they could not ask for directions or go to a site with "their people". Picking a spot gets tougher when the attendees do not already know, or heavily interact with, other vanlifers going to the same meetup. When coming to the meetup they seek out familiar looking vans, identified by their colour, body style, or unique elements (PS4), or visit the area where the organizers are located. The organization of the meetups was driven primarily by strong online relationships, formed when they either comment on the same posts online (PS2, PS3, PS4) or by membership of shared Facebook groups (PS2). When these did not exist, people defaulted to what felt familiar. However, this was not always what vanlifers wanted.

I needed to get some furniture work done, so I've had to move twice now. I

am currently parked here waiting for a space to become available to modify my bed. (P8)

One vanlifer parked next to vans with antennas, assuming they had good internet:

I wanted to sleep before tomorrow and saw these people who would have good internet [they did not]. They had campfires every night, and I don't want to park with them next time. I can't move now because I will run into them again and they are active [on a shared common Facebook group]. (P9)

There is no current tool to help real-time spatial organization. There is a need for technology that helps vanlifers self-organize and create more meaningful temporary neighbourhoods while maintaining their sense of identity and belonging.

4.5.2 Provocation 8: Allow the reduction and reuse of physical gaming artifacts across multiple games while enriching gameplay.

One element that was constant in the lives of vanlifers was their affinity to games and gaming, both digital and physical (board or card games). Games for some vanlifers go beyond recreation, reflecting their work as well:

Nothing really makes it [work in #vanlife] easy... I guess working with games? I did it for three years and never really felt like I was doing work because I was playing games. (P4)

Out of the participants, seven stored and played board games and eight played digital games of some form in their van. The primary deciding factor in type of games selected was storage space. One participant wanted to play games, but had limited space:

[I] have like an emulator on my phone for like, old console games or something but no, no PlayStation or anything. (P9)

P1 and P2 have taken travel versions of games and further shrunk them down by replacing playing pieces with smaller versions to allow the games to fit in their van. The primary reason for vanlifers carrying board games was to connect with new people and reconnect with old acquaintances (PS1,PS3); while electronic games were usually for the vanlifers' own use (P4,P7,PS3). Additionally, it was noted at PS1 and PS5 that vanlifers would want to carry more games if they could fit them in their van. Together, this represents an opportunity for technology solutions that allow:

1. Reducing the number of physical artifacts across different games;
2. Reducing the size of assets required for gameplay; and
3. Assets that can be used across multiple games to reduce storage space.

4.5.3 Provocation 9: Technology should enable dispersed collective effervescence.

Vanlifers have built community on the road and plan their lives to ensure they are present for important activities at specific locations. Vanlifers report missing out on the sense of connection and meaning that comes from collective events. They especially miss that connection from their chosen places of worship or religious service. Previous literature has identified this phenomenon as "Collective Effervescence" (Gabriel et al., 2020).

> *I miss out on going to my hometown church that I visited for almost 30 years. Videos and live-streaming just don't do it for me. A lot of time, I can't live-stream because it keeps [buffering].* (P7)

A combination of lack of access to their favourite churches or sports arenas leave vanlifers missing the collective effervescence they felt living in traditional homes. At M2, a number of attendees went to church on Sunday, but felt like they would have preferred to go to "their" church (PS2, PS3, PS5). This lack of connection was not alleviated by live-streams, virtual reality, or other similar technologies (PS5).

> *Watching a game (on the phone) isn't like real life, you can't feel the energy! My school football game was on, and I wanted to fly back for it!* (P5)

Technology should be able to create and sustain dispersed collective effervescence, whether for religion, sports, or other collective events.

4.5.4 Provocation 10: Technology should allow location-based planning and reminiscing about the future.

Vanlifers are constantly on the move as a community, but they find ways to reconnect at different events or venues, with some venues being of particular importance to individual vanlifers. P7 goes to the Vanbuild Fest every year.

> *I've never volunteered for anything before, and this is my second year volunteering for the Vanbuild Fest. I like meeting all kinds of people, I'm usually not very outgoing.* (P7)

Other vanlifers also have blocks in their calendars where they expect to be on specific weeks and days, and they organize their travel and relationships around these calendars. There is an issue through this planning, however, where some vanlifers feel that they are not making the most of their time and space.

> *I wanted to go to [a meetup in Oregon] and [a meetup in Texas] but I thought I couldn't. [Other vanlifer] was able to do it and he was also able to spend some time in Utah at a national park.* (P9)

Vanlifers report that while planning and anticipation is a pleasant process, it is also stress-inducing. The current mode of planning uses a combination of spreadsheets, Google maps, and pen and paper. They find that the reminiscing helps them plan with less stress (PS2, PS3, PS5). Reminiscing could be through pictures tagged to specific locations, journals, other people's YouTube videos, etc. Vanlifers also plan their travel collaboratively, oftentimes with clients (P1, P2), spouses (P5, P6), siblings (P7, P4, P9), or children (P8). This planning is done through collaborative documentation tools, email, or phone calls. Vanlifers do not want to lose the collaborative and reminiscing-driven nature of their planning, but want to lose the stress of missing an email or sense of FOMO (fear of missing out) on missing an important event. Technology should bring together reminiscing for the future and spatial planning in a way that helps people plan their travel collaboratively while in variable internet situations.

4.5.5 Provocation 11: Online, everyone is a gatekeeper, and researchers are strangers at the gate

While not a direct result of the thematic analysis, this provocation is a reflection on our attempts at recruitment before attending vanlife meetups. The research team originally intended to use Facebook to recruit participants for a diary study. The members of the research team, using their personal Facebook pages, were granted membership into a number of Facebook groups for vanlife. We then explained the nature of the studies to the admins and moderators of the groups (the gatekeepers for Facebook groups). Of the five groups we joined, four allowed us to post our recruitment message. We posted the recruitment post in the remaining four groups, and received predominantly positive feedback. The negative feedback was primarily concerned with where the data was being shared:

> *Huh, Sooo you want to build a database of every ones personal info and pics of everything they do and give all that to who?* (Facebook Group Member 1)

> *Why would anyone volunteer all that info, expose themselves to spam* (Facebook Group Member 2)

It is also worth noting that the negative posts were just from a very small set of individuals who clearly misread our intentions, but there were many who came to our defence and did not see it as problematic.

> *[...] you only need to provide data you are comfortable with. Nothing close to what you share about yourself on the internet everyday.* (Admin of the Group)

While not based on in-person observations of vanlife, we believe this provocation is important for people studying and participating in online communities. Technology has created a space where anyone belonging to a group could now be a gatekeeper for that online space, and that could either be to the betterment and detriment of the group. This experience is related to other research in HCI (Le Dantec & Fox, 2015) that highlights how, when entering a new, unknown community with the intention of understanding and designing technology for them, it is important to recognize that the researcher may not be welcome (i.e., a "stranger at the gate"), and that work needs to be done up front to gain trust in that community.

4.6 Interpretive Insights

During the thematic analysis, there were three themes that did not result in provocations. These are listed below:

1. Security: With constant movement and oft repeated incidents, we assumed that security of the vans would be a concern of vanlifers. However, participants reported feeling safe and confident in their vans and surroundings. There were some concerns about leaving valuables in the van (PS3, PS4)—and some vanlifers had created hidden compartments to store valuables. Some people used IP cameras or motion sensing household cameras, and found that those worked well for their needs (PS4).

2. Living Situation: In each interview we asked participants if they would change to another living situation, and the answer was overwhelmingly negative. In public spaces, one older adult stated that they may buy "some land" and start a co-living space, others (mostly older adults) said that they would "come visit", but would continue living in their vans.

3. Community: With their mobile lifestyle, we planned to ask questions about a sense of lack of community. We heard the opposite in the public spaces, with vanlifers expressing that they felt more at home in the vanlife community than their previous situations, which included apartments, elder care facilities, and detached single family homes (PS1, PS2, PS4, PS5, P1, P2, P3, P5, P9).

4.7 Discussion

While often romanticized as a lifestyle of freedom and minimalism, vanlife is in practice a complex negotiation of mobility, infrastructure, and spatial improvisation. Our findings suggest that vanlifers engage in active placemaking—not within fixed or architecturally defined interiors, but across a shifting ecology of vans, campsites, public spaces, and digital platforms. These practices are deeply contingent, shaped by infrastructural scarcity, environmental constraints, and the need to maintain continuity across spatial transitions. Rather than treating technology as a neutral enabler, this section explores how technological configurations participate in the construction, negotiation, and disruption of everyday life on the road.

A key insight is that placemaking in vanlife occurs within highly specific, often improvised places—sites of comfort, work, leisure, or connection—carved out from spatial and infrastructural limitations. These places are not merely physical zones but socio-technical configurations, shaped and reshaped through routines, artifacts, and intentions. To better understand how technology could support such practices, we re-frame our provocations through the lens of this emergent place typology. Table 4.4 maps each provocation onto both the design space of small spaces—articulated through the dimensions of boundaries, temporality, mastery, and future-thinking—and the types of places users create. This richer mapping moves beyond abstract needs or constraints and foregrounds the lived, situated realities of vanlife, where placemaking is an ongoing negotiation between constraint and agency.

Provocation	**Design Space Dimension**	**Design Space Reasoning**	**Place(s)**	**Place Reasoning**
Express through physical tech	Boundaries, Mastery	Personalization reinforces ownership; control over form builds spatial mastery	Comfort, Proficiency	Enhances emotional security and competence in constrained, personalized spaces
Visualize and monitor environmental data	Mastery, Temporality	Monitoring hidden factors like condensation builds long-term awareness and control	Work, Comfort	Stabilizes basic functionality and physical well-being in daily routines
Multi-functional peripherals	Mastery, Boundaries	Flexible tech asserts control across use zones and task contexts	Work, Proficiency	Enables functional, competent task completion in tight, multi-use areas
Enable dynamic homesteading	Boundaries, Temporality	Shifting mobile boundaries require constant redefinition and adaptation	Shared, Unfamiliar	Transforms temporary, unfamiliar spaces into shared or familiarized places
Adaptive exergames	Mastery, Temporality	Sustains habits despite spatial and infrastructural variability	Proficiency, Comfort	Encourages physical autonomy and health in tight or variable spaces
Support yearnings for incomplete spaces	Future-Thinking	Envisions unrealized spatial aspirations; supports projected identity	Familiar, Future-Oriented	Projects identity across time by aligning current space with aspirational futures
Belonging and self-organization	Boundaries, Future-Thinking	Temporary spatial control and community planning in gatherings	Shared, Familiar	Facilitates group cohesion through social planning and micro-geography
Reusable gaming artifacts	Mastery	Resource-efficient, strategic play enhances agency and capability	Leisure, Shared	Enables playful sociality without increasing clutter or storage burden
Dispersed collective effervescence	Temporality, Future-Thinking	Supports emotionally resonant rituals across time and space	Comfort, Shared	Creates socio-emotional anchors in nomadic life through ritual and connection
Location-based planning and reminiscing	Temporality, Future-Thinking	Combines memory, planning, and movement across contexts	Familiar, Unfamiliar	Strengthens continuity through place-based storytelling and itinerary planning
Gatekeeping and online uncertainty	Boundaries	Online norms structure access and trust, shaping participation	Unfamiliar	Highlights social limits and mistrust in digital vanlife spaces

Table 4.4: Mapping of provocations to the design space of small spaces and the places created within them

4.7.1 Drivers of Vanlife

Vanlifers are a diverse community of people in various life stages. The vans that they travel in have a total cost of anywhere between 5000 USD to 200,000 USD (as of 2019 numbers), with monthly living costs between 800 USD to over 4,000 USD (including fuel, food, insurance, etc.). We noted a few primary demographics during interactions at the vanlife meetups:

1. **Working-age adults:** The first demographic, and also the one that garners most attention, is working-age adults. We noticed a variety of careers being represented that reflect on the descriptions of mobile work made by Cohen (2010). Some people who were not interviewed but the researchers interacted with did seasonal work, or contract construction work and travel around the country for job opportunities. Another large group of working adults usually work in knowledge jobs that are location-independent, and travel as couples. These people could afford apartments or other living situations, but usually pick vanlife to live a life of travel and adventure. #vanlife as a social media phenomenon is romanticized by this demographic. Their vans are usually converted vans that are made to look "glamorous" while being functional.
2. **Families with young children:** A number of families with young children (sometimes up to four) are embracing vanlife as a way to reduce housing costs. The children are usually home-schooled, and such families will convert larger vans and old school buses (a sub-culture of vanlife called "skoolies").
3. **Retirees:** Retirees, who usually receive a fixed pension each month, form one of the larger groups within vanlife. These persons usually travel alone. While they do not work, they volunteer and spend a majority of their time building up the vanlife community. Their motivations are split between being economic and maintaining a sense of community. Their vans range from the cheapest to the most expensive.

4.7.2 Laws, Legality, & Glorifying Homelessness

Laws and legality of their lifestyle are an important concern among vanlifers. During the course of this study, we were also made aware of a concern amongst the laboratory group to which we belong—that studying and creating solutions for vanlife could have the effect of glorifying homelessness. We thought deeply about the ethics of this study and we believe that this study is important for a number of reasons:

1. Vanlifers usually choose this lifestyle of their own volition (PS1, PS2, PS3, PS4). Even with that choice, some vanlifers (PS3) do believe they are homeless, though that is not a reason to exclude them in technology design considerations. To further that point, Woelfer and Hendry (2011) and Markwei and Rasmussen (2015) among others have investigated how technology can improve the lives of homeless people (none of the previous investigations included vanlifers).

2. The four core concerns noted above manifest themselves in other populations as well. For instance; First Nations and Indigenous peoples, military bases, and cities and settlements outside of major populated centres show some combination of these factors.

Beyond interactive technology, we believe there is a requirement for additional research around the economic foundations and day to day realities of vanlifers—research that we did not find during our extensive literature review process.

4.7.3 Limitations

Our research seeks to expand currently existing understanding of nomadic lifestyle, specifically the technical challenges that people in the #vanlife community face in hopes that considerations for designing technology and tools will include groups of people that live outside typical spaces. One limitation to this study is the lack of diversity of participants (predominantly Caucasian, knowledge workers) that were recruited to participate in interviews. This limitation is due to the nature of recruitment, which was volunteer based. In M2 primary recruitment was done in the central area of the camp, where very social people homesteaded. Another limitation lies in the research teams lack of experience with #vanlife and limited rapport among the #vanlife community. The combination of the two resulted in a large amount of time being spent scouting the location during M2 and establishing connection with people. This also resulted in fewer people being interviewed. We tried to alleviate the impact of location by conducting fieldwork in two countries, the US and Canada, but this would still limit the findings to a North American perspective.

4.8 Chapter Summary

This chapter has developed a conceptual and design-oriented portrait of placemaking in mobile living contexts, with a focus on the socio-technical practices of the vanlife community.

By synthesizing insights from ethnographically informed fieldwork and thematic reflection, the chapter illustrates how mobile domesticity demands a rethinking of infrastructural assumptions within HCI. It foregrounds the ways in which technology—though not designed for non-traditional contexts—is actively repurposed, concealed, shared, and constrained within the rhythms of life on the road.

4.8.1 Chapter Contribution

This chapter addresses **RQ2: How is technology currently used by people living the vanlife?** (chapter 4)

1. **C2.1:** I identify eleven design provocations that articulate how technology can be re-imagined to support the subjective well-being of vanlifers, offering the HCI community actionable directions for future critical and speculative design.
2. **C2.2:** I develop a situated understanding of the constraints and values that shape technology use in the vanlife community, including concerns around affordability, energy efficiency, modularity, and infrastructural independence.

4.9 Context in the Thesis

This chapter extends the theoretical groundwork of Chapter 3 by exploring how space becomes place in mobile, non-stationary contexts. Unlike Chapter 3, which explicitly framed its analysis through the lens of placemaking, this study was conducted earlier in the research trajectory—before placemaking had emerged as a core analytic frame. As a result, while this chapter speaks primarily in terms of spatial practices, a retrospective reading reveals strong continuities with the later, more explicitly theorized mechanisms of placemaking.

Chapter 3 identified four key processes—boundary-making, temporality, mastery, and future orientation—that underpin placemaking in small, fixed spaces. Each of these is reflected in vanlife, though expressed through forms specific to mobility. Boundaries were created not only through curtains and interior layouts, but also externally—by parking orientation, van clustering to create ad hoc neighbourhoods, and by constructing symbolic thresholds through rugs, clotheslines, or outdoor cooking setups that transformed open

land into semi-private extensions of the home. Temporality was layered through daily cycles of solar charging, water use, and movement, with participants coordinating routines around natural and infrastructural rhythms (Becerik-Gerber et al., 2022). Mastery emerged in both embodied and material forms, as individuals developed fluency with power management, storage optimization, and the delicate calibration of tools and tasks within mobile constraints. Future-thinking, while less aspirational than in small homes, manifested in route planning, anticipated upgrades, and decisions to remain on or leave the road—acts that projected values and possibilities across space and time (Malpas, 2012; Pink, 2015).

What vanlife offers, then, is a view of placemaking as inherently contingent, mobile, and infrastructurally entangled. Place is made through daily acts of setup, breakdown, and coordination with shifting environments, not through permanence or enclosure. The design provocations surfaced in this chapter open onto the tensions of mobile domesticity: connectivity, privacy, and control were never static affordances, but outcomes of constant negotiation and skilled improvisation (McDowell & Sundberg, 2001; Suchman, 1987). Homes were both transient and symbolically rich; spatial control emerged not through fixed boundaries, but through mobility, rhythm, and responsiveness. These insights expand the thesis's broader argument that constraint is not merely a backdrop but a generative condition—one through which meaningful, situated, and adaptive forms of place can emerge (Cresswell, 2014).

Social lives and entanglements also played a crucial role in shaping how space became place on the road. Vanlifers cultivated informal communities through parking proximity, routine greetings, shared infrastructure, and tacit codes of presence. Even in the absence of permanent ties, temporary constellations of co-location enabled rituals of belonging—morning coffee routines, shared meals, spontaneous repairs, and collective decisions about when to move. These practices transformed otherwise anonymous or transitional locations into socially meaningful places, however fleeting. In this way, affective density was not dependent on duration, but on relational attunement and shared rhythms. Place, in vanlife, was often co-produced across vehicles and anchored through patterns of mutual recognition, care, and spatial signalling—subtle, embodied acts that made others feel welcome, or at times, signalled the need for solitude (Dourish, 2006).

Taken together, these findings reveal a set of interactional patterns and infrastructural improvisations that are directly relevant to system design. Vanlife foregrounds the need for technology that can accommodate environmental volatility, support flexible routines, and adapt to spatial reconfiguration. It shows how coordination unfolds across material and temporal boundaries, how routines act as stabilizing forces, and how meaning is created through situational control rather than fixed infrastructure. These insights sharpen

our understanding of what interaction looks like when movement, constraint, and partial connectivity are baseline conditions, not exceptions. The next chapter builds on these lessons by asking how such patterns might be engaged through design. In particular, it examines how a tangible system might operationalize these practices by treating constraint as a material condition for shaping interaction.

Chapter 5

Proteus

5.1 Introduction

The previous chapters examined how people cultivate meaningful interaction and place-making in constrained environments, ranging from studio apartments and shared homes to mobile vans and informal neighbourhoods. Across these studies, I found that spatial and infrastructural limitations did not simply restrict behaviour; rather, they prompted expressive adaptations. Participants made do through boundary-setting, material improvisation, and temporal coordination. Technology played a key role in these practices, yet often lacked the tactile, social, and adaptable qualities necessary to support interaction in tight or fragmented contexts, especially when presence was distributed across distance. In this chapter, I present Proteus as a research artifact developed through iterative design, and evaluate its effectiveness in supporting usability, player experience, social connection, and social presence across constrained co-located and remote settings.

