Cocreation In Context: An Evaluation of Participatory Technology Design for Enhancing Community Engagement with Public Spaces

Anna R. L. Carter
[redacted]

Submitted to Swansea University in fulfilment
of the requirements for the Degree of Doctor of Philosophy

Swansea University
Prifysgol Abertawe

Department of Computer Science
Swansea University

April 5, 2024

“The greatest teacher, failure is.”
– Yoda, Episode VIII

Declaration

This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ....[redacted]................... (candidate)

Date ....

Statement 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by cited giving explicit references. A bibliography is appended.

Signed ....[redacted]................... (candidate)

Date ....

Statement 2

I hereby give my consent for my work, if accepted, to be archived and available for reference use, and for the title and summary to be made available to outside organisations.

Signed ....[redacted].................. (candidate)

Date ....

Statement 3

The University's ethical procedures have been followed and, where appropriate, that ethical approval has been granted.

Signed ....[redacted].................. (candidate)

Date ....

Abstract

The integration of interactive public displays into urban regeneration is a dynamic research area, extending beyond traditional screens to offer accessible, alternative interactions in outdoor settings. These displays not only provide users with a wealth of information but also provide in depth emotionally charged interactions, evoking nostalgia and re-engaging people with a space.

In the ever-evolving urban landscape, this thesis addresses the challenges posed by adapting spaces and the effect this can have on the way people engage with these spaces, highlighting a need for innovative interventions to help communities to remain engaged with their local spaces. This work centres on integrating interactive public displays into urban environments, with a primary focus on evoking nostalgia (an affectionate feeling for the past [54]) and topophilia (emotional connections to a space [271]).

This thesis embarks on a journey, engaging a diverse range of users, including designers, children, regeneration experts, and community members. It commences with a nine-month deployment of a tangible embedded interface into a dynamic urban context, receiving over 10,000 session interactions. This real-world experience shows the importance of incorporating aspects of cultural heritage and immersive content into informative designs. Subsequently, the journey explores uncharted territories, navigating the landscape of cocreation methods and collaborative efforts, culminating in the development of a multisensory installation, that integrates olfactory, auditory, and visual elements. This exploration delves into the intricacies of community engagement, technology integration, nostalgia, and the dynamics of urban regeneration. As these chapters unfold, valuable lessons are drawn from field experiences, guiding a reflective journey through the design process with an aim to advance interactive public display creation by addressing gaps in design tools and methodologies. Resulting in feature requirements for an overarching master design suite, this contribution advances the field of HCI within urban regeneration. It brings together valuable lessons learned and recommendations for integrating novel multimodal installations of the future, while also addressing the need for adaptable tools to facilitate their design. This holistic approach underscores the transformative potential of technology in shaping urban environments and community engagement.

Acknowledgements

I would like to express my gratitude to the many people and organisations who have supported me throughout this PhD.

First, I would like to thank Jennifer Pearson and Matt Jones, my supervisors. I thank them both for their guidance, encouragement, and wisdom which pushed me forward.

I would like to thank Alan Dix and Miriam Sturdee, my mentors for their collaborative spirit and enrichment of this research, broadening my horizons. To my fellow collaborators a big thank you for your support and input in shaping the direction of this research, with special thanks to Gavin Bailey, Marianna Obrist, Elizabeth Churchill and Tiffany Knearem for you ongoing support.

To my funding support EPSRC and Swansea Council and in particular Jonathan Hicks and Spencer Winter, I would like to thank for their shared expertise and vision throughout this process.

To my friends and fellow CDT members at Swansea University who made my time completing this PhD so enjoyable. Thank you for the support, coffee breaks, much needed distractions to chat and encouragement. You made this journey much more enjoyable. To my family, I am profoundly grateful. Your belief in me has been a source of strength.

Lastly, to my amazing husband, Kyle, who has been my rock, my confidant, and my biggest cheerleader, I can never thank you enough for your unwavering support and understanding. Your love and encouragement sustained me through every challenge.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

In a time marked by urban revitalisation and technological advancements in 2019, Swansea Council embarked on a journey to revamp Swansea city centre. This extensive project, supported by the substantial £1.3 billion City Deal Investment Program [59], aimed to breathe new life into the heart of the city. While involving users in the overall design of the urban regeneration was of interest to the author, this was not possible as the building was already underway when the PhD began. However, as stakeholders in the author's work at the EPSRC Centre for Doctoral Training (CDT) [276], Swansea Council provided the researcher with three key objectives to enhance the redevelopment: develop, implement, and evaluate interactive public installations with diverse modalities, explore ways of providing connection to the space through coherent digital interactions, and ensure these efforts were rooted in community engagement and cocreation. This urban revamp took place against a backdrop of shifting urban dynamics, heightened by the rise of online alternatives impacting traditional activities like shopping and office work [221, 225, 227], and the challenges imposed by the global COVID-19 pandemic. These factors limited activities that traditionally drew people to cities [37, 235], making the demand for innovative solutions to rejuvenate urban spaces evident. Swansea Council's revitalisation initiative for the city centre exceeded mere redevelopment; it was a response to these changing urban landscapes, a step toward a more vibrant, community-centred, and technologically empowered future.

Therefore, this thesis explores how cocreated multimodal public installations could help people to re-engage with Swansea city centre - a journey at the intersection of urban design, participatory cocreation, and novel technology integration. Here, the city centre is not just a backdrop of the work but an active participant in the narrative, a canvas upon which innovation, inclusivity and community engagement unfold. Fundamentally, this thesis tackles with the question: How can urban designers, researchers and planners effectively harness the power of cocreation and technology within their unique contexts to invigorate city centres? The answer does not lie in a single path but in a journey of intensive participation with a wide range of users, creation and iteration of multiple novel displays, rigorous evaluation, and the proposal of tools that can transform the way designs are envisioned and technologies are experienced within our urban environments.

Some of this work was initiated during the onset of the COVID-19 pandemic and, consequently, had to adapt and align with these challenges (see Thesis Timeline 1.1). The evolution of Swansea's urban landscape, fuelled by the extensive redevelopment efforts and the challenges brought on by the pandemic, created a need to explore innovative approaches to ensure community engagement, enrich cultural heritage, and harness the potential of technology. Additionally, this thesis studies the intersection between nostalgia, an effectionate feeling one has for the past [54] and topophilia, a concept that explores the emotional bonds and connections individuals form with their surroundings [271]. While these notions have been widely examined in various disciplines, its application within the context of interactive, outdoor, multisensory urban installations represents a captivating dimension. Understanding how topophilia and nostalgia can influence people's relationships with their urban environments is particularly pertinent during the transformations occurring in Swansea city centre. The study of these concepts in this context especially while undergoing major redevelopment offers a perspective on how the design of these installations can authentically resonate with the community's emotional connections to their city centre spaces. It also highlights the potential for these installations to foster a sense of belonging, ownership, and cultural identity within a changing urban landscapes. By unravelling the intricate dynamics of nostalgia and topophilia, this research contributes to the enrichment and sustainability of city centre environments.

Furthermore, this thesis explores the development of interactive, outdoor installations that embrace multiple modalities, such as scent, audio, lighting, and elbow interactions, to prioritise inclusivity. The project's scope extends to working with individuals of diverse abilities, encompassing the visually and physically impaired, as well as children, to ensure the accessibility and enjoyment of these installations for a wide range of users. Iterative design processes will be incorporated, allowing for ongoing refinement and optimisation based on real-time feedback. One intriguing aspect of this research is the exploration of scent within a city context, introducing a unique layer to the multisensory experience of these urban installations. This inclusion of scent within a city deployment represents an unexplored experience in the field.

Figure 1.1, presents a thesis timeline, encapsulating the entire doctoral research project. This timeline is segmented into the four contribution chapters, encompassing interactive elbow-based installations, cocreation workshops, multisensory urban installations, and the blueprint for the redesign of design tools. Moreover, the significant impact of COVID-19 regulations in Wales, UK during this research period is indicated, signifying the adaptability required to overcome these challenges. Furthermore, this figure highlights collaborative endeavours that extend beyond the scope of this thesis but were completed within this time frame and served as extensions of the work described here. These collaborations underscore the interdisciplinary nature of the research and its promising prospects for future exploration. Additional opportunities were also incorporated, highlighting the uniqueness of the CDT program, which facilitated lab visits (Prof. Marianna Obrist Multisensory Lab, UCL) and engagement visits with stakeholders (Elizabeth Churchill, San Francisco, Google and Tiffany Knearem, Boston, Google). The program also provided support for the organisation and setup of conferences (Festival of Ideas, EICS), as well as retreats and launchpad crucibles to enhance cross-cohort integration, collaboration and improve research skills.

In the next section, this thesis will explore its objectives, guiding the journey towards a vibrant, inclusive, culturally rich urban future, empowering communities, engaging with cultural heritage, and enhancing urban engagement. Each chapter reveals insights and innovations uncovering the potential within urban centres. The research extends beyond this thesis, inspiring those envisioning revitalised city centres.

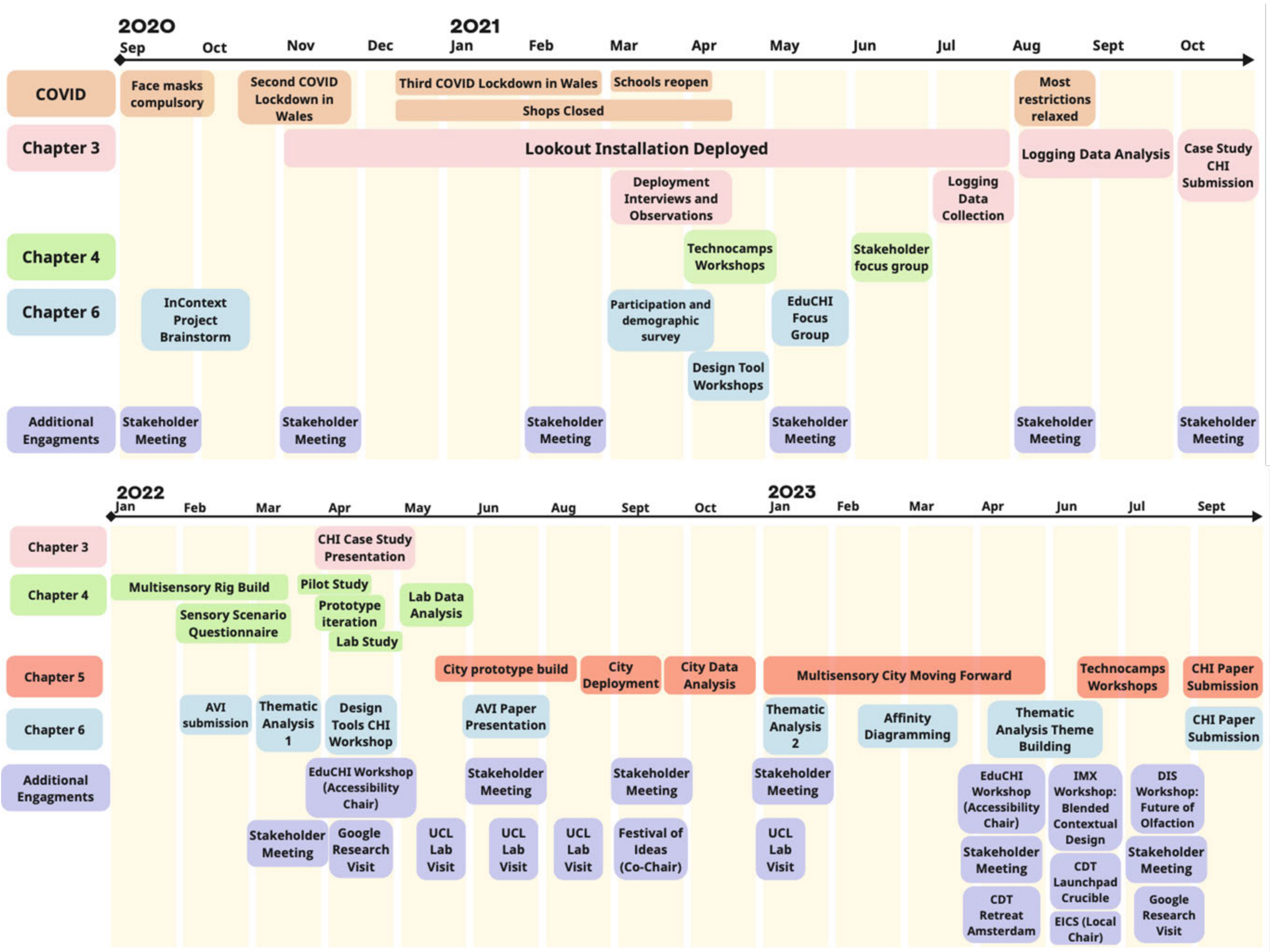

Figure 1.1: PhD Timeline (2020-2023): This timeline summarises the four contribution chapters of the PhD, alongside COVID-19 regulations and supplementary activities encompassing lab visits, stakeholder engagement, publications, and Centre for Doctoral Training (CDT) events.

1.1 Research Objectives

Based on the research gaps identified in the section above, this work had an overall aim to advance the field of alternate modality technology design for urban regeneration and community engagement by investigating, developing, and evaluating innovative interactive installations, tools, and methodologies. This thesis has addressed these challenges through the following:

1. ***To investigate and demonstrate the pivotal role of user feedback and active participation in the cocreation process of urban regeneration projects***

   Exploring the significance of user feedback and active participation in the cocreation process is paramount in the realm of interactive technology design [161,185,230]. It places the user at the centre of innovation, ensuring that designs are not just technologically advanced but also resonate with the needs and desires of the community they serve. User feedback during cocreation also fosters a sense of ownership and empowerment amongst all the cocreators, cultivating a collaborative spirit that enriches the final product. Moreover, contributing to the creation of more inclusive, user-centric, and culturally relevant technologies, enhancing their effectiveness and impact within urban regeneration settings. Through this approach inclusivity has been at the forefront, trying to ensure that marginalised voices were heard in the development of interactive technologies.

2. ***To conceptualise, design, and deploy novel interactive installations, that leverage diverse sensory modalities to create immersive and captivating experiences***

   In today's society, community ties can erode, particularly during urban redevelopment, a process currently underway in Swansea city centre. Investigating how technology can fast-track the process of reconnecting people with each other and their changing environments, can reinvigorate community bonds. Developing and designing interactive public displays with alternate modalities (moving away from screens) for urban regeneration is an endeavour that stands to benefit cities and communities in numerous ways, from enhancing public spaces and community bonds to promoting innovation and cultural vibrancy. Interactive displays not only offer engaging experiences but also bridge the gap between the physical and digital worlds, making cities more inclusive and technologically advanced.

3. ***To assess the real-world impact and effectiveness of alternate modality urban installations in city centre environments***

   Do interactive public displays have the potential to breathe new life into urban areas undergoing regeneration? Can they help people to re-engage with these spaces? The aim is to, leverage the tools of empirical analysis and user feedback to uncover insights, confront challenges, and distill best practices. Also seeking to answer the question - how can these interactive displays offer opportunities for residents and visitors alike to connect, share experiences, and engage in communal activities? With the ultimate goal of strengthening the social fabric of the urban communities.

4. ***To address the lack of accessible tools for designing alternate modality technologies***

   Researching and developing practical design tools that facilitate iterative design processes in context responds to a pressing need that resonates across multiple domains. It is the need for practical design tools that can seamlessly integrate alternate modalities, thereby unlocking the doors to innovation and the creation of inclusive user-centric solutions. The absence of such tools has presented a barrier to progress and innovation. Thus, this thesis embarks on a mission to bridge this gap through rigorous research and development.

These research objectives align with the overarching goal of advancing the field of cocreative technology design in the context of urban regeneration and community interaction. They encompass the practical design and deployment of installations, user engagement, expert collaboration, tool development and versatile methodologies.

1.2 Methodologies

The experimental chapters in this thesis used the following methods in unison:

A User-Centred Design (UCD) approach, as advocated by experts like Müller et al. [184, 186], held a pivotal role within the research methodology. This approach ensured that the community and stakeholders remained not only active participants but were deeply embedded in every phase of prototype development and interaction design. It entailed a comprehensive commitment to understanding the unique needs, preferences, and perspectives of the intended user base. Through iterative design processes, usability testing, and ongoing feedback collection, the UCD approach fostered a sense of ownership and cocreation among the community and stakeholders. This collaborative engagement was central to crafting interactive solutions that were not only technologically advanced but also truly resonated with the community's values and aspirations, ultimately contributing to the success of the thesis.

Additionally, the user-centred design approach embraced a diverse array of methodologies across the design and deployment phases of each prototype. The user's perspectives remained paramount, as evidenced by the use of questionnaires to grasp the problem's scope, gather user insights, and inform initial design decisions. Rigorous focus groups, lab studies and interviews assessed prototype usability, driving iterative design processes that led to a series of prototypes, each tailored to address identified issues. Subsequent city-based deployments evaluated solution effectiveness and charted the way forward for potential interaction types. This commitment to user-centric design not only fulfilled the research objectives but also provided a robust framework for the entire design journey.

A Context-Centred Design (CCD) approach, influenced by experts such as Chen et al. [48] and Barry [23], became a cornerstone of the research methodology. This approach elevated the context of interaction and the environment to a central position in the design philosophy. As the projects detailed within this work, were based within the specific context of Swansea city centre (Swansea City Council stakeholders of this thesis), CCD was used to explore the intricate web of factors to be considered including those that surround the user, including the physical environment, social dynamics, cultural influences, and the broader context in which the technology was situated.

The CCD approach prompted a deep dive into the specific context of each interaction and the environment where the prototypes would be deployed. This involved extensive field studies, ethnographic research, and in-depth environmental assessments. The goal was to create interactive solutions that seamlessly integrated into the fabric of the user's world, enriching their experiences in a meaningful and contextually relevant manner. This approach provided the necessary framework to ensure that the research outcomes were not abstract technological advancements but practical, contextually aware solutions that resonated with the users and their environment.

A Research-through-design (RtD) approach, guided by experts like Frayling [93] and Zimmerman et al. [299], was fundamental to the research methodology. RtD seamlessly integrates design practices and research activities, allowing the generation of knowledge, insights, and innovative solutions. RtD is characterised by its iterative nature, involving cycles of design, prototyping, testing, and refinement. Design is not just an outcome but a means of inquiry, enabling the gain of a deeper understanding of complex problems. It excels in tackling open-ended and multifaceted real-world challenges and can produce various outputs, from prototypes to simulations.

Cross-disciplinary collaboration is often integral, bringing diverse perspectives into the process. While RtD results in practical solutions, it also contributes to theoretical knowledge, enriching the discourse in relevant domains. In essence, the Research-through-design approach has been used to leverage design thinking and to explore complex problems, generate insights, and develop innovative solutions.

1.3 Research Questions

The overarching research question this thesis addresses is:

> *How does context-specific cocreation enhance interactive technology design for community engagement in public spaces?*

This main question guides the exploration of how cocreation, technology design, and community engagement connect in city centres undergoing regeneration.

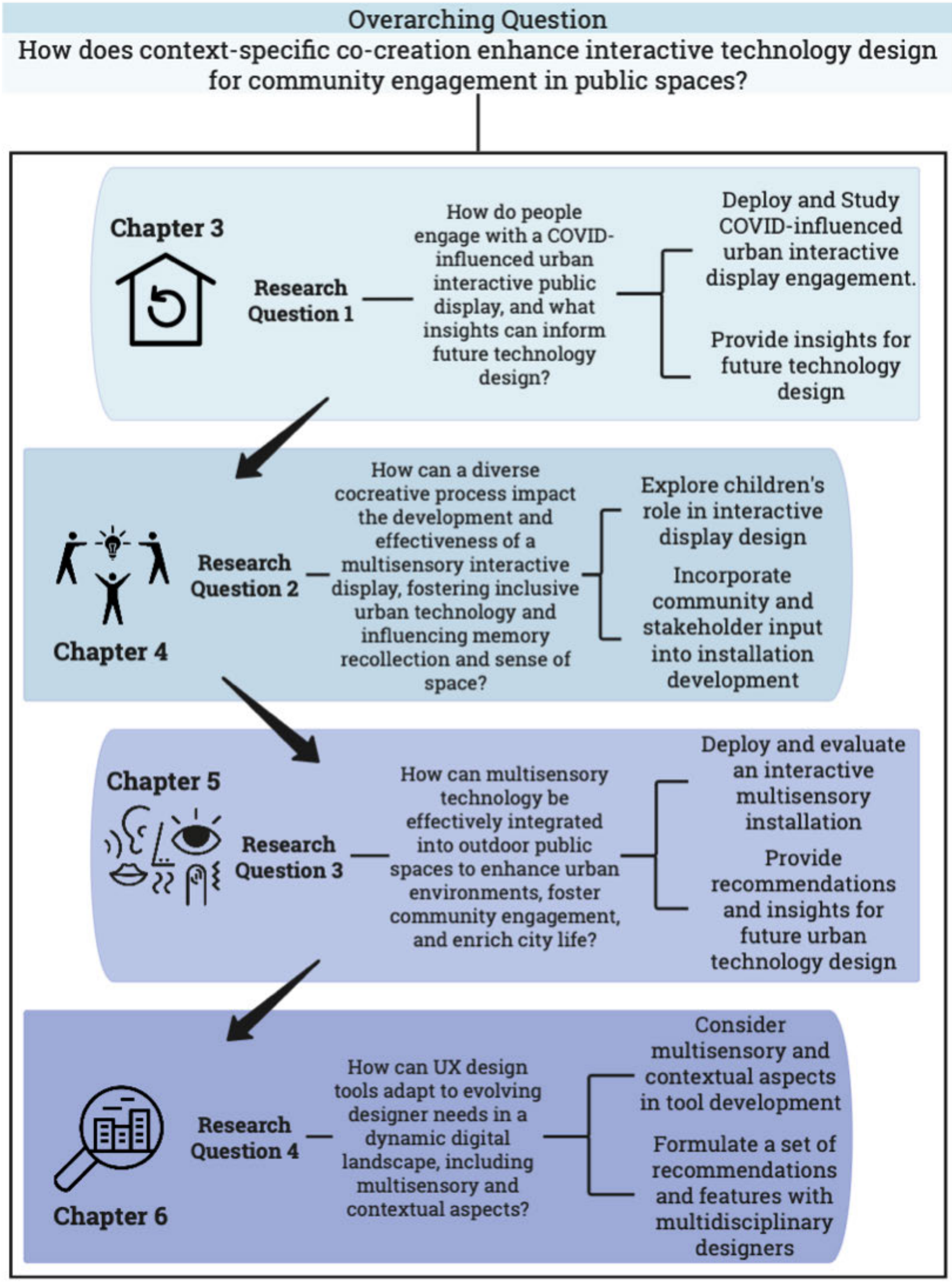

Figure 1.2: Breakdown of research questions addressed in the thesis.