5.1.1 Tensions Across Studies

A consistent tension emerged: while digital tools enabled communication and flexibility, they often failed to support embodied, shared, or temporally grounded activity. In small homes, screens created clutter and fragmented interaction. In mobile contexts, power constraints, unreliable internet, and lack of stable surfaces made traditional computing untenable. Even

in hybrid settings, digital systems often ignored the rhythms, routines, and improvisational strategies that made place possible.

Participants repeatedly worked around these limitations by reclaiming physical materials, establishing rituals, or customizing space to reintroduce presence and rhythm. These observations underscored the gap between existing digital tools and the lived needs of people in constrained environments. The Proteus Card Deck designed and evaluated in this chapter addresses this gap.

5.1.2 Design Spaces Identified

The first two studies revealed distinct but overlapping design spaces. From the study in chapter 3, I identified four recurring mechanisms that shaped how people created place through technology:

Boundaries: Participants used objects, routines, and gestures to mark off functional zones within tight quarters—transforming beds into desks, kitchen counters into offices, or corners into social zones. Tools that reinforced these boundaries were seen as helpful in maintaining focus, privacy, and identity within shared environments.

Temporality: Time was layered and negotiated rather than rigidly scheduled. Participants engaged in cyclical, embodied routines—rituals like morning tea, evening calls, or weekly planning—that provided rhythm and continuity. Systems that synced with or supported these rhythms were more likely to be embraced.

Mastery: Mastery emerged not from technical fluency but from adaptive control over space and tool use. People hacked together routines and interfaces, often re-purposing devices beyond their intended use. Simplicity, predictability, and responsiveness were more valued than feature-richness.

Future Thinking: Despite material limitations, participants planned ahead—visualising better layouts, saving for upgrades, or imagining different futures. Technology became a way to project into those futures, and systems that afforded such projection (without overwhelming) offered more than just function—they offered hope and continuity.

The vanlife and mobile living contexts (chapter 4) brought additional environmental constraints to the fore:

Limited Power: Electricity was scarce and often generated intermittently. Devices had to be low-power, charge-efficient, and usable even when offline.

Variable Internet: Internet connectivity was unreliable and inconsistent. This shaped not only access but also expectations, requiring systems to be functional across bandwidth conditions, and to enable asynchronous or buffered interaction when needed.

Limited Space: Surfaces were minimal, and every object needed to earn its footprint. Participants preferred modular, lightweight, and multi-use systems that could be easily packed, stowed, or repositioned.

Limited Income: Many participants lived within strict financial constraints. Systems needed to be not just affordable, but repairable, durable, and understandable—able to be maintained or passed along without technical servicing.

Taken together, these constraints suggest that effective systems for constrained settings must go beyond minimalism or durability. They must be rhythmically attuned, materially expressive, and socially aware—supporting not just task completion but connection, presence, and aspiration. *Proteus* was built with these principles in mind, treating constraint not as a limitation to be designed around, but as a generative force for rethinking interaction itself.

5.1.3 From Design Space to Artifact

To instantiate the design space surfaced across the previous chapters, we needed an artifact that could support subtle, embodied social interactions without requiring screens or high infrastructure. Across both studies, participants highlighted the importance of rhythm, mutual awareness, and tangible practices in maintaining connection. The resulting system had to allow for sequencing, coordination, and lightweight physical negotiation, while remaining legible and portable in cluttered or mobile contexts. It also needed to work across hybrid conditions—whether remote or co-located—and enable investigation of both technology-mediated and directly embodied interactions.

Several directions were explored during early ideation, including exergames, mobile-based systems, VR spatial tools, and robot companions. While promising, each fell short of the design needs. VR and screen-based solutions introduced interaction overhead and drew visual attention away from the shared space. Mobile systems lacked consistent physical affordances and often felt too personal. Robotic agents and physical monitors were difficult

to iterate on and harder to deploy meaningfully in hybrid setups. We ultimately shortlisted two concepts: a card-based system, and a grid-less communication tool for asynchronous messaging across vans. The latter would have enabled low-bandwidth interaction without internet connectivity, but was discarded due to COVID-era constraints that prevented access to vanlife meetup locations for testing.

Cards emerged as the most promising form factor. They offered a modular, familiar, and highly adaptable medium that aligned closely with the dynamics observed in earlier fieldwork. Their physicality allowed for layering of interaction across timing, placement, and visibility; their tactility encouraged turn-taking and pacing; and their low-friction nature made them equally suitable for play, brainstorming, and coordination. Cards preserved embodied and social qualities that mattered to participants, while providing a flexible platform for exploring nuanced hybrid interactions under constraint. These affordances made cards not only viable, but uniquely well-suited to the design goals at hand.

This chapter introduces *Proteus*, a tangible-digital research artifact developed to instantiate the design spaces identified in the previous studies. Named after the adaptable sea god of Greek myth, it blends the physicality of traditional cards with the versatility of digital systems. Each card is equipped with a wireless e-ink display, enabling content to be updated dynamically while preserving gestures like fanning, dealing, and stacking. The system was shaped through an iterative Research through Design (RtD) process.

Prototypes were first refined through gaming—an obvious starting point because it demanded the very qualities I was designing for: turn-taking, coordination, and a strong sense of social presence. Games also provided a controlled yet engaging way to stress-test Proteus' ability to maintain rhythm, shared awareness, and tactile engagement across both co-located and remote contexts, echoing the placemaking and embodied coordination challenges surfaced in my earlier small-space and vanlife studies.

My goal, thus, was to answer the research question: "How can a tangible-digital system, grounded in the constraints of small and mobile living, be designed to support connection and flexible interaction across contexts?"

To address the research question, I conducted a mixed-methods user study ($N = 36$) that compared Proteus to both traditional cards and a tabletop simulator across four conditions: Proteus vs. traditional, and remote vs. co-located. Crucially, the study was conducted *in situ*, in small and often shared environments including a Slum Rehabilitation Project (often called a "vertical slum" by its inhabitants) in India. Participants played structured games under each condition. I measured usability (UMUX-LITE), player experience (PXI),

interpersonal closeness (IOS), and social presence (Networked Minds), and complemented these with interviews and field observations.

This chapter represents the culmination of a reflexive arc. It draws on the empirical findings of the first two studies, translates them into design principles, and then tests those principles through a concrete artifact. Proteus offers a proof of concept: that hybrid systems can be designed to support place-making, connection, and coordinated activity when presence is distributed and space is limited.

5.1.4 Contributions

This chapter makes three contributions:

1. **C3.1:** I develop the Proteus Card Deck, a tangible-digital card system that directly designs for the spatial, infrastructural, and temporal constraints identified in earlier studies.
2. **C3.2:** Through a field-based evaluation, I show that Proteus enables comparable usability, connection, and coordination to traditional alternatives (physical cards and online games) in both remote and co-located settings.
3. **C3.3:** I provide a set of seven design strategies for hybrid systems (systems that can be used in co-located or remote settings) that operate under constraint.

5.2 System Design: Proteus Card Deck

5.2.1 Research through Design

I adopted a Research through Design (RtD) approach to develop Proteus as a tangible card system for hybrid and remote interaction. RtD foregrounds the artifact as a central mode of inquiry, using iterative prototyping to generate knowledge through design practice (Zimmerman et al., 2007). Rather than beginning with fixed technical specifications, I let each prototype evolve in response to failures, affordances, and domain-specific constraints encountered during testing.

My process was anchored in gaming, with present numerous demands: real-time responsiveness, flexible visual updating, and scalable coordination. This provided design provocations that shaped the evolution of the system. Across multiple iterations, I followed a cycle of making, using, reflecting, and remaking. For each prototype, I conducted internal evaluations that considered tactile feel, cognitive load, update latency, and multi-user coordination. These reflections drove design changes, such as shifting from wired to wireless communication, adding centralized control interfaces, and adjusting the form factor for comfort and recognizability.

Insights from early failures and cross-domain testing informed the shift from speculative design to concrete system goals. Rather than treat requirements as static checklists, I used them as design scaffolds—shaped by literature but stress-tested through hands-on evaluation. The next section presents ten initial requirements that structured the development of Proteus across multiple use cases and guided decisions around hardware, interaction, and orchestration.

5.2.2 Initial Design Considerations

The initial requirements for the research artifact were formulated based on existing literature, observations from traditional and digital card games, and practical design constraints. Rather than emerging through an iterative Research through Design (RtD) process, these requirements were identified before development as guiding principles to ensure that the system could effectively preserve the familiarity of traditional card decks while leveraging the advantages of digital interactivity.

The literature on tangible interaction, digital card decks, and hybrid collaboration (e.g., Casais et al., 2016; Wallace et al., 2012) highlighted the importance of maintaining manual affordances such as shuffling, while enabling automated updates for remote plat. My observations from card-based gameplay reinforced the necessity of real-time synchronization, player card knowledge, and a centralized control system to facilitate seamless interactions in co-located and remote scenarios.

The complete list of design considerations is shown in Table 5.1 and can be categorized into three key dimensions:

1. Form Factor and Usability Considerations (e.g., DC1, DC8, DC9, DC4) ensured that the physical form factor and usability closely resembled traditional card decks, allowing for intuitive adaptation by users.

2. Social Interaction Considerations (e.g., DC5, DC6, DC10) focused on how players engage with the deck, balancing physical affordances with digital augmentation for hybrid play.

3. Technical Feasibility (e.g., DC2, DC3, DC7) ensured that Proteus could function in multiple settings, supporting synchronized updates, remote play, and player-specific interactions.

These initial requirements framed the design and development of Proteus, informing subsequent prototype iterations and user testing to refine its hardware, software, and user experience. Following this, I iterated multiple times with the goal of building a deck of cards that is testable and usable by the HCI community.

5.2.3 RtD Process

The RtD process began with understanding prior art. Following initial research, I started with a set of initial design considerations, designed, built, and then reflected. Each cycle, there was a playful phase of testing that consisted of the following steps at a minimum (for some iterations, I conducted additional tests):

1. **Tactile Experience:** To assess the tactile ergonomics and user experience of the Proteus Card Deck, a qualitative evaluation was conducted by the first author, who has a high score on the Need for Touch (NFT) scale (Peck & Childers, 2003). This assessment focused on key haptic attributes, including surface texture, weight distribution, flexibility, and grip comfort, to ensure that the cards maintained a familiar and intuitive feel akin to traditional playing cards. The feedback from this evaluation informed material selection and design refinements, optimizing the deck for both manual handling and extended gameplay interactions.

2. **Utility:** To evaluate the functional versatility of the Proteus Card Deck, systematic usability checks was conducted through gaming. These checks assessed interaction efficiency, cognitive load, and user engagement within each domain. For gaming, authors used the deck in structured gameplay sessions to evaluate mechanics such as shuffling, dealing, and in-game updates. This was further expanded upon in the user study. The findings from these evaluations, detailed in the case studies, guided refinements in design, usability, and content updating mechanisms.

ID	Category	Requirement	Description	Source
DC1	Design	Deck Composition	The system must consist of multiple 'cards' that work together as a deck, maintaining the familiar structure of traditional card decks.	Literature: Research on tangible interaction (Casais et al., 2016; Wallace et al., 2012) emphasizes preserving familiar form factors for better user engagement.
DC2	Technical Feasibility	Centralized Control	A single system should be able to control all cards remotely, ensuring synchronized updates and seamless operation.	Gameplay & Digital Card Systems: Centralized control is common in digital card platforms(Sakamoto et al., 2014) to maintain game state consistency.
DC3	Technical Feasibility	Multi-location Usability	The system must support use across multiple locations, enabling both remote and in-person interactions.	Hybrid Board Gaming Literature & Remote Collaboration: Tangible components improve social engagement in remote settings (Wallace et al., 2012).
DC4	Design	Affordability & Scalability	The deck should be cost-effective for large-scale production and consumer-friendly pricing.	HCI Research on Constrained Environments: Affordability is key for tangible computing adoption (Desjardins et al., 2019a); COTS (Commercial Off-The-Shelf) solutions help scale production (Kohtake et al., 2005).
DC5	Interaction Requirements	Manual Shuffle Support	Users should be able to physically shuffle the cards as they would with a traditional deck.	Gameplay & Literature: Studies on tangible play experiences (Lucero & Arrasvuori, 2010) highlight the importance of manual interactions for immersion.
DC6	Interaction Requirements	Automatic Card Updates	Each display in the deck should update its content in sync, ensuring smooth transitions during play.	Digital Board Gaming & Augmented Card Game Research: ATCG studies (Sakamoto et al., 2014) and smart tabletop research (Magerkurth et al., 2004) show that automation enhances usability.
DC7	Technical Feasibility	Player Card Knowledge	The system should recognize which player holds which card, supporting interactive and game-specific mechanics.	Gameplay & Interactive Card Systems: PEPA Deck (Kirshenbaum & Robertson, 2018) and tracking mechanisms in digital card games improve game mechanics.
DC8	Design	Familiar Form Factor	The physical design should closely resemble traditional playing cards for easy adaptation and intuitive use.	HCI Research & Cognitive Psychology: Skeuomorphic design supports familiarity-based usability (Spiliotopoulos et al., 2018).
DC9	Design	Portability & Ease of Setup	The deck should be compact, easily transportable, and require minimal setup in new locations.	Design Constraints & Small Space Studies: Portability is essential for mobile and small space use cases (Rizvi et al., 2021).
DC10	Interaction Requirements	Multi-application Support	The system should accommodate various use cases, across gaming applications.	HCI Research & Tangible Computing Literature: Card decks (Roy & Warren, 2019) demonstrate the need for flexible applications.

Table 5.1: Design Considerations for the Proteus Card Deck

3. **Robustness:** To ensure the robustness and durability of the Proteus Card Deck across multiple use cases, a controlled drop test was conducted for iterations following the first prototype. The test involved dropping the cards from a height of 3 meters (10 feet) onto a hard surface, simulating real-world accidental drops that might occur during gameplay or transportation. Each card was subjected to 15 consecutive drops, and post-drop inspections assessed structural integrity, display functionality, and electronic performance. Results indicated that subsequent iterations maintained full operational capability with no significant physical damage, whereas Iteration 1's display components failed under these conditions, informing the need for improved material selection and reinforced casing in later designs.

4. **Ease of Use:** To assess the subjective ease of use across gaming, a task-based usability evaluation was conducted. This evaluation focused on the complete interaction flow, from content updates on the cards to their practical application. The assessment measured two key metrics:

   (a) Interaction Complexity: quantified by counting the number of discrete steps required to update and deploy six cards (the minimum set necessary for effective use in all tested scenarios).

   (b) Task Completion Time: recorded from the initiation of the update process to the point at which the cards were fully operational for their respective application.

   By analyzing these factors, I aimed to identify potential bottlenecks in usability, optimize update efficiency, and ensure that the deck maintains seamless integration across the use cases identified above. Findings from this analysis informed iterations in both hardware and software design, improving the overall user experience and interaction fluidity.

5. **Graphics:** To evaluate the effectiveness of the Proteus Card Deck in supporting graphically intensive card games, such as Set[1], a usability and performance assessment was conducted. This test aimed to determine how well the deck handled complex visual elements, which are critical for gameplay mechanics that rely on rapid visual recognition and pattern matching. The evaluation focused on two key factors:

   (a) Update Speed and Processing Efficiency: measured by tracking the time required to update six cards with high-contrast, detail-rich images, ensuring that gameplay flow remains uninterrupted.

[1]Available at https://www.setgame.com/set/puzzle

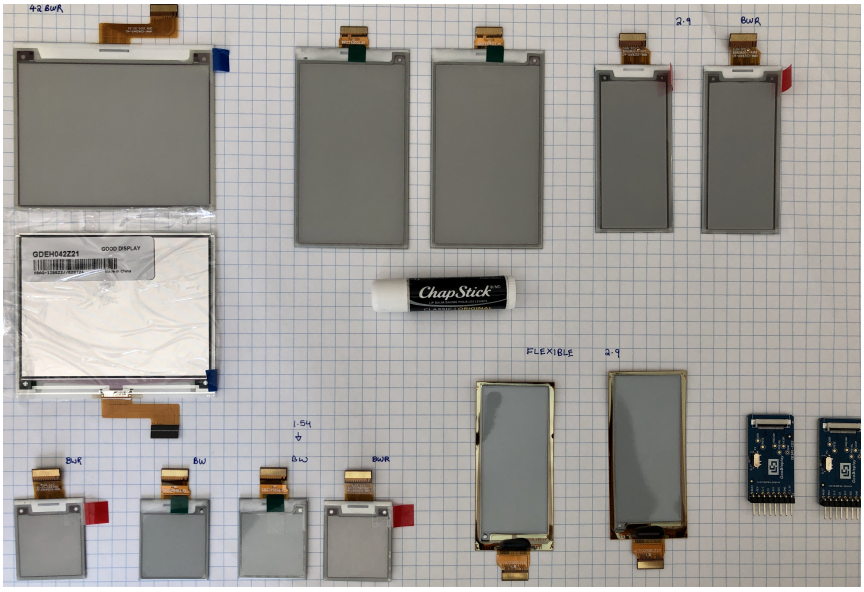


Figure 5.1: Display comparison during Iteration 1. I evaluated multiple e-ink modules for size, readability, and form factor. Only the 2.9" tri-colour display satisfied both visual clarity and tactile handling requirements. That is the last display in the bottom row.

(b) Visual Clarity and Readability: assessed by analyzing contrast ratios, refresh accuracy, and player feedback on ease of identifying patterns, colours, and symbols.

By correlating these results, I ensured that updating and using graphically intensive content did not introduce unnecessary delays or cognitive load. Findings from this study informed refinements in display resolution optimization, update synchronization, and latency reduction, ensuring that the deck remains viable for visually demanding games while maintaining an intuitive user experience.

I describe three of the iterations and the changes made therein in the subsections that follow. Each iteration described here demonstrate significant changes between iterations and incorporate the relevant leaps in progress.

This prototype confirmed the feasibility of e-ink cards but exposed major limitations in update flow and scalability. It served as a valuable material probe, prompting a transition toward wireless communication in the next iteration.

5.2.4 Iteration One: Wired Proof of Concept

- ♣ *Connection Type:* Wired (24-pin SPI via Arduino Uno)
- ♦ *Display:* 2.9" e-ink (black and white)
- ♥ *Cost:* $60 per card (unscalable)
- ♠ *Limitations:* Single-update workflow, tethered to base

This first iteration tested whether an e-ink display could function convincingly as a tangible card. The goal was to explore DC1 (Deck Composition), DC5 (Manual Shuffle), and DC8 (Form Factor). To evaluate these, I conducted a comparative assessment of multiple e-ink modules varying in size, resolution, and color capability. As shown in Figure 5.1, I examined over half a dozen display variants across vendors to determine which formats could be comfortably held, shuffled, and visually parsed. Displays larger than 3 inches became difficult to fan or grip, and higher-resolution versions provided minimal perceptual benefit for card-based content. I selected a 2.9-inch black-white-red display as the optimal trade-off between tactile handling, visual clarity, and cost.

Each card had to be connected via wired SPI to an Arduino Uno for updates. This severely limited usability (DC6: Automatic Updates) and failed DC2 (Central Control) and DC9 (Portability). Although e-ink retained its image post-update, switching images required unplugging and reconnecting displays one-by-one—an unacceptable friction point during gameplay.

5.2.5 Iteration Two: NFC-Based Cards

- ♣ *Connection Type*: Near Field Communication (NFC: Passive, no battery)
- ♦ *Form Factor:* 3D-printed plastic casing (semi-transparent, 3–4mm)
- ♥ *Cost:* $3.00 per card (hardware only)
- ♠ *Limitations:* Manual updates, no real-time orchestration

In this iteration, I explored whether eliminating on-board power could yield a thinner, cheaper, and more scalable design. Each card was embedded with a passive NFC chip

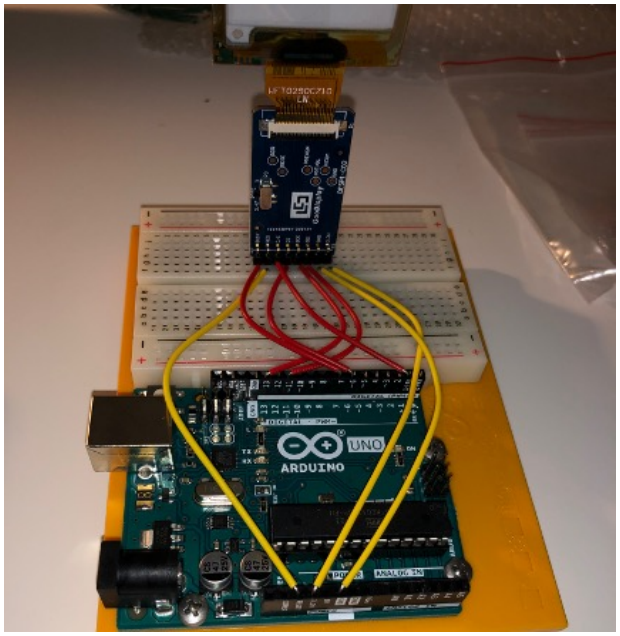


Figure 5.2: The first iteration consisted of an Arduino board connected to an e-ink display via a standard Serial Peripheral Interface (SPI). Due to the persistent nature of e-ink technology, the display retained the rendered image even after being disconnected from the board.

and e-ink display, powered wirelessly by a smartphone during updates. This architecture significantly advanced goals around affordability (DC4), portability (DC9), and simplicity of deployment.

I designed and tested multiple 3D-printed casings to improve shuffle-ability and protect the components. As shown in Figure 5.4, the casings preserved a familiar card-like feel while preventing damage to the fragile ribbon cables and NFC modules. Early versions were boxy or brittle, but later prints struck a usable balance between rigidity and comfort. The semi-transparent shells also allowed for debugging without disassembly.

Users updated cards by tapping their phone to each one individually. However, the one-at-a-time update model proved too slow (violating DC2: Central Control and DC6: Automatic Updates). The process also required users to keep a phone nearby, complicating flow during in-person sessions.

Overall, this prototype validated the potential of low-cost, un-powered cards and helped us fine-tune the physical form factor. But the lack of synchronous control and real-time

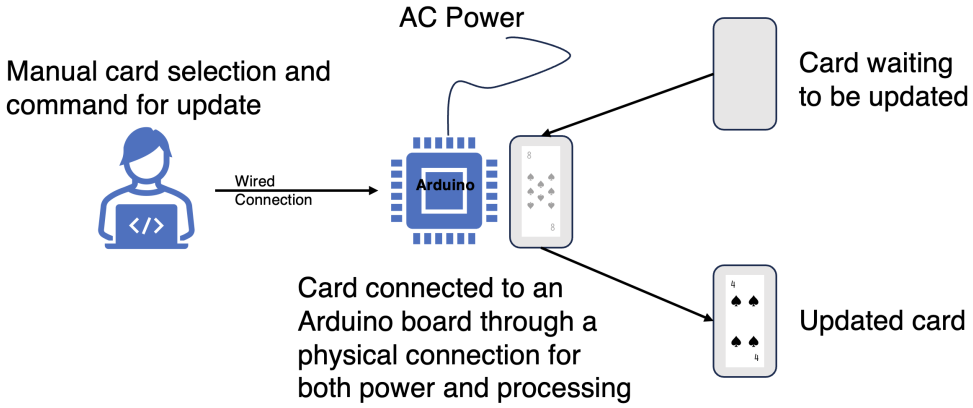


Figure 5.3: A flowchart showing the information and power flow in the first prototype

responsiveness prompted a shift toward active communication and centralized orchestration in the next phase.

5.2.6 Iteration Three: BLE Shelf Label Platform

- ♣ *Connection Type*: Bluetooth Low Energy (BLE)
- ♦ *Power:* Embedded battery (10+ year lifespan)
- ♥ *Cost:* $11 (off-the-shelf unit), $1.50 (bill of materials for custom build)
- ♠ *Limitations:* Slight increase in thickness (approx. 12mm thick), battery replacement required eventually

In the third and final iteration, I shifted toward a solution capable of real-time updates, centralized orchestration, and robust field deployment. I repurposed commercial electronic shelf labels (ESLs) designed for retail signage—devices with ultra-low-power e-ink displays and BLE modules embedded in sealed enclosures.

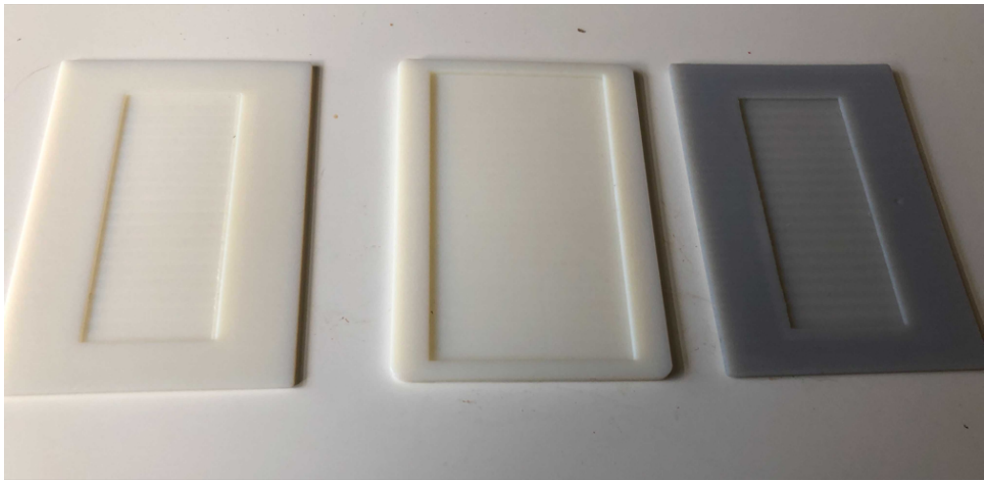
This version finally satisfied critical requirements that earlier prototypes struggled with: cards could be updated wirelessly in bulk (DC2: Central Control), content could change in near real-time (DC6: Automatic Updates), and cards could operate entirely offline between updates (DC3: Multi-Location Use). Each card had a unique identifier (UID), enabling individualized state tracking and role assignment (DC7: Player Card Knowledge).



(a) Proteus Prototype: Front



(b) Cards enclosed in a casing



(c) 3D Printed Cases for the Proteus Cards System

Figure 5.4: The second iteration of prototypes for the Proteus Cards System

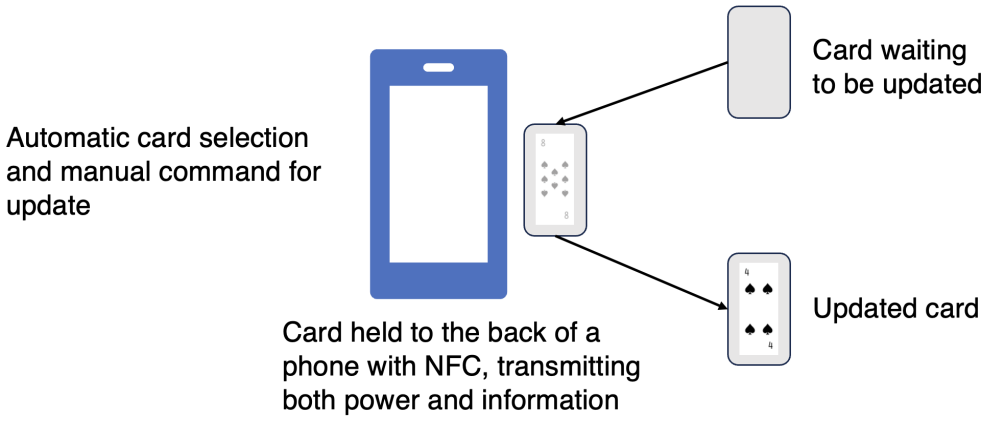


Figure 5.5: A flowchart showing the information and power flow in the second prototype

I initially experimented with 3D-printed casings to improve grip and visual familiarity, but durability and reliability issues (e.g., cracking, poor alignment) led us to adopt standard ABS enclosures designed for the ESL form factor. While this resulted in a thicker card body (12mm), the tradeoff was increased robustness and near-zero setup issues during field use.

I also developed a Python-based orchestration interface that allowed facilitators or researchers to trigger real-time updates across all cards simultaneously. This was crucial for classroom and gameplay use, where synchronized information delivery matters. The BLE cards were tested across remote and co-located conditions, forming the hardware foundation for the user study discussed in section 5.3.

Iteration Three demonstrated that a robust, scalable, and tactile remote deck is possible using commercial hardware—making Proteus deployable in constrained, low-infrastructure, or distributed settings.

5.2.7 Reflective Practice in the Creation of the Proteus Card Deck

Throughout the iterative development of Proteus, design decisions were shaped by technical constraints, empirical findings from earlier studies, and cycles of reflection characteristic of Research through Design (Gaver, 2012; Zimmerman et al., 2007). For example, early prototypes involving Arduino and tethered displays revealed the fragility and impracticality of cable-based setups for mobile or shared contexts. This recognition led to a pivot toward modular, wireless enclosures using commercial shelf labels. Likewise, initial explorations with



Figure 5.6: Final Proteus card used in the user study, built from commercial off-the-shelf BLE-enabled shelf labels enclosed in custom ABS casings. Remote synchronization and content updates were achieved through a custom orchestration layer.

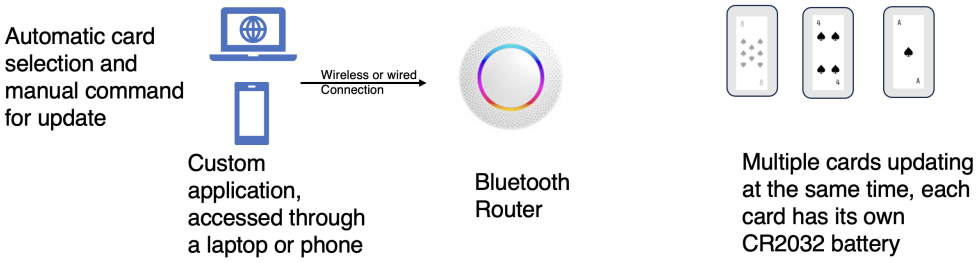


Figure 5.7: A flowchart showing the information and power flow in the third prototype

dynamic content interfaces surfaced a counterintuitive insight: that visual familiarity and material recognizability were more valuable to users in constrained settings than expansive interface flexibility. This insight informed the retention of the conventional card form factor. These inflection points reflect an RtD logic of inquiry, where breakdowns, trade-offs, and material tensions become opportunities for knowledge generation. The design trajectory, including the evolving choices of display technology, power supply, communication protocols, and form factor, is summarized in Table 5.2. This process, thus, met the stated goal to surface situated design insights applicable to hybrid systems for spatially constrained social interaction.

Iteration	Display Technology	Power Supply	Communication Method	Form Factor	Key Features	Limitations
Iteration 1	2.9" Tri-color e-ink	Wired via SPI	SPI	Prototypical wired module	Persistent display without power; testing of display readability	Cumbersome wiring, limited scalability
Iteration 2	NFC-based e-ink	Power through NFC	NFC	Improved casing, NFC reader	Wireless updates via proximity; reduced wiring	Limited range, NFC proximity required
Iteration 3	BLE-enabled shelf label e-ink	Battery-less with BLE coordination	BLE	Custom ABS case, commercial label	Remote orchestration; scalable, production-ready form	Latency and sync reliability under stress

Table 5.2: Summary of Proteus Card Deck Design Iterations

5.3 Study Design: Proteus as a Gaming System

Building on prior design iterations of the Proteus Card Deck, I conducted a structured evaluation aimed at assessing how Proteus performs in real-world collaborative settings. While earlier phases of this RtD process focused on surfacing situated constraints and refining the form factor through qualitative feedback, the goal here was to empirically examine Proteus in comparison to existing card-based systems. Specifically, we examined how the artifact supports usability, social connection, and interaction quality across physical and digital modalities, in both co-located and remote settings.

We conducted a within-subjects study to evaluate Proteus against both traditional and digital card platforms across two spatial contexts: remote and co-located. Each participant experienced all four conditions, enabling direct comparison within dyads and across modalities. The study followed a 2×2 factorial design with the following factors:

- **Modality:** Traditional Cards vs. Proteus Cards
- **Location:** Co-located vs. Remote

This structure yielded the following four conditions:

1. **Co-located Traditional:** Playing with physical cards while sitting together
2. **Co-located Proteus:** Playing with Proteus cards while sitting together
3. **Remote Traditional:** Playing via a tabletop simulator over Zoom
4. **Remote Proteus:** Playing with Proteus cards at a distance, each participant using a synchronized deck

Each session was conducted in pairs to reflect the collaborative nature of Proteus and the underlying game task. Participants played *Pico 2*, held constant across all conditions. The order of conditions was counterbalanced across participants to reduce ordering effects, and short breaks were provided between rounds.

This design enabled us to isolate the effects of both spatial context and card modality, while maintaining ecological validity through paired play and consistent task structure.

5.3.1 Participants and Recruitment

We recruited a total of 38 participants in India from two distinct populations to reflect key criteria for the study: spatial constraint and socio-economic diversity. Participants were drawn from a university campus and a Slum Rehabilitation Authority (SRA) housing community in Mumbai. The former comprised younger individuals living in shared, often compact accommodations, while the latter represented low-income households residing in government-allocated small homes. After one dyad withdrew, the final sample consisted of 36 participants organized into 18 self-selected dyads to preserve natural rapport and social familiarity. More details are provided in Table 5.3.

Table 5.3: Summary of Participant Demographics (N=36)

Category	Count
Gender	
Man (M)	21
Woman (W)	15
Age (years)	
Median (IQR)	24.5 (13.25)
Range	18–40
Education Level	
Less than high school diploma	4
High school diploma or equivalent	9
Bachelor's degree	17
Master's degree	6
Relationship Type	
Friends	24
Family members	8
Strangers	4

- **SRA housing cohort** ($N = 16$): To intentionally include participants from low socio-economic backgrounds living in spatially constrained environments, I recruited from a government-built residential complex in Mumbai constructed under the Slum Rehabilitation Authority (SRA) scheme. These units are typically compact, with multi-generational families cohabiting in limited space, offering a critical context for examining technology-mediated placemaking under constraint.
- **University cohort** ($N = 20$): Recruited from undergraduate and graduate programs at a university in India. The study initially included 22 participants, but two members of a dyad withdrew midway during the study due to a scheduling conflict.

For the university participants, all sessions were conducted in a shared space. This environment provided stable internet connectivity, controlled lighting, and minimal background noise, offering an ideal setting for both co-located and remote gameplay. Each dyad was seated at separate stations for remote sessions and at a single table for co-located ones, with a researcher supervising unobtrusively.

In contrast, sessions involving participants from the Slum Rehabilitation Authority (SRA) housing community were conducted in markedly different environments. I facilitated

sessions inside an SRA apartment (typically a compact space shared by multiple family members), and in a semi-public community room located in the same building. These settings reflected the spatial and infrastructural constraints of dense, urban low-income housing.

To ensure ecological validity, I intentionally met participants in the settings where they would naturally engage in recreational play. In the SRA context, this meant configuring gameplay on windowsills, floors, or compact table surfaces, rather than artificially controlled lab-like setups. This approach not only respected participants' routines but also enabled a more authentic evaluation of the system under real-world use conditions.

Internet access posed a major challenge in these settings, particularly during remote conditions. To enable gameplay, researchers tethered study laptops to personal mobile phone hotspots. While Tabletop Simulator occasionally crashed due to unstable connectivity, the research team resolved these interruptions discretely and resumed the game without exposing participants to any technical complexity. This process ensured the integrity of the study while highlighting the adaptability of the Proteus system in infrastructure-constrained environments.

5.3.2 Procedure

Each session involved a single dyad completing all four conditions of the study. Sessions were held in person for co-located conditions, and via Zoom for remote conditions. For each pair, the four conditions were presented in a counterbalanced order using a Latin square to minimize ordering effects.

In each condition, dyads engaged in a complete game of *Pico 2*.

We initially considered a range of simple card games, including *Uno*, *Go Fish*, *Crazy Eights*, and *3-Card Poker*. *Uno* was excluded due to its proprietary design and rule complexity, which conflicted with our goal of maintaining an open, easily modifiable system. *Go Fish* relied on verbal information exchange, which introduced asymmetry and potential usability issues in remote conditions. *Crazy Eights* involved multiple layers of turn-based strategy and special cards, making it less suitable for short sessions and potentially overwhelming for novice players. *3-Card Poker*, while simple in mechanics, was ultimately ruled out due to its association with gambling—raising ethical concerns and potential discomfort, particularly in cross-cultural contexts where gambling is stigmatized or restricted.

In contrast, *Pico 2* was chosen as a simple, non-gambling card game that could be learned within minutes, making it well-suited to the time-frame of a short experiment. Its straightforward rules minimized cognitive load and reduced the likelihood of rule-related errors, allowing participants to focus on interaction dynamics rather than game mechanics. Additionally, its low barrier to entry ensured accessibility for players of varying gaming experience, while avoiding themes or mechanics (such as gambling) that might have introduced ethical concerns or excluded certain participants. Its instructions, adapted from those printed on one page in the game's manual, are as follows:

- Deal five cards face down to each player. Place the extra card face up in the centre of the table. The face up card is not used in the game.
- Each player chooses a card from their hand and places it face down in front of them.
- Simultaneously reveal the card you played. The card with the higher face value wins, unless its face value is more than twice that of the lower card. In this case, the lower card wins.
- See the reference table below for assistance.
- The winning card is placed face up in front of the player who played it. The losing card is returned to the hand of the player who played it (i.e., it can be played again).
- Continue playing and revealing cards until one player is left with one card remaining in their hand.
- Each player totals the points (the red dots) for the winning cards in front of them. Cards that are still in your hand count for nothing. Keep track of the score.
- Exchange your sets of cards and play a second round (see steps 2 to 6).
- After the second round, the player with the most points across both rounds wins.

The study was introduced in either English or Hindi, depending on the site. Consent procedures were administered by a researcher and, where necessary, translated with the help of a trusted community liaison to ensure participant understanding. All participants provided informed consent prior to the study and received a modest cash honorarium (INR 200, equivalent to CAD 3.2 at the time of payment) as compensation.

Following consent, the following process was adopted for each dyad:

- **Study briefing and orientation**: Participants were introduced to the study and the rules of *Pico 2* using printed instructions (as noted above). Each dyad completed a tutorial and practice round across all three modalities—traditional cards, Proteus cards, and the digital version via Tabletop Simulator.
- **Gameplay sessions**: Participants played one full round of *Pico 2* in each of the four experimental conditions. The order of conditions was counterbalanced using a Latin Square to mitigate sequencing effects. A researcher facilitated each session to ensure smooth gameplay and adherence to protocol.
- **Post-condition questionnaires**: After each gameplay session, participants completed a set of validated questionnaires assessing usability, player experience, and social presence (subsection 5.3.3). Demographic data were also collected during this phase.
- **Semi-structured focus group**: After completing all four conditions, participants as dyads engaged in a brief semi-structured discussion reflecting on their experiences across the different modalities and contexts of play.
- **Debrief and informal feedback**: Each session concluded with a debrief, during which participants were invited to share final impressions and feedback. Compensation was provided at this stage.