To address the complexities of this central question, this thesis embarks on a multifaceted journey consisting of four distinct research projects. Each of these projects is a stepping stone that contributes to the larger narrative. Together, they form a cohesive narrative that delves into the design, construction, and evaluation of interactive public displays. Furthermore, this journey reimagines and proposes innovative design tools, crucial for crafting multimodal technologies and their contextual applications. Figure 1.2 provides a visual roadmap of the breakdown of the four research questions, detailed as follows:

1. How do people engage with a COVID-influenced urban interactive public installation, and what insights can inform future technology design?
   (Addressed in Chapter 3)

2. How can a diverse cocreative process impact the development and effectiveness of a multisensory interactive installation, fostering inclusive urban technology and influencing memory recollection (nostalgia) and sense of space (topophilia)?
   (Addressed in Chapter 4)

3. How can multisensory technology be effectively integrated into outdoor public spaces to enhance urban environments, foster community engagement, and enrich city life?
   (Addressed in Chapter 5)

4. How can UX design tools adapt to evolving designer needs in a dynamic digital landscape, including multisensory and contextual aspects?
   (Addressed in Chapter 6)

1.4 Chapter Outlines & Contributions

This thesis is divided into five results chapters, each addressing an aspect of the research questions. Together, they provide a detailed exploration of how context-specific cocreation can enhance the design of interactive technologies for community engagement within public spaces. Each chapter has its own approach, and is subsequently self-contained in respect to methodology and discussion. The final chapter takes the from of a meta-discussion, pulling together the themes from each chapter, and consolidating the work contained within the thesis. An overview of the whole thesis can be seen in Figure 1.2: with a breakdown of the chapters and contributions (beginning with the first results chapter) for each research question detailed below:

1. ***How do people engage with a COVID-influenced urban interactive public installation, and what insights can inform future technology design?***

   Chapter 3 investigates user engagement and interactions with the "Lookout", an innovative interactive device designed to disseminate information about a civic project amidst the challenges posed by the COVID-19 pandemic. Recognising the crucial role of public engagement in urban redevelopment, it explores how interactive public technologies can evoke nostalgia and foster topophilia, particularly within urban spaces where physical and digital interactions converge. By fostering inclusivity and involving both community members and civic project developers in urban planning, this chapter aims to shed light on how this inclusive approach can positively impact community engagement, strengthen community bonds, and promote emotional connections to places. In addition, this exploration led to two significant paths that continue throughout the remainder of the thesis: first, an aspiration to involve children in the design process to cultivate captivating interactive displays; second, a critical examination of the contextual design process departing from conventional screen-based approaches, emphasising the need to adapt existing tools to better support these innovative design methodologies. The major contributions of this chapter are as follows:

   a) **Comprehensive Deployment Analysis:** Examining the final deployment designs of a tangible embedded installation, analysing the nine-month deployment period, incorporating logging data from over $10,000$ sessions, interviews, and observations to explore user preferences for urban technologies. This exploration also considers the implications for community-driven initiatives and the potential of public installations of the future.

b) **Navigating Nostalgia & Sense of Place:** Exploring the dynamics of sense of place and recollections of that space's past during a city centre deployment in the midst of a global pandemic, and examining the role of public installations in shaping this experience. This chapter offers insights and lessons learned from this challenging context.

2. ***How can a diverse cocreative process impact the development and effectiveness of a multisensory interactive installation, fostering inclusive urban technology and influencing memory recollection and sense of space?***

   Chapter 4 takes a different path, focusing on touchless displays and sensory exploration. Building on insights from the Lookout deployment, where a desire for immersive experiences, especially for children, became evident, this chapter investigates the cocreation of an interactive multisensory installation. Motivated by the belief that such displays can enhance city centre engagement, especially among young citizens, and inspired by the observation that children's interactions can inspire others to engage with urban technology, this chapter focuses on designing a multisensory installation incorporating olfactory, auditory, tactile and visual elements. The chapter emphasises the significance of community involvement in context-specific deployments, showcases community-tailored designs, and highlights the possibilities for multisensory experiences. Feedback collected during this process significantly contributes to refining the final design deployed in a city centre setting, as explored in Chapter 5. The major contributions of this chapter are as follows:

   a) **Collaborative Design Workshops:** Involving children, regeneration experts, and the broader community in the cocreation process to emphasise the importance of inclusive design and expert collaboration in shaping future urban landscapes.

   b) **Expert Input and Questionnaire Analysis:** Detailed multisensory scenario creation, engaging regeneration experts and analysing feedback from a questionnaire with 62 participants to refine and validate the sensory cues of the scenarios, contributing to the development of a multisensory prototype.

c) **Proof of Concept Multisensory Prototype:** Designing, implementing, and evaluating a proof of concept multisensory prototype through iterative studies, showcasing the feasibility and potential impact of multisensory technologies for urban regeneration.

3. ***How can multisensory technology be effectively integrated into outdoor public spaces to enhance urban environments, foster community engagement, and enrich city life?***

   Chapter 5 explores the cocreation of a multisensory rig for outdoor public spaces, marking an exploration into the realm of interactive urban experiences in the context of the outdoor environment. Building upon insights gained from the collaborative efforts of experts, children, and the broader community (Chapter 4). This chapter reimagines the potential of outdoor urban spaces by envisioning immersive multisensory installations as an alternative to conventional screens. It contributes to our understanding of multisensory technologies in outdoor public spaces, an area previously under-explored within the literature. The combined efforts result in the development of a multisensory prototype, tested in controlled lab scenarios and refined for real-world deployment. Gathering feedback from young citizens, who played a role in the initial design phase, completes the circle. The lessons learnt can be used as a guide for cities, offering insights and practical recommendations to leverage multisensory installations for enhancing urban environments, fostering community engagement, and enriching city life. The major contributions of this chapter are as follows:

   a) **Outdoor Multisensory Exploration:** Explores multisensory installations in outdoor urban spaces, providing a fresh perspective on design and application.

   b) **Comprehensive Implementation Guidelines:** Offers cities a comprehensive guide for seamlessly incorporating multisensory technologies into outdoor public spaces, facilitating the enhancement of urban landscapes and the promotion of vibrant, inclusive communities.

c) **Community-Centric Approach:** Collaboration with experts, children, and the broader community, highlighting the importance of community involvement in the integration of multisensory technology in public spaces.

d) **Lessons Learnt:** Synthesising the extensive work and analysis conducted across Chapters 4 and 5 to generate a comprehensive set of lessons learnt from incorporating multisensory installations into outdoor public spaces.

4. ***How can UX design tools adapt to evolving designer needs in a dynamic digital landscape, including multisensory and contextual aspects?***

   Chapter 6 examines the changing paradigms of UX design, recognising the need to adapt to individual user capabilities and the multifaceted world of technology. This work emerges from the challenges encountered in previous chapters in designing multimodal interactions within a specific context, leading to the motivation to explore the challenges of designing in a contextual, multisensory, and rapidly evolving digital environment. Completing workshops with a range of designers, researchers, and students led to findings that assess the alignment of UX design tools with recent advancements in interface and application design. Furthermore, it explores the integration of multisensory elements into design practices. The contributions of this chapter include insights into the evolving needs of the design community and recommendations for the future of UX design tools, addressing the demands of designing whole experiences, environments, accessible technology, and individual user needs. The major contributions of this chapter are as follows:

a) **Evolving UX Design Needs:** Identifies the changing needs of the UX design community, shifting from screen-based and application design to designing holistic experiences, environments, and technology that caters to individual users and designers.

b) **Futuring UX Design Tools:** Through four exploratory online workshops, this work presents the concept of contextual and environmental cues in UX design, laying the groundwork for future tools that support full context and environment design.

c) **Qualitative Analysis and Insights:** A detailed qualitative analysis of workshop data offers insights into the future of UX design tools, providing valuable guidance for industry professionals, academic researchers, and students in navigating the evolving UX landscape.

d) **Community-Centred Exploration:** Underscores the importance of addressing the evolving needs of the UX design community and advocates for user-centric advancements in UX design tools, aligning them with the ever-changing technology landscape and user expectations.

5. ***What does this body of work mean for the field of cocreation and community engagement in public spaces?***

   The discussion presented in **Chapter 7** underscores the significance of user feedback and active participation in cocreation processes during real-world deployments. It reflects on the outcomes derived from the deployment of two interactive installations in bustling outdoor city centre settings. This introspective analysis assesses both the efficacy of public engagement and the lessons learnt from the challenges encountered along the way. The chapter then analyses the outcomes of expert workshops, where collaborative insights have yielded recommendations that resonate across a spectrum of contexts and disciplines. It establishes linkages between the research's achievements and the overarching theme of cocreation within an urban regeneration. In essence, the chapter showcases the evolutionary journey from a nine-month deployment analysis to the real-world deployment of multimodal installations to the requirements for designing these technologies in the future, covering lessons to shape the future of urban revitalisation and community interaction.

1.5 Contributing Publications

The works below include published material from this thesis as well as additional publications that build upon this research.

1. **Anna R L Carter**, Gavin Bailey, Jennifer Pearson, Matt Jones, Simon Robinson, Dani Kalarikalayil Raju, Jonathan Hicks, Spencer Winter. 2022. Designing and Embedding a Tangible Public Interface in the Covid Era. In CHI '22: ACM CHI Conference on Human Factors in Computing Systems Extended Abstracts, April 30 – May 06 2022, New Orleans USA. ACM.

2. **Anna R L Carter**, Miriam Sturdee, Alan Dix, Dani Kalarikalayil Raju, Martha Aldridge, Eunice Sari, Wendy Mackay, Elizabeth Churchill. 2022. InContext: Futuring User-Experience Design Tools. In CHI '22: ACM CHI Conference on Human Factors in Computing Systems Workshops and Symposia, April 30 – May 06 2022, New Orleans USA. ACM.

3. **Anna R L Carter**, Miriam Sturdee and Alan Dix. 2022. InContext: Exploring New Paradigms in User Experience Tools. In Proceedings of the 2022 International Conference on Advanced Visual Interfaces (AVI 2022). Association for Computing Machinery, Rome, Italy. ACM.

4. **Anna R. L. Carter**, Marianna Obrist, Christopher Dawes, Alan Dix, Jennifer Pearson, Matt Jones, Dimitrios Zampelis and Ceylan Besevli. 2023. Scent In-Context: Design and Development around Smell in Public and Private Spaces. In Designing Interactive Systems Conference (DIS Comapnion '23), July 10-14 2023, Pittsburgh, PA, USA. ACM.

5. Alan Dix, **Anna R L Carter**, Miriam Sturdee: "Where, Who Why? Tools to Encourage Design In Context" In EduCHI 2021 Workshop, part of CHI 2021.

6. Jennifer Pearson, Gavin Bailey, Simon Robinson, Tom Owen, Chi Zhang, Thomas Reitmaier, Cameron Steer, **Anna R L Carter**, Matt Jones, Deepak Ranjan Sahoo, Dani Kalarikalayil Raju.l 2022. Can't Touch This: Rethinking Public

Technology in a COVID-19 Era. InCHI '22: ACM CHI Conference on Human Factors in Computing Systems, April 30 – May 06 2022, New Orleans, USA. ACM.

7. Craig MacDonald, Olivier St-Cyr, Colin M Gray, Leigh Ellen Potter, Carine Lallemand, Anna Vasilchenko, Jaisie Sin, **Anna R L Carter**, Caroline Pitt, Eunice Sari, Deepak Ranjan Padhi, Ajit G Pillai. 2022. EduCHI 2022: 4th Annual Symposium on HCI Education. InCHI '22: ACM CHI Conference on Human Factors in Computing Systems Workshops and Symposia, April 30 – May 06 2022, New Orleans USA. ACM.

8. Colin M Gray, Craig M. MacDonald, Carine Lallemand, Alannah Oleson, **Anna R L Carter**, Olivier St- Cyr, Caroline Pitt 2023. EduCHI 2023: 5th Annual Symposium on HCI Education. InCHI '23: ACM CHI Conference on Human Factors in Computing Systems Workshops and Symposia, April 23 – April 28 2023, Hamburg, Germany.ACM.

9. Brian O'Keefe, Tom Flint, Miriam Sturdee, Andrea Resmini, **Anna R L Carter**, Mike Mastermaker and Andrea Chirico. 2023. Dancing with Technology – Towards a Choreography of Blended Experiences at ACM IMX '23. In IMX'23: ACM International Conference on Interactive Media Experiences. Workshops, June 12-15 2023, Nantes, France.

Table 1.1: Publications, Their Relevance to Thesis Chapters, and Author Contributions

Publication	Contributing Chapter	Chapter Association	This Author's Contributions
1	Chap. 3	An overview of the cocreational process and minor data analysis of the nine-month deployment of the Lookout.	Project lead, blueprint design creation, data logging, interviews, obeservations, analysis, and paper writing (exception of minor editing) conducted by AC. (Deployed installations created by Tom Henderson and GB).
2	Chap. 6	Delving deeper into the future of design tools, in a workshop format at CHI building upon the analytical groundwork laid out in Chap 6.	Project lead, writing (exception of minor editing), call for participation, workshop organisation, website design and maintenance, conducted by AC. Activity planning and paper reviews, completed collaboratively with AD and MS.
3	Chap. 6	Introduction and explanation of two prototypes for prototype design tools for futuring design tools, and minor workshop analsis.	Project lead, writing (exception of minor editing), and analysis completed by AC. Prototypes and designs created by AD and MS.
4	Chap. 5	Building upon discoveries in Chap 5, this workshop at DIS sought expert collaboration to formulate recommendations for the integration of olfactory devices into various contexts.	Project lead, writing (exception of minor editing), call for participation, workshop organisation, website design and maintenance and paper reviews conducted by AC. Activity planning completed collaboratively with CB and CD.
5	Chap. 6	An examination of the absence of contextual design tools in HCI education, progressing using examples e.g., Lookout to prompt discussion (EduCHI session).	Overall editing, and writing about physically situated designs (relating to Lookout) and the lack of tools in this area completed by AC.

Publication	Contributing Chapter	Chapter Association	This Author's Contributions
6	Chap. 3	Explores the possibilities of touchless interactions within public spaces, particularly in response to the challenges posed by COVID-19.	City deployment, interviews, observations and analysis of a facial recognition voting system, conducted by AC (system created by CZ).
7	Chap. 4 & 6	Initiating discussion on enhancing HCI education. Invited to collaborate following Publication 6 with personal motivation in integrating cocreational, and accessible design principles into HCI education following work completed in Chap 4.	Accessibility Chair, overall editing, serving as the accessibility contact point, ensuring content accessibility, and chairing of a session conducted by AC.
8	Chap. 4 & 6	The same association as described for Publication 8.	The same as Publication 8 with the addition of paper reviewing (joint with all co-authors) and documentation of the symposium via social media conducted by AC.
9	Chap. 4	Exploring the notion of designing in Blended Spaces as a means for working across the physical/digital divide.	Overall editing, design, writing, organisation and completion of collaborative thinking 'outside-the-box' exercises completed by AC.

Chapter 2

Literature Review

In the following sections, this chapter presents key literature relevant to the work completed throughout the four exploration chapters. Through these explorations, the thesis seeks to uncover gaps and ultimately contribute to a more inclusive and innovative approach to urban regeneration, underpinned by the enhancement of topophilia, user-centred design principles and the integration of emerging technologies.

Throughout this thesis, several key concepts will be frequently referenced, establishing a framework for understanding and analysing the literature and findings presented:

Topophilia: The emotional bond that individuals develop with a particular place or setting, encompassing sentiments of attachment and connection.

Nostalgia: Emotional recollections of the past, often tied to specific locations, fostering feelings of longing and sentimentality.

Cocreation: The inclusion of collaborative input and feedback from participants in the design process leading to adaptations and changes that resulted in new iterations and deployments shaped by collective contributions.

Engagement: An increased involvement, interest or interaction that an individual or group demonstrates towards a specific area, space, or regeneration project, reflecting active participation and a heightened sense of connection previously absent.

2.1 Topophilia and Nostalgia

Sense of place is a complex and multi-layered notion, which underpins topophilia [138]. Topophilia, plays a crucial role in city centre settings, significantly influencing the success of public installations in urban settings. Tuan [271] characterises sense of place as "the affective bond between people and place or setting", while Scannell et al. describe place attachment as "the bonding that occurs between individuals and their meaningful environment" [231]. Although it has been extensively studied in fields like psychology [251], geography [115], urban design [39, 182, 205], environment [17, 47], tourism [144], planning [74, 193, 290], and architecture [211], the HCI community has not extensively explored this idea within outdoor public spaces. Instead, the focus within HCI has primarily revolved around differences in space and place [114] and spatiality [72].

In conjunction, nostalgia, is a complex phenomenon oriented around both emotional feeling and recollections of the past, it is an interesting concept to explore in relation to sense of place and changing urban spaces. While nostalgia has been evaluated within Geography [22, 99] and Urban Studies [2, 152], there is limited exploration of its use in evoking nostalgia through interactive technologies or within the field of Human-Computer Interaction (HCI).

Understanding the context of a place and nostalgia is essential when exploring the intricate relationship between individuals and their surroundings, as it significantly influences individual responses [17]. This concept is closely tied to urban identity, which encompasses the awareness of people's intimacy with places and their familiarity with place-related facilities and activities [97, 144, 148]. Place attachment, the emotional connection individuals form with places filled with meaning, is typically a positive relationship with the environment [8, 231, 271] and is a concept intrinsically related to a person's sense of nostalgia for a place.

Houghton et al.'s [127] categorisation of place-based technology in urban planning and community engagement provides a framework for understanding the various dimensions of technology's role in shaping urban environments, defining the possibilities for urban interaction and sense of place as: (a) technology for analysis of place; (b) technology to enhance peoples experience of place; and, (c) technology for community engagement of place. This framework guides our exploration of technology's impact on urban spaces and the sense of place.

Through this thesis, the aim is to show that technology can serve as a potential catalyst for individuals to recharge their emotional connection with urban spaces even amid extensive transformations. As urban landscapes undergo developments such as regeneration projects, it becomes increasingly important to sustain community involvement and emotional bonds with the evolving space (nostalgia) [42, 52, 147]. Failure to do so may lead to people losing their emotional connection with the place, emphasising the significance of this work, particularly in light of the influence of COVID-19 on these dynamics. Urban environments are inherently dynamic, where communities continuously interact with various facets of their surroundings. Scholars like Carr et al. [41] have highlighted the potential for public spaces to serve as canvases for novel discoveries and interactions, thereby fostering innovative forms of engagement. One example is the Augurscope, deployed in Nottingham, which introduced a portable display capable of overlaying historical architectural structures onto contemporary urban landscapes [232]. These self-directed approaches have been shown to significantly heighten topophilia [233].

2.1.1 Cultural Heritage and Topophilia

In the context of heritage, familiarity with a place involves an intimate connection with its physical environment, encompassing both tangible and intangible aspects [62], including historic structures, landmarks, traditions, and collective memories [20,240,294]. Heritage interpretation serves a critical function, aiming to enrich visitors' sense of place and place identity [277]. This approach is exemplified in a study that assessed a museum's effectiveness in enhancing visitors' sense of place and their awareness of a town's heritage [277]. Heritage interpretation plays a pivotal role in elevating people's awareness, understanding, and appreciation of time and place [277]. Vong [284] further explored how heritage tourism in Macau positively influenced the sense of place among local residents, drawing from Jorgensen et al.'s [139] three dimensions of sense of place: place attachment - relating to an individual's reliance on a particular place;

place identity - involving the emotional and symbolic attachment an individual has to a specific place; and, place dependence - the emotional bond and affection that individuals develop for a place over time, which can lead to a feeling of nostalgia.

In cultural heritage, cognitive perception is central to the formation of place identity, involving processes like observation, knowledge, and thought, particularly evident in historic places [62]. The expression of identity through heritage encompasses both past and ongoing human experiences [246], with even the landscapes themselves representing a repository of knowledge for preserving societal memory and identity [124]. Smith [245] underscores this by highlighting that places not only represent past human experiences but also shape current perceptions and experiences of the world.

2.1.2 COVID-19 Pandemic and Topophilia

The initial deployments explored within this thesis were carried out in a city centre during the COVID-19 lockdowns, and the impact of the pandemic had significant implications for these urban spaces [50, 87, 215]. Many businesses, particularly small retailers and hospitality establishments, faced financial hardships and closures, causing economic instability [88]. Moreover, the enforcement of social distancing measures exacerbated feelings of isolation and loneliness among residents [132]. Consequently, there arose a need for the creation of spaces that promoted social interaction and help users to re-engage with their sense of place while adhering to stringent health guidelines.

The rise of remote work as a pandemic response prompted a shift in the traditional role of city centres as bustling workplace hubs. In response, city spaces had to adapt to accommodate hybrid work models [78, 101] and begin to think about ways to fortify themselves against future epidemics [102, 217].

Despite these challenges, the pandemic also offered opportunities for re-imagining city centre spaces [197]. Vacant commercial spaces provided opportunities for adaptive reuse, such as the transformation of empty storefronts into art installations [58, 198], community hubs [179] and vaccination sites [141]. These adaptive reuses offered a source of re-engagement, especially when other conventional city centre attractions, such as clothing stores were closed.

Furthermore, there was a renewed emphasis on outdoor spaces and open-air venues, as they allowed for safer gatherings, rekindling appreciation for outdoor amenities [170] some of which have remained popular, such as outdoor movie screenings [259]. The pandemic also accelerated digital innovation, fostering the emergence of virtual events like virtual comedy nights [55], a global 8-hour concert [202], and augmented reality experiences for previewing items, such as luxury fashion [210], effectively expanding the scope of city centre activities.

In essence, the COVID-19 pandemic effected many aspects of life including city centres, which arguably have returned almost to pre-COVID interactions but have left space that is intriguing to explore. The transformation of vacant spaces, the embrace of outdoor amenities, and the integration of digital experiences have all contributed to how city centres can be reshaped into more adaptable environments for the future.

Summary

This section explored the concept of Topophilia (Sense of Place) and Nostalgia emphasising the significance of considering a place's context in urban planning, history and community engagement. It has also examined the connection between cultural heritage and topophilia, underlining the role of heritage interpretation in evoking nostalgia and enriching the sense of place. The thesis's objective is to discover how technology can strengthen the bonds between individuals and evolving urban spaces. The prior studies mentioned in this section laid the foundation for integrating citizen engagement into the design process and deploying technological experiences into Swansea city centre, particularly in the context of topophilia.

2.2 Engagement in Urban Environments

Engagement in urban spaces refers to the active involvement of community members, stakeholders, and residents in decision-making processes that directly affect the design and development of their city centre [121, 156]. It entails a collaborative approach that seeks to bridge the gap between urban planners and the public [28]. This collaborative aspect is central communities becoming co-designers of public installations.

Factors for success include, effective communication strategies, transparent decision-making processes, and mechanisms for collecting and incorporating community feedback [18,133,156]. Engaging residents through workshops, surveys, and public meetings, can build trust and a sense of belonging [63, 109, 252], fostering a sense of ownership and pride among community members regarding the installations [16]. These workshops can bring together diverse viewpoints and foster consensus-building among participants [94]. Such convergence is essential for placemaking, which pays particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution [89]. However, the effectiveness of community's engagement depends on the readiness of citizens to partake in urban development [204]. This work is relevant to the thesis as it emphasises the importance of engaging people in the process and ensuring that it fosters a sense of belonging and trust, an aim within the thesis.

Terrenghi et al. [266] introduced a taxonomy for multi-person display ecosystems, offering a structured framework that informs the design of interactive elements within urban spaces. Their taxonomy provides an approach to understanding these ecosystems, which are prominent in settings such as interactive public displays, collaborative workspaces, and entertainment environments [266]. Therefore aligning with a broader shift toward more democratic and inclusive processes, empowering communities to actively participate in shaping their urban environment. Whereas, Rantala et al.'s research [147] emphasises open innovation-based strategies and methods in reshaping collaboration practices within the context of community engagement and urban planning. This exploration helps ensure that the engagement process is appropriately scoped and the community input is maximised [1, 98].

2.2.1 Incorporating Children into Urban Technology Design Through Sketching

Participatory design (PD) principles, rooted in Scandinavian workplace contexts, advocate for users' control over design processes [191]. Building on this, cooperative inquiry extends this approach to children, positioning them as equal partners in design [76]. In this context, sketching plays an important role [272], serving as a cornerstone in the design process and forming the basis for low-fidelity prototypes known for generating design solutions [272], an approach that will be further explored within this thesis. Beyond its design capabilities, sketching empowers children to actively engage with their urban surroundings and articulate their ideas [128]. This active involvement is a starting point for fostering innovative technological solutions [183]. Furthermore, sketching offers an alternative means of expression, fostering creativity, especially for children who may struggle with verbalising their thoughts [76].

Furthermore, during sketching workshops, Shokeen et al. [238] observed that children use sketches to communicate their expectations, experiences, beliefs, and knowledge. Whilst Hourcade [128] emphasised that sketching effectively facilitates children's experiential knowledge construction through interaction with their environment. Therefore, sketching sessions not only offer insights into children's preferences, informing improved technology design, but also nurture valuable skills such as collaboration, and innovation [238]. This holistic view of sketchings role underscores its significance in the context of children's active engagement with technology design.

It has been shown that children can play a role in urban planning, offering a unique perspective due to their extensive use of technology [136]. Their proficiency with interactive technologies, as emphasised by Antle [14], underscores the need for tailored design approaches that align with their distinct needs and preferences. In today's technology-driven landscape, it is important to empower children to actively shape these technologies to suit their interests and requirements [26, 117, 145, 169]. Moreover, nurturing early engagement and positive experiences with STEM subjects is vital for economic development [168, 189]. Encouraging children to invent and think creatively can lead to valuable innovations, while sharing and discussing classmates' inventions can further inspire their inventive potential [237].

Summary

This section explored the concept of engagement in urban environments, emphasising the active involvement of community members, stakeholders, and residents in the decision-making processes that shape city centres. Understanding this concept was crucial to foster trust, belonging, and a sense of ownership among community members -

essential for their engagement with deployed technologies. The research discussed here forms the basis for integrating citizen engagement into the cocreation process of public installations, shaping the thesis's direction and methodology.

2.3 Cocreating Installations for Urban Environments

In the realm of urban development and placemaking, the creation of vibrant and engaging public spaces fosters community identity and enhances the quality of life for residents and visitors [63, 109]. Within this context, the concept of cocreation has gained prominence, emphasising the active involvement of diverse stakeholders in the design and development of urban installations aimed at enhancing sense of space [92,231]. The concept of cocreating designs with a community is a practice used in the development of designs tailored to specific community needs and preferences [230]. e.g., commitment levels and technological proficiency [33].

Cocreation has been reported as a key tool within the development of visually immersive [229] and auditory displays [215], especially when the content was tied to a specific location [215, 229]. Collaborating with the community has been found to play a pivotal role in seamlessly integrating the installation into the urban landscape [256], not only as a tool for garnering local support but also to spark enthusiasm among residents, enticing them to explore the interactive experiences and share its merits with others [256].

For example, Frohlich et al. [96] implemented a substantial interactive audiovisual display in Budikote, India with the primary aim to empower the local community to craft and share stories with each other. It not only led to valuable insights for further iterations within the community but also offered valuable lessons for innovations in using storytelling in more technologically advanced settings [96].

The implementation of cocreation within city centre settings has demonstrated significant impact on the quality of public spaces [111]. Urban planning and design have evolved beyond aesthetics and functionality; they have been reported to be expressions of the collective identity and aspirations of the communities they serve [6]. Cocreation allows residents to actively shape their urban environment, fostering a sense of belonging as it supports the gathering of knowledge and requirements needed for innovation and creativity towards achieving an equitable community for social sustainability [28]. This could then also lead to the preservation of cultural heritage by celebrating history within a modern context.

Furthermore, the concept of "Participatory Urbanism" reported by Paulos et al. [212] aligns with a cocreative approach and underscores the importance of active participation from the community in shaping urban spaces. Overall, the aim is for designers to not just focus on the production of new knowledge and understanding but in parallel analyse this new understanding to inform new iterations of design [91]. This literature collection not only reinforces the need for a multidisciplinary perspective but also offers different lenses through which to view the cocreation of urban experiences, enriching the research context and approach.

2.3.1 Cocreation and Topophilia

Forlano [90] suggests that place can be cocreated through sociotechnical practices in three distinct ways: visualisation, lived experience, and imagination. In addition, Frantzeskaki et al.'s [92] longitudinal case study on urban living labs emphasised the potential of collaborative place narrative creation, knowledge co-production, and meaningful place co-design to facilitate sustainability transitions in evolving urban spaces [92].

Some scholars have shifted their focus towards highlighting privacy concerns within urban centres and exploring ways to empower communities in navigating these challenges [236]. For instance, Shepard et al. [236] adopted design fiction to envision innovative tools such as an umbrella designed to be visible only to CCTV systems and Radio Frequency Identification (RFID)-detecting underwear. In contrast, this work seeks to reignite participants' connection with their city and the opportunities it offers.

User interactions with public installations are inherently nuanced, influenced by personality traits and the presence of other users in the vicinity [185]. The responses and behaviours of interacting users can significantly impact another user's willingness to engage with an installation. For instance, a user displaying excitement about an interaction can encourage others to feel more comfortable attempting the interaction without hesitation or apprehension [33] (i.e. creating a more accepting space). Peltonen et al. [216]

conducted a study involving a large multi-touch display in Finland and found that users were more hesitant to use the display when they did not observe other users interacting with it. Understanding these nuances in user interactions becomes particularly crucial when designing and deploying tangible installations in a city centre, as it allows us to create engaging and user-friendly experiences that encourage community participation and enhance the overall impact of the installation.

2.3.2 Cocreation of Urban Probes

Participatory design approaches have been used to facilitate the cocreation of installations within city centres by actively engaging the community in decision-making and encouraging their input to shape urban projects [10], as will be explored within this thesis. Collaborative workshops provide a platform for residents to contribute their perspectives, fostering consensus-building and a sense of ownership [94]. Furthermore, the concept of "Technology Probes," as discussed by Graham et al. [104], offers a means to involve users in the design and enhancement of city centre installations. These probes are deployed to align technologies with user needs and desires, facilitating data collection and increasing participation [27].

Urban probes, introduced by Paulos et al. [213], use thought-provoking urban proto-tasks to encourage direct discussions among residents about their urban landscape. By integrating probes into the context of city centre installations, urban planners and designers can leverage the insights gained from user engagement to create more responsive, community-centric, and innovative installations [213]. Probes can bridge the gap between the designers' vision and the lived experiences of the community, contributing to the enhancement of city centre spaces [171]. This holistic approach emphasises the importance of community involvement in the design and development of city centre installations, resulting in more meaningful and relevant outcomes.

Summary

This section discussed the concept of developing designs tailored to specific community needs and preferences through cocreation. This participatory approach has been found to actively engage participants through collaborative workshops and technology probes, successfully bridging the gap between designers and the communities lived experiences. While it was not feasible to directly involve participants in the cocreation of the urban regeneration itself in Swansea, these insights served as a valuable models for integrating citizen engagement into the design process of public installations. This theme is explored throughout this thesis, highlighting the significance of participatory approaches in shaping inclusive and innovative urban environments.

2.4 Alternate Modality Experiences and Urban Regeneration

Transitioning from a more general exploration of cocreation and topophilia, this section explores specific design deployments, exploring a move into alternate modality installations. Here, 'alternate modality' refers to designs that do not primarily rely on visual or screen-focused elements, encompassing a broader range of sensory experiences. Many studies in the field of urban regeneration have traditionally used digital screens to assess public engagement, often relying on large touchscreen displays (32"+) to collect feedback on urban renovation initiatives [7, 126, 135]. For instance, Hosio et al.'s [125] project enabled community members to visualise proposed urban designs, resulting in increased public engagement.

Additionally, Memarovic et al. [176] emphasised that designing public spaces to meet human needs involves elements of passive engagement, active engagement, and discovery. The rising prevalence of multisensory experiences in private entertainment, including the adoption of 4D technologies in theme parks [122, 287], educational classrooms [200], galleries [64, 160], museums [157], restaurants [296], and even space exploration [268], underscoring the growing interest in this domain [199, 280]. However, as cities progress towards more autonomous and "Smart" spaces, the integration of diverse technologies from various contexts becomes crucial. These smart spaces are characterised by the incorporation of digital technologies, data, and connectivity to enhance efficiency and sustainability [56]. While controlled walk-through [21, 84, 239, 283] and ride-through [68,269] sensory experiences have gained popularity in private settings, the application of such experiences in outdoor public spaces remains relatively unexplored. Whilst outdoor public spaces are often graced by art installations, they typically rely on visual cues, overlooking the potential of multisensory engagement [154, 172, 207]. In contrast, sound artist Suzuki has created sonic installations in London, demonstrating the possibilities of multisensory displays in dynamic urban environments [257, 258].

2.4.1 Multisensory Experiences

In our daily lives, people encounter a rich array of multisensory experiences that extend beyond touch-based interactions to include smell, taste, sound, and various tactile senses like temperature [75, 279]. These multisensory encounters hold potential, not only for shaping society and consumer markets but also for revolutionising marketing communications [195, 288]. They have the ability to create richer, more memorable, and emotionally charged experiences for consumers by engaging a broader range of senses [196]. This sensory engagement goes beyond traditional approaches, promising innovative ways to connect with and influence consumers in a rapidly evolving marketplace [15]. In fact, Winograd [291] underscored the idea that software should not only be functionally efficient but should also provide a pleasant and meaningful sensory experience to users. Previous work has suggested that this is something difficult to achieve with only visual outputs [291]. In conjunction, Michel et al. [279] emphasise the pivotal role of multisensory experiences in forming lasting memories and their potential impact, with their findings suggesting that enhanced memory performance results from the integration of information across multiple modalities. Despite this potential, research into the use of multisensory technologies within outdoor public spaces is scarce, with limited guidance available for designing beyond traditional visual and audio displays [166]. Hence, the work in this thesis aims to bridge this gap by leveraging insights from indoor multisensory deployments and extending this knowledge to the outdoor context.

Multisensory experiences have shown their versatility by their ability to both enhance existing spatial experiences and create new ones [174]. Smell has been shown to influence attraction or repulsion towards objects or spaces, aiding recognition [165]. For instance, Maggioni et al. [165] developed a Virtual Reality (VR) scenario where users located spatial sources within the VR environment using olfactory, auditory, and audio-olfactory cues. However, applying multisensory cues effectively in public settings presents challenges that necessitate a multidisciplinary approach encompassing Human Computer Interaction (HCI), psychology, neuroscience, and sensory science [165, 195]. The successful integration of multisensory experiences necessitates a deep understanding of how different sensory cues interact with one another and with human cognition and behaviour [196]. This multidisciplinary collaboration ensures that the design and deployment of multisensory installations are not only engaging and immersive but also culturally sensitive and inclusive, promoting a deeper connection between individuals and their urban environments.

Engaging multiple sensory modalities, offers a more inclusive interaction approach, potentially widening the audience [280]. Evaluating these experiences in public spaces within this thesis is significant as it extends technology's accessibility to a broader range of individuals, including those with varying sensory preferences and abilities.

2.4.2 Exploring the Potential of Olfactory Integration

A relatively underused aspect within Human-Computer Interaction (HCI) is olfaction (sense of smell [297]) [11, 165]. While olfactory displays have generated interest in various contexts, digital adaptations have primarily been confined to indoor spaces and indoor ticketed entertainment venues (e.g., museums) [196]. Olfaction's immersive potential, emotional [34, 49, 142] and memory-evoking capacity [120, 166, 289], and potential benefits for well-being [106, 129, 267] and safety make it a compelling area for exploration [36, 175]. This presents a unique opportunity to investigate the potential of olfaction in enhancing the urban experience in outdoor settings, providing new insights and perspectives on its impact in public spaces. Furthermore, various scents have the ability to stimulate diverse neurons and trigger a wide range of memory responses [34, 49, 142]. The emotional richness of scent-induced memories can forge remarkably robust connections in our minds [120, 165, 289], offering potential benefits for individuals affected by conditions such as Alzheimer's disease [129]. This is relevant to this research as it aims to explore the use of alternate modality installations in engaging citizens within their city centre while facilitating scenario recognition infused with emotional depth.

In the context of city centres, calming scent technologies hold promise for alleviating the stress experienced by many individuals [273]. Lavender, for instance, is widely recognised for its stress-reducing properties, ability to enhance sleep quality, and empowerment-evoking effects [106, 267]. In addition, scent-based wearables, such as necklaces that release scents tailored to the user's needs, have found applications in fashion [267], stress relief within indoor environments [11], and even in enhancing teamwork during collaborative writing tasks [175]. In fact, research has shown that participants wearing such scent necklaces tend to engage more openly in discussions [175]. Drawing inspiration from these insights, this work will explore olfactory outputs within public spaces to explore its potential in the context of outdoor public spaces.

Summary

This section examined the concept of alternate modality experiences in the context of urban regeneration, highlighting the transition from traditional screen-focused designs to multisensory installations, broadening the scope of sensory engagement within urban spaces. It has emphasised the relevance of such experiences, particularly in the context of smart cities and the need to integrate diverse technologies. The lessons learnt from multisensory installations within private settings was used as a basis for exploring alternate modality installations within outdoor urban spaces, a relatively unexplored application. Furthermore, this thesis will explore olfactory outputs to investigate its potential in the context of outdoor public spaces.

2.5 Exploring the Landscape of UX Design Tools in Evolving Interaction Contexts

The focus now turns toward examining the extensive field of tools used in the design of these experiences. This landscape encompasses a wide spectrum of academic literature that critiques, designs, and proposes fresh approaches to thinking, designing, and executing. It is worth noting that this work predates the release of ChatGPT and other AI tools, which are not discussed here. This exploration is relevant as an aspect of this thesis focuses on the state of current design tools and how they can be reimagined to support physical and multisensory designs.

2.5.1 Current UX Design Tool Ecosystem

The annual UX Design Tools Survey [209] serves as a valuable resource for gaining insights into industry needs. In 2022, this survey collected responses from 4,260 participants worldwide and showed Adobe, Figma, Sketch and Axure as prominent tools. The survey addresses various aspects of UX design, encompassing prototyping and user testing, highlighting the diverse toolkit required for different design activities. This survey underscores the complexity of the UX design process, with varying requirements for different projects. The market for UX design tools is expected to continue its growth, particularly with the emergence of new interaction hardware (e.g. [43, 214]). McCarthy et al.'s [174] framework emphasises the importance of the user experience, encompassing four key dimensions: compositional, sensual, emotional, and spatio-temporal. While current tools address most of these aspects, there is still room for improvement in achieving a coherent whole, especially in newer interfaces that integrate different modalities alongside existing 2D interactions. An increasing number of designers are working on physical and multimodal experiences, as evidenced in prior sections [44, 164, 206, 222], indicating a growing market for such design tools.

Offline methods like collaborative sketching, paper prototyping, and physical prototyping continue to play a role in the design process, despite the wide variety of digital tools. In fact, Khan et al. [143] propose the possibility of complementing traditional physical methods, such as sketching and paper-prototyping, and digital tools with unconventional approaches. In parallel, some have used familiar methods to reimagine complex challenges, like designing shape-changing interfaces (3D physically manipulated interfaces with actuation) using nature-inspired card decks [220]. The repurposing of the familiar has potential to support the ongoing development of new interfaces and their applications, particularly in the realm of designing alternate modality installations.

In light of these trends, there are two directions to consider: future tools for existing interactions and tools for future interactions (see Figure 2.1). These directions are not mutually exclusive. On one hand, new interaction technologies will emphasise the

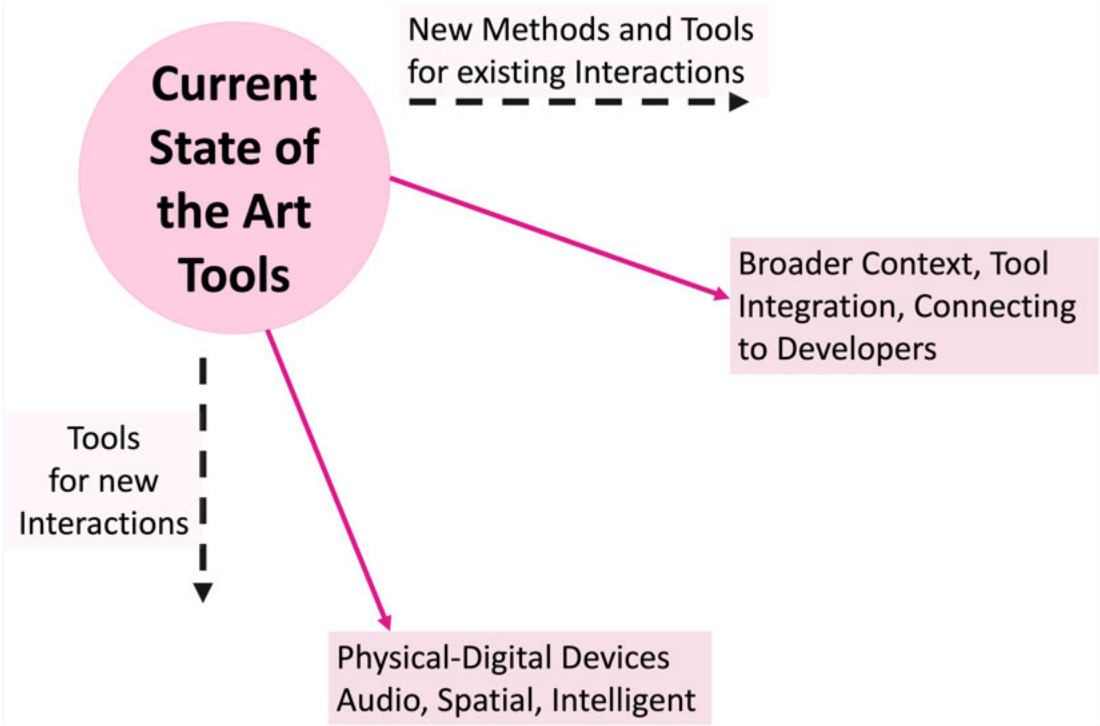

Figure 2.1: Future tools for existing interactions and tools for future interactions.

limitations of existing design tools. On the other, shifting design tools away from a screen focus towards a broader context, while enhancing the overall user experience, will increase their adaptability to evolving technologies and shifting usage patterns.

2.5.2 Design Tools for Alternate Modalities

Within UX research there is a lack of multimodal prototyping techniques that enable users to create designs without manual sketching which does not require the user to hand sketch the design. Sinha et al. [241] claim to have a multimodal prototyping tool that enables the design of perceptual user interfaces. However, the tool focuses on screen-based usage and uploaded hand sketches. Their command transitions mainly focus on standard computer-based transitions with the exception of an occasional speech-based command [65, 242]. Nevertheless, the main focus for the uploaded sketches is to showcase screen-based multi-device prototypes with no physical aspects incorporated.