Figure 5.8 presents representative scenes from training and gameplay across the four study conditions in the SRA location.

5.3.3 Measures

We employed four validated instruments to assess usability, player experience, and social connection:

1. **Usability Metric for User Experience-LITE (UMUX)** (Lewis et al., 2013): A two-item usability scale aligned with ISO 9241-11. Items were rated on a 7-point Likert scale and averaged.
2. **Mini Player Experience Inventory (PXI)** (Haider et al., 2022): An 11-item short form measuring immersion, control, tension, and enjoyment on a 7-point scale.



(a) Training session with traditional physical cards before gameplay begins.



(b) Two participants playing Pico 2 using Proteus in a co-located setup.



(c) Participant playing Pico 2 remotely using Tabletop Simulator in a low-resource environment.



(d) Group gameplay session using Proteus in a shared indoor space.



(e) Participant engaging in a remote traditional gameplay session via laptop.



(f) Remote session where a participant uses Proteus while connected via mobile video call.

Figure 5.8: Montage of study activities spanning training and gameplay sessions. The images depict participants engaged in co-located and remote settings, using both traditional cards and the Proteus system. The visual variety highlights the study's comparative scope across physical, digital, and hybrid interaction modalities.

3. **Inclusion of Other in the Self (IOS)** (Aron et al., 1992): A single-item 7-point pictorial scale measuring interpersonal closeness, widely used in social psychology and HCI.

4. **Networked Minds Social Presence Inventory (NM)** (Biocca et al., 2001): A multi-dimensional scale assessing social presence along affective, behavioural, and cognitive dimensions in mediated interaction. Items were rated on a 7-point Likert scale and combined for an NM score, as suggested by Biocca et al. (2001).

Surveys were administered in English for university participants and in Hindi for participants from the Slum Rehabilitation Authority (SRA) community. Hindi versions of all instruments were developed using a standard double-forward, single-back translation

protocol Beaton et al., 2000 to ensure semantic and conceptual equivalence. Two independent translators produced forward translations, which were reconciled into a single draft, then translated back into English by a third translator. Discrepancies were resolved through team discussion to maintain fidelity to the original scales.

5.3.4 Hypotheses

The Proteus study was designed to build on insights from the previous two deployments—small homes (chapter 3) and mobile living contexts (chapter 4)—which together highlighted how social interaction in constrained environments depends not only on digital connectivity, but on material engagement, embodied co-presence, and infrastructural simplicity. From these earlier studies, several recurring strategies for placemaking emerged: the importance of tactile and rhythmic practices, the negotiation of shared space and time, and the value of lightweight systems that blend seamlessly into everyday life.

Participants in the small spaces study described the necessity of physical routines and embodied gestures to mark transitions between roles (e.g., worker, guest, gamer). Similarly, the vanlife study underscored the value of adaptable, tangible tools that support co-located activity while minimizing setup and infrastructural demands. In both cases, screen-based systems were described as either visually dominant, infrastructurally burdensome, or socially isolating—particularly in tight, shared quarters or on the move.

Proteus was designed to take up these findings by offering a tangible-digital hybrid that could support shared activity without requiring conventional screens, apps, or installations. As such, the study tested whether Proteus could close the usability and experience gap often observed between remote and co-located interaction, particularly under resource constraints. Based on this trajectory of design and prior empirical results, the following hypotheses were formulated:

H1: *When used remotely, Proteus will outperform traditional screen-based remote systems on (a) usability, (b) player experience, (c) social connection, and (d) social presence.* This hypothesis reflects findings from both prior studies, where participants expressed a lack of embodied and co-present qualities in remote digital tools. In spatially constrained contexts, users noted that technology often failed to support shared rhythms and material engagement. Similarly, vanlifers described how remote interactions, such as video calls or digital games, felt disembodied or insufficiently "human." Proteus,

as a hybrid tangible system, is hypothesized to restore some of the tactile, temporal, and spatial cues missing in remote digital play.

H2: *Traditional remote play will (a) maintain usability but have (b) lower social connection and (c) social presence than all three other conditions.*
This hypothesis is grounded in the vanlife study's accounts of digital tools being functional but affectively hollow. While screen-based systems (e.g., mobile games or collaborative tools) were usable, they did not replicate the social dynamics or embodied engagement of co-located interaction. Thus, we expect traditional remote play to preserve basic usability but suffer on interpersonal and experiential dimensions.

H3: *Proteus (in both remote and co-located conditions) will match traditional co-located play in terms of (a) usability, (b) player experience, (c) social closeness, and (d) social presence.*
This hypothesis builds on findings from the small-space study, where users crafted rich places through boundary-setting, shared attention, and improvisation. It also draws on vanlife participants' yearning for technologies that enable spontaneous, shared rituals. We anticipate that Proteus, whether remote or co-located, will approximate the embodied and rhythmic qualities that make traditional co-located play feel socially connected and experientially rich.

Taken together, these hypotheses operationalize the central goal of Proteus: to enable tangible, low-friction interaction that preserves the socio-material character of co-located play, even under spatial and infrastructural constraint. They also test whether the theoretical commitments of placemaking can be effectively embedded in hybrid systems.

5.4 Study Results

In this section, I first present quantitative results from validated scales, using non-parametric tests to compare ratings across conditions. I then report qualitative insights from interviews and open-ended responses, highlighting how participants perceived the strengths and limitations of Proteus in different contexts.

5.4.1 Data Analysis

To assess the effects of two within-subjects factors—*Modality* (Proteus vs. Traditional) and *Location* (Remote vs. Co-located), I adopted a mixed-methods analytical approach that combined parametric and non-parametric techniques. Each participant experienced all four condition combinations, with responses nested within dyads, introducing both repeated measures and interdependence.

Planned Parametric Modelling. Our initial analysis plan involved fitting linear mixed-effects models (LMEMs) to evaluate the main effects of *Modality* and *Location*, while accounting for the nested structure of the data. Participant ID and dyad were entered as random effects. I also included the following co-variates to control for individual and relational differences: gender, education level, socio-economic status, prior relationship with partner, and experience with both online and card games.

Assumption Testing. Prior to estimating LMEMs, I conducted assumption checks:

- **Shapiro–Wilk tests** revealed significant deviations from normality across all outcome variables ($p < .0001$).
- **Levene's test** indicated heteroscedasticity in IOS scores ($p = .003$).

Visual inspection of Q–Q plots, however, suggested that residuals for several outcome variables—UMUX, PXI, and Networked Minds (NM)—were approximately normally distributed. Residuals for IOS scores clearly violated normality. As such, I report LMEM results for UMUX, PXI, and NM as exploratory, while primary inference is based on non-parametric analyses. Further details on LMEM output are provided in subsection 5.4.8.

Non-Parametric Analyses. Given the violations of distributional assumptions and the ordinal nature of several instruments, I conducted non-parametric analyses as the primary approach within this study:

- **Friedman tests** assessed main effects across the four within-subjects conditions.
- **Wilcoxon signed-rank tests** (Bonferroni-corrected) were used for post hoc pairwise comparisons.

- **Mann–Whitney U tests** evaluated between-group effects of gender, SES, education level, and gaming experience (online and card-based).

To strengthen statistical reporting, I computed Kendall's W as an effect size estimate for each Friedman test: UMUX ($W = .184$), PXI ($W = .115$), IOS ($W = .258$), and NM ($W = .053$). The first three indicate small-to-moderate within-subject agreement; Networked Minds (NM), while directionally aligned with other results, did not show significant condition differences in the Friedman test ($p = .1377$), although LMEM results and median differences suggest potential subtle effects.

I conducted Wilcoxon signed-rank tests on both the full dataset and a reduced dataset excluding participants flagged for inconsistent or low-effort responses. The direction, significance, and relative magnitude of all key comparisons remained stable across both versions of the data. This suggests that the primary findings were robust and not overly sensitive to outlier or low-quality participant behaviour.

Sensitivity and Data Quality. We conducted participant-level quality checks to flag flat or inconsistent responses. Results remained consistent, supporting the robustness of our findings.

5.4.2 Summary Table

I begin by presenting descriptive statistics across all four conditions to provide a high-level overview of participant responses. This is presented in Table 5.4. Given the non-parametric analysis approach, all descriptive statistics are reported as medians and inter-quartile ranges, and visualizations use boxplots with jittered points to reflect data spread and skew.

Condition	UMUX	PXI	IOS	NM
Proteus - Co-located	6.50 [6.00, 7.00]	6.45 [6.09, 6.68]	7.00 [6.00, 7.00]	5.03 [4.50, 5.45]
Proteus - Remote	6.00 [6.00, 7.00]	6.45 [6.09, 6.64]	7.00 [6.00, 7.00]	5.00 [4.35, 5.33]
Traditional - Co-located	6.00 [5.50, 7.00]	6.18 [5.68, 6.59]	6.00 [6.00, 7.00]	4.88 [4.33, 5.31]
Traditional - Remote	6.00 [5.00, 6.25]	6.00 [5.55, 6.41]	5.00 [4.00, 6.00]	4.73 [4.18, 5.20]

Table 5.4: Median scores with interquartile ranges [IQR] across experimental conditions.

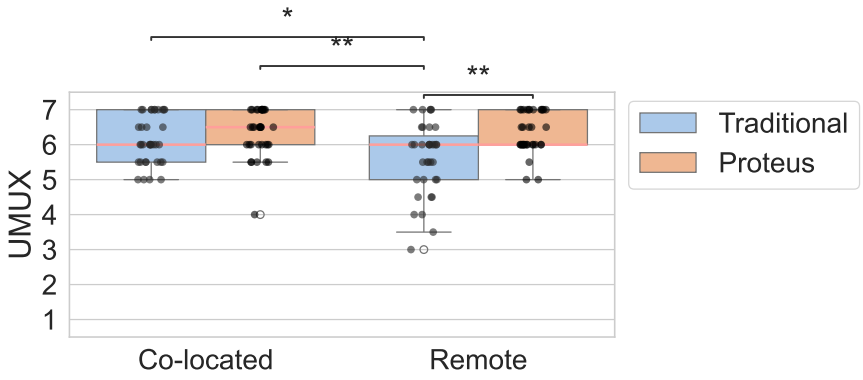


Figure 5.9: UMUX-LITE usability scores across experimental conditions. Boxes show medians and IQRs; dots represent individual participant ratings.

5.4.3 Usability (UMUX-LITE)

A Friedman test indicated a significant effect of condition on UMUX-LITE usability scores, $\chi^2(3) = 19.31$, $p < .001$, Kendall's $W = .184$. Post-hoc Wilcoxon signed-rank tests (Bonferroni-corrected) revealed:

- Proteus Co-located scored higher than Traditional Remote, $p = .0042$.
- Proteus Remote also scored higher than Traditional Remote, $p = .0058$.
- Traditional Co-located scored higher than Traditional Remote, $p = .0485$.
- Proteus Co-located did not differ significantly from Proteus Remote ($p = 1.000$) or Traditional Co-located ($p = .269$).
- Proteus Remote did not differ from Traditional Co-located ($p = .746$).

Figure 5.9 shows that usability declined for remote play overall, but this drop was mitigated when Proteus was used. Traditional Remote settings had the lowest usability scores.

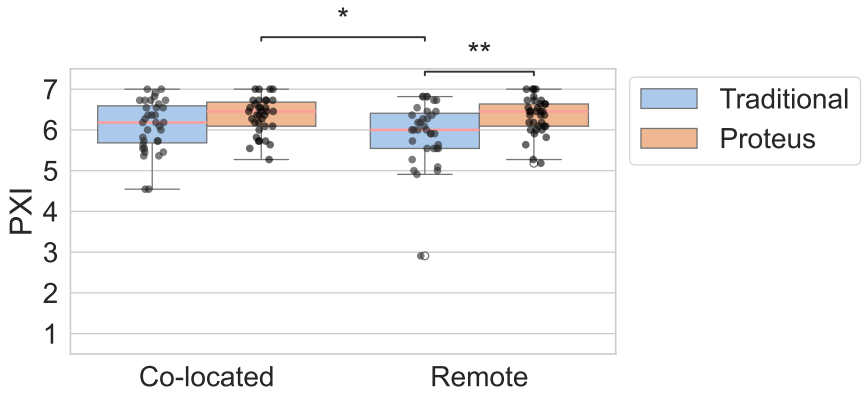


Figure 5.10: PXI (Player Experience Inventory) scores across conditions. Each box shows medians and IQRs with jittered individual scores.

5.4.4 Player Experience (PXI)

A Friedman test found a significant difference in PXI scores across conditions, $\chi^2(3) = 12.07$, $p = .007$, Kendall's $W = .115$. Pairwise Wilcoxon tests (corrected) showed:

- Proteus Co-located scored higher than Traditional Remote, $p = .0433$.
- Proteus Remote scored higher than Traditional Remote, $p = .0059$.
- Proteus Remote did not significantly differ from Traditional Co-located ($p = .1419$).
- Proteus Co-located did not differ from Proteus Remote or Traditional Co-located.
- Traditional Co-located and Traditional Remote were not significantly different ($p = 1.000$).

Figure 5.10 shows that while remote play reduced player experience overall, Proteus narrowed this gap.

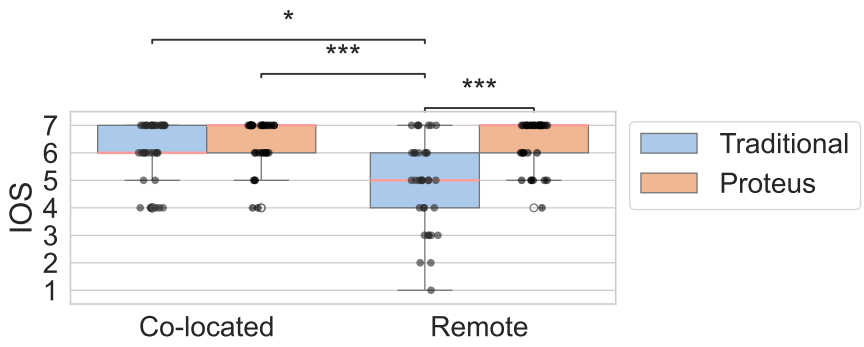


Figure 5.11: IOS (Inclusion of Other in Self) scores across conditions. Boxplots display medians and IQRs; dots reflect raw scores.

5.4.5 Social Closeness (IOS)

IOS scores varied significantly by condition, $\chi^2(3) = 27.13$, $p < .001$, Kendall's $W = .258$. Wilcoxon pairwise tests showed:

- Proteus Co-located scored significantly higher than Traditional Remote, $p = .0003$.
- Proteus Remote also scored higher than Traditional Remote, $p = .0007$.
- Traditional Co-located scored higher than Traditional Remote, $p = .0159$.
- No significant differences were observed among the other comparisons ($p > .69$).

Figure 5.11 illustrates that traditional remote settings produced the lowest social closeness ratings. Proteus, particularly in remote conditions, improved feelings of closeness.

5.4.6 Social Presence (Networked Minds)

A Friedman test revealed no statistically significant difference in Networked Minds scores across conditions, $\chi^2(3) = 5.52$, $p = .138$. While pairwise differences were not significant after correction, raw values suggest:

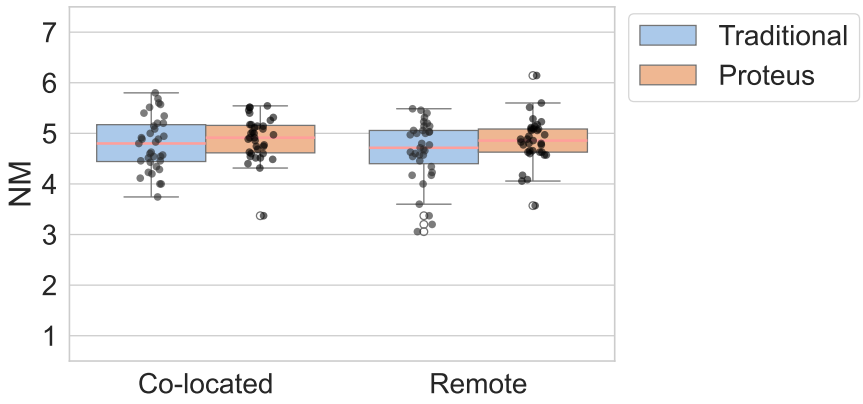


Figure 5.12: Networked Minds social presence scores across conditions. No condition significantly outperformed others.

- Proteus Co-located scored higher than Traditional Remote (*uncorrected* $p = .0187$, corrected $p = .1123$).
- No other comparisons reached significance (all corrected $p > .59$).

As shown in Figure 5.12, there is a visual trend favouring Proteus, particularly in co-located contexts, though not statistically significant.

5.4.7 Effect of Socioeconomic Status and Demographics

To evaluate whether participant demographics influenced outcomes, I conducted Mann–Whitney U tests for the effects of socioeconomic status (SES), gender, age, and education on all three primary dependent variables: usability (UMUX), player experience (PXI), and social closeness (IOS).

- **SES:** A statistically significant effect was found on PXI scores ($U = 1868.0$, $p = .018$), with participants from lower SES backgrounds reporting different player experiences. No significant effects were observed for UMUX ($U = 2105.5$, $p = .160$) or IOS ($U = 2143.5$, $p = .198$).

- **Gender:** No significant differences were found for any outcome variable.
- **Education:** No significant differences were found for any outcome variable.
- **Age:** No significant differences were found for any outcome variable.

These findings indicate that among all demographic variables tested, only socioeconomic status (SES) had a statistically significant effect—specifically on player experience (PXI). Participants from lower SES backgrounds reported notably higher median PXI scores, potentially reflecting engagement or enjoyment during gameplay. No significant differences were observed for usability (UMUX) or social closeness (IOS) based on SES, gender, education, or age. Notably, all participants from lower SES groups reported regular access to smartphones and were familiar with mobile-based digital interactions, indicating that limited exposure to technology does not explain these differences. Instead, the stronger PXI scores may reflect a higher perceived novelty or appreciation of the tactile, hybrid format offered by Proteus. This highlights the system's potential to offer enriching experiences even in resource-constrained settings.