In contrast, Klemmer et al. [146] created an interfacing tool for speech-based prototypes – SUEDE which allows users to create response-based speech interfaces using the Wizard of Oz technique capturing test data which the participants can then analyse, something which would be more useful for a speech-based prototype.

Tools such as the Telling Board enable interaction with a physical prototype to drive creative thinking and in this case encourage children to practice verbal communication [219]. This emphasises the need for physicality within computer-embedded devices, something rarely seen within prototyping tools [113]. The ability to add this type of tool online where users could add different sections of the board into a virtual version with a selection of different aspects would enable a wider range of children to interact.

Defining what qualifies as a 'novel' or future interface can be a complex task. In this context, prototyping often serves as a platform for innovative thinking rather than problem-solving, as it seeks to emulate hardware that remains on the horizon. However, it is important to also address theoretical problem spaces, such as the implications of introducing new technology [224] and ethical considerations [298]. Artificial Intelligence, while offering efficiency, brings its own set of challenges, reliant on the quality of data and human input [228]. Therefore, the development of new design tools must adapt to the evolving environment and technologies, taking into account these ongoing changes and challenges [224, 228, 298].

Summary

In this section, the landscape of UX design tools for creating user experiences across various contexts is explored. The discussion covers the current state of UX design tools, the need for a variety of tools to meet different project requirements, and the growing market for such tools. The lack of multimodal prototyping tools in UX research is highlighted, along with the importance of addressing physical and multimodal experiences, a concept that will be explored within this thesis.

2.6 Summary

Through the explorations of existing research, this thesis seeks to uncover gaps and ultimately contribute to a more inclusive and innovative approach to urban regeneration, underpinned by user-centred design principles and the integration of emerging technologies. The main themes and identified gaps are detailed below.

The role of topophilia within the context of urban design emphasises the importance of understanding the context of place, which can influence individuals experiences within urban settings. Furthermore, it shows the technologies possible role in shaping urban environments and sense of place, ranging from analysing place to enhancing experiences and fostering community engagement.

Following this, cocreation was shown to be a central approach to urban engagement as it led to more vibrant and meaningful public spaces. Engagement techniques such as workshops, surveys and focus groups were found to build trust and instill a sense of belonging leading to a sense of pride for urban installations. Additionally, urban probes were found to result in more responsive, community centric urban spaces.

The exploration then shifted to the examination of alternate modality experiences. The research shows that multisensory experiences have the ability to create memorable and emotionally engaging interactions. The exploration of olfaction - the sense of smell, within this context shows the potential for memory evocation, despite its deployments being primarily limited to research settings and indoor deployments. Moreover, it demonstrates a potential for alleviating stress and providing a unique approach for engaging people within city centres.

Finally, this chapter covers the current state of user experience design tools with an emphasis on their use for designing user experiences. It shows that a wide variety of tools are used across the design process but that there is no one tool that can be used across the entire process. Additionally, it is highlighted that there is a growing market for tools that cater to physical and multimodal experiences.

2.6.1 Gaps in the Literature

Through an exploration of existing research, this thesis aims to identify and address key gaps in the field, contributing to a more inclusive and innovative approach to urban regeneration. Here are the main identified gaps:

1. **Evoking Nostalgia & Enhancing Topophilia in Outdoor Public Spaces:** There is a research gap in using technology to evoke nostalgia and enhance topophilia within HCI and in particular, outdoor public spaces, especially in the context of the challenges and opportunities presented by the COVID-19 pandemic. Chapters 3 and 5 will address this gap by deploying and analysing interactive tangible installations in a regenerating city and exploring the role of multisensory outputs in enhancing a sense of place.

2. **Aligning Cocreation with Topophilia Enhancement:** The literature lacks exploration of the alignment between cocreation for engagement and enhancing topophilia. The potential of collaborative place narrative creation, knowledge co-production, and meaningful place co-design to facilitate engagement and topophilia is explored in Chapters 4 and 5.

3. **Engaging Multiple Senses in Outdoor Settings:** While digital screens have traditionally been used for public engagement in urban settings, there is a gap in considering the engagement of multiple senses within outdoor settings. This work bridges the gap by drawing insights from indoor multisensory deployments and extending them to the outdoor context. Chapter 4 explores the cocreation of a multisensory rig, including scent, while Chapter 5 analyses its deployment and suitability for outdoor public spaces.

4. **Lack of Adequate Design Tools:** Current design tools do not fully support the prototyping of all modalities within their specific contexts or the incorporation of physicality within designs. Additionally, they may not accommodate emerging technologies and shifts in usage patterns. Chapter 6 addresses this gap by conducting a series of workshops with designers, researchers, and students, col-

lecting extensive data on current usage patterns and the required features for a comprehensive tool capable of designing physical and multimodal experiences.

In the field and literature, this thesis highlights the potential of cocreation in dynamic urban environments. Through the development and implementation of several cocreated installations in a city undergoing regeneration, it provides participatory experiences that offer insights into urban design, community engagement, and cultural heritage enhancement. These installations serve as technology probes for innovative approaches, exploring how technology can enhance the urban experience. The research also goes beyond practice, examining the creation of tools and methodologies to facilitate and enhance the cocreation process, aiming for more inclusive and responsive urban development. This contribution adds depth to academic discourse and provides practical solutions for urban planners, designers, and policymakers working to create vibrant, culturally rich, and sustainable city centres in a constantly evolving urban landscape.

Chapter 3

Empowering Urban Engagement: The Lookout - A Tangible Embedded Interface for a Transforming Cityscape in the COVID-19 Era

3.1 Introduction

This chapter explores user engagement and interactions with the *"Lookout"*, a device designed to share information about a civic project amidst the challenges posed by the COVID-19 pandemic. Research has shown that engaging the public in urban redevelopment projects is essential for community integration in urban planning, fostering a convergence of ideas [42, 52, 147]. The focus here is on how interactive public technologies can enhance topophilia (emotional connections to places [271]), particularly in urban spaces, where physical and digital interactions intersect. Involving both community members and civic project developers in urban planning can positively impact community engagement and promote topophilia [52, 140, 147]. Additionally, this work departs from the reliance on public screens for disseminating city-based information, as previous evaluations have explored [7, 125, 126, 135]. Instead, it aims to evaluate an interactive installation cocreated with community members and regeneration experts.

The cocreation of a tangible, embedded device for deployment in Swansea city centre was the culmination of a Masters project, documented as a thesis [42] and a CHI case study [43]. While the thesis delved into detailed design processes and blueprints, the case study provided an overview of the process and a limited analysis of the deployment. This chapter, in contrast, offers a comprehensive presentation of the final deployment designs, coupled with an in-depth analysis of the nine-month deployment period. This analysis incorporates logging data, interviews, observations, and the implications of this installation.

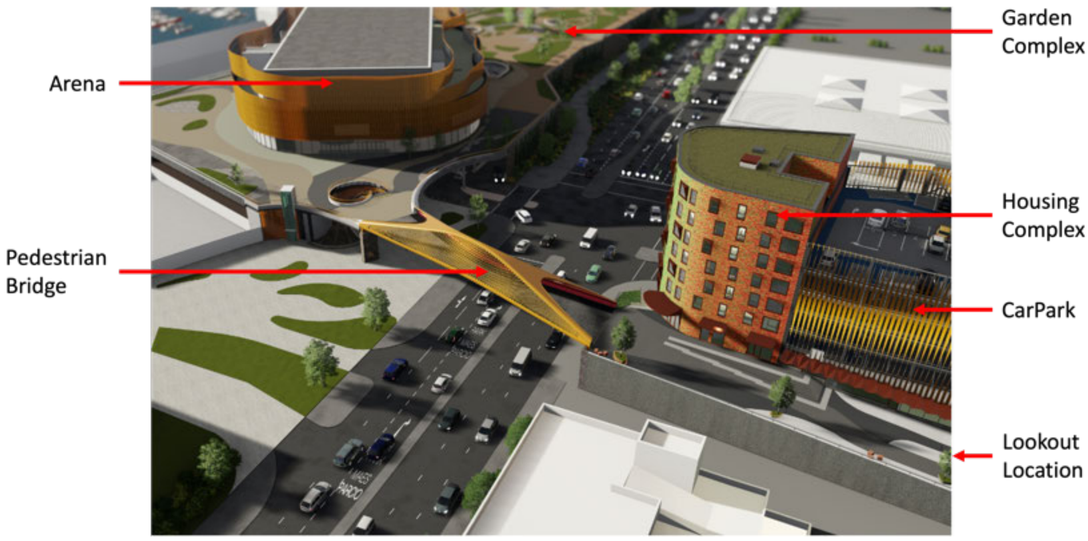

Figure 3.1: Virtual map of Swansea city centre's regeneration project, displaying all major developments, as showcased through the Lookout device.

The project originated from sandpit discussions with Swansea Council, envisioning the deployment of a Virtual Reality headset-like device in the city for users to explore the new regeneration site. However, as the COVID-19 pandemic unfolded after the thesis work commenced (see Figure 1.1), the design was adapted to incorporate elbow-based interaction, ensuring safe engagement despite the challenges posed by the pandemic. The council's primary aim for this aspect of the PhD was to integrate technology into the city to enhance public understanding of the forthcoming regeneration. While the author found the idea of cocreating the regeneration site intriguing, it was not feasible due to finalised designs. Instead, this chapter focuses on leveraging technology to provide insight into future changes and foster public awareness and participation in the urban transformation process.

At the time of this deployment, residents were confined to their homes due to multiple COVID-19 lockdowns. Simultaneously, the city was undergoing a regeneration, including the construction of an Arena, Pedestrian Bridge, Coastal Park, Housing Complex, and Car Park. Therefore, this work presents the evaluation of an interactive installation across an unprecedented time. Figure 3.1 illustrates the anticipated locations of these elements, with the Lookout device marked at the end of the walkway on the right, these elements form the major content explored by participants on the Lookout device.

Furthermore, there is an exploration into user preferences for urban technologies, shedding light on the future of community-driven initiatives and the potential of public installations for topophilia. This project not only serves as a case study for designing public displays with a unique COVID-19 perspective but also involves the analysis of interactions from over $10,000$ sessions during a time when people were cautious about using public technology [31, 214, 275, 285]. Additionally, the evaluation of this nine-month deployment sparked the work completed throughout the remainder of the thesis.

3.2 Cocreational Design Process

The detailed cocreational process was written and described within the author's Master's thesis [42] for clarity an overview of this process will be provided to explain the decisions made in the final deployment which are detailed here. Over three months, a set of seven cocreational design workshops were completed with community members, stakeholders, and extraordinary users; five were zoom based, one teleconferencing and one in person. The aim of the workshops was to retrieve feedback about both the physical and digital aspects of the deployment design with a particular focus on ensuring inclusivity within the design for as many users as possible with differing abilities. A further underlying theme was the need to recreate a sense of place for people re-entering the city centre, therefore focusing on new aspects of the regeneration design. This was achieved by creating a series of storyboards illustrating the interactions a user would have with the physical and digital aspects of the display whilst describing the context of use and interaction to provide prompts for discussion (see Figure 3.2). The storyboards underwent seven iterations upgrading from pencil-paper sketching to an Android Studio prototype application and spanning from a Virtual Reality headset to foot-based interactions and finally elbow based movements.

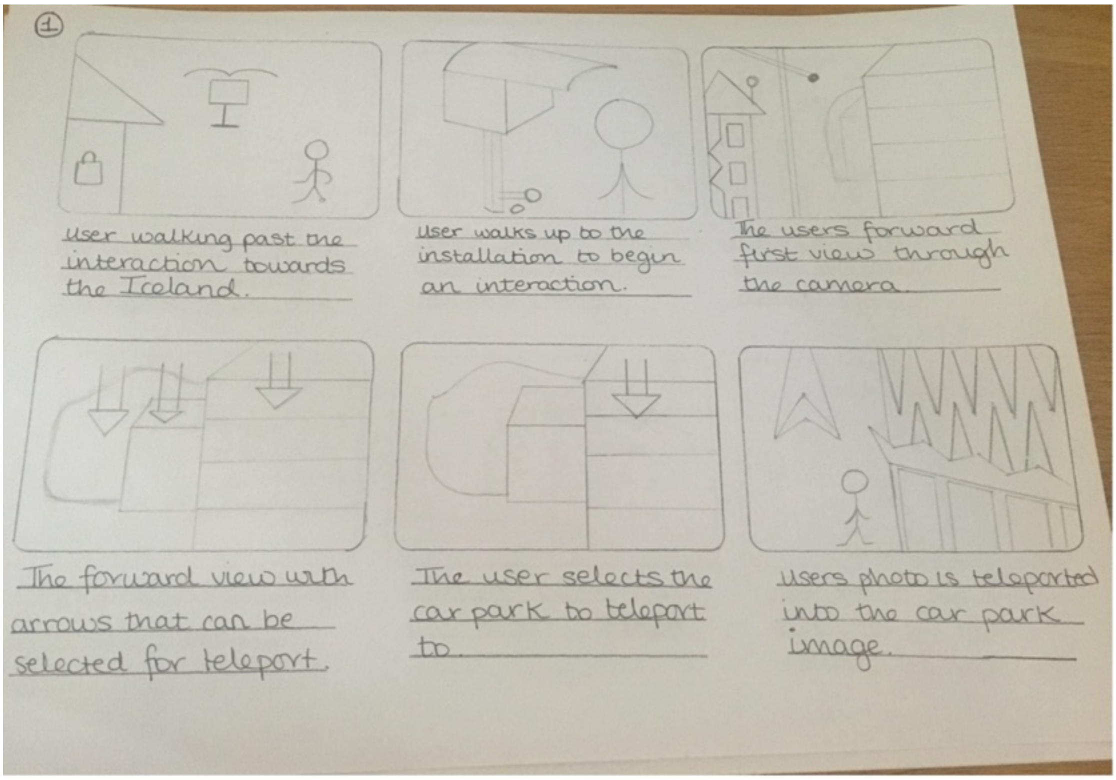

Figure 3.2: Storyboard showing a user discovering the device in a public setting, engaging with it through foot-based interaction, and selecting various features of the software design, including the car park. This storyboard was the second interaction evaluating whether foot-based interaction would be effective.

3.2.1 Virtual Workshops

A team of 10 people external to the research team were involved across the project from the regeneration team, with five or more present at each online workshop. Their backgrounds ranged from cultural developer, regeneration specialist, major events leader, and project director. The participants broad spectrum of understanding provided us with an inclusive overview of Swansea city centre and its community, the redevelopment project, building and development, and the previous deployment successes and failures within the city centre. The online workshops were between 1 and 1.5 hours in length, where the digital and physical design of the Lookout was discussed using storyboards as prompts. As we were unable to complete the session in person due to the COVID-19 pandemic this was the most effective way to demonstrate to the stakeholders the possible interactions that could be had with the Lookout. After each workshop the storyboard designs were iterated leading to final changes in the digital and physical design of the display.

3.2.2 Socially Distanced Workshop

A further on-site workshop was completed with the redevelopment contractor, site manager, engineer, and project director. This workshop focused on the physical design of the encasing of the Lookout, including the possible dimensions, robustness, and the area in which it would be located. The original heights were reduced by 10cm to accommodate for the average height of females, and a robust metal (E.g. aluminium) was suggested to prevent vandalism (see Figure 3.3a). The installations were placed at the bottom of the city's high street to maximise foot traffic and also offer a good view of the regeneration site.

3.2.3 Involving Extraordinary Users

A teleconferencing workshop was held with 15 members of Sight Life, a charity that aims to help the partially and non-sighted to live independent lives [159]. The participants provided a perspective which enabled changes to be made to ensure safety for them and the remainder of the community [153]. The concept, content and physical design of the Lookout were provided as verbal explanations to the group and based on the storyboards discussed above. The discussions focused on two aspects: the physical design of the Lookout and the location it would be based in. For the physical design of the Lookout, the use of elbow-based and foot-based levers were evaluated.

3.2.4 Cocreational Adaptations

The following adaptations were implemented based on discussions and feedback received during workshops:

Elbow Levers: The final design was adjusted for COVID-19 safety, using elbow-based levers for navigation and buttons for actions like picture-taking. This was the COVID-19 friendly adapted design that the stakeholders, extraordinary users and our own research team believed would provide the safest COVID-19 friendly interactions whilst still enabling a physical interaction with the device and being less hazardous for the partially sighted.

Differing Abilities: The final deployment was adapted to include two installations at varying heights: one at 1m for wheelchair users/children and another at 1.4m for adult pedestrians. This adjustment aimed to eliminate the need for assistance, ensuring all users could interact independently.

Surrounding Design: To create a safer area around the installation, colour and texture contrasts were used to distinguish from the main walking path and planters/chairs to create a boundary for walking canes to pick up on.

Pictograms: Pictograms were added to guide users on interacting with the design, demonstrating the use of elbows instead of hands or touching the screen for COVID-19 safety.

Timer: Considering users may approach the content at different times, a timeout feature was implemented to ensure consistent interaction for all.

Personalisation: The participants requested a more immersive and personalised experience. This led to two adaptations: the incorporation of a picture-taking opportunity including Augmented Reality (AR) filters and drone footage with teleportation filters to provide a sense of the scale of the regeneration project.

3.3 Adapting Blueprints for Deployment

In this section, an overview of the deployed designs for the Lookout installations will be provided. These designs were shaped by the cocreation process detailed in the previous section, which contributed blueprints for two interactive elbow-based installations. It is worth noting that the final deployment designs, which were not part of the original Masters thesis [42], were developed subsequently (i.e., during the work for this PhD thesis). Also due to the constraints imposed by the COVID-19 pandemic during the Masters work, the testing carried out and reported in that thesis was conducted solely in controlled lab environments and online via Zoom. Given the device's need for extended, unsupervised deployment in public spaces, ensuring the prototype's robustness and quality was of utmost importance. Therefore, the final deployable designs were outsourced to Tom Henderson for the physical designs and Dr. Gavin Bailey, for the software components. Additionally, the surrounding environmental design, initially conceptualised by the author, was further adapted and executed by Swansea Council. These final designs, which were not part of the Masters thesis form the groundwork for deploying the device, with the author's analysis of the prototype's extensive outdoor deployment usage presented within this chapter.

3.3.1 Hardware

The Lookout's physical design for its exterior drew inspiration from seaside binoculars commonly found near Swansea's coastal city centre and was based on the researcher's initial blueprints and concepts. The design aimed to make the concept relatable to the community, emphasising the city centre's future. The design included:

- A long, slender pole to conceal wires from power sockets beneath the installation
- A rotating centre atop the pole, allowing the elbow levers to move the device 30cm in each direction (60cm total, left to right)
- An additional aluminum rod welded onto the rear of the pole for stability and vandalism prevention

- The use of robust, waterproof aluminum to withstand the Lookout's permanent deployment in a bustling city centre for several months, without interfering with the magnetometer readings

The top box, encasing the Samsung tablet, mimicked the shape of binoculars with pop-out circles at the back, creating the illusion that the device was looking into the distance (see Figure 3.3b). The tablet was safeguarded by a shatterproof, anti-glare glass screen securely bolted in place. To address the diverse needs of the community, two physical versions of the Lookout were created. The first version, for Adult Pedestrians, had the height at 1.4 metres, while the second version for Children and Wheelchair users had the tablet at a height of 1 metre (see Figure 3.4). Additionally, in the second version, the supporting pole was placed further back, and longer elbow levers were added for ease of accessibility (see Figure 3.3a). An elbow button, similar to disability access buttons, allowed interaction and featured a copper-coated surface, aiming to reduce concerns during the COVID-19 pandemic about public touch interactions [177, 214].

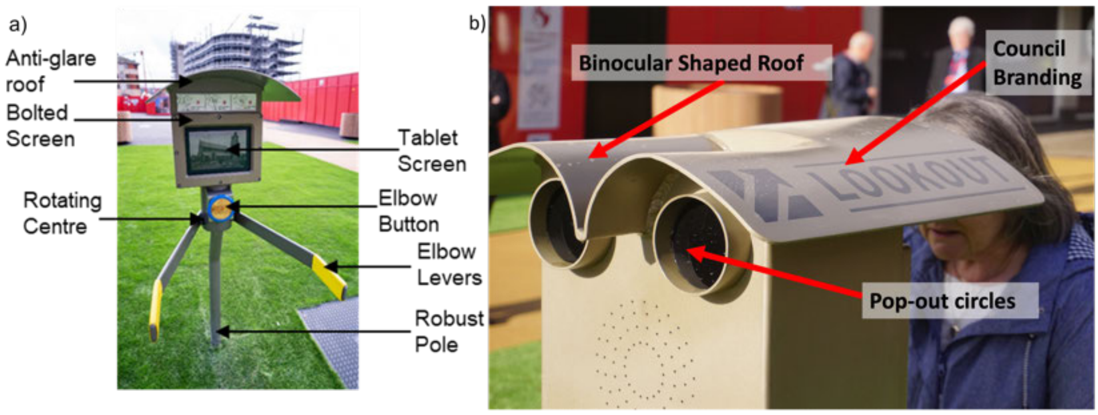

Figure 3.3: a) Completed Lookout rig for children and wheelchair users; b) Backside of Lookout, resembling binoculars with curved roof and pop-out circles.

3.3.2 Software Design

The software design, initially based on this author's designs, underwent refinements to align with the hardware and user interactions. The visual component of the installation was developed using an Android app, on a Samsung Galaxy Tablet. The choice of this tablet was deliberate, as it featured a highly accurate inbuilt magnetometer, which enabled the content on the screen to respond to the movement of the elbow levers. For instance, the design was configured to allow participants to shift the elbow levers from left to right and vice versa, thereby navigating through the available selections. This interaction would enable a participant to select various options, such as the Coastal Park, which was positioned on the far left of the panoramic construction and could only be accessed through physical movement.