5.4.8 Exploratory Linear Mixed-Effects Models (LMEMs)

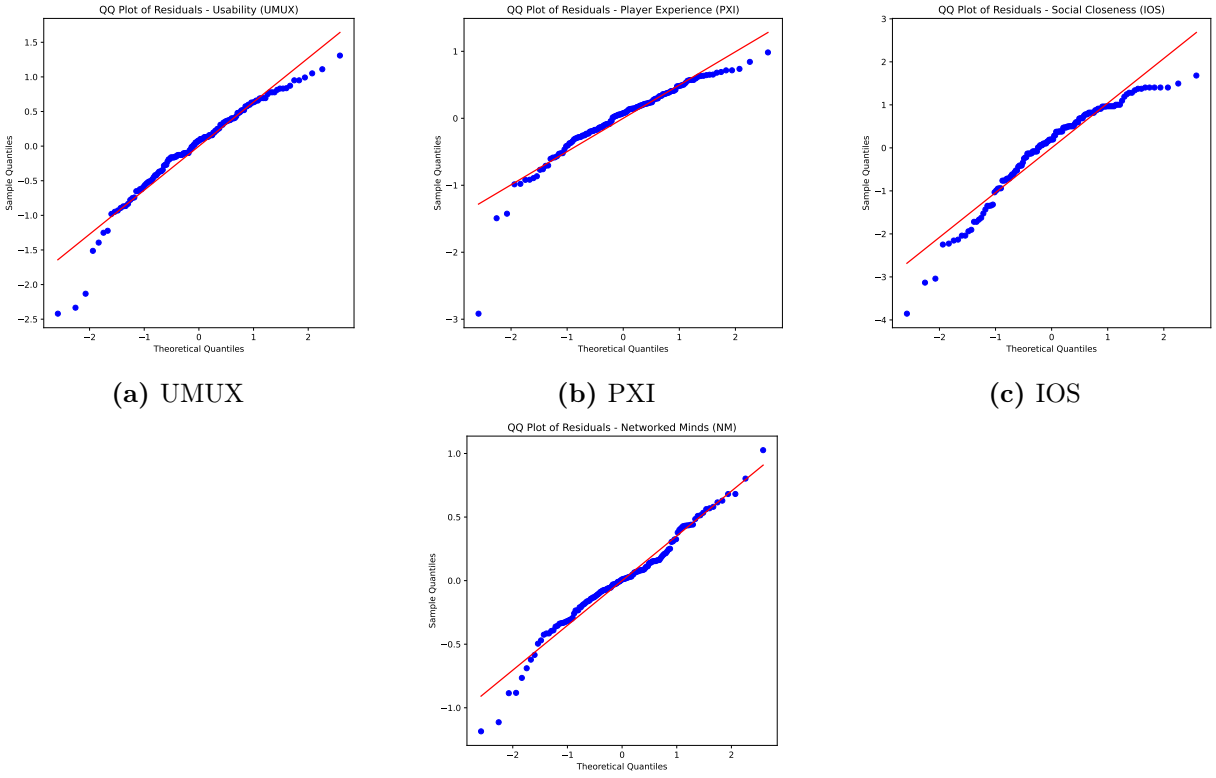
Despite assumption violations that limited the use of linear mixed-effects models (LMEMs) as confirmatory tools, I initially attempted to specify a full LMEM with fixed effects for *modality* and *location*, covariates including gender, education, SES, prior relationship, and game experience (online and card), and random intercepts for both participant ID (PID) and dyad. However, these models routinely failed to converge, showing singular matrix errors and signs of overfitting.

The convergence issues appeared to stem from multicollinearity among covariates, imbalance across categorical variables (e.g., education, relationship status), and limited statistical power relative to the number of random effect levels. Systematic simplification—first by dropping covariates, then by reducing the random structure—revealed that convergence was only possible when retaining a single random effect.

Across all instruments, models with dyad as the random effect converged, and highlighted consistent main effects of modality. Proteus outperformed traditional setups on all four measures: usability (UMUX), player experience (PXI), inclusion of other in self (IOS),

and social presence (Networked Minds). Location effects were less consistent, reaching significance only for UMUX and IOS, with remote play associated with lower ratings.

Q–Q plots of residuals are included in Figure 5.13 to aid inspection of distributional assumptions.



(a) UMUX **(b)** PXI **(c)** IOS

(d) NM

Figure 5.13: Q–Q plots of residuals for each instrument (UMUX, PXI, IOS, NM), comparing sample quantiles to a normal distribution.

LMEM Results (Dyad Random Effect).

- **UMUX**: Proteus was associated with significantly higher usability ($\beta = -0.47$, $p < .001$). Remote play was rated lower than co-located ($\beta = -0.26$, $p = .027$).

- **PXI**: Proteus again outperformed traditional ($\beta = -0.33$, $p < .001$). Location had no significant effect ($p = .36$).
- **IOS**: Strong modality ($\beta = -0.90$, $p < .001$) and location effects ($\beta = -0.59$, $p = .002$) showed reduced self–other merging in traditional and remote setups.
- **Networked Minds**: Proteus led to higher social presence ($\beta = -0.16$, $p = .016$), though location was not significant ($p = .18$).

Taken together, these dyad-level LMEMs corroborate the non-parametric findings: Proteus enhanced usability and interpersonal experience, with some degradation in remote contexts. While PID-based models produced marginally tighter estimates for PXI and NM, they suffered from greater convergence issues and less interpretability in relational terms. As dyads were more stable units of social interaction, I report them as the preferred random structure for exploratory modeling.

5.4.9 Participant Preferences and Qualitative Observations

To contextualize the quantitative findings, I conducted semi-structured interviews at the end of each session. These interviews were transcribed and analyzed using reflexive thematic analysis (RTA) following the approach outlined by Braun and Clarke (2006, 2021). RTA was selected for its suitability in capturing both explicit content and latent meanings while acknowledging the active role of the researcher in theme development. Through iterative coding and memoing, I identified three recurring themes across the dataset: tactile engagement as a social anchor, perceived "aliveness" in remote play, and the invisibility of orchestration. These themes were not pre-specified, but inductively surfaced through immersion in the data, and reflect participants' interpretive experiences of hybrid interaction with the Proteus system.

Tactile Matters, Even When Remote

Participants repeatedly highlighted the value of being able to physically manipulate the Proteus cards, especially in remote settings. The tactile interaction appeared to compensate for the physical distance between partners:

> It felt like we were actually playing together—even though we were far apart, I was still flipping something in sync with them. (P116)

This sense of synchronized materiality contributed to a feeling of co-presence that traditional digital interfaces (e.g., Tabletop Simulator) failed to provide.

Proteus Felt More Alive Than Screens

Participants described Proteus cards as having a presence of their own, "less static" than paper, yet not as "cold" or "cluttered" as a screen. Several referred to the system as feeling alive or reactive, even though it had no animations or sound.

> It was quiet, but still felt like something was happening. Like it was aware of the game. (102)

This perception seemed tied to the timing and synchronicity of updates, reinforcing the feeling of a shared, responsive system.

Invisible Infrastructure Was a Win

Unlike traditional tech setups that required apps or logins, Proteus worked without needing much explanation. Participants appreciated that there was no visible system overhead:

> We didn't need to install anything. It just worked, like regular cards, but magic. (P15)

This contributed to ease of on-boarding and reduced friction in casual or time-constrained environments (notably at the SRA site).

Reduced Cognitive Load Was a Plus

While most participants preferred Proteus for its tactile presence, nearly half ($N = 12$) favoured the Tabletop Simulator condition. They appreciated that it handled mechanics like drawing, reshuffling, and visual updates automatically, thereby reducing their cognitive burden and allowing them to focus purely on strategic collaboration.

> I didn't have to remember who played what or move anything myself—the system handled that, so I could just think about the game. (P18)

These comments showcased the value of system-managed gameplay for certain users or contexts, and suggest that Proteus may benefit from offering optional automation or hybrid digital scaffolding in future iterations.

Caveats and Suggestions

A few participants expressed concern about card thickness or lag in updates during the Proteus Co-located condition. These comments point to areas for future refinement. Some also requested more expressive cards—e.g., with vibration, colour, or LEDs—which could support richer signalling in games or classroom use.

Taken together, these findings suggest that Proteus operates as a research artifact that embodies and enacts the central theoretical commitments of this thesis. Developed through a Research through Design process grounded in the constraints surfaced in prior studies, Proteus demonstrates how interaction systems can materially support hybrid placemaking. Participants consistently rated it higher in usability, player experience, and social connection, particularly in remote contexts where traditional systems faltered. These outcomes reflect Proteus's capacity to sustain not just functionality, but the socio-material qualities of shared place: embodied coordination, temporal rhythm, and interpersonal attunement. Like the adaptive practices observed in vanlife and small space living, Proteus enables transitions between roles (e.g., player, collaborator, learner) and between modalities (e.g., physical handling, digital synchronization), making it both expressive and infrastructurally lightweight. As a research artifact, it concretizes how tangible-digital systems can scaffold meaningful interaction under constraint by reconfiguring how presence, play, and connection can manifest in compact living contexts.

5.5 Overall Discussion and Interpretation

This section synthesizes the key quantitative and qualitative results to evaluate the study's original hypotheses and reflect on the broader implications of the findings. The primary goal was to assess whether Proteus could close the gap between co-located and remote interaction while supporting usability, social connection, and experiential engagement. Results broadly confirm this goal while also revealing unanticipated nuances.

5.5.1 Summary of Key Findings

- **Proteus improved usability and player experience:** Across all instruments, Proteus conditions consistently outperformed Traditional Remote and, in many cases, matched or exceeded Traditional Co-located setups. This held for usability (UMUX), player experience (PXI), and social closeness (IOS).
- **Remote interaction was supported more effectively by Proteus:** Although remote settings generally reduced ratings compared to co-located play, Proteus substantially mitigated this drop—especially for usability and social closeness—showing its ability to sustain interaction quality across distances.
- **Traditional Remote was consistently weakest:** It yielded the lowest scores on all measures, reinforcing the challenges of screen-based remote systems in supporting shared play and presence.
- **Social presence (Networked Minds) showed weaker effects:** This measure did not reach statistical significance in non-parametric tests, though LMEM results suggested subtle effects favoring Proteus.
- **SES influenced player experience:** Lower SES participants reported significantly higher PXI scores, suggesting greater appreciation or novelty value, despite similar levels of access to digital technology.
- **Qualitative themes aligned with core design goals:** Interviews revealed that Proteus was perceived as tactile, alive, and minimally demanding in setup. Its simplicity and responsiveness supported ease of use without sacrificing shared experience.

5.5.2 Hypothesis Confirmation

This section interprets whether each hypothesis was supported based on the user study results. Statistical results are detailed in the previous section; what follows is a summary of directional patterns and significance in relation to the study's predictions.

H1: *Proteus, used remotely, will outperform traditional screen-based remote systems on (a) usability, (b) player experience, (c) social connection, and (d) social presence.*

Supported.

(a) Remote use of Proteus was perceived as more usable than traditional remote setups, aligning with prior findings on tactile systems reducing friction in constrained contexts.

(b) Proteus also offered a more satisfying player experience, reflecting smoother interaction and more consistent engagement.

(c) Participants reported stronger interpersonal connection in Proteus remote sessions, suggesting that shared physical rhythms can translate even across distance.

(d) Although differences in social presence were more modest, Proteus still outperformed traditional remote play in supporting a sense of co-presence.

H2: *Traditional remote play will (a) maintain usability but have (b) lower social connection and (c) social presence than all three other conditions.*

Partially supported.

(a) Usability was not maintained: participants found traditional remote systems have lower median usability than both Proteus and traditional co-located play.

(b) Social connection was consistently lowest in traditional remote sessions, reinforcing earlier concerns about remote digital interaction.

(c) Social presence medians for traditional remote play similarly lagged behind other conditions, with participants noting a lack of immediacy or shared rhythm.

H3: *Proteus (in both remote and co-located conditions) will match traditional co-located play in terms of (a) usability, (b) player experience, (c) social connection, and (d)*

social presence.

Largely supported.

(a) Both modalities of Proteus were rated comparably to traditional co-located systems in terms of usability.

(b) Player experience also aligned across these three conditions, indicating that Proteus supports equally immersive engagement.

(c) Social connection scores showed no meaningful difference between Proteus and traditional co-located sessions, highlighting Proteus's capacity to scaffold interpersonal closeness.

(d) Social presence was slightly lower in remote Proteus sessions compared to co-located play, but not significantly so—suggesting the system effectively approximates in-person presence even when distributed.

5.5.3 Unexpected Findings and Interpretive Notes

One unexpected outcome was the significant effect of socioeconomic status on PXI scores. Participants from lower SES backgrounds reported notably higher enjoyment, possibly due to increased appreciation of novel or tactile experiences, or a greater contrast with their typical digital gameplay settings. This finding underscores the value of designing interaction systems that resonate across diverse experiential baselines.

Another surprise was the lack of significant difference in Networked Minds scores. Despite strong results in usability and connectedness, these more granular measures of social presence may be less sensitive to the physical-digital distinction, or perhaps too diffused to capture momentary coordination effects.

The preference among some participants for Tabletop Simulator, due to its automation of game mechanics, also complicates the narrative. While Proteus supports agency and embodiment, not all users prioritized these qualities equally, pointing to the need for adaptable interfaces that can toggle between manual and system-managed modes.

5.5.4 Conclusion

This study confirms that Proteus, as a deliberately constructed research artifact, achieved the outcomes it was designed to produce within the constrained interactional design space identified in earlier studies. As an artifact specifically intended to function under spatial and infrastructural limitations—supporting usability, player experience, and social connection where conventional screen-based tools often fail. Quantitative results across the primary instruments validate this: Proteus reliably outperformed traditional remote systems and, in many cases, matched or exceeded co-located benchmarks. These findings demonstrate that a system designed in response to empirical constraints can concretely deliver on its intended goals, reinforcing the broader argument that constraint is a generative condition for interaction design.

5.6 Discussion

The aim of this research was to design a system that meaningfully supports social connection in environments marked by spatial and infrastructural constraint. Across the studies, participants encountered a recurring set of material limitations: limited power, variable internet, restricted space, and low income. These constraints consistently shaped not only what technologies were feasible, but also what kinds of interactions were possible, sustainable, or worth pursuing.

Through sustained engagement with these contexts, I identified a set of design considerations that responded to both infrastructural conditions and lived practices: spatial constraint, infrastructural fragility, temporal variability, and resource-conscious pragmatics. These were not abstract categories; they emerged through observation of how people adapted, improvised, and coordinated technology use in everyday life. Designing for such contexts required systems that could operate reliably, reduce friction, and support shared activity without placing further demands on already fragile environments.

The earlier fieldwork also offered insight into how people made place under constraint, through strategies like boundary-setting, temporal structuring, developing mastery over tools, and engaging in future-oriented planning. These patterns became central to the design of Proteus. Rather than treat these strategies as background conditions, the system was built to actively support them, particularly in situations where screens or immersive technologies would be inappropriate or inaccessible.

The evaluation helped close the loop between design intent and user experience. Proteus significantly improved measures of social connectedness and usability in remote settings compared to Tabletop Simulator, and matched or exceeded traditional card play in co-located contexts. These outcomes suggest that systems designed with constraint in mind can function across challenging settings while sustaining the kinds of shared experience and mutual awareness that make connection possible.

5.6.1 Learning Through Proteus

Reflexivity shaped my engagement with Proteus from the beginning. Each prototype embedded design logics that emerged from earlier fieldwork, and each iteration became an opportunity to test, evolve, or reframe those logics in practice. I approached this project through a Research through Design (RtD) lens, treating design as a way to ask better questions. I used Proteus to explore tensions, surface insight, and produce situated knowledge through direct engagement with material conditions (Gaver, 2012; Zimmerman et al., 2007). This process echoed Schön's model of reflection-in-action, where understanding grows through ongoing, embodied negotiation with design situations (Schön, 2017).

5.6.2 Learning in Use

I started the project thinking the main insights would come from the process of building Proteus—figuring out how to manage power, deal with the quirks of e-ink, and make the form factor work in tight, resource-limited environments. That technical work was important: it showed what was materially possible. But the real learning happened once people started using it. That's when patterns of rhythm, coordination, and improvisation really came into view—not as things we designed into the system, but as things people brought to it. For example, latency and instability weren't treated as bugs to be fixed. One participant said, "It just means we're not in a rush" (P109)

, reframing delay as part of the experience. It is similar to Gaver's idea that "the value of a design may lie not in what it definitively tells us, but in how it encourages us to think differently" (Gaver, 2012). Proteus became a way for the participants to engage with constraint, and to shape meaning around it.

The physicality of the cards also influenced how information was handled. The limited surface area led participants to stack, cluster, and spatially sequence cards—strategies I

had seen in homes and vans across chapter 3 and chapter 4. Even the shuffle "blinking" (which happens when we update the cards to shuffle them or similar, and is an inherent quality of e-ink displays) played a role: "We play until the blink starts," a participant noted. People anchored their sessions in the material feedback of the system.

Through these patterns, I saw how constraint shapes, guides, and gives form to interaction. Proteus offered a living environment where those dynamics unfolded in real time.

Re-Encountering Experiential Structuring

The experiential constructs I developed in chapter 3—boundaries, temporality, mastery, and future-thinking—surfaced again during Proteus sessions. These were no longer just codes or themes; they were lived, repeated, and elaborated on through direct use.

- **Boundaries** appeared in how participants managed the space of play. They created stacks and zones, and used placement to signal control and progression.
- **Temporality** emerged through the choreography of interaction. Gestures like pausing, flipping, and shuffling marked transitions and established pacing.
- **Mastery** showed up in technique. Users refined how they held, organized, and navigated the cards. One participant said, "I finally figured out how to stack them like tabs."
- **Future-thinking** came through speculation. Participants imagined Proteus in classrooms, therapy sessions, travel planning, and collaborative facilitation.

These re-encounters affirmed that the structuring strategies I had identified earlier were not confined to specific homes or vehicles. They translated into a new setting, took on new forms, and revealed their durability through interaction. Proteus helped me move from observing these structures in the field to designing with them in mind.

Situated Reinforcement

When I brought Proteus to fieldwork in India, I gained further perspective on how experiential and infrastructural insights travel. The technical infrastructure remained consistent, but facilitator presence and rhythm played a major role in shaping interaction. Children picked up the system easily and engaged autonomously. Adults were more tentative, often asking for guidance. One teacher remarked, "I keep waiting for it to tell me what to do." These moments underscored the importance of scaffolding, role clarity, and shared rhythm.

Participants leaned into familiar modes of coordination—spreading, stacking, exchanging—to build structure. These gestures echoed earlier fieldwork, confirming that embodied strategies adapt across contexts. I found Haraway's notion of situated knowledge deeply relevant here: interaction made the most sense when it aligned with pre-existing rhythms of care, coordination, and attention (Haraway, 2013).

Reframing the Design Stance

Working with Proteus reshaped how I understood the design problem. I started to think of durability not in terms of material robustness, but as the ability to sustain flow and rhythm. I saw that coordination across participants often mattered more than the successful completion of isolated tasks. Some groups created their own rules—like a five-card active stack—to improve focus and pacing: "This is our active stack," they explained.

These insights shifted both my technical direction and theoretical orientation. Each iteration prompted me to reconsider what I was really designing for. In other terms, I was redefining the problem rather than just the artifact (paraphrased from Schön, 2017).

Closing

Proteus became both the object and method of inquiry. Through it, I was able to observe how constraint actively shapes interaction, how people structure experience in real time, and how design decisions can support adaptation across a range of conditions. The project yielded two outcomes: a functioning system built for use in constrained environments, and a deeper understanding of how interaction, structure, and adaptation evolve together when space, time, and infrastructure are limited.

5.6.3 Separating Iterative Design from Evaluation

The development of the Proteus Card Deck followed a Research through Design (RtD) approach characterized by iterative prototyping, deployment, and reflection. These design iterations were guided by prior findings and informal feedback from participants in vanlife and spatially constrained environments. However, these formative activities were distinct from the final summative evaluation, which employed a within-subjects experimental design to systematically assess Proteus against traditional card decks. While the iterative phase was exploratory and generative, intended to surface design opportunities and constraints, the evaluation phase was structured, hypothesis-driven, and used validated instruments to compare conditions. This separation ensures that the knowledge generated from this RtD process remains situated and reflective, while also enabling empirical claims about usability, connection, and interaction quality through structured comparison.

5.6.4 Design Implications

The Research through Design process yielded two distinct clusters of design implications: (1) system-level insights across interaction, coordination, and usability that map to the original design considerations (DC1–DC10), and (2) affordance-level insights into gameplay mechanics and expressive potential, uncovered through iterative prototyping and deployment. I discuss both below.