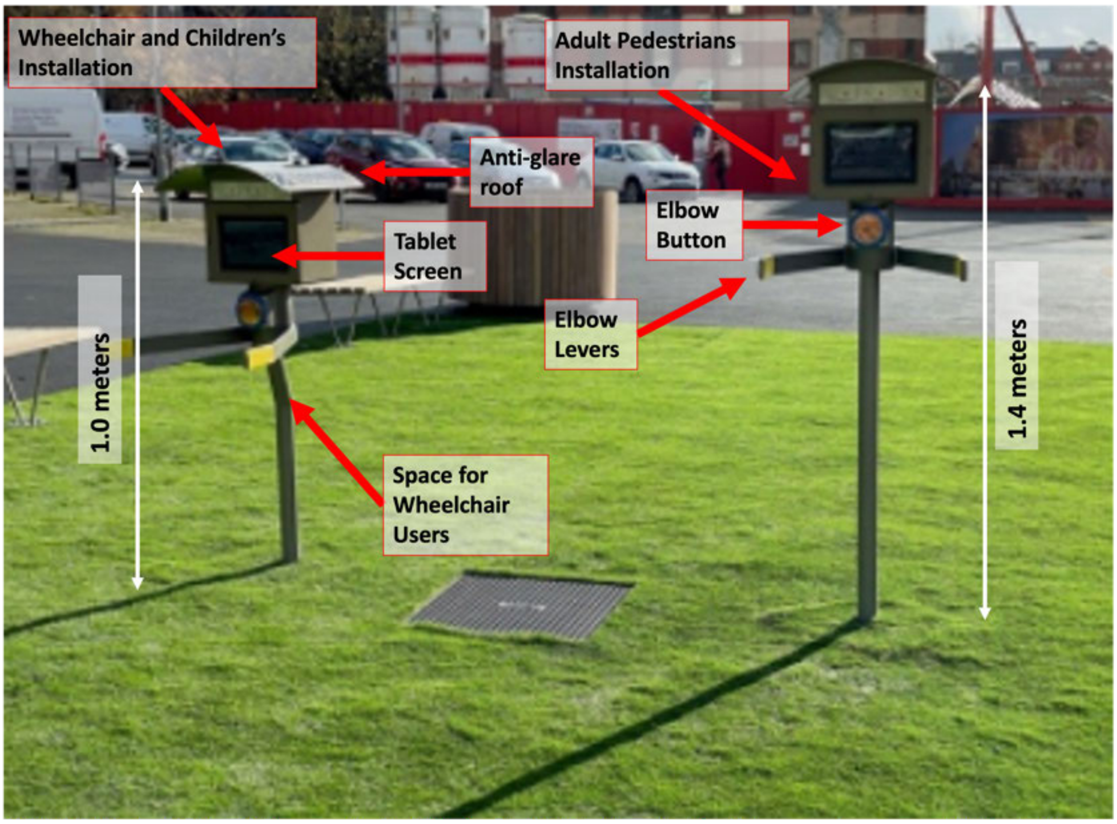

Figure 3.4: Final deployment of the Adult Pedestrian and Children's/Wheelchair-accessible installations, positioned approximately 1 metre apart.

To ensure a consistent experience for all users, the content automatically re-centred to the starting screen after each interaction, and it would timeout after 15 seconds of inactivity. The 15-second timeout period was determined through lab testing. It was deemed to allow users enough time to interact with a location but also ensured that if someone stopped an interaction quickly, the device would timeout before another user potentially saw the previous user's picture, a scenario we aimed to prevent. The software design remained consistent across both installations to maintain continuity. Pictograms were incorporated above the screen to instruct users on how to interact with the design, emphasising the use of elbows instead of hands or touchscreen interaction, in line with COVID-19 safety measures.

Figure 3.5 illustrates a user journey, divided into four stages, commencing with a holding screen. The design was structured so that participants initiated their experience with a historical photo slideshow, triggered by interacting with the elbow levers or a designated button, leading them to *Stage 1*. In this phase, users made two selections: their preferred interaction language (English/Welsh) and preferred Augmented Reality (AR) filter. Users were presented with a range of filters, such as virtual sunglasses, which were superimposed over their live video feed in real-time. They could either capture photos with their selected filter or proceed directly to the primary content. Photos captured during interactions were displayed at each visited location and automatically deleted at the end of each session (after 15 seconds of inactivity), returning the system to the historical slideshow.

Stage 2 provided a current day regeneration site view with selection buttons for predicted visuals, courtesy of Swansea Council. *Stage 3* offered participants the opportunity to select one of the four main panoramic views: Arena, Bridge, Garden, and CarPark (see Figure 3.1). Upon selection, the application seamlessly transitioned users from their current position to their chosen location, such as the Arena, by displaying drone footage from the installation area to the target location. Each *Stage 3* location could further lead participants to *Stage 4*, where they could view more detailed aspects of each location. For instance, if the Arena was initially selected, users could choose from three alternate Arena views (Hendrix Skin, Foyer, Stage) by panning the screen using the elbow levers and selecting a new viewpoint. From *Stage 4*, participants had the option to return to *Stage 3* and then to *Stage 2*, allowing them to select another location to explore, or they could choose to conclude the session. At each stage, a 15-second timeout would appear so that the participant knew to interact if they wished to continue.

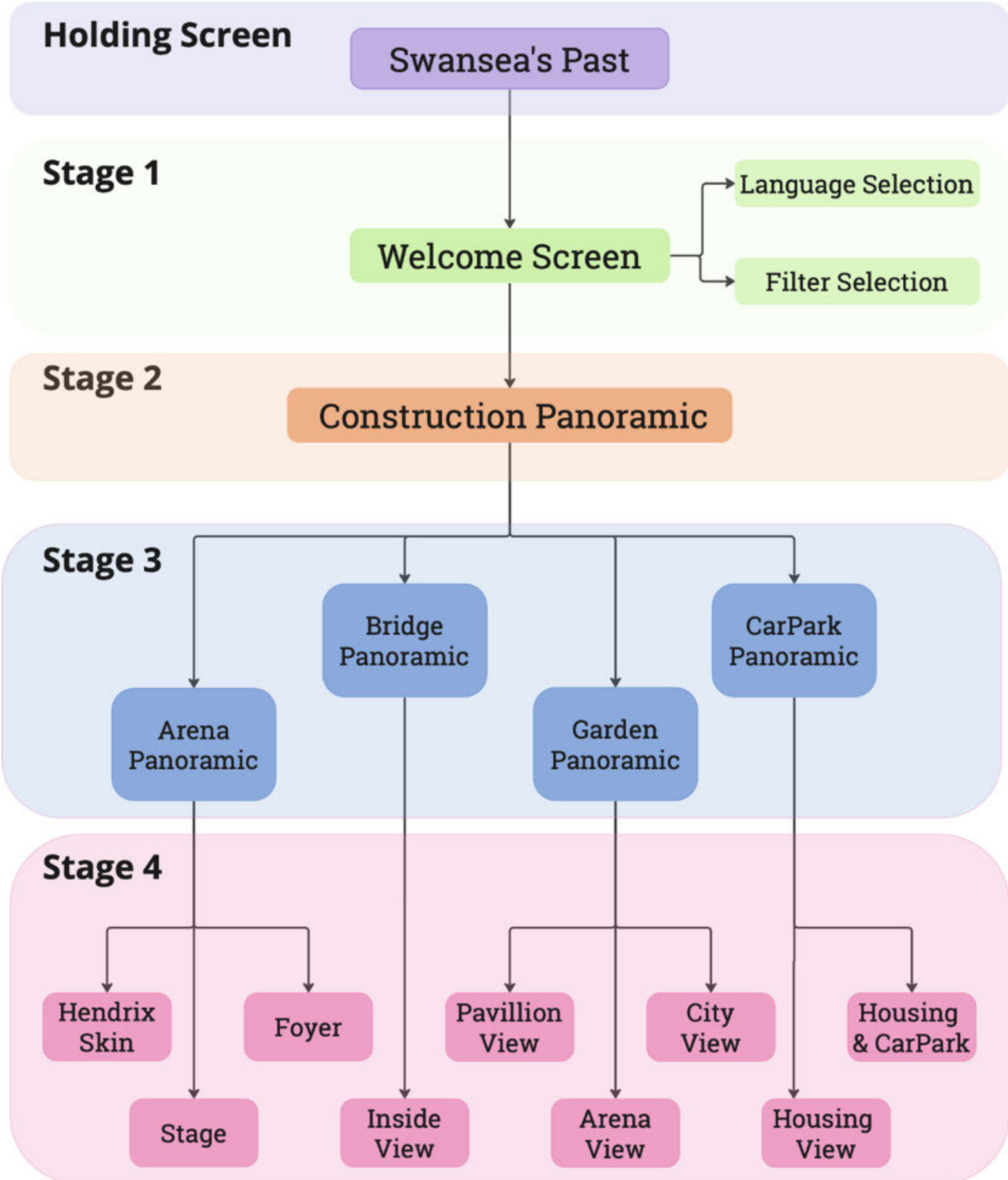

Figure 3.5: Schematic diagram providing an overview of the Lookout software, divided into a holding screen and four stages, each requiring interaction to progress to the subsequent stage

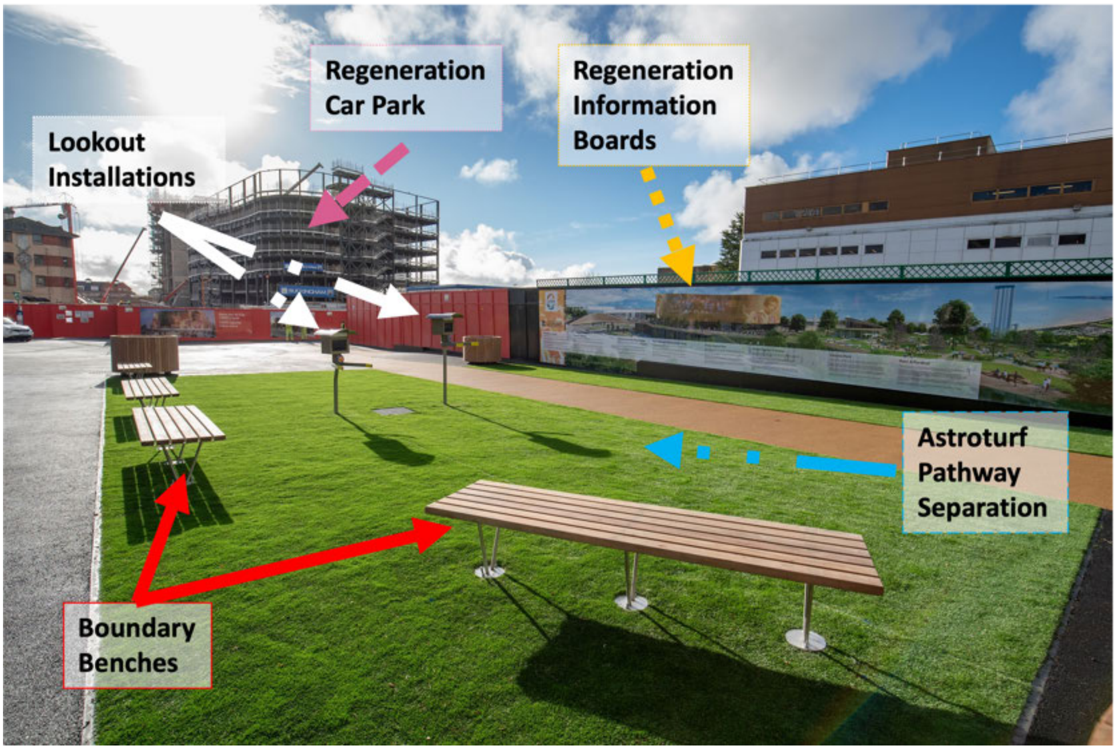

Figure 3.6: Lookout surrounding environment, with benches used to provide a border.

3.3.3 Surrounding Environment

The design of the context and environment surrounding the installation was as important as the Lookout's design. The installation location positioned the display at the crossroads of the city's high street and the new regeneration site. This strategic placement ensured that the display would be situated in an area with a high pedestrian traffic and a viewpoint for observing the ongoing developments within the regeneration site.

Figure 3.6 illustrates the final deployment area, featuring AstroTurf beneath the installation. This choice served two purposes: it created a noticeable colour and texture contrast compared to the surrounding concrete, aiding users with partial sight in distinguishing pathways. Additionally, an arrangement of chairs and planters along the AstroTurf boundary provided tactile indicators, guiding users from the pathway to the installation area. Surrounding display boards offered information accessible to diverse visitors, ensuring everyone could benefit from the content, regardless of their ability to interact with the Lookout.

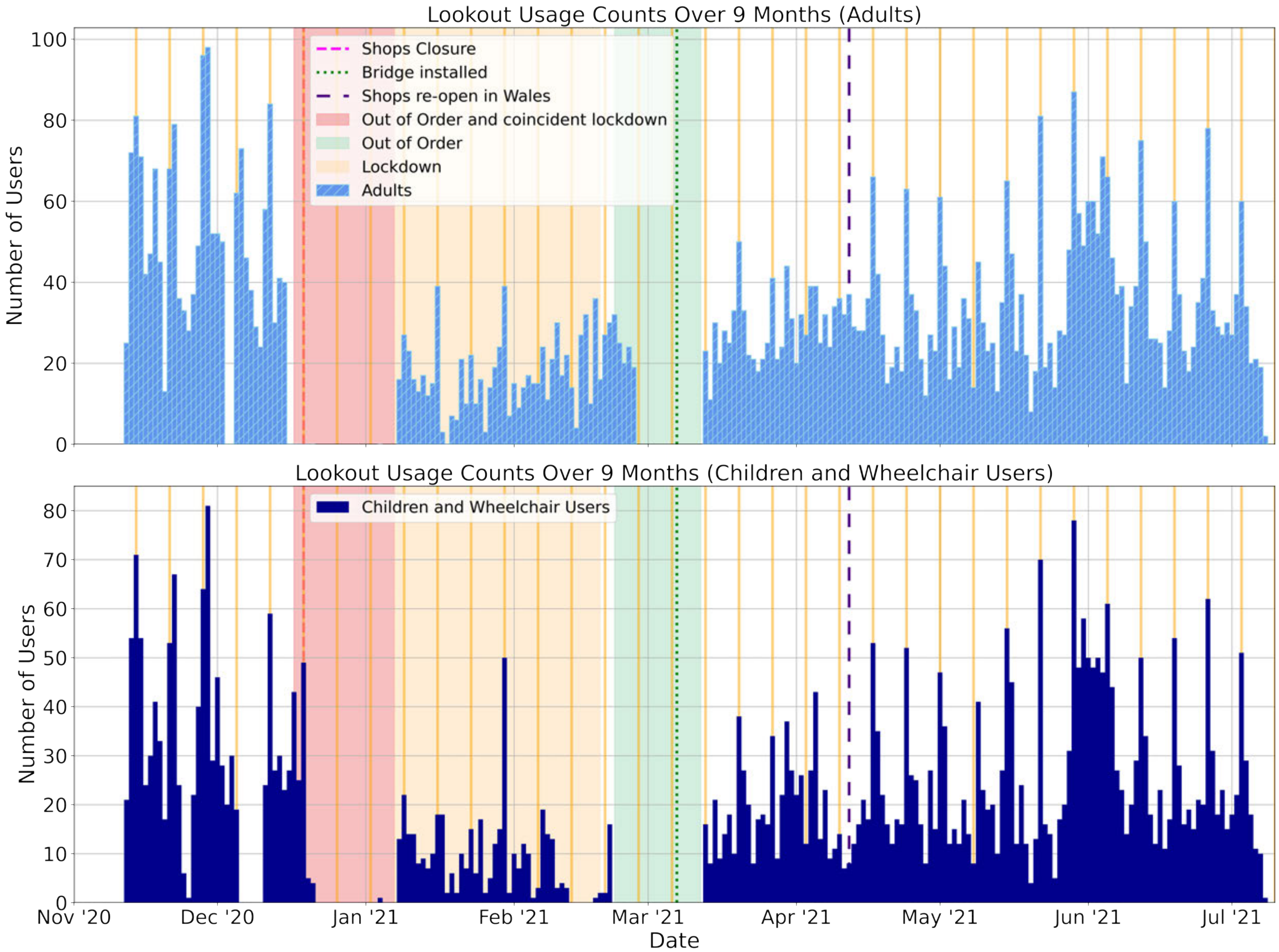

Figure 3.7: Graph showing the number of participants interacting with the Lookout across a nine-month period. The graph shows the difference in usage for the two devices, the Adult Pedestrian (Top) and Children and Wheelchair Users (Bottom). It also includes the labelling of significant events across this time frame including, national lockdowns, out of order times, weekends and shop closures.

3.4 Deployment Evaluation

From November 2020 to July 2021, the Lookout was deployed and evaluated within Swansea city centre. This evaluation encompassed the analysis of three distinct types of data collection: logging data to gain insights into user interactions with content (with a strict policy of not collecting personal data), passive observations to document user behaviours during interaction, and interviews to evaluate engagement effectiveness and collect user perspectives on future city-based technologies. It is important to emphasise that this evaluation represents a new contribution, as the Lookout deployment occurred subsequent to the completion of the Masters thesis.

3.4.1 User Interaction Data

Over the course of the nine-months, the Lookout logged a total of $10,991$ sessions. Among these, $6,514$ sessions were logged on the Adult Pedestrians installation, while $4,477$ sessions were logged on the Children and Wheelchair Users installation. A session was defined as the initial interaction with the installation, commencing from the moment a participant progressed beyond the welcome screen until the installation timed out after 15 seconds of inactivity.

The data collected from both installations for each session encompassed information such as the date and time of usage, total interaction duration, locations visited, time spent at each location, end of session location, language chosen, and selected filter. 13% of users opted to interact with the minority language version, highlighting the significance of offering alternative options to enhance accessibility, particularly in the context of research involving multilingual public displays.

Figure 3.7 provides an overview of the Lookout's usage over the nine-month deployment period. This deployment took place during a period marked by fluctuating lockdown measures due to the ongoing COVID-19 pandemic. The first two months of deployment (November and December 2020) accounted for 26% ($2,858$) of the overall usage, with a particular interest in viewing the Arena during this period. Subsequently, Wales entered a national lockdown from 16th December 2020, to 19th February 2021, which included the closure of non-essential shops from 19th December 2020, onwards, and restrictions on non-essential travel. In addition, due to a power outage caused by water damage, the Lookout was out of order from the 17th December 2020, to 7th January 2021, and again from the 22nd February 2021, to 12th March 2021. Although interactions continued during the lockdown period, it was evident that the number of people in the city centre significantly decreased. Lookout interactions were 44% lower for the Adult Pedestrians installation and 58% lower for the Children and Wheelchair users installation compared to the non-lockdown months. Following the second power outage, two significant factors could have influenced usage. First, following the installation of the pedestrian bridge directly in front of the Lookout's location the overall usage increased by 43%. The data suggests that the bridge's installation piqued the public's interest in the regeneration site, which was challenging to observe before this addition, particularly during lockdown. While the public could not walk through the site, they could see the bridge from the main road, which could have motivated them to interact with the Lookout to explore the changes in the city centre. Second, the reopening of non-essential shops in the city on 12^{th} April 2021, led to a 14% increase in sessions on the Adult Pedestrians device and a 25% increase in sessions on the Children and Wheelchair users' device, following the installation of the bridge. This usage pattern underscores the unique nature of the Lookout's deployment and its potential as a research and engagement tool, even in challenging circumstances.

Usage Patterns and Social Dynamics

Over the course of the nine-month deployment, the Lookout exhibited a trend in usage, with weekends, especially Saturdays, standing out as peak interaction times. Figure 3.8 displays a heatmap depicting the total usage of the Adult Pedestrians device throughout each day of the week within the operating hours of 8am to 8pm. The data highlights that the highest volume of interactions consistently occurred on Saturday afternoons, typically between 12pm and 4pm, with slightly fewer interactions observed at the same times on Sundays. Similarly, the Children and Wheelchair users device experienced its peak interaction period between 1pm and 3pm on Saturdays, with Sundays following closely behind (as illustrated in Figure 3.9).

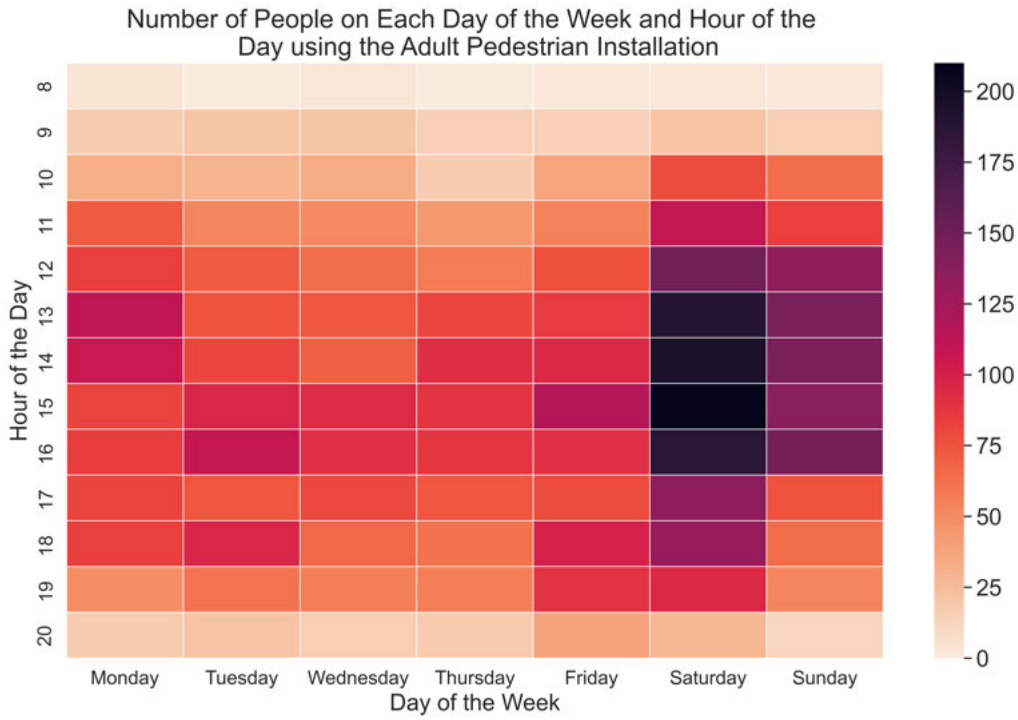

Figure 3.8: Combined average usage patterns over nine months for the Adult Pedestrians device by Time and Day of the Week.