Hybrid Orchestration Framework: System-Level Design Considerations

The findings from this study extend the original Design Considerations (DC1–DC10) into reusable design implications for hybrid orchestration of tangible systems. Unlike prior work that focused on fixed installations or localized augmentation (for instance, the work by Liao et al. (2007) and Nakagaki et al. (2022)), these implications support physically distributed interactions with centralized control logic. The new addition, DC11, emerged during deployments in constrained environments where connectivity issues disrupted shared awareness, motivating the inclusion of a global state clock to maintain temporal synchrony and co-presence.

To consolidate the knowledge produced through this research, I organize the system-level considerations into three interdependent layers: physical design, orchestration infrastructure,

and deployment fidelity. This framework reflects the interplay between tangible interaction, system coordination, and contextual robustness—each layer addressing a distinct but overlapping aspect of designing for constrained and hybrid environments. Grounded in empirical findings from the field deployments, it highlights how Proteus accommodates infrastructural limitations, supports situated social practices, and challenges assumptions common in prior hybrid or tangible systems.

Physical design refers to the tangible and material characteristics of the system, how the cards are shaped, held, manipulated, and visually interpreted in constrained settings. This includes considerations such as display readability, affordances for fanning or stacking, and the integration of form with everyday spatial routines.

Orchestration infrastructure addresses the underlying coordination mechanisms that manage system state across distributed devices. It includes communication protocols, update logic, power management, and synchronization strategies that ensure Proteus functions reliably in environments with limited connectivity, fluctuating power, or ad hoc configurations.

Deployment fidelity captures how well the system performs when situated in real-world use contexts, including both co-located and remote scenarios. This layer focuses on whether the system preserves essential interactional qualities—such as shared attention, turn-taking, and spatial negotiation—across diverse conditions, and how well it adapts to the embodied practices of its users.

Table Table 5.5 summarizes the mapping between these categories, the insights they emerged from, and how they diverge from or extend previous work.

Proteus contributes to the lineage of systems architecture and orchestration work by supporting centralized orchestration of distributed BLE-connected cards, allowing real-time updates across displays with minimal infrastructure. Its architecture enables mobile, reconfigurable use in settings that lack traditional connectivity, marking an evolution from fixed-location UbiComp systems to truly hybrid, tangible-digital experiences.

Taken together, these hybrid systems illustrate the evolving relationship between physical form and digital coordination. Proteus draws on these traditions while adapting them to low-infrastructure, mobile contexts, creating a design space for hybrid tangible-digital experiences that span learning, play, and collaboration.

Table 5.5: Design Considerations Grouped as a Hybrid Orchestration Framework

Category	DC ID	Design Consideration and Implication	Contrasts With
Physical Design	DC1	Familiar multi-card deck structure enables intuitive physical manipulation.	Generic touchpads or bespoke shapes (e.g., PaperCP)
	DC5	Manual shuffling and fanning preserve turn-taking and embodied flow.	Static or screen-based interfaces
	DC8	Traditional card form factor reduced onboarding friction.	Actuated but nonstandard shapes
Orchestration Infrastructure	DC2	Centralized backend ensures global synchronization and low user burden.	Fully local computation (e.g., PaperCP's camera tracking)
	DC6	Real-time update logic created perception of system "aliveness."	Non-reactive or polling-based updates
	DC7	Individualized card displays support private roles and asymmetric logic.	Homogenous card content
	DC11	Temporal synchrony emerged as essential to maintaining co-presence.	Rarely addressed in prior tangible decks
Deployment Fidelity	DC3	Performance validated in constrained, real-world spaces (e.g., slums, schools).	Typically lab-only or with high infrastructure
	DC4	BLE shelf displays enabled low-cost, scalable deployment.	Custom hardware
	DC9	Plug-and-play usability required no training or local network setup.	High setup overhead or complex calibration
	DC10	Core interaction model generalized across ideation, teaching, and play.	Often domain-locked or demo-only

Domain	**Key Examples**	**Challenges**	**Proteus Contribution**
Remote Tangible Play	*Eye of Judgment*, Augmented Trading Card Game (Sakamoto et al., 2014), PEPA Deck (Kirshenbaum & Robertson, 2018)	Hardware constraints; co-location assumptions; scalability limitations	Supports distributed, remote gameplay with familiar form factor and scalable orchestration
Card-Based Ideation	Inspiration Cards (Halskov & Dalsgård, 2006), Brainstorm Decks (Wölfel & Merritt, 2013), Learning Games (Kordaki & Gousiou, 2017)	Static content; limited updateability; hard to deploy remotely	Dynamic, updateable cards; tactile UX retained
Distributed Coordination Architectures	Coordinated Display Patterns (Kohtake et al., 2005), UbiComp orchestration layers (Omicini & Zambonelli, 2016b; Tolmie et al., 2010)	Fixed-location bias; high infrastructure needs; limited mobility	BLE-enabled e-ink cards with centralized orchestration for mobile, reconfigurable use

Table 5.6: Proteus Contribution Across Domains

Design Strategies for Tangible Hybrid Systems

The field deployments and structured study revealed several strategies that extend beyond Proteus and can inform future tangible-digital systems. These strategies are grounded in the observed impact of the design considerations (DC1–DC11) and their manifestation across use contexts.

- **Preserve Tangible Familiarity:** Recognizable physical grammars (e.g., shuffling, fanning) foster immediate, low-friction adoption. In the user testing, skeuomorphic elements (DC1: Deck Composition, DC5: Manual Shuffle Support, DC8: Familiar Form Factor) were instrumental in reducing training overhead and encouraging natural interaction, especially in non-academic and low-tech settings. As one instance of this familiarity, Figure 5.14 illustrates how participants constructed their own physical interaction patterns while using Proteus. These improvised behaviours underscore the system's adaptability and support for emergent play styles.
- **Externalize and Simplify Orchestration:** Participants consistently preferred systems that "just worked." Proteus achieved this through centralized orchestration (DC2: Centralized Control), which remained perceptually invisible. This design choice reduced cognitive load and minimized the need for user-side configuration—critical for hybrid and time-sensitive use cases.
- **Embed Temporal Fidelity as a Design Material:** The perception of "aliveness" in Proteus stemmed from its precisely synchronized updates. Timing supported turn-taking and co-presence, in addition to being functional. These qualities were tied directly to DC6 (Automatic Card Updates) and the new addition DC11 (Temporal Synchrony), which proved vital for interactional rhythm in remote and hybrid contexts.
- **Support Role-Asymmetry through Modular Logic:** Proteus enabled individualized card displays and logic assignments (DC7: Player Card Knowledge), allowing distinct roles in gameplay, teaching, or collaborative tasks. Combined with DC10 (Multi-application Support), this supported asymmetric interaction models that enriched engagement and flexibility.
- **Design for Infrastructure Variability:** Proteus was deployed in environments with limited internet and minimal technical infrastructure. Its success hinged on portability and robustness (DC3: Multi-location Usability, DC9: Portability), ensuring functionality without reliance on apps, Wi-Fi, or cloud services.

- **Make Affordability and Durability Core Constraints:** Cost-effective materials and durable construction (DC4: Affordability & Scalability, DC9: Portability) enabled deployments in schools, community spaces, and dense urban housing. These attributes were not optional optimizations but foundational to real-world adoption.
- **Build Interaction Models from Reusable Primitives:** Proteus reused simple operations like assign, reveal, and shuffle. This domain transferability (DC10) shows that tangible hybrid systems benefit from a modular design language that can flex across contexts without re-engineering the core.



Figure 5.14: Participants quickly developed their own strategies for physically handling the Proteus cards. Rather than replicating traditional card grips, they adapted to the weight and surface of the e-ink cards with gestures that suited their environment—fanning, stacking, or laying them out spatially. This emergent handling behaviour suggests that Proteus enabled new forms of embodied play that were context-sensitive and intuitive.

Gameplay Affordances and Emerging Mechanics

A second layer of design implications emerged around how Proteus enables new forms of interaction that are inaccessible to traditional or static digital card systems. These affordances are not merely derivative of either physical or digital paradigms—they are hybrid.

These mechanics illustrate how Proteus opens new design space, where physicality, memory, and dynamic updating converge. I argue that hybrid systems like Proteus are enabling interactional primitives that were previously impossible.

5.6.5 Technical Limitations

While Proteus proved viable across diverse contexts, the deployments also revealed systemic limitations that shaped its current capabilities and point toward concrete future directions.

Table 5.7: Gameplay Mechanics Supported by the Proteus Card Deck

Demonstrated Mechanics (Implemented in a Lab Setting)	
Wildcard	Cards dynamically changed content during gameplay (e.g., draw-pile substitutions or rule triggers) based on backend logic.
Counters	Cards displayed dynamic counters (e.g., turn number, card draw count) that updated in response to game state.
Virtually Write-on Cards	Used for games requiring writing input: cards updated mid-session with participant input or shuffled prompts.
Weighted Distribution	Game master interface adjusted draw probabilities to influence pacing and strategic dynamics.
Speculative Mechanics (Future Capabilities Based on Architecture)	
History	Cards could log past owners or states, enabling cumulative effects or narrative branching across sessions.
Degrading Cards	Cards visually fade or evolve over time to simulate damage, fatigue, or temporary powers.
Transference	Networked decks transfer card identities remotely, enabling location-jumping mechanics or trades.
Peeking	Cards temporarily reveal data to specific players, supporting hidden role or bluffing mechanics.
Random Decks	Procedural generation of deck content mid-play, adapting to player behavior or external triggers.

First, communication is unidirectional. Cards receive state updates but do not send feedback. In collaborative settings, facilitators lacked visibility into whether a participant had seen or acted on a card, leading to moments of ambiguity. Incorporating lightweight sensing (e.g., touch, orientation, or movement detection) would allow cards to register user actions and enable bidirectional interaction, improving coordination and shared awareness.

Second, the low-resolution BLE e-ink displays, while power-efficient and physically expressive, constrained the richness of communication. Participants occasionally struggled with slow refresh rates and limited symbolic expressiveness, especially during fast-paced exchanges. Upgrading to higher-refresh e-ink variants or layered symbolic overlays could enhance clarity without sacrificing energy efficiency.

Third, all timing logic was externally controlled—updates were pushed from a central server via a web interface. Introducing local timing logic or autonomous pacing rules would reduce facilitation overhead and allow Proteus to respond dynamically to local interactions or group progress.

Fourth, Proteus cards currently have no local state persistence. Once disconnected from the host, they lose session memory, limiting their utility in low-connectivity environments

or asynchronous workflows. Local caching and session recall could enable new use cases, such as distributed gameplay or staggered collaboration.

Fifth, the orchestration backend is tightly coupled to a custom web infrastructure, reducing portability and modular reuse. Future work should explore decoupling the deck logic from a specific UI or host platform—e.g., by exposing a clean API or enabling offline configuration via mobile devices—thereby making Proteus more deployable across different infrastructures and interaction models.

Finally, while the form factor proved effective for dyadic play, multi-party coordination remains an open area. Future iterations should explore how deck identity, group awareness, and context-specific interactions scale beyond two users without overwhelming the physical interface or social dynamics.

These limitations emerged directly from real-world frictions in gameplay scenarios. Each challenge signals a technical refinement, which is based on a human need: to interact seamlessly, improvise fluidly, and collaborate meaningfully in environments that are small, shared, and resource-constrained. Addressing these gaps will bring Proteus closer to realizing its potential as a versatile, resilient platform for hybrid interaction.

5.6.6 Roadmap and Future Development

Ongoing work will focus on enhancing Proteus' interactivity, scalability, and application flexibility. Planned directions include:

1. Bidirectional communication: Incorporating lightweight sensing (e.g., touch, motion) to support richer interaction loops.
2. Thin and flexible displays: Exploring curved or modular e-ink surfaces for more adaptive physical forms, leading to thinner, more realistic cards. A flexible display is shown in Figure 5.15.
3. Local computation and state persistence: Allowing cards to manage state transitions independently, supporting more autonomous behaviour.
4. Generalizable orchestration platform: Abstracting and releasing the backend logic as a toolkit for other researchers or designers.



Figure 5.15: Flexible e-Ink displays for future Proteus Card Decks

5. Multi-modal integration: Pairing cards with mobile, audio, or spatial interfaces for more immersive use cases.

These directions aim to expand the repertoire of tools and principles available to researchers exploring hybrid tangible systems, while exploring the possibility of building a commercial product.

In designing Proteus, I aimed to explore how a tangible research artifact might scaffold hybrid coordination in small, shared, or distributed contexts. Across co-located and remote settings, Proteus helped participants align, respond, and co-construct meaning without relying on screens or rigid interfaces. Its value lies not in raw technical capability, but in how it rethinks presence, timing, and orchestration as physical, social acts.

We hope this work supports others experimenting at the edges of physical-digital interaction, and reminds us all that sometimes, the best way to rethink computing is to start with a good old-fashioned deck of cards.

5.7 Chapter Summary

This chapter has explored the design, deployment, and evaluation of the Proteus Card Deck, a tangible-digital system that extends and embodies placemaking practices in constrained and mobile environments. By translating earlier conceptual insights into an applied technological artifact, this chapter demonstrates how hybrid systems can respond to spatial, infrastructural, and social constraints through careful material and interaction design. Through iterative

prototyping and empirical evaluation, I showed that tangible-digital systems, when grounded in lived constraint, can offer meaningful affordances for connection, play, and everyday interaction.

This chapter addresses the research question: *How can a tangible-digital system, grounded in the constraints of small and mobile living, be designed to support connection and flexible interaction across contexts?*

1. **C3.1:** I develop the Proteus Card Deck, a tangible-digital card system that directly designs for the spatial, infrastructural, and temporal constraints identified in earlier studies.
2. **C3.2:** Through a field-based evaluation, I show that Proteus enables comparable usability, connection, and coordination to traditional alternatives (physical cards and online games) in both remote and co-located settings.
3. **C3.3:** I provide a set of seven design strategies for hybrid systems (systems that can be used in co-located or remote settings) that operate under constraint.

Through this design-led exploration, the chapter extends the thesis's central theoretical arc in several ways. First, it offers an empirical comparison of Proteus against traditional and digital systems across modalities, socio-economic status, and physical context (i.e., co-located versus remote settings), using validated measures of usability, player experience, and social connectedness. Second, it extends the paradigm of tangible interaction by embedding low-power, networked e-ink displays into a familiar, portable card format—rendering the system programmable, expressive, and physically intuitive for a range of everyday uses. Third, it advances a framework for designing constraint-responsive technologies: systems that explicitly account for limitations in power, space, connectivity, and routine. Finally, it surfaces new affordances—such as flexible embodiment and distributed presence—that support placemaking and collaboration in remote, mobile, and spatially constrained settings.

Positioned within the broader thesis, this chapter completes the arc from conceptual framing (chapter 3) to situated theories (chapter 4) to technological intervention. It shows how the four core elements of placemaking—boundaries, temporality, mastery, and future-thinking—can be embedded in material form. The boundary between physical and digital space becomes programmable; temporality is inscribed into flexible use patterns; mastery emerges as users learn and adapt to the system; and future-thinking is invoked through its portability and re-configurability. Proteus thus embodies the argument that constraint

is not only a design challenge, but a foundation for interaction design that is responsive, situated, and imaginative.

More broadly, this chapter points to the value of tangible-digital hybrids as tools for enabling connection and meaning in everyday contexts that are under-served by conventional interfaces. It invites future HCI work to build on this approach—designing with, rather than despite, constraint—as a means of supporting more inclusive, grounded, and relational forms of technological engagement.

Chapter 6

Design Guidelines and Theoretical Synthesis

This chapter brings together findings from three studies to present a set of design guidelines and theoretical contributions. The studies were conducted in small homes, mobile living contexts, and hybrid system deployments. All focused on how people create and sustain place in situations shaped by limited space, fragile infrastructure, and shared use. The goal is to show how these everyday constraints influence technology use, spatial routines, and interaction design.

The chapter has three parts. First, it shows how practical observations—such as moving furniture, reusing devices, or signalling presence—led to specific provocations and design decisions. Second, it outlines six design guidelines that support technology development in constrained environments. Third, it describes five theoretical contributions that explain how people use technology to manage space, coordinate socially, and imagine future use.

This integration was developed by comparing interviews, observations, and design iterations. Table 6.1 shows how examples from my fieldwork informed both design thinking and technical implementation. These linkages highlight how well-designed hybrid systems can grow from close attention to real-world practices.

	Example from chapter 3	Provocation	Design Consideration	Design Implication
L1	Faith uses YouTube on a tablet to signal spatial "ownership"	Visualize and monitor data to control for root causes of temperature related issues	DC2: Centralized back-end ensures global synchronization and low user burden; DC6: Real-time update logic created perception of system "aliveness"	Systems should support ambient orchestration that minimizes user input and adapts to non-verbal signalling.
L2	Participant cooked in garage using a smaller oven to avoid smell inside home	Technology should enable dynamic homesteading	DC9: Portability; DC10: Multi-application support	Systems must support shifting spatial routines, allowing technology to be reconfigured or moved as needed.
L3	Participant left paper notes and magnets for shared communication due to lack of messaging systems	Allow the reduction and reuse of physical gaming artifacts across multiple games while enriching gameplay	DC7: Individualized card displays support private roles and asymmetric logic; DC10: Multi-application support	Systems should enable informal, modular reconfiguration that supports appropriation and situated reuse.
L4	Participant adjusted lighting and furniture layout depending on guests or time of day	Technology should allow location-based planning and reminiscing about the future	DC3: Performance validated in constrained, real-world spaces; DC6: Real-time update logic created perception of system "aliveness"	Hybrid systems must adapt to evolving temporal routines and contextual configurations of space.
L5	Faith placed food on table as a non-verbal signal for elders to come eat	Visualize and monitor data to control for root causes of temperature related issues	DC2: Centralized back-end ensures global synchronization and low user burden; DC6: Real-time update logic created perception of system "aliveness"	Tools should allow social signalling through shared surfaces without requiring direct interaction or device ownership.
L6	Anya repurposed desk into a dinner table for hosting guests	Technology should enable dynamic homesteading	DC9: Portability; DC10: Multi-application support	Systems should accommodate objects that change roles, supporting multi-use without reconfiguration overhead.
L7	Milo's workspace was used by others for dining, leading to friction	Computing peripherals should be multi-functional and go beyond their intended use	DC1: Familiar multi-card deck structure enables intuitive physical manipulation; DC8: Traditional card form factor reduced onboarding friction	Design must support transient task contexts and overlapping spatial boundaries in domestic life.
L8	Faith described communal table setup designed for aging grandparents	Technology should create a sense of belonging whilst aiding in self-organization	DC2: Centralized back-end ensures global synchronization and low user burden; DC9: Portability	Systems must support inter-generational use and communal access without assuming individual setup or ownership.
L9	Vanlifer slid a table in/out of van to chase sunlight while charging	Technology should function across changing power and surface conditions	DC6: BLE-based wireless sync; DC9: No local software installation	Systems should remain functional across fluctuating infrastructure and mobile contexts.
L10	Players in SRA home experienced turn confusion due to de-synced game states	Shared timing matters more than raw speed in collaborative systems	DC11: Global clock for synchronizing turn order across devices	Temporal consistency is vital for fluency in remote or hybrid collaboration.

Table 6.1: Linkages (L1–L10) showing how empirical practices from chapter 3 mapped to provocations from chapter 4 and system-level design considerations from chapter 5.