Throughout the week, both devices had the highest average interactions between 1pm and 2pm, indicating users engaged with the Lookout during lunch breaks, while heading to get food, or during leisure moments. Increased weekend usage may be due to higher weekend city footfall for shopping, socialising, and family outings.

The increased weekend interactions aligns with the findings of Malone [167], who observed a similar trend in a study involving a large multi-touch display. Malone's research highlighted a social feedback loop, wherein users were motivated to engage with the display due to the direct influence of others' interactions [167]. This social reinforcement promoted further engagement and interaction, creating a positive cycle. This observed pattern in the Lookout's usage underscores the role of social dynamics and the communal aspect of public installations, indicating the potential for such devices to foster community engagement and interaction within urban spaces, particularly during peak social hours.

Furthermore, Table 3.1 shows the average usage in minutes per day, based upon the overall 199 days of usage. It reveals that, on average, the Lookout was in use for roughly 15% of its overall operational time. This level of engagement is notable given the reduced population within the city during the COVID-19 pandemic. Despite the challenges posed by the pandemic, the data suggests significant use of the Lookout, underscoring its possibilities for increased usage in post COVID conditions.

Table 3.1: Usage Statistics of Sessions by Day of the Week for the Lookout

Day of Week	Total Number of Sessions	Avg. Number of Sessions per Day	Avg. Usage per Day (Minutes)	Percentage Use (%)
Monday	1370	50	89	13
Tuesday	1242	44	79	11
Wednesday	1152	43	77	11
Thursday	1185	43	80	12
Friday	1450	51	94	13
Saturday	2708	94	198	28
Sunday	1879	66	130	18

Photograph Taking Opportunity

The inclusion of a photograph-taking opportunity was influenced by the desire to provide a personalised aspect for each participant, a feature requested during community cocreation sessions [42]. Originally, the plan involved emailing these pictures to participants after their interaction, offering them a memorable keepsake of their engagement with the installation. However, technical constraints, including Wi-Fi/data limitations within the deployment area, halted this plan. Despite these limitations, the photograph-taking opportunity remained popular, with 93% of participants choosing a filter.

The "mask" filter emerged as the top choice among available filters, selected by 32% of participants. This popularity could be attributed to its convenient positioning as the first filter, requiring no physical movement to select, thereby ensuring easy accessibility for users. A similar pattern was observed for the second and third most favoured filters: the crown (19.5%) and glasses (14.4%) filters, respectively, positioned to the right and left of the central selection point. The remaining filters (Moustache, Masquerade, Beard, and No Filter) were each selected by approximately 10% or fewer participants.

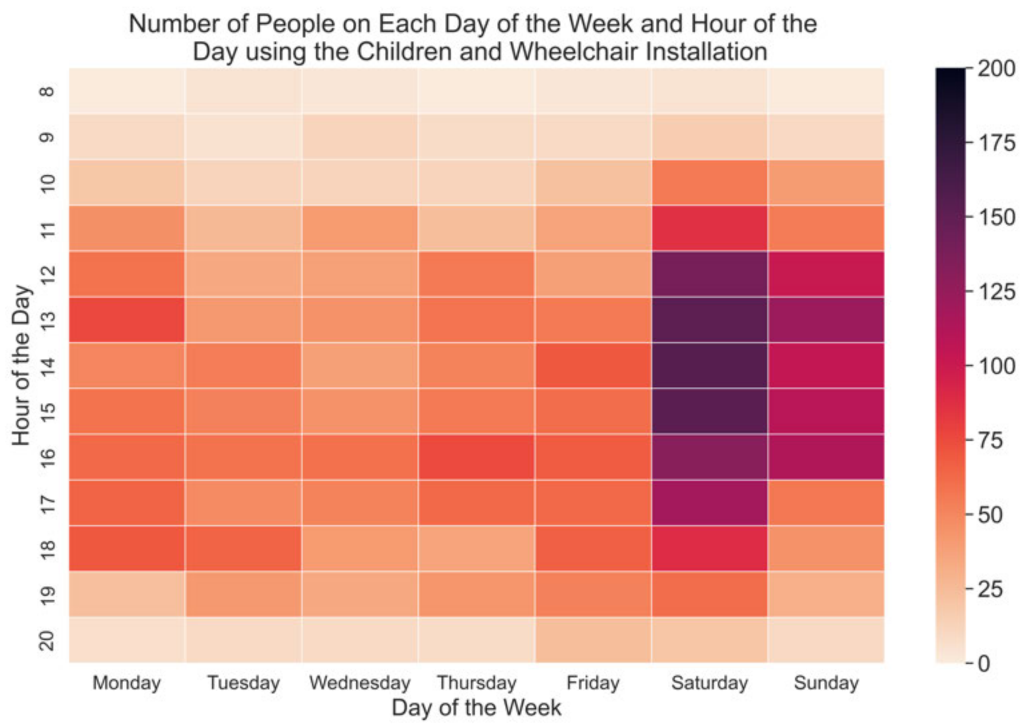

Figure 3.9: Combined average usage patterns over nine months for the Children and Wheelchair Users device by Time and Day of the Week.

The data suggests that the filters themselves were not particularly important in the selection process. Instead, the data indicates that the locations in relation to the centre of selections and the ease of choosing them played a more significant role. Furthermore, the preference to favour the right-of-centre filters (6% more than left-of-centre) aligns with the tendency for approximately 90% of people to favour their right hand for manual tasks [40].

The user preferences and interactions with the filters in the Lookout installation emphasised the joy of personalisation and the understanding that users prioritise easily accessible selections. This discovery highlights the importance of user-centric design and accessibility in interactive urban installations. It ensures these installations engage a diverse audience, providing a personalised experience that ultimately enhances the overall impact and success of urban interventions.

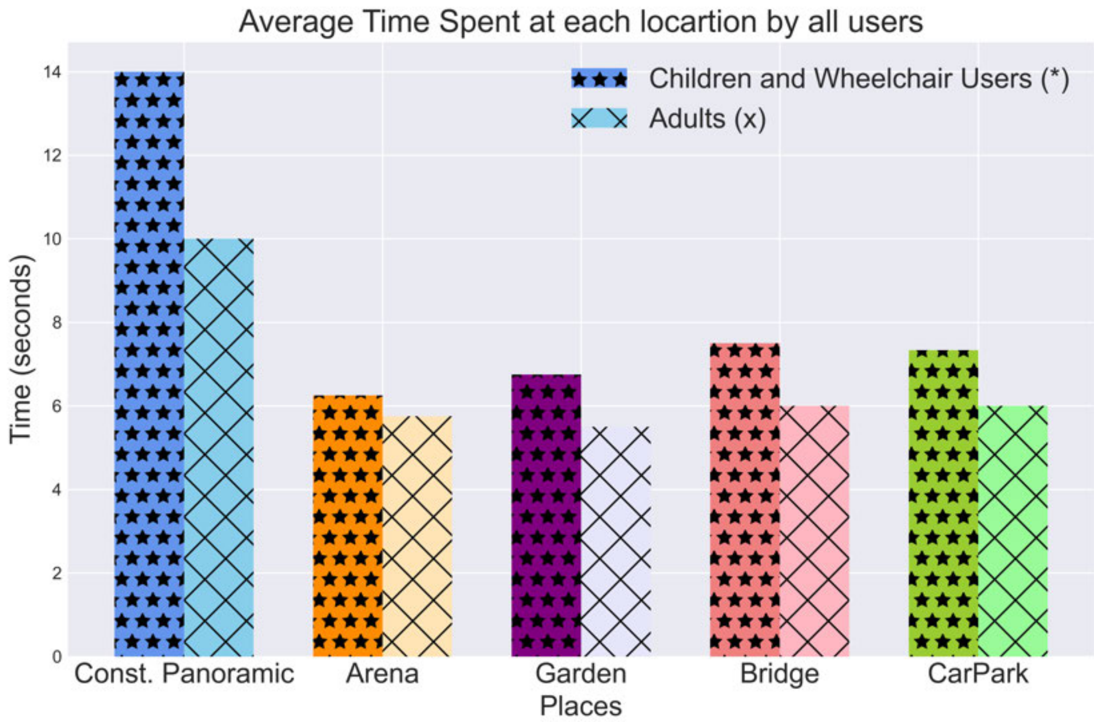

Figure 3.10: The average visit duration for locations over nine months, categorised by installation type: Adult Pedestrians device and Children/Wheelchair Users device.

Comparing Interactions and Average Viewing Times

Over the nine-month deployment, participants engaged with the Adult Pedestrian device for an average of 2 minutes 40 seconds, while the Children and Wheelchair users device had a slightly lower average interaction time of 2 minutes 20 seconds. These durations are higher than the average interaction times of approximately 23 seconds typically observed within other interactive displays (e.g., [100, 185, 278]). However, it's challenging to establish a definitive correlation due to the unique deployment of the Lookout. Nonetheless, it demonstrates promising potential for future civic probe designs focusing on urban regeneration, indicating that up to 2.5 minutes of content can be generated for interaction.

On average, users explored six locations, with the Arena attracting visits from 94% of all participants. The distribution of average time spent at each location revealed that participants using the Children and Wheelchair users device spent an average of 2 seconds more at each location compared to Adult Pedestrians device (see Figure 3.10). This observation suggests that Children and Wheelchair users device may have been more likely to engage participants in group interactions, leading to longer periods of content exploration. The observations of numerous multi-person interactions within the installation further supports this hypothesis. These observations highlighted the complexity of user interactions with interactive installations and provide insights into user behaviour and preferences, which can inform future design and content decisions.

To gain a broader perspective on user interactions, the individual location data was aggregated and categorised into five main areas: Construction Panoramic, Arena, Bridge, Garden, and CarPark (see Figure 3.10). The overall interactions for the construction panoramic locations showed that during the lockdown period, there was a decrease (64%) in selection screen interactions, which continued to remain at lower levels post-lockdown. While the number of interactions did not return to pre-lockdown levels, they did increase (37%) following the installation of the bridge in March and continued to increase exponentially until data collection ended in July. It is interesting to note the differences in user behaviour between the two installations. While the number of interactions on the Children and Wheelchair users device was lower (see Figure 3.11), the average time spent at each location was higher (see Figure 3.10). This suggests that although there were fewer interactions, the engagement with the content was more extended, possibly indicating a deeper level of interest or exploration.

The majority of locations had higher interaction numbers on the Adult Pedestrian device, but a shift occurred during the summer. The Adult Pedestrians device saw exponential growth in usage, coinciding with shop reopenings and people returning to the city centre following lockdown. During this period, the Children and Wheelchair device also experienced a substantial increase in usage (46% from April to June), particularly for the Arena. This trend highlighted the influx of people into the city centre following shop reopenings, attracting a diverse range of users and contributing to the overall engagement success for the Lookout.

Additionally, the data revealed trends regarding specific content locations. For example, the Arena had the highest interactions (Figure 3.11) but the shortest average viewing time (Figure 3.10). This suggests users quickly engaged with the Arena but didn't explore it deeply. The Arena was a focal point in the regeneration development's advertising efforts, and this emphasis was reflected in the initial location selections. In November, it garnered substantial engagement, with over 800 interactions on the Adult Pedestrians device and 600 interactions on the Children and Wheelchair users device (see Figure 3.11), with an interaction constituting the user selecting to view a location for 5 seconds or more. In fact, the Arena maintained high interaction numbers throughout the deployment, even during January and February when external factors like lockdowns and power outages affected half of this period. During these months, the Arena still received over 300 overall interactions.

In contrast, the Bridge and CarPark locations had the lowest number of overall interactions, but the highest average viewing times. This implied that participants' lower knowledge about these areas could have led to fewer users and longer interaction times. Conversely, Car Park-based content had the lowest number of interactions overall, possibly due to the more mundane nature of the content. However, the usage patterns for Car Park content were distinct for Children and Wheelchair Users device as while the interactions increased slightly following the bridge installation ($\approx 10\%$), the opening of shops in April led to a 100% increase in interactions from April to June (see Figure 3.11). In comparison, the bridge installation and the end of lockdown in March had a more pronounced impact on the Adult Pedestrians device, resulting in a 42% increase, compared to the 4% increase from April to June (see Figure 3.11).

Data Analysis Summary

The data analysis of user interactions and engagement with the Lookout during the COVID-19 pandemic yielded insights. It highlighted the fact that, despite the disruptions caused by the pandemic, aspects of the regeneration, such as the Arena, managed to sustain substantial user engagement. This data underscored the resilience and enduring appeal of public installations, even when faced with challenging circumstances. Furthermore, the substantial number of sessions logged on both devices emphasised the role of accessibility and inclusivity in public installation design. It showed that accessibility-focused installations can serve diverse user groups, including those with varying mobility needs.

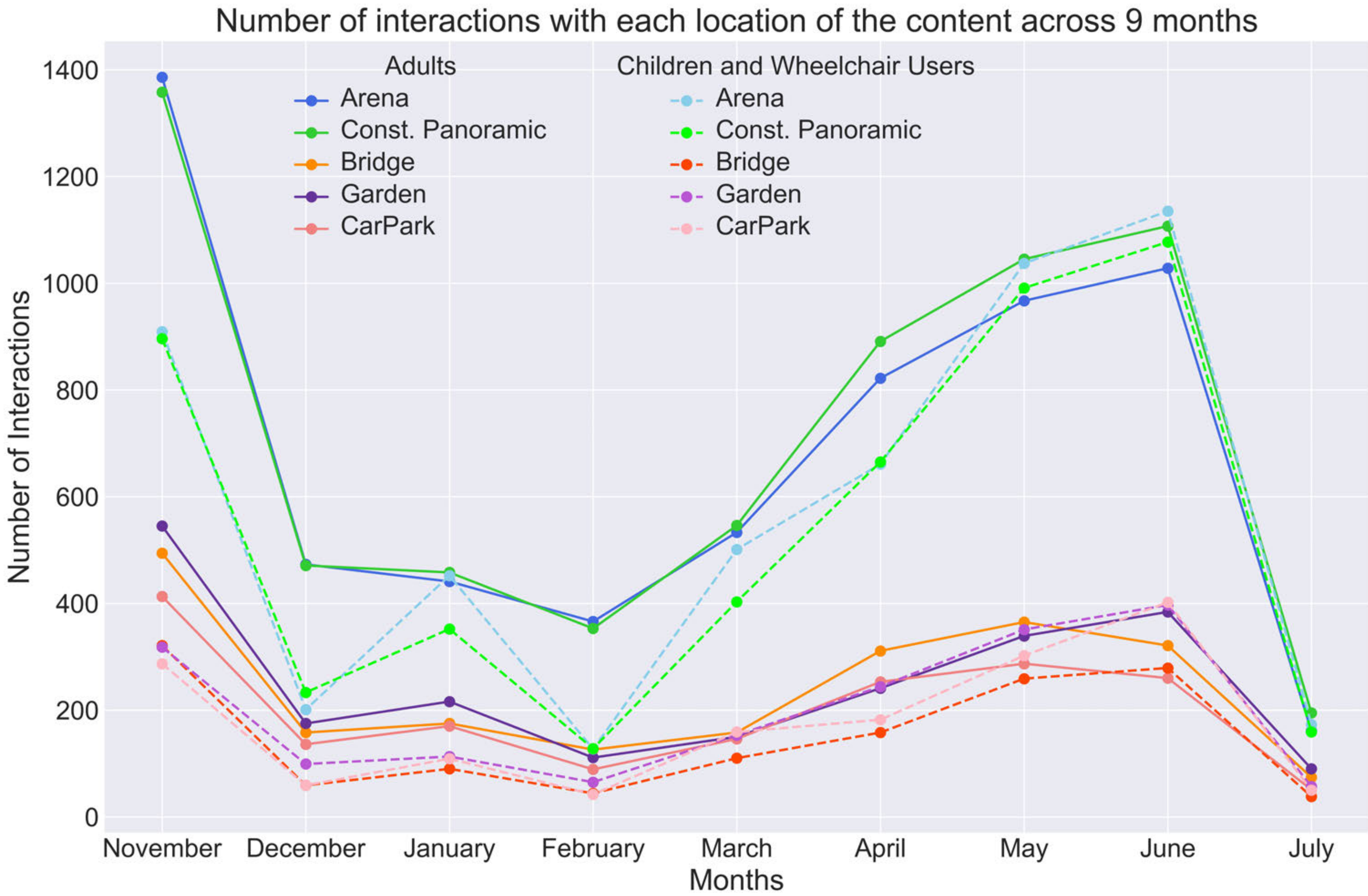

Figure 3.11: Line graph showing the number of interactions that occurred for all locations for both the Adult Pedestrians (solid line) and Children and Wheelchair Users (dashed line) installations.

The Lookout recorded over $10,000$ sessions across a nine-month period, making it a source of data for comprehending user behaviour and preferences in public installations. This dataset holds significance as it encompasses interactions spanning the COVID-19 pandemic and its aftermath. This time frame had been relatively unexplored in existing literature, making the dataset a valuable resource for investigating the effects of this period. The data highlighted how user interactions adapted in response to lockdowns and other pandemic-related challenges, providing insights into the adaptability and resilience of public installations in the face of external disruptions. The heightened usage of the Lookout on weekends, especially on Saturdays, underscored the role of public installations in engaging people with their urban spaces during their leisure hours. A comprehension of these usage patterns can aid in optimising installation locations and operating hours.

In summary, the data garnered from the Lookout installation stands as a contribution to the advancement of research in the realm of public installations and urban development, particularly within the unique context of an extended deployment during the COVID-19 pandemic. It offers insights into user behaviour, preferences, and the robustness of public installations in confronting unprecedented challenges. This data, ultimately, enriches our understanding of how accessible public installations can catalyse engagement, inclusivity, and the rejuvenation of urban spaces, even in times of adversity.

3.4.2 Behavioural Observations

Logging data from every interaction was a pivotal aspect of the Lookout deployment, as it allowed the installation to function without the need for constant supervision. In comparison, this approach ensured the continuous collection of valuable data about user interactions while minimising the potential for the Hawthorne effect, where individuals alter their behaviour when they are aware of being observed [163].

Observational Study Procedure

The aim of the observational studies was to gather insights into how individuals engaged with the Lookout, while maintaining social distancing due to the ongoing COVID-19 pandemic. To alleviate any concerns of passersby who might have been uncomfortable with others being too close to them, which was a significant concern at the time [80,103]. The observation procedure was as follows:

1. Maintain a minimum distance of two metres from the installation and participants to adhere to pandemic-related safety measures
2. Conduct observations during months with fewer pandemic-related restrictions (e.g., March and April) to minimise potential influences
3. Group Dynamics: Document whether users interact alone, with children, or in pairs/groups
4. Observational Learning: Record instances where individuals observe others interacting before engaging themselves
5. Conduct observations with respect for individuals' privacy and without interference in their interactions

The chosen procedure diverged from a more ethnomethodological approach due to time constraints, which limited the author's ability to observe participants extensively. Employing an ethnomethodological study would have introduced complexity to the understanding and analysis, posing challenges in interpretation. Thus, the adopted procedure aimed to provide insights into how users' interactions with the Lookout were influenced by others, particularly in post-lockdown circumstances.

Observational Study Analysis

Observations were conducted over 10 days in March and April, averaging 5 hours per day. These observations highlighted how different user groups engaged with the Lookout and contributed to the understanding of the installation's impact on the public space. This process involved reviewing the observations to identify recurring patterns, behaviours, and interactions among different user groups at the Lookout. Key elements such as group dynamics, observational learning and social dynamics were scrutinised.

Figure 3.12: Participants interacted with Lookout installations. On the left, Swansea Council leader Rob Stewart used the Adult Pedestrian device during the installation opening [108, 286]. On the right, two participants engaged with the Children and Wheelchair users device, taking turns to select content.

The analysis revealed interesting trends, such as the tendency for adults to interact in pairs or groups (as proposed within the data analysis) not only created a shared experience but also promoted a sense of togetherness and community, reinforcing the Lookout's role in enhancing topophilia (see Figure 3.12). On the other hand, children and their families inadvertently created an inviting and inclusive environment by their individual interactions and uninhibited playfulness, encouraging others to participate without hesitation. This aspect of the research underscores the Lookout's potential to enhance social connections and revitalise urban spaces.

While the photograph-taking opportunity was popular and used by 93% of participants, it was observed that the more elderly participants encountered challenges when trying to interact with this feature. They were more inclined to tap the screen to engage with the content directly, avoiding the elbow-based interactions. However, a passersby would often stop to offer assistance, explaining how to use the device. Interestingly, elderly participants frequently chose to interact with the Children and Wheelchair users installation. When asked about their preference for the smaller installation, they mentioned that it appeared to be designed for children, implying it might offer more narration or explanations and be easier to use. This discovery highlights the importance of designing for users of varying abilities, technology literacy levels, and age groups.

Furthermore, it was observed that children often engaged with the installations in creative and unexpected ways, deviating from their intended purposes. For instance, one group of children transformed the installations into props for a dramatic play. Two children moved the installations as if they were movie cameras, while others acted out scenes on the other side. This unanticipated usage showcased the potential for interactive and imaginative play within the regenerating urban space. These observations underscore the importance of inclusive design for public installations, particularly for elderly users. They also shed light on how design choices can influence user preferences and how interactive installations can encourage creative and spontaneous play, contributing valuable insights to the fields of urban design, technology, and public space use. Additionally, the presence on families and particularly children was shown to provide a more inclusive feeling environment.

3.4.3 Participant Interviews

Interviews completed at the Lookout installation served as a valuable tool to gauge the effectiveness of its content, inform future enhancements, and explore users' visions for technology integration in city centres. They offered an understanding of user engagement and contributed to the broader discourse on public installations' role in urban revitalisation and community engagement.

Interview Procedure

The interviews sought to assess the informativeness of the Lookout content and gather insights into users' visions for future interactions within the city centre, leveraging the Lookout as a probe, as described by Paulos et al. [213]. Given the ongoing pandemic and the prevailing concerns about interpersonal interactions beyond one's household, these interviews adhered to strict social distancing guidelines, maintaining a minimum distance of over two metres. The interview process at the Lookout involved two approaches:

1. *Participants Who Used the Installation Without Prompting:* In this approach, interviews were conducted with individuals who engaged with the installation with-

out any verbal encouragement. Users who engaged with the Lookout without any prompting were selected randomly for interviews and were offered the choice to decline participation.

2. *Prompted Participants:* As a result of the constrained capacity for the researcher to engage in face-to-face interactions, primarily due to pandemic-related restrictions, prompted participants were identified based on their interest in the Lookout. More specifically, individuals who glanced toward the Lookout were approached for interviews.

Overall, a total of 20 users (10 from each group), were interviewed across 5 days. The interviews aimed to explore participants' knowledge of the redevelopment site before and after their interaction with the Lookout. Additionally, participants were asked about their hopes for future technologies in the city centre. It is noteworthy that participants who engaged with the installation without prompting tended to be more enthusiastic about answering questions and often expressed curiosity about the Lookout project and the larger regeneration initiative.

Navigating the representativeness of interviewee's throughout the deployment proved challenging, particularly given limited interview access time. However, their random selection over several days implies they likely reflected the average demographic of daily users. Nevertheless, the author acknowledges the constraints of the small interviewee sample size and the potential for broader demographic representation.

Interview Analysis

The interview transcriptions underwent content analysis, a method selected because of the limited sample size. This process involved identifying crucial elements within the interviews, which were then highlighted and noted on post-it notes. These post-it notes were subsequently organised into five themes, as outlined below:

Knowledge of the Regeneration: User feedback suggested that due to their inability to enter the city centre during the pandemic the participants had little to no knowledge of the regeneration project, prior to using the Lookout, with 80% not knowing of a regeneration occurring in the city before entering the city that day, with the remainder focusing on the installation of the Pedestrian Bridge. Overall, the interviewee's found the Lookout to be informative and enjoyed the interactive nature of the design. Interestingly, even as the structures were erected and became more visible, the users only expressed knowledge and interest in the installation of the new Pedestrian Bridge, with concerns about how it would affect the use of other bridges across the city. The majority of participants suggested that they were using the Lookout to discover more information about the buildings being installed, with 20% having a main interest in the Bridge based content. This interest was reflected in the increase of interactions shown in Figure 3.11 and is intriguing to see how users adapted their usage based on the aspects they could visually see being built throughout the deployment.

Successful Features: A favourite feature for the participants was the drone footage. They were fascinated to see the scale of the project from a bird's-eye view and the ability to see the progress that had been completed so far from above. This aspect in particular was perceived as one of the most useful aspects of the design to disseminate information about the regeneration site, as it not only showed the overall scale of the site but also the progress that had been made so far within the real world context, with old locations removed and new locations being formed. This aspect shows the importance of providing users with a real life context. For the participants that might not have grown up in Swansea and did not understand the changes being made, this aspect showed them the overall location, what had changed and helping them to further understand where exactly the new locations would be located. Therefore, helping the participants to immerse themselves into those new locations more thoroughly.

Interactions for the Future: Finally, the users were asked about the types of technologies they would like to see within the city centre in the future. All were initially reticent due to their perceived lack of technology expertise. For example, one user said:

> "I don't know I'm not good with technology".

However, after further prompting and explanation of the purpose of the Lookout, several mentioned that they particularly enjoyed interactive technologies placed within an urban space for all to use but had no suggestions about what these technologies would do. Several users also mentioned that if new technologies were to be incorporated, they would like them to be aimed around Swansea city's activities such as the annual air shows, re-emphasising the need to make public interactions with and for the community. The most inquisitive users were families. When asked about the technologies they would hope to see in the city's future, they said that they would like to see technologies for children/teenagers to interact with.

Sense of Place: The feedback gathered from users underscored the Lookout's role in enhancing the sense of place and community pride within Swansea. Prior to their interactions with the installation, 80% of participants had little to no knowledge of the city's regeneration project, exemplifying the Lookout's capacity to bridge the information gap. While the Pedestrian Bridge garnered significant attention, users found the Lookout's informative content to be a resource for understanding the broader context of the regeneration.

Drone Footage: The drone footage feature emerged as a highlight, allowing users to grasp the project's scale, evolution, and real-world impact. This immersive experience contributed to a deeper connection with the changing urban landscape, particularly for those with long-standing ties to Swansea. Furthermore, participants' interest in future technologies aligned with the Lookout's potential to serve as a hub for community interaction and engagement. Their desire for technology integrated into city activities underscored the importance of public installations as catalysts for community-focused innovation and showcased the Lookout's role in fostering a sense of pride and belonging within the evolving cityscape. These insights have far-reaching implications for urban revitalisation projects and their ability to create meaningful connections between residents and their urban environments.

3.5 Discussion

In summary, the impact of the Lookout installation within Swansea during the COVID-19 pandemic has been explored. This chapter evaluated a nine month deployment, offering a lens through which to examine the installation's influence on the sense of place, community identity, and urban revitalisation. As the intricacies of this discussion are navigated, the unraveling of how the Lookout, amid social distancing and evolving restrictions, emerged as a source of information, connection, and community pride becomes apparent. The exploration extends to the broader implications of the findings for urban planning, public installations, and the importance of community-driven initiatives during times of adversity.

3.5.1 Data Collection

The Lookout's extensive dataset, comprising over $10,000$ sessions over a nine-month period, stands as a resource for comprehending user behaviour and preferences in public installations. Its significance is magnified by its capture of interactions during the COVID-19 pandemic, a context scarcely explored in the existing literature.

The data analysis undertaken here underscores the possibilities for effective community engagement in urban regeneration projects, particularly when countering the gradual decline of traditional retail establishments. While the overall community's involvement in the civic design had its limitations, the cocreated design facilitated a renewed connection between the community and their urban space, reinstating a sense of ownership over their city - as discussed by Carr et al. [41]. Moreover, the installation of the Pedestrian Bridge brought about a surge in foot traffic, benefiting both the Lookout and the local shops essential to the city centre. By involving the community in the design process, it created an accessible interactive information hub. These interactions not only supplied helpful information to rekindle the community's connection with their space but also delivered a fun experience that heightened excitement for the regeneration's unveiling. The impact of the bridge's installation and subsequent interviews underscored the lack of knowledge regarding the regeneration site and its attributes, reinforcing the necessity of the Lookout device.

This deployment occurred within an extraordinary timeframe, hopefully not to be replicated in the foreseeable future. It occurred in a city centre undergoing regeneration while the community grappled with a global pandemic that confined them to their homes. This unique convergence not only offered a rare glimpse of the regeneration's development, hidden from the view of the population, but also highlighted the disparities in the usage of public displays and underscored the vital role city centres play in the lives of communities. The experience emphasised the importance of building on the presence of these urban spaces to foster community engagement and revitalisation, an aspect that merits further exploration in the context of urban studies.

The data regarding user interactions and engagement with the Lookout during the pandemic provided important insights. It showed that despite the pandemic's disruptions, certain locations, like the Arena, continued to attract substantial user engagement. The data demonstrated the resilience and enduring appeal of accessible public installations, even in challenging times. Additionally, the fact that a significant number of sessions were observed on both the Adult Pedestrians and Children/Wheelchair users installations underscored the importance of accessibility and inclusivity in public installation design. It demonstrated that accessibility-focused designs can cater to diverse user groups, including those with different mobility needs. In addition, it emphasised that this extensive data collection within such a unique time frame provided a contribution to the literature.

3.5.2 Resilience and Inclusivity

The data emphasised the significance of accessibility and inclusivity in the design of public installations, as it recorded a substantial number of interactions across both the Adult Pedestrians and Children/Wheelchair users installations. This observation underscored the capacity of accessible installations to accommodate diverse user groups, including individuals with varying mobility needs, a critical consideration for urban planners and designers.

However, elderly users encountered challenges when attempting to interact with the Lookout devices, primarily due to their discomfort with technology. The lack of written instructions and the unfamiliar nature of technology exacerbated their unease. Age UK estimated that 65% of users aged 75 or older have never used the internet [274], highlighting the importance of ensuring resilience and inclusivity in technological innovations for public spaces. Consequently, promoting transparency about the technologies deployed in our cities becomes even more critical. For instance, an effective approach to enhance transparency with the Lookout could have involved incorporating a scrolling information panel within the installation. This panel would provide detailed descriptions of the interaction types. To cater to users with different levels of technological literacy, audible explanations of these technologies' functions and data collection practices could also be included. This multimodal approach could ensure that even those less familiar with technology could engage.

3.5.3 Multilingual Accessibility

The inclusion of a minority language version, used within 13% of sessions, highlights the importance of offering alternative choices to enhance accessibility in public installations, including multilingual options. Whilst work has been completed within inclusive design (e.g., [5, 25, 53]), this work delves into the realm of user diversity and inclusivity, shedding light on the importance of embracing linguistically diverse settings, moving beyond language preference. This finding extended the understanding of how public installations can cater to a broader audience by accommodating linguistic diversity. While conventional approaches might focus solely on the dominant language or languages, this work highlights the value of embracing linguistic inclusivity as an essential aspect of enhancing user engagement, which is something to be explored further bearing in mind that 17.5% of adults in the UK are bilingual and approximately 33 million people globally [105]. Furthermore, this aspect has the potential to contribute to broader discussions surrounding language preservation, cultural representation, and the role of technology in bridging linguistic divides within diverse urban communities.

The successful integration of a minority language version within the Lookout's interactive design demonstrates the adaptability and responsiveness required in modern public installations. It reflects a forward-looking approach to technology's role in fostering inclusive urban spaces, a concept that holds promise for the future developments in this field.

3.5.4 User Behaviour Insights

The observations of user behaviours offered a perspective on the various ways different user groups can engage with public installations, enhancing the understanding of the installation's impact on public spaces. Whilst Peltonen et al. [216] found that users were more hesitant to interact when they did not observe others interacting. In addition, children and their families inadvertently created an inviting and inclusive environment through individual interactions and uninhibited playfulness, thereby encouraging others to join without hesitation. This in conjunction with the interviewee's interest in technologies for children in cities, led to a series of design innovation workshops in schools across Wales (discussed in the following chapter).

Furthermore, these observations emphasise the impact of shared experiences in public spaces. The presence of a companion to create and share memories with, can influence a person's perception of a space. Additionally, the study highlights the transformative effect of children's play and camaraderie on the overall ambiance of a space, suggesting the significance of creating interactive environments. These findings underscore the importance of environmental and emotional spaces in public interactions, often surpassing the significance of the device itself. Universally accessible surroundings and the presence of non-judgmental participants can significantly alter an individual's perception of a device, motivating increased interaction. Moreover, the research underscores that accessibility encompasses not only physical needs but also the varied perceptions of technology literacy. Users' perceptions of their own limitations and apprehensions about technology, particularly in public spaces, were evident during interviews, where participants often hesitated to share ideas, citing limited technological knowledge to avoid appearing uninformed or embarrassed.

3.5.5 Sense of Place and Community Identity

Within this context, it is evident that new and intriguing interaction types are paramount for engaging users with public installations. Individuals are inherently drawn to fresh, innovative experiences, a concept substantiated by the works of Ojala et al. [201] and Creswell [60]. The incorporation of drone footage within the design played a pivotal role in offering users a comprehensive understanding of the development site's scale and its evolving aspects. This approach empowered users to perceive the site in both its entirety and granular detail. Their overwhelming satisfaction with this feature underscored its role in conveying comprehensive information about the new site. Of particular significance, this feature resonated deeply with long-term residents of Swansea, enabling them to join their existing memories with the evolving urban landscape.

The feedback collected from users underscored the Lookout's significance in enhancing the sense of place and fostering community pride in Swansea. Interestingly, as mentioned earlier 80% of participants interviewed had limited to no prior knowledge of the city's regeneration project before engaging with the installation. This underscores the Lookout's capacity to fill an information void. Moreover, while the Pedestrian Bridge garnered significant attention, users found the informative content provided by the Lookout to be a valuable resource for understanding the wider context of the regeneration initiative. The unique and informative nature of the content made it a worthwhile experience for users, offering them insights that would have been otherwise inaccessible, thus adding substantial value to their interactions with the installation.

In the realm of civic engagement, this study contributes a novel perspective by shedding light on how technology, even in the face of a global pandemic, can serve as a powerful tool for fostering community bonds and enriching the urban experience. The Lookout's success in engaging diverse user groups, including those with varying degrees of technological familiarity and age groups, underscores its potential as a catalyst for positive change within urban regeneration projects. Coupled with the detailed cocreation work completed within the author's masters, this work provides a jump off point for urban developers to incorporate their own Lookout's into city regeneration's globally.

3.5.6 Limitations

As previously mentioned the COVID-19 pandemic caused a number of challenges. Whilst not described within this thesis the limited ability to conduct preliminary studies involving users' interactions with prototypes prior to deployment prevented early adjustments to enhance accessibility, which could have been beneficial within the deployment. Additionally, given the difficulty in demonstrating physical designs using online tools (explored further in Chapter 6), testing interactions with the community and as shown particularly with the elderly demographic was constrained.

Furthermore, a mid-deployment lockdown significantly reduced the number of people in the city centre and subsequently impacted Lookout usage. However, the closure of non-essential shops provided the opportunity to observe two distinct user groups:

key workers commuting within the city centre and all users returning to the city centre post lockdown. The limitations mentioned here highlight the importance of adapting research methods to accommodate unforeseen circumstances and the need for future studies to explore strategies for engaging diverse user demographics, especially in times of crisis or restrictions. These considerations offer insights into the evolving field of public installations during extraordinary circumstances, an area that remains relatively unexplored in existing literature.

3.6 Lessons Learnt from the Deployment

Based on the findings and insights from the research conducted, several lessons can be incorporated for future public deployments. These lessons can be divided into positive feedback and benefits derived from the Lookout, as well as negative aspects stemming from missed features or considerations:

These are the positive insights gained from the deployment and analysis:

Communication Potential: The Lookout showed that there is an ability to facilitate greater awareness and understanding of urban regeneration projects among the public using interactive technologies.

Multilingual Accessibility: Embracing linguistic diversity by providing multilingual options in public installations to cater to a broader audience not only recognises the value of linguistic inclusivity in enhancing user engagement but also fosters a stronger sense of belonging within diverse urban communities, making it a recommended approach to ensure inclusivity by enabling users to interact in their first language.

Community Engagement and Ownership: Promoting community involvement in the design and planning of public installations to foster a sense of ownership and pride in the local community is a recommended strategy, as it recognises the potential of public installations as effective tools for building social connections and strengthening community bonds, particularly during challenging times, and thus should be encouraged in future urban planning endeavours.

Innovative Technology Integration: Exploring innovative ways to provide a wider overview of urban developments by integrating technology, such as drone footage. As it can offer users unique and engaging experiences, fostering a deeper connection with their sense of space (topophilia).

These are the insights gained which showed areas for improvement from the deployment and analysis:

Enhancing Accessibility and Transparency: The observations revealed a demographic overlooked during the design of the Lookouts: the elderly. Strategies should be developed to enhance the accessibility of interactive installations for elderly users, those with limited technology literacy, and those with differing abilities. This includes incorporating clear instructions, promoting transparency to alleviate concerns and build trust, and ensuring a wider demographic can effectively engage with and benefit from such installations. Additionally, providing installations of varying heights can improve ease of access.

Community Engagement and Ownership: Encouraging community participation in the design and planning of urban regeneration can foster a sense of ownership and pride within the local community, recognising the potential of participants themselves. While the Lookout effectively informed users about the new area, there was a missed opportunity to directly involve them in the redesign of the regeneration process. Though this was of interest to the author, it wasn't possible.

The lessons learnt can help urban planners, designers, researchers and community organisers to create more resilient, inclusive, and engaging public installations. They also emphasise the importance of adapting to unique challenges, such as those posed by a global pandemic, and the potential of technology to facilitate positive change within urban environments.

3.7 Conclusion

In conclusion, in this journey spanning nine months, the deployment of two interactive Lookout installations in Swansea's city centre stood as a testament to the potential of technology in enhancing urban regeneration. Through collaborative workshops with diverse stakeholders, the installation emerged as a beacon of community engagement, rekindling the public's connection to their evolving urban space. In fact, not only are the Lookouts still in place, but two additional installations have been developed and installed as part of a seperate project, offering glimpses into Swansea's past, in another area of the regeneration.

The extensive analysis of over $10,000$ sessions shed light on the impact of a global pandemic on public engagement and the preferences of residents. It revealed that inclusive design principles, wheelchair accessibility, and safe interaction zones were paramount for creating interactive, immersive experiences tailored to a diverse community. The addition of personalised elements, such as the photograph-taking opportunity, underlined the importance of customisation in public installations.

The findings highlighted the significant role played by children and families in infusing energy into public spaces. Inclusive and enjoyable interactions within these spaces not only catered to young citizens but also positively influenced others' comfort in engaging with public displays. Furthermore, the observations uncovered the missed demographic of elderly users, emphasising the need for clear instructions and transparency in technology deployment, especially in public spaces.

The incorporation of real-life content, such as drone footage, proved instrumental in helping users grasp the scale and features of the Swansea regeneration project. Participants left the Lookout with a newfound understanding of their city's transformation. Looking ahead, the public expressed a desire for engaging installations that captivate children's imagination which will be explored in the following chapter.

Two overarching lessons emerged from this work. First, the importance of involving a wide range of demographics, with specific attention to children and the elderly, in the design process of public displays to ensure equitable interaction opportunities. Second, the Lookout's success in engaging the public underscored its potential to foster positive engagement with civic projects, such as the Swansea regeneration initiative.

The integration of intriguing technologies into urban regeneration represents an ability to redefine how communities can engage with and contribute to their environments. This proposition, aims to inspire urban developers to explore new ways in which technologies can be used to enhance topophilia across a multitude of contexts.

3.7.1 Chapter Contributions

A comprehensive assessment of a nine-month urban deployment has unfolded exploring user engagement and interactions with the "Lookout," an interactive device designed to disseminate information about a civic project amidst the challenges posed by the COVID-19 pandemic. This exploration recognised the fundamental role of public engagement in urban redevelopment and showed how interactive public technologies could foster topophilia, especially within urban spaces where physical and digital interactions converge. In summary, this chapter contributed an extensive analysis of logging data from over $10,000$ sessions, interviews, observations, and their implications, deepening the understanding of user engagement and informing subsequent research directions. Leading to an exploration of user preferences for urban technologies, particularly in the context of community-driven initiatives and public installations. Finally, providing insights into the design considerations necessary for future urban technology projects.

Chapter 4

Exploring Future City Technologies: From Sketching to Multisensory Prototypes

4.1 Introduction

In the previous chapter, the evaluation of the Lookout was explored, offering an interactive experience within Swansea city centre. However, in this chapter, a different journey unfolds—one that explores the realm of touchless displays and sensory exploration. Building upon insights gained from the Lookout deployment, where observations and interviews highlighted a growing desire for immersive experiences, particularly for children, this chapter explores the cocreation of an interactive multisensory display.

The author's aim behind this exploration stemmed from two key factors: first, the belief that such interactive displays could infuse more joy and engagement into the city centre. By incorporating multisensory elements into an interactive prototype, the intention was to create a dynamic urban environment that sparked curiosity and possibly foster a sense of connection with the city. Second, the observation that interactions initiated by children and families could inspire and encourage others to engage with urban technology installations.

Additionally, the council's aims were to increase awareness about events occurring in Swansea and to provide interactive experiences that excited people about the new aspects of the city. By creating interactive experiences, the council aimed to attract new visitors and stimulate new economic acitivity in the city centre. As a result, the focus of this chapter is on the collaborative design and development of an interactive multisensory device, incorporating olfactory, auditory, visual and tactile elements. The feedback collected during this process contributes to the iterative refinement of a final design that was deployed into Swansea city centre (explored in Chapter 5).

Through the Lookout interactions, a discovery was made: the presence and interactions of children can provide accepting spaces where others feel more at ease to interact. Their fearless and uninhibited approach to interacting with technology in outdoor spaces can create an atmosphere of acceptance and encourage others to join in without fear of embarrassment. In essence, children not only represent the future of our communities but also play a role in fostering more inclusive and accepting urban environments. Therefore, the process of cocreation was facilitated through a series of workshops involving children, regeneration experts, and the broader community, leading to the creation of a multisensory prototype.

4.2 Designing Next Generation Technologies with Primary School Pupils

During the interviews conducted at the Lookout device, there was a desire expressed by the participants for the development of technologies to enhance the experiences of children within the city centre. This emphasis was underpinned by two primary motivations. First, there existed an aspiration to provide children with more engaging and immersive experiences in the city. This aspiration was grounded in the recognition of the significance of creating memorable and enjoyable moments for children, adding to the vibrancy to the city centre. Second, an observation emerged during the deployment, highlighting that when children interacted with the technology, it had a positive effect on other members of the public, making them more inclined to engage as well. This finding expanded the focus beyond children alone and underscored a broader commitment to inclusivity and accessibility for all user groups.

As a result, there emerged a strong motivation to engage children in the design process of crafting a new interactive installation for the city. With Child-Computer Interaction (CCI) steadily growing as a field [155] it was intriguing to understand how CCI could play a role in the cocreative design of interactive public installations. This chapter's motivation also aims to inspire the next generation of designers to explore the potential of city centres and technology.

Therefore, a collaboration was organised with Technocamps [261], a digital program with a goal to increase young people's engagement with Science, Technology, Engineering and Maths (STEM) subjects across Wales. Organising these workshops with Technocamps ensured all regulations were covered when entering schools (e.g., Disclosure Barring Service (DBS) checks) and that the content would not only complete the research objectives but also inspire and engage the students. Technocamps organised the dates and timings with the schools for each workshop whilst the content was created and hosted by the author, with a Technocamps assistant present to help manage. The workshop content was reviewed by Technocamps with an aim to discover the types of technologies the children would like to see in the cities of the future but also inspire them about the possibilities for technology in the future.