6.1 Cross-Study Integration

This section synthesizes findings across the three studies presented in this thesis: technology use in small homes (chapter 3), mobile domestic practices among vanlifers (chapter 4), and the design and evaluation of the Proteus card deck system (chapter 5). These studies were conducted independently but share a common focus: how people appropriate and adapt technology in contexts marked by spatial constraints, infrastructural fragility, and shared routines. This framing builds on foundational work in HCI and environmental psychology that views place as co-constituted through routine, memory, and adaptation (Dourish, 2006; Harrison & Dourish, 1996; Malpas, 2012), as well as feminist and postcolonial critiques that emphasize the centrality of constraint, care, and improvisation in spatial experience (Cresswell, 2014; McDowell & Sundberg, 2001; Suchman, 1987). Table 6.1 summarizes key linkages across these studies, tracing how observations in real places informed critical provocations and ultimately shaped technical design decisions. This table illustrates representative, not exhaustive, trajectories from fieldwork to design. Each linkage was triangulated from empirical observations, thematic coding, and deployment iterations.

In small homes, participants frequently reclassified surfaces and technologies depending on time, activity, or presence of others. For example (Table 6.1, L1), Faith used a running YouTube video on her tablet to signal that food was available, rather than for watching content. She also cooked in the garage using a secondary oven to manage odour and avoid disturbing others (L2). These examples highlight that in such homes, physical and digital artifacts are continuously reassigned functions. This supports Provocation 2 from the vanlife study—that technology use should not assume stable placement or personal control—and informed Proteus design choices such as centralized control (DC2) and automatic updates (DC6). These observations echo work in human-building interaction that emphasizes the configurational and socio-cultural layers of spatial adaptation (Alavi et al., 2019; Becerik-Gerber et al., 2022), as well as prior HCI studies on domestic media routines and improvisation in technology use in the home (Crabtree, 2003; Desjardins & Wakkary, 2016). The implication for design is that systems should not rely on fixed device configurations or ownership; instead, orchestration should be resilient to transient use and shifting physical locations.

Participants also moved devices frequently in small spaces (Table 6.1, L7). Laptops were stored in beds or under tables and pulled out temporarily for specific tasks. This reinforces Provocation 3, which states that peripherals must be multifunctional, not just mobile. In Proteus, this was addressed by maintaining the familiar shape and tactility of cards (DC1, DC5, DC8), ensuring they could be passed, stacked, or held easily in different postures

and locations. These findings align with Oogjes et al. (2018) who explore how devices in alternative homes are stowed, rotated, or temporarily activated based on ongoing routines. The takeaway for other hybrid system designers is that form factor matters: recognizable artifacts support seamless integration into constrained or ad-hoc setups.

Vanlife participants extended these challenges to new domains. At Arizona meetups, one participant described sliding a work table in and out of the van to chase sunlight while charging a device (Table 6.1, L9). The table doubled as a dining surface. Others reconfigured cords and chargers multiple times a day. These examples point to the need for infrastructure-agnostic systems. Proteus addressed this with wireless BLE synchronization (DC6) and no requirement for local software installation (DC9). This reflects observations by Zafiroglu and Chang (2007a) and Ferreira et al. (2019), who describe how mobile and nomadic communities adapt sociotechnical configurations in response to energy, spatial, and environmental constraints. Designers working in mobile or transitional contexts should prioritize systems that remain functional across fluctuating power, surface, and device conditions.

Social and temporal coordination were also fragile. In both vanlife and Mumbai SRA settings, connectivity issues disrupted turn-taking and shared awareness during gameplay (Table 6.1, L10). For example, Tabletop Simulator sessions suffered from de-synchronization, which confused players and broke engagement. This motivated the inclusion of a global state clock in Proteus (DC11) to maintain consistent update timing across devices. These concerns are echoed in distributed interaction research that highlights how latency, asynchrony, and misalignment degrade collaborative fluency (Kohtake et al., 2005; Tolmie et al., 2010). Designers of distributed or hybrid systems should treat temporal drift not only as a technical issue, but as a disruption to social flow. Shared timing mechanisms are critical for preserving coherence during collaboration or play.

Across all three sites, participants frequently repurposed household items as tools (Table 6.1, L3). In small homes, magnets and scraps of paper were used as communication boards. In vans, paper games were invented and modified nightly. These practices map to Provocations 4 and 5 from the vanlife study, which call for systems that enable creative reinterpretation. This was operationalized in Proteus through multi-application support (DC10) and per-card logic assignment (DC7). These findings resonate with the principles of critical and speculative design, which emphasize user appropriation, open-ended affordances, and generativity in design practice (Bardzell et al., 2012; Gaver, 2012; Park et al., 2006), as well as feminist HCI's call for systems that foreground participation, flexibility, and situated agency (Bardzell, 2010).

Another recurring theme was infrastructural fragility (Table 6.1, L8). For instance, in the SRA home, wifi internet, and even cellular hotspot connectivity was costly and unreliable; while in vans, even addresses were transitory. Proteus was designed to accommodate these realities by using a central orchestration model (DC2) that pushed updates to all devices without requiring setup, login, or app installation by the user. This aligns with Provocation 6 from the vanlife study and underscores a broader principle: assume no administrative control, no consistent bandwidth, and no dedicated hardware. These observations are consistent with work in HCI4D and mobile infrastructure studies that reject idealized assumptions about technology access and instead foreground intermittent, shared, and communal use models (Desjardins & Wakkary, 2016; Ferreira et al., 2019; A. Lee, Toombs, Erickson, et al., 2019).

These examples show that constraint is an everyday reality for many users. Rather than abstracting away from these conditions, this thesis treats them as primary design inputs.

6.1.1 Hybrid Placemaking as Situated Practice

In traditional HCI, much research has relied on controlled, lab-based studies that isolate variables to produce generalizable findings. As noted in Desjardins et al. (2019a), this has led to the design of domestic technologies for a stereotypical North American nuclear household, often neglecting diverse spatial and cultural configurations . In MacArthur et al. (2021), the authors have similarly critiqued the field's bias toward sanitized experimental setups, arguing for deeper engagement with the social and material conditions of everyday life. This thesis instead aligns with more recent calls in HCI for research that is situated, embedded, and reflective of everyday complexity (Desjardins & Wakkary, 2016; W. Odom et al., 2012).

Across the three studies, participants created places not by adapting to constraint through spatial improvisation, temporal coordination, and shared technology use. I use "improvisation" to describe emergent, situated adaptation by users in response to contingent needs, as theorized in the critique of plan-based system design in Suchman (1987). In contrast, "orchestration" refers to deliberate coordination architectures embedded within systems to manage synchrony, state, and flow, especially under constraint. In small homes, placemaking emerged from affectively charged routines: family members co-inhabiting rooms managed spatial tension through object positioning, media use, and negotiated silence.

The use of YouTube as a signal (Table 6.1, L1), or re-purposing a garage oven to reduce odour in the main living space (Table 6.1, L2), reflected how digital and material artifacts

were entangled in embodied routines. These findings echo foundational perspectives in geography and architecture that emphasize the co-constitution of space, body, and memory in place-making (Bachelard, 1964; Casey, 1996; Malpas, 2012). These dynamics also align with architectural and humanistic theories that view space as relational and emergent. For example, Lefebvre's theory of the production of space frames spatial experience as continuously shaped through lived routines, representations, and practices (Lefebvre, 2014). Similarly, de Certeau's notion of spatial "tactics" emphasizes how ordinary users appropriate space in improvised, everyday acts that resist fixed planning (de Certeau, 1984). Placemaking in this thesis reflects these ideas: place is not a static container but an outcome of interaction under constraint.

In vanlife, placemaking extended into mobility. Participants reconfigured furniture, chargers, and social arrangements based on sunlight, energy availability, and weather. At van meetups in Arizona, users slid marine-grade tables in and out of vehicles to optimize solar exposure while maintaining a surface for work and dining. These situated configurations resonate with previous studies' observations that mobile domesticity is shaped less by architectural permanence than by affective engagement and infrastructural improvisation Desjardins and Wakkary (2016) and Oogjes et al. (2018).

In the final study, placemaking was evident in how Proteus cards were used across borrowed, improvised, or multi-use surfaces (floors, shared tables, and mobile devices, amongst others). Unlike the earlier studies, Proteus introduced a formal design response to these dynamics. Its affordances made placemaking practices legible, showing how hybrid systems can scaffold flexible spatial routines. Across all settings, place was not the result of fixed configurations, but of continuous negotiation involving digital and analog materials. Designers must therefore treat place not as a stable or personal attribute, but as an emergent, relational achievement, that hybrid technologies must support rather than override.

6.2 Guidelines for the Design of Interactive Technology in Constrained Spaces

This section distills design insights that emerged across the three studies. While Proteus served as a culminating research artifact that made prior findings actionable, it also functioned as a reflexive instrument—testing, extending, and reaffirming the patterns surfaced in earlier fieldwork.

Across the research trajectory, three patterns consistently stood out: *improvisation*, *coordination*, and *constraint navigation*. These patterns appeared in fixed, mobile, and hybrid environments, and were deeply shaped by infrastructural fragility, limited spatial control, and shared use. Participants used technology not only to solve functional problems, but to build rhythm, maintain presence, and make meaning in constrained contexts.

The first two studies surfaced experiential mechanisms such as boundary-making, temporal layering, and material improvisation. Participants negotiated shared zones, coordinated routines with environmental cycles, and built flexible infrastructures around shared objects and temporary contexts. These behaviours reflected an active sensitivity to both physical and infrastructural constraint.

Proteus provided a site to evaluate how those same mechanisms performed when embedded in a designed system. The interactions it enabled reaffirmed earlier findings while offering a space to reflect on how rhythm, control, and flow are mediated through both constraint and affordance. These are further elaborated on in subsection 5.6.1. Across all three studies, users demonstrated that interaction is shaped by technology while being co-structured with the limitations and possibilities of their environments. A visual representation is shown in Figure 6.1 and the sections below outline the list of elements that form a set of design guidelines (middle of figure) grounded in these insights.

6.2.1 Spatial Constraints

Definition: Physical limitations of the environment—size, layout, permanence.

- Support *micro-zoning* (e.g., non-contiguous ownership within shared rooms).
- Enable *temporal reconfiguration* of space (e.g., work and leisure in the same physical zone).
- Allow *multi-functionality* of physical objects (e.g., a dining table also used for work).
- Respect *spatial ambiguity* in shared or mobile spaces.

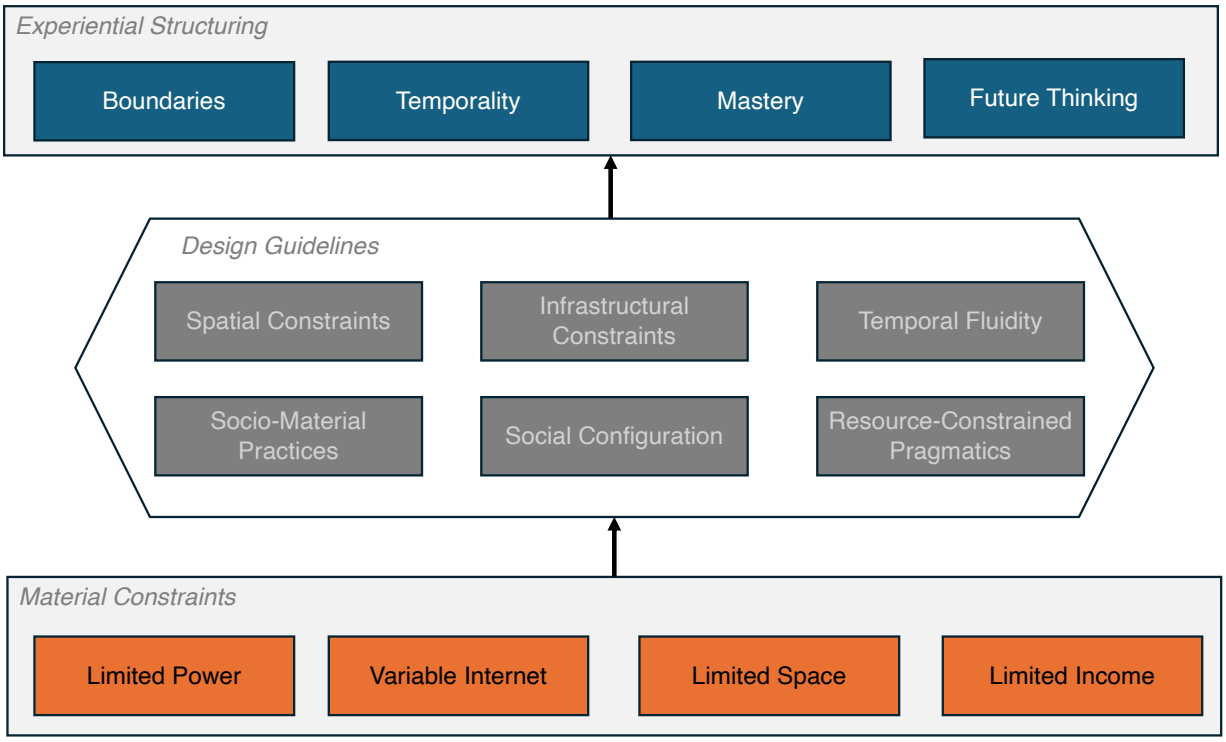


Figure 6.1: Design guidelines to create technology that mediates between material constraints and experiential structuring in constrained environments.

6.2.2 Infrastructural Constraints

Definition: Irregular access to electricity, internet, or fixed installations.

- Operate under *low-power or intermittent power* conditions.
- Function with *intermittent or no connectivity.*
- Avoid assumptions of *installed infrastructure.*

6.2.3 Temporal Fluidity

Definition: Temporal dynamics of how space is used across hours, days, or life stages.

- Facilitate *placemaking routines* that evolve over time.
- Support *anticipatory design* (e.g., preparing space for future imagined use).
- Adapt to *mobility-based temporalities* such as travel schedules or shifting communal use.

6.2.4 Socio-Material Practices

Definition: Embodied, expressive, and relational ways people live with and through objects.

- Enable *embodied interaction* (e.g., physical manipulation of shared tools or systems).
- Preserve *expressive materiality* (e.g., personal decor, spatial markers, DIY builds).
- Leverage *artifacts for boundary-making* (e.g., leaving a light or screen active to signal occupation).

6.2.5 Social Configuration

Definition: Modes of social interaction and coordination in constrained/mobile settings.

- Support *shared presence* across distance or asynchronous time.
- Address *belonging and signalling* in impermanent or rotating arrangements.
- Enable *collective effervescence* (e.g., spiritual or recreational gatherings, shared rituals).

6.2.6 Resource-Constrained Pragmatics

Definition: Limitations related to cost, maintenance, and cognitive or physical burden.

- Design for *affordability* and *repairability*.
- Minimize *setup burden* and enhance *learnability*.
- Optimize *function-per-volume* and *impact-per-dollar*.

6.3 Theoretical Contributions

Across this thesis, I examine how people create place in constrained environments by drawing on four key mechanisms: boundaries, temporality, mastery, and future-thinking. Through three interlinked studies, I explore how individuals use technology to navigate spatial limitations, design for infrastructural fragility, and make meaning in homes that are small, shared, or mobile. The result is a set of theoretical contributions that contribute to both placemaking and design in contemporary HCI.

1. **Boundaries are enacted through technological routines.** In small and shared spaces, place is often carved through light, noise, and digital screens that signal presence or availability. Participants used boundary routines—like setting up tablets, dimming lights, or putting on headphones—to create temporary enclosures and signal spatial ownership. These routines were not abstract markers but deeply embedded in daily practice. I show that boundaries in constrained settings are flexible, negotiated, and technologically enacted.

2. **Temporality structures place through rhythm and repetition.** Participants repeatedly associated place with temporal routines. Whether it was D&D every Saturday or bedtime rituals shaped by screens, technology mediated recurring events that grounded participants in time. This insight recasts place not only as spatially bounded, but temporally anchored: created through repeatable, situated rhythms that organize memory, interaction, and coordination.

3. **Mastery emerges through autonomy and competence.** Participants used digital and material tools to gain mastery over their space, often in subtle and affective ways. Mastery was expressed not just in control, but in the ability to adapt—arranging furniture for flexibility, using appliances that reduced cognitive load, or finding joy in minor reconfigurations. Across studies, I trace how technology supports both autonomy (control over environment) and competence (confidence in use), turning constraint into a catalyst for personal expression.

4. **Future-thinking is embedded in placemaking practices.** Participants designed spaces not just for the present, but with imagined futures in mind—partners not yet moved in, jobs not yet started, or aspirations not yet fulfilled. Spatial arrangements were often symbolic gestures toward anticipated life changes. These practices, I argue, are not exceptional but fundamental to how place is shaped over time. Future-thinking

ties together temporality, aspiration, and spatial imagination into a cohesive force for placemaking.

5. **Improvisation and orchestration are co-constitutive.** The Proteus study adds a systems-level perspective by showing how tangible-digital technologies can support both improvised use and centralized coordination. I frame this as a dialectic between improvisation (adaptive use, local decisions) and orchestration (system-wide consistency, remote control). Rather than resolving this tension, Proteus embraces it—offering asynchronous updates, flexible form factors, and infrastructure-independence as ways to sustain both sides of this interaction logic.

These five contributions move beyond individual study findings to form a conceptual framework that links the phenomenology of small homes, the speculative designs of mobile living, and the material realities of tangible systems. Together, they demonstrate that place is a relational construct—shaped through negotiation, timing, skill, and projection. This framework provides the field of HCI with a deeper understanding of how technology mediates place when space, infrastructure, and stability cannot be taken for granted.

6.4 Summary

This chapter articulated six cross-cutting design guidelines and five theoretical contributions that together extend the thesis' foundation into a broader scholarly conversation. Together, these contributions advance a broader shift in HCI—from designing for stable, idealized contexts to responding to the contingencies of lived experience. When embedded in constraint, hybrid systems can support not only functional utility but also resilience, social coordination, and the creation of place.

Chapter 7

Discussion and Conclusion

7.1 Research Contributions

The primary contributions through this thesis are: RQ1: How can technology mediate a sense of place for people living in small spaces? (chapter 3)

1. **C1.1:** I provide a deeper theoretical understanding of technology-mediated placemaking in small domestic environments by identifying four core elements (boundaries, temporality, mastery, and future-thinking) that enable the emergence of a multiplicity of places within a physically constrained space.
2. **C1.2:** I challenge assumptions in HCI that meaningful placemaking requires expansive environments, and instead demonstrate how users transform spatial limitations into opportunities for rich, layered place-experiences through creative and affective uses of everyday technology. This offers design guidance for technologies that better support co-located and remote life in compact, multi-use spaces.

RQ2: How is technology currently used by people living the vanlife? (chapter 4)

1. **C2.1:** I identify eleven design provocations that articulate how technology can be reimagined to support the subjective well-being of vanlifers, offering the HCI community actionable directions for future critical and speculative design.

2. **C2.2:** I develop a situated understanding of the constraints and values that shape technology use in the vanlife community, including concerns around affordability, energy efficiency, modularity, and infrastructural independence.

RQ3: How can a tangible-digital system, grounded in the constraints of small and mobile living, be designed to support connection and flexible interaction across contexts? (chapter 5)

1. **C3.1:** I develop the Proteus Card Deck, a tangible-digital card system that directly designs for the spatial, infrastructural, and temporal constraints identified in earlier studies.
2. **C3.2:** Through a field-based evaluation, I show that Proteus enables comparable usability, connection, and coordination to traditional alternatives (physical cards and online games) in both remote and co-located settings.
3. **C3.3:** I provide a set of seven design strategies for hybrid systems (systems that can be used in co-located or remote settings) that operate under constraint.

7.2 Discussion

The purpose of this chapter is to synthesize findings across the three core studies and situate them within broader conversations in Human-Computer Interaction. While each study offered its own contribution, this chapter integrates them into a coherent account of how people make place under conditions of infrastructural and spatial limitation. In doing so, I aim to articulate a cumulative research trajectory that advances placemaking as both an analytic and design-relevant concept in HCI.

Cross-Study Trajectory

The trajectory across studies reflects a movement from interpretation to intervention. The first study adopted a descriptive, phenomenological orientation: I sought to understand how people create a sense of place in constrained homes, without presuming technological goals. The second study expanded this frame through a mobile lens, using critical ethnographic

methods to identify how constraint, mobility, and improvisation intersect in vanlife communities. The third study translated these insights into design by building and evaluating Proteus, a tangible-digital system explicitly tailored to the demands of spatially constrained, hybrid contexts.

This trajectory also mirrors my methodological development—from passive interpretation to co-creation and deployment—and a growing commitment to situating design within real infrastructural conditions. Each phase built on the previous one, with increasing levels of abstraction, scale, and intervention. The sequence reflects a recursive process of theory-building through practice and a sustained interest in how constraints shape, rather than inhibit, creative human-technology relations.

Key Integrative Themes

Three integrative themes connect the studies:

- **Placemaking as Practice:** Across all contexts, users enacted a sense of place through boundary-setting, temporal structuring, and sensory attunement. This was visible in routines, layout adaptations, and symbolic markers. Placemaking emerged as an ongoing negotiation, not a stable outcome.
- **Constraint as Generative:** Constraint was not merely a problem to be solved, but a design condition that revealed new affordances and relational practices. In small homes and vans, constraint prompted spatial improvisation, infrastructural workarounds, and affective resourcefulness. Proteus was explicitly designed to operate within such constraints.
- **Hybrid Systems for Situated Living:** The final study demonstrated that hybrid systems can support placemaking when they are responsive to the rhythms, limitations, and practices of everyday life. Proteus provided flexible orchestration and tangible affordances, illustrating how hybrid interaction can restore social presence and coordination in spatially fragmented contexts.

These themes underpin a broader theoretical and design contribution: that technologies should not aim to erase constraint, but work with it—supporting users in their everyday acts of making place.

7.3 Cross-Cutting Tensions

Mobility vs. Infrastructure Dependence

Across the studies, I repeatedly encountered a tension between the promise of mobility and the constraints of infrastructure. In the vanlife study, participants described mobility as a core value—linked to freedom, minimalism, and self-determination. However, sustaining this mobility required continuous infrastructural negotiation: access to power, water, cellular connectivity, and safe parking. Similarly, small space dwellers in fixed homes articulated desires for flexibility and movement, but were often tethered to spatially fixed utilities and landlord-imposed constraints.

This tension shaped the design of Proteus. I aimed to create a system that was mobile in form and orchestration, but also resilient to infrastructural variability. Designing for mobility thus meant designing for independence from stable infrastructures, while still offering reliable, socially meaningful interaction.

Autonomy vs. Interdependence

A second tension emerged between autonomy and interdependence. Participants in all studies expressed a desire for self-sufficiency—whether in managing small homes, navigating vanlife, or using hybrid systems in remote contexts. Yet their practices revealed deep interdependence: on community knowledge, shared digital resources, and mutual support for repairs, logistics, or connectivity.

Rather than treat autonomy and interdependence as oppositional, I came to understand them as co-constitutive. Technologies that support constrained living must enable both: the feeling of control and competence, and the ability to reach out, synchronize, and rely on others. Proteus, for example, allowed users to locally manage their decks while remaining socially coordinated with distributed collaborators.

Private Modularity vs. Social Signalling

In all three studies, modularity and reconfiguration were central to participants' spatial and technological practices. Yet these modifications were not purely functional or private. They

also served as acts of social signalling: communicating competence, aesthetic preference, and lifestyle identity.

In vanlife, spatial modularity was often aestheticized through social media, reinforcing norms of creativity and minimalism. In small homes, layout decisions conveyed boundaries, roles, or aspirations. Proteus users, too, reconfigured their card arrangements to express strategy or presence. These examples highlight that even in highly modular or constrained contexts, people use design not only for utility, but to communicate socially situated meaning.

Situated Specificity vs. Transferability

A final tension concerns the specificity of findings versus their applicability. Each study was grounded in a particular spatial, cultural, and infrastructural context. The placemaking practices I observed in vans or small apartments may not directly translate to other settings. Yet, the analytic lenses—placemaking, constraint, orchestration—appear to hold across contexts.

Rather than seek universal principles, I frame these contributions as transferable in orientation rather than in form. The goal is not to provide a one-size-fits-all solution, but to offer concepts, heuristics, and design approaches that others can adapt to their own infrastructural and spatial conditions. Transferability thus lies not in replication, but in resonance.

7.4 Meta-Reflections on Research Approach

Methodological Pluralism

I approached this thesis with a commitment to methodological pluralism, guided by my positionality as a pragmatic researcher with professional experience in product development and applied systems. Rather than follow a single methodological tradition, I selected tools best suited to the questions and constraints of each study. I combined descriptive phenomenology, reflexive thematic analysis, ethnographic observation, and Research through Design (RtD) to explore different layers of lived experience and system design. This pluralist

stance aligns with calls in HCI to tailor methods to context (Creswell & Poth, 2016) and reflects the epistemic openness of RtD as a knowledge-generating activity (Gaver, 2012; Zimmerman et al., 2007). My decisions were consistently grounded in practical relevance and analytic utility, not methodological orthodoxy.

This methodological pluralism unfolded in a structured arc across the three studies. The first study used descriptive phenomenology to surface the lived experience of placemaking in small spaces, emphasizing experiential fidelity and reduction. The second extended this foundation through reflexive thematic analysis and multi-modal ethnography to examine placemaking in mobile, resource-constrained contexts. The third transitioned into a constructive mode through RtD, developing and evaluating a hybrid system grounded in empirical insights from the earlier studies. While each method was appropriate to its respective research question, this trajectory also reflects a coherent knowledge strategy: from describing phenomena, to interpreting situated practices, to materializing knowledge in artefactual form. This progression mirrors shifts in epistemic goals, from understanding *what is*, to exploring *what matters*, to probing *what might be*. Although each study was methodologically self-contained, earlier findings recursively informed design decisions and evaluation criteria in later phases. This sequencing demonstrates how I layered qualitative and constructive methods to generate practice-relevant contributions.

Temporal and Spatial Situatedness

All of the research reported here was embedded in concrete temporal and spatial contexts. I used diary studies, in-situ interviews, and field observations to surface how people experience and respond to everyday rhythms, material shifts, and spatial transitions. My methods were informed by and extended work in temporal design and infrastructural rhythm in HCI (Bliss, 2016; Chunhui et al., 2013; W. T. Odom et al., 2014, 2018). Rather than treat time and space as background variables, I treated them as central analytic constructs. The goal was to understand how interaction unfolds not just in abstract systems but in lived, temporally situated space.

Geographic Specificity

I chose to conduct fieldwork in geographically specific, infrastructurally diverse sites—ranging from microhomes in Ontario to vanlife gatherings across North America and informal settlements in Mumbai. These contexts were analytically central to the framing of constraint

and placemaking. I selected them because they surfaced tensions—between mobility and infrastructure, constraint and aspiration—that are underrepresented in mainstream HCI literature. These environments pushed me to think beyond dominant assumptions about stability, bandwidth, and space, and informed the design of systems like Proteus. My focus on geographic specificity aligns with ongoing calls in HCI to attend to infrastructural realism and spatial justice (Desjardins & Wakkary, 2016; Ferreira et al., 2019).

Qualitative Focus

I grounded this thesis in qualitative inquiry because it allowed me to stay close to user experience and surface patterns of meaning, adaptation, and improvisation. I used semi-structured interviews, diary methods, and field observations to access everyday routines and interpretations. These methods supported an interpretive approach aligned with third-wave HCI's emphasis on experience, embodiment, and practice (Gunkel, 2018; Harrison et al., 2007). I drew on descriptive phenomenology (Giorgi, 2009), reflexive thematic analysis (Braun & Clarke, 2006, 2021), and trustworthiness frameworks (Nowell et al., 2017) to analyze the data. My qualitative orientation reflected both my pragmatic stance and my belief that understanding everyday life is critical to designing meaningful systems—especially under conditions of spatial and infrastructural constraint.

7.5 Limitations and Considerations

Limitations

In this thesis, I examined how people make meaningful use of space in small or mobile settings. Two of the studies focused on everyday life in small homes and vans, and the third involved the design and deployment of a new interactive system—Proteus. While I believe these studies offer valuable insights, I also recognize several important limitations in what I was able to cover.

- **Voluntariness of Constraint:** All participants in the studies chose to live in small or mobile spaces. Their decisions were often driven by lifestyle values, remote work preferences, or the cost of urban housing. I did not include participants who were forced into spatial constraint by poverty, displacement, or structural uncertainty. As a result, these findings do not fully represent the experience of involuntary constraint.

- **Infrastructure Preconditions:** Everyone I spoke with had some access to electricity, mobile phones, and internet connectivity. I did not study contexts where such infrastructure is completely absent—such as emergency shelters, rural villages, or post-disaster sites. The design implications therefore depend on at least a minimal level of infrastructural access.
- **Temporal Duration:** All studies were short-term. I was able to capture snapshots of everyday routines, spatial adaptations, and interactions with technology, but I did not study how these practices evolve over longer durations. I cannot speak to how technologies like Proteus might change in use over months or years.
- **Scale and Distribution:** I deliberately focused on small cohorts and deep qualitative engagement. I did not examine large-scale system deployments, complex coordination across organizations, or infrastructural integration in institutional settings. These findings are not intended to generalize at scale but to offer situated insight.

Analytical Boundaries

In this thesis, I adopted a pluralistic methodological stance—drawing on phenomenology, reflexive thematic analysis, ethnography, and Research through Design (RtD)—to examine how individuals negotiate placemaking within spatial and infrastructural constraint. These approaches were selected to yield valid, situated insights into context-specific practices. While appropriate to the aims of this work, these decisions shaped the interpretive boundaries of my analysis. Below, I outline six such boundaries that delimit the analytical scope of the thesis.

- **Contextual Stratification over Comparative Analysis:** While all three studies engage with the theme of constraint, they were not structured for empirical comparison. Each was designed as a self-contained inquiry, embedded in a particular socio-technical context: urban small spaces, vanlife, and hybrid system deployment. I do not claim transferability across these settings; instead, I treat them as parallel articulations of how spatial, social, and technical constraints are navigated in practice.
- **System Evaluation Focused on Use Qualities:** Proteus was developed and evaluated as a research artifact rather than a production-ready system. I focused on qualities of interaction, user experience, and mediated social connection. I did not assess technical dimensions such as fault tolerance, power efficiency, or system stability

under load. These metrics—while important for real-world deployment—fall outside the scope of this thesis, which positions Proteus as a generative tool for surfacing design insights and not a benchmarked technical solution.

- **Selective Treatment of Demographics Across Studies:** In the Proteus study, I statistically modelled the effects of participant demographics—including gender, income, education, and age—and found no significant differences across key measures. However, in the earlier qualitative studies, demographic variables were not consistently analyzed or foregrounded in thematic interpretation. I did not examine how intersecting identities may have shaped spatial or technological practices in those settings. While demographic data was collected throughout, a deeper intersectional analysis remains an opportunity for future research.

- **Exclusion of Longitudinal Engagement:** None of the studies included long-term participant tracking or repeated engagements over extended timeframes. While diary methods and field observations provided temporal slices of activity, I did not examine how placemaking evolves with prolonged exposure to technological or spatial change. This constrains the analysis to snapshots rather than extended trajectories.

- **Material Constraints of Research Artifacts:** The material form of Proteus was limited by available fabrication resources. The system used commercial e-ink displays embedded in 3D-printed housings, which constrained interactivity to pre-scripted, monochrome updates. Real-time input and expressive visual interaction were not feasible within the scope of this implementation. These constraints shaped how participants engaged with the system and limit conclusions about its general usability in more richly interactive contexts.

- **Cross-Cultural Scope Not Systematically Analyzed:** The first two studies were conducted in North America, with participants from the United States and Canada. The final study, which evaluated the Proteus system, included participants from India. I did not, however, design the research to explicitly compare cultural or geographic contexts. Cross-cultural variation in interaction norms, design expectations, or social interpretation was not foregrounded in the analysis. While the inclusion of multiple regions broadens the empirical base, cultural specificity was not an explicit analytical focus of this thesis.

- **Tension Between Generative Intent and Evaluative Framing:** While the thesis adopts an RtD approach aligned with Gaver's call for provisional and aspirational theory (Gaver, 2012), it also incorporates structured instrument-based evaluation (e.g.,

PXI, UMUX-LITE). This dual stance may introduce tension between open-ended, interpretive exploration and the empirical framing of results. Future work could more explicitly position evaluation as annotation rather than validation.

- **Potential Underuse of Annotated Portfolios:** The thesis presents Proteus as a culmination of prior fieldwork, yet stops short of developing a broader annotated portfolio of related design artifacts. The contribution might be strengthened by elaborating Proteus in relation to sibling explorations or alternative instantiations along the same conceptual axes.

These analytical boundaries reflect the methodological and practical contours of this research. Rather than limiting its value, they clarify the intended contribution: to offer a grounded, multi sited account of how people design, adapt, and make place within the margins of infrastructure and space. The insights generated here are intended to be conceptually portable and design-relevant.

7.6 Positioning within HCI and Future Directions

Contribution to the Design of Interactive Technology

In this thesis, I contribute to the design of interactive technology by framing constraint not as an obstacle to be overcome, but as a foundational condition that shapes how people engage with technology in their everyday lives. Unlike dominant HCI paradigms that often presume stable infrastructure, personal ownership of devices, and spatial permanence, I foreground how people navigate intermittent connectivity, shared or mobile environments, and infrastructural uncertainty. These findings align with research in mobile domesticity and HCI4D that challenge universalist assumptions and instead emphasize situated adaptation and infrastructural improvisation (Desjardins & Wakkary, 2016; Ferreira et al., 2019).

Through three studies, I advance interaction design in constrained contexts in several ways: first, through phenomenological accounts of technology-mediated placemaking in small homes; second, through critical-ethnographic engagement with vanlife communities; and third, through the Research through Design development of Proteus—a hybrid card system designed for use in constrained domestic and remote environments. This work builds on RtD traditions that treat artifacts as epistemic tools for inquiry and iterative design (Gaver, 2012; Zimmerman et al., 2007).

In working within constraint, I observed a recurring tension between improvisation and orchestration. In all settings, participants reconfigured routines, devices, and spaces to create meaningful interactions and maintain coordination. I designed Proteus to address these needs through infrastructure-independent orchestration and tangible-digital flexibility (Kohtake et al., 2005). The findings demonstrate that hybrid systems situated in constraint must support both emergent behaviours and reliable synchrony—extending current approaches in tangible interaction and hybrid collaborative systems (Kirshenbaum & Robertson, 2018; Rogers et al., 2004).

Placemaking as a Lens in HCI

I introduce placemaking as both a conceptual and methodological lens for HCI. While much of traditional domestic computing has focused on function and automation, I argue that placemaking draws attention to how people generate meaning and identity within constrained, shared, or mobile spaces. My theoretical foundation draws from phenomenology, where place is seen as an emergent structure shaped by embodied perception, temporality, and material engagement (Casey, 1996; Malpas, 2012). Within HCI, this approach aligns with Dourish's notion of place as interpretively produced, rather than geometrically fixed (Harrison & Dourish, 1996).

Placemaking enabled me to re-frame familiar design concerns: shifting from spatial coverage to spatial negotiation; from device provision to routine construction; and from seamlessness to lived improvisation. In both the vanlife and small space studies, I observed placemaking through affectively charged routines, material adaptations, and hybrid digital-physical setups. These practices resonate with feminist and critical geographies that foreground power, agency, and care (Cresswell, 2014; McDowell & Sundberg, 2001; Tieken, 2010), and they extend participatory and critical HCI traditions that value lived experience, appropriation, and situated knowledge (Bardzell, 2010; Suchman, 2007).

I see placemaking as offering HCI a conceptual bridge across a range of emerging contexts: from micro-housing and shared co-living to post-disaster shelters and mobile, nomadic environments. It provides both an interpretive grammar for analyzing how space becomes meaningful, and a generative heuristic for designing with—not despite—constraint.

Avenues for Further Research

Three future directions emerge from this thesis:

- **Longitudinal and Multi-modal Placemaking Studies:** Future work should trace how spatial practices evolve over time, especially in households experiencing transitions (e.g., seasonal work, migration, aging). This could involve diary-based or sensor-augmented methods to capture shifts in spatial routines and technological adaptations.
- **Technological Support for Fictional Futures:** Building on the speculative provocations surfaced in the vanlife study, future research can explore how constrained users envision alternative technological futures. Approaches like speculative design and fictional inquiry offer tools for engaging users in imagining and co-designing systems responsive to their aspirations (Gaver, 2012; Lindley & Coulton, 2016).
- **Placemaking in Precarious Contexts:** Beyond vans and micro-homes, the principles of constraint-based interaction can extend to humanitarian, post-disaster, or rapidly urbanizing settings. These environments often lack persistent infrastructure but exhibit high degrees of spatial creativity and social coordination. HCI has a critical role to play in developing low-footprint, flexible systems that align with these material and social realities (Desjardins & Wakkary, 2016; Oogjes et al., 2018).

Together, these directions aim to expand the scope of HCI's engagement with contemporary dwelling, infrastructural constraint, and the lived experience of spatial limitation using placemaking as both a diagnostic lens and a generative design construct.

7.7 Conclusion

In this thesis, I investigated how people adapt technology and spatial practices to create livable and meaningful environments under conditions of constraint. Through three studies—focused on small domestic spaces, mobile vanlife, and the design of a hybrid tangible system—I examined how limitations in space, power, connectivity, and infrastructure shape everyday interaction and technological use.

My findings show that constraint is a structuring condition that actively shapes how people live, work, and design. In small homes, residents reorganized space and repurposed technologies to support everyday life within physical and infrastructural limits. In vanlife, participants faced compounded constraints but responded with improvisation, community support, and inventive configurations of conventional technologies. Building on these insights,

I designed and evaluated the Proteus card deck—a low-power, modular system—that demonstrates how constraint-responsive technologies can support social interaction in remote and mobile settings.

Across the studies, three key themes emerged: the everyday role of improvisation in adapting technology; the potential of hybrid and modular systems to support continuity across changing contexts; and the situated enactment of place through interaction. These insights extend current understandings of interaction in constrained, transitional, and hybrid environments.

This thesis makes several contributions. Conceptually, it extends the re-framing of constraint as a productive and ongoing condition for design. Practically, it offers principles for designing systems that are modular, low-power, and adaptable to real-world limitations. Methodologically, it demonstrates how phenomenology, field-based design research, and Research through Design can be combined to study lived experience in non-standard contexts.

Overall, I argue that HCI must broaden its scope to include settings where stability, infrastructure, and space cannot be assumed. Designing for constraint is not only relevant for edge cases, but increasingly for mainstream users navigating housing uncertainty, remote work, and mobile living. This work provides a foundation for creating systems that are robust, flexible, and responsive to the realities of constrained life.

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Glossary

HCI The research field of Human-Computer Interaction 49, 53, 63

Human Building Interaction A field of study that explores the connections between humans and the buildings they occupy 63

vanlife A modern nomadic movement where members of the community live and work in converted commercial vans xix, 4, 12, 68–70, 72, 78, 79, 84, 85, 87, 89–91, 94, 95, 97–99, 168

Vanlifer A person who lives the vanlife 69

vanlifer A person who lives the vanlife 12, 68–72, 77–80, 83, 85–87, 89–93, 95, 97–99, 167