In addition, each class to complete a workshop was presented with a *Sphero Robot Ball*, designed to inspire exploration into creativity, coding skills and inventiveness [249], to help them to continue their interest in STEM. This initiative aimed to provide the children with an introduction to coding and STEM concepts through the integration of a user-friendly coding device which they could continue to explore, post-workshop.

4.2.1 Innovation and Sketching Workshop Plan

In each class, a one-hour workshop was designed to accommodate both in-person and virtual participation via Zoom. The workshop comprised five stages: (1) innovation, encouraging out-of-the-box thinking; (2) sketching 1, focusing on technology sketches envisioning cities of the future; (3) sketching 2, exploring contextual considerations for these concepts; (4) show and tell, providing a platform for participants to present their ideas to the group; and (5) a concluding Quiz segment, providing aspirations for the future. This structured workshop format aimed to engage and stimulate creative thinking among participants while fostering collaborative discussions and idea sharing. Each stage would take roughly 10 minutes, leaving a further 10 minutes to allow room for pupils setting up, registering etc. Figure 4.1 provides an overview for the five stages.

Stage One would provide the students with a basis to help them feel comfortable in innovating and thinking outside-the-box. In this stage, the workshop aimed to inspire pupils to think beyond current technological boundaries without biasing them with existing examples. Therefore, the innovation stage began with a short overview of who the researcher was and the workshop agenda (see Figure 4.1). The workshop then moved into discussing the types of technologies they had seen throughout city centres. The aim of this exercise was to prompt thoughts both about current available technologies, but also where those technologies were located, to help them think of technologies they would want to see in these spaces instead. To further evoke innovation and out of the box thinking a video was displayed: The World's Future In 2100 [79]. The purpose of this video was to demonstrate a range of areas within cities that could benefit from technological enhancement, with *out-of-the-box* examples which were not currently in production but may be created in the next 100 years. For example, building underwater cities to help with the housing crisis and tangible holograms to help with loneliness.

Stage Two, moved the pupils into the first stage of designing their own city centre based technology with the first steps including sketching their technology and naming it. The sketching requirements included labelling the main features of the designs and keeping the design to one $A4$ sheet of paper. Within this section, the pupils were encouraged to create as many designs as they would like (each on a separate sheet of paper), with only their favourite design moving forward to the next stage. *Stage Three* required the pupils to focus on their favourite sketch, adding explanations for how it could be used, and what types of users could interact with it (e.g., children only). Following this, the children were asked to describe what their technology could do and where they would like it to be located in Swansea city centre. To complete the designing section (*Stage Four*) of the workshop the pupils were given the opportunity to present their favourite design to the rest of the class and explain what it could do.

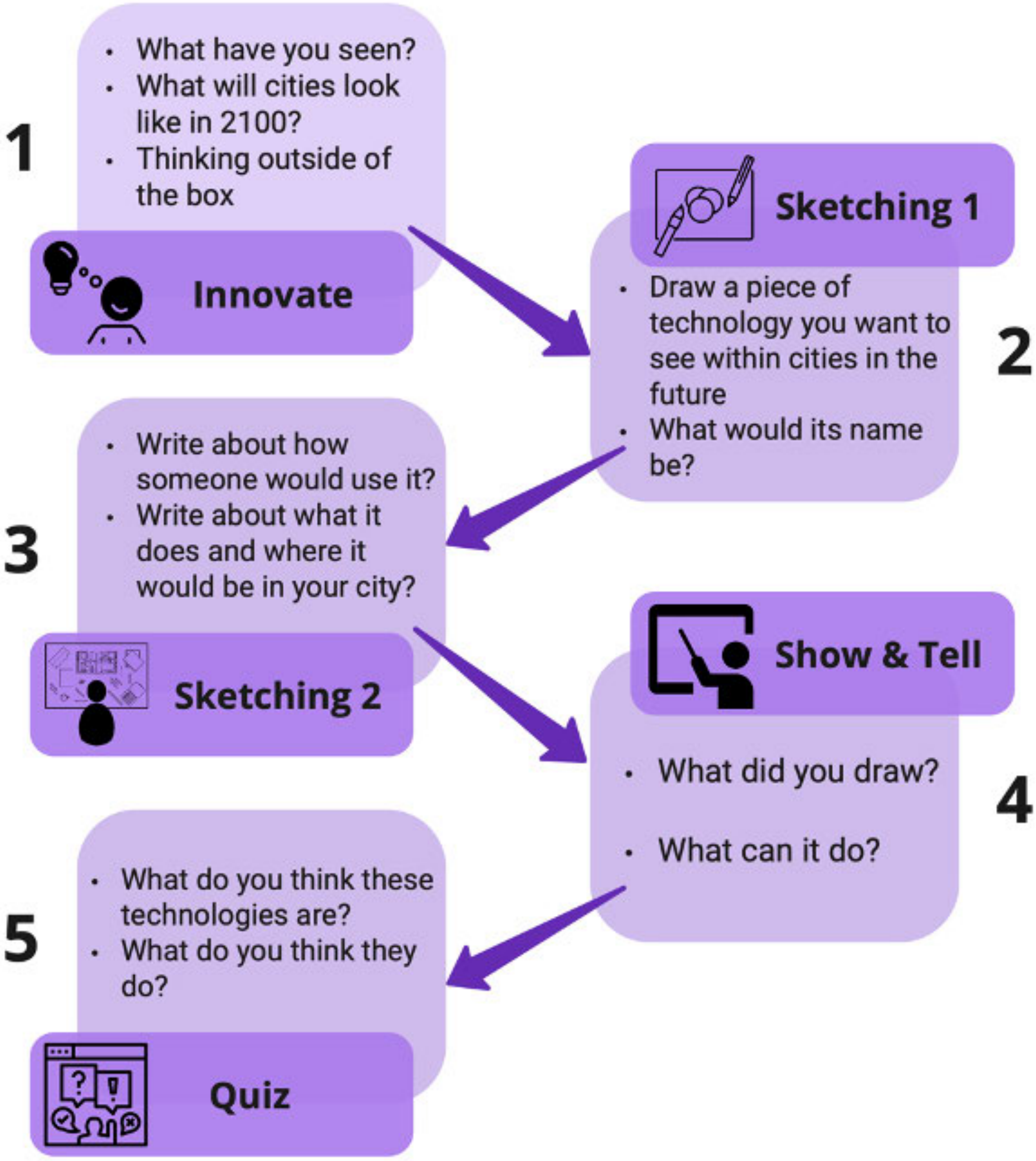

Figure 4.1: Schematic diagram showing the session overview for the one hour Technocamps workshop including: Innovation, Sketching 1 & 2, Show and Tell and a Quiz.

Stage Five of the workshop was comprised of a quiz with a range of technologies to inspire them about the technologies of the future, as shown in Figure 4.2. This activity served solely to engage and encourage pupils about the possibilities for new technologies and was not intended for analytical purposes. The pupils had 30 seconds per technology to write what they thought the name of each technology was and what it could do, followed by the answers. The quiz was inclusive of the following ten technologies:

(a) Amazon Alexa [9] - A virtual assistant AI that uses speech recognition to understand spoken commands, meaning it can answer questions and execute specific tasks, such as playing music (see Figure 4.2a). Alexa was selected to introduce a well-recognised technology that showcased the capabilities of voice-activated, hands-free interfaces.

(b) Apple iPhone [123] - A handheld screen-based multi-functional device that combines a phone, camera, multimedia player and computer into one compact package (see Figure 4.2b). The iPhone was chosen to introduce a familiar and highly popular technology, whilst being able to refer to its major capabilities particularly given its small size, such as the extensive app ecosystem.

(c) Virtual Reality headset [73] - A cutting-edge device that immerses users in a digitally simulated 3D environment, covering the eyes and occasionally the ears (see Figure 4.2c). The VR headset was chosen to introduce immersive experience possibilities within digital realms.

(d) Talk Technologies [263] - A privacy microphone designed to enable a user to speak in privacy, even in noisy environments (see Figure 4.2d). It was selected for its innovative design and forward-thinking approach that addresses the evolving needs of its customers, making it a practical and timely technology choice.

(e) Nike Joyride [295] - A set of immersive games to inspire users to run, jump, bounce and laugh (see Figure 4.2e). It was chosen due to its innovate approach to fitness and well-being, providing creative and entertaining ways to stay active.

(f) Paro [180] - A therapy robot equipped with the ability to sense a user's emotions and movements, offering companionship and support in a unique way that can sense a users feelings and movements (see Figure 4.2f). The choice was driven by its ability to show an intriguing way robots can be integrated into daily life.

(g) Luminotherapy [69] - A series of interactive loops where users could immerse themselves and control the lighting to promote happiness (see Figure 4.2g). The decision to include Luminotherapy was based on its ability to demonstrate how alternate visual cues (lighting) could be used to create an interactive environment, enhancing experiences within outdoor public spaces.

(h) Police Security [226] - A police robot deployed within California to reduce crime by patrolling the streets (see Figure 4.2h). It was chosen to showcase a visionary approach to policing, highlighting how robots could contribute to community security.

(i) Light Cube [187] - A giant, 3D illuminated cube that responds to people's individual movements (see Figure 4.2i). It was chosen as it provided an example of the possibility for relationships between the physical and the digital.

(j) Lookout [43] - A public installation that offers elbow-based interactions and the ability to glimpse into the future of Swansea city centre (see Figure 4.2j). This technology was chosen to represent a new approach to public engagement and interaction, showcasing an interface that could provide new ways to engage with city information, with the pupils local city.

4.2.2 Innovation and Sketching Workshop Analysis

Eight hybrid workshops were conducted across four primary schools in South Wales. These workshops were structured according to the detailed plan outlined in the previous section. In total, these workshops engaged 248 pupils, ranging from 7 to 11 years old, involving an average of 32 students in each class. Due to COVID-19 regulations, the initial three workshops were conducted fully remotely via Zoom. However, for the remaining five workshops the pupils were able to attend school in-person whilst the Technocamps representative and author were remote via Zoom, as COVID-19 regulations still prevented non-school staff, from entering the schools.

Figure 4.2: The images shown for each technology within the workshop Quiz. a) Alexa [9]; b) iPhone [123]; c) Virtual Reality headset [73]; d) Talk Technologies [263]; e) Nike Joyride [295]; f) Paro [180]; g) Luminotherapy [69]; h) Police robot [226]; i) Interactive Light Cube [187] j) The Lookout [43].

Having the pupils within their classrooms enabled them to collaborate and chat about the designs they were creating more easily and ensured they were able to access the same stationary which may not have been present at home. As the first three workshops had the pupils sketching at home, it was not possible to collect and analyse their sketches. Hence, a content analysis was conducted on the 158 collected sketches. Each sketch was categorised based on predominant themes integrated by the pupils, and points were assigned accordingly. After identifying all predominant themes, the author reanalysed each sketch to ensure comprehensive coverage of points, including types of technology and their primary usage. The age distribution of these 158 pupils was: $7-8$ yrs: 22%, $8-9$ yrs: 37%, $9-10$ yrs: 41%.

Innovate

The innovation session elicited a range of technological suggestions the pupils had noticed within city centres with 44% of the technologies converging around screen-based technologies, such as announcement boards in bus stations. A further 31% focused on transport-based technologies such as, electric vehicles and bikes. These emerging products are relatively new, and it's likely that children had some awareness of their capabilities. Since these products are still emerging, they hold the potential to spark curiosity and excitement among both children and adults as they explore their functionalities and possibilities together. Figure 4.3 shows the distribution of technologies that the pupils mentioned observing in city centres across the eight workshops. This shows the prominent use of screens within public spaces, and whilst clearly effective at grasping attention, the majority focused on individual, limited interactivity technologies e.g., bus announcement screens have no interactive modality.

Sketching

The agency for innovation within the sketching sessions was very popular with the pupils. The children enjoyed creating their own additional criteria for the designs, with one class adding price tags to each design and another specifying the shops in which they would be happy to sell their technologies from. The sketches were collated and analysed using content analysis which led to the classification of the sketches into three

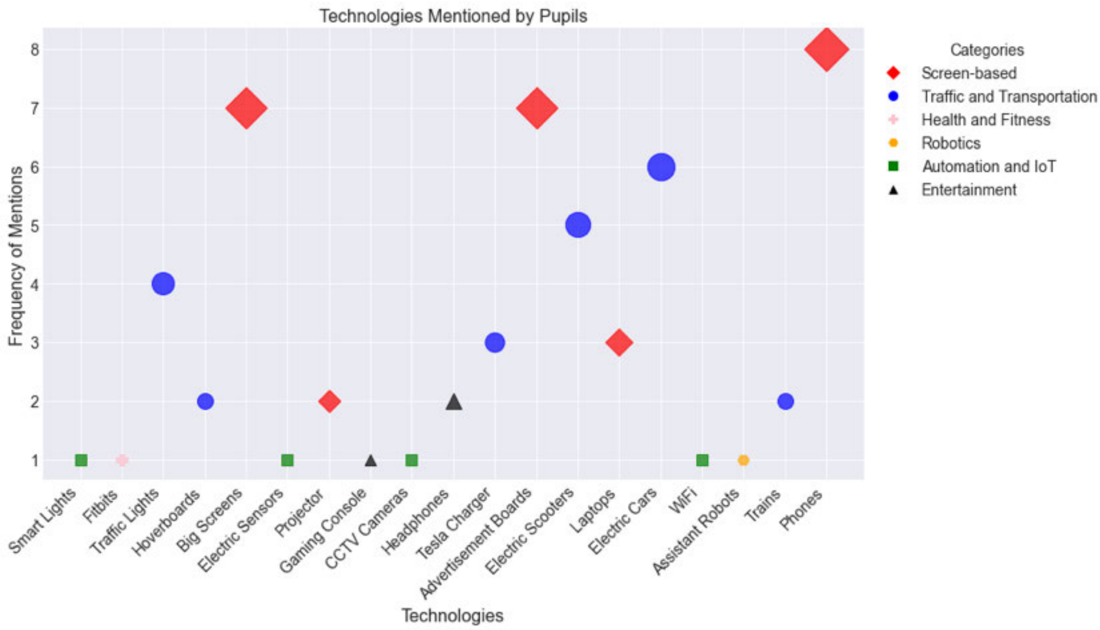

Figure 4.3: Bubble Scatter Graph showing the frequency of technologies mentioned across eight workshops observed by pupils within city centres.

categories, with each sketch able to cross over several of the classifications. e.g., a voice assisted robot designed to clean rubbish out of the sea would receive one point each for: Robot, Outdoors, Touch, Sight and Audio. The three categories to emerge from the analysis are given as follows:

1. **Location:** Classifying the environment where the technology would be used within, with technologies able to be classified into multiple locations, inclusive of: Shops, Home, Wearable, Indoors and Outdoors. The overall points for each location type are shown in Figure 4.4
2. **Type of technology:** Classifying the type of technology used within the design, with technologies able to be classified into multiple types, inclusive of: Tangible, Robot, Wearable, Transport, Screen-based. The overall points for each technology type are shown in Figure 4.5
3. **Sensory Outputs:** The types of sensory outputs created by the technology, with one point for each sense used, inclusive of: Taste, Smell, Touch, Sight and Audio. The overall points for each sense are shown in Figure 4.7

As shown in Figure 4.4, the majority of pupils (89%) preferred outdoor technologies for public use. In conjunction, 51% designed transportable technologies that could be placed within more than one location. For example, one student designed a pram able to follow a parent using a wearable tracking device, which would need to able to be transported across all of the location categories, so received one point for each.

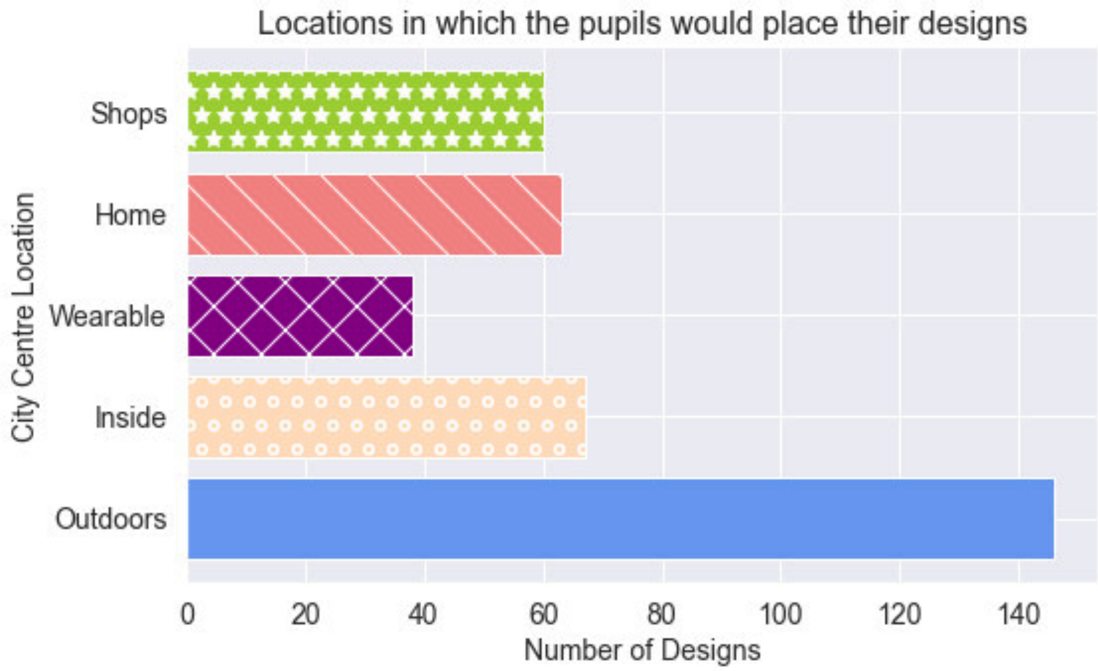

Figure 4.4: Classification of technology usage environments, with each design earning a point for every potential technology placement.

As with this example, 38 pupils (25%) designed a wearable technology including clothes, watches and necklaces. Several of these designs would have the wearable device transform into another technology, such as from a *Smart Watch* into a flying car. One pupil created this design as their Father often struggled to find a place to park and therefore wanted to be able to click a button which could be worn.

Many of the children's designs resembled the imaginative innovations often seen in science fiction, similar to the imaginative concepts found in Transformers. These designs went beyond current technology, imagining everyday objects and wearables that could transform into entirely different forms or functions with a simple action or button press. These creative and forward-looking ideas seemed to stem from the students' innate curiosity and limitless imaginations, reflecting their excitement to explore possibilities beyond what technology currently offers. This connection to sci-fi highlights the impact of popular culture on young minds and suggests that these imaginative ideas could potentially influence the future of technology as these young innovators continue to explore STEM fields.

Figure 4.5 illustrates the distribution of technology categories, where robots and transportation emerge as the most prevalent choices. However, the categories of transportation and wearables showed overlap, with 30 of the wearable designs transforming into various forms of transportation, for instance, a flying therapy taxi.

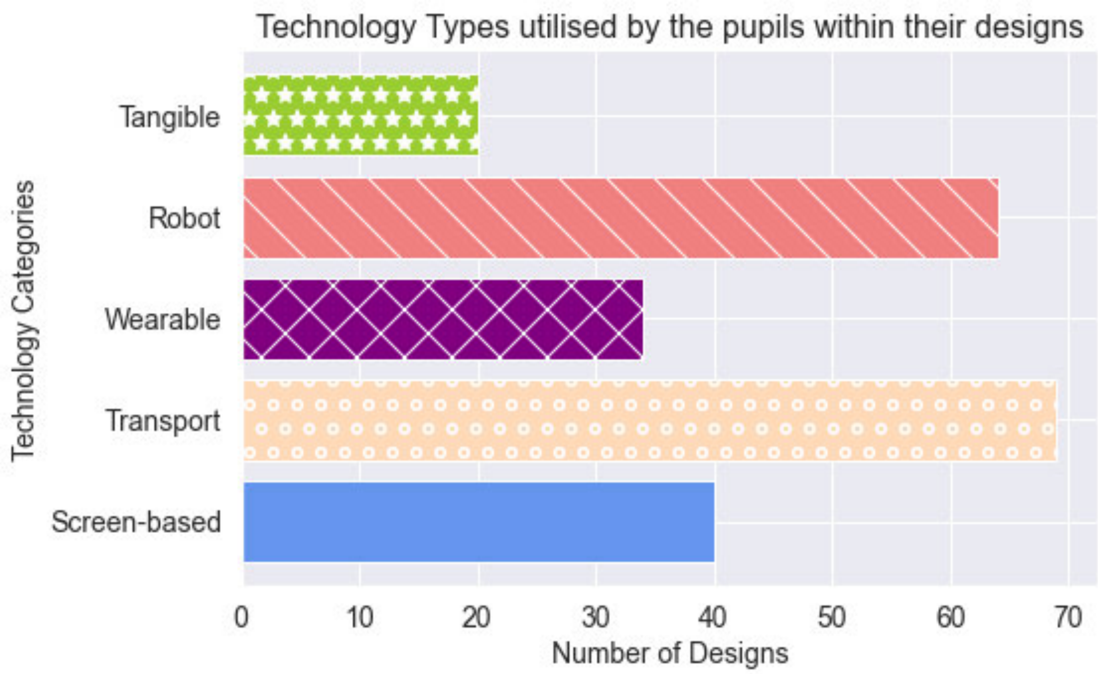

Figure 4.5: Classification of technology types, with each design earning a point for every potential technology placement.

It was entirely possible that the children found the process of creating these designs particularly engaging, especially if they had pre-existing interests in wearables and transportation. Their enthusiasm may have primarily centred around the tangible and interactive aspects of these products, while the more technical or information-related aspects, such as planning and data management, may be areas typically handled by their caregivers or adults. This underscores the importance of tailoring technological experiences to align with children's interests and developmental stages. Furthermore, even though screens were prominently observed in the centre, only 25% of the students opted to incorporate screens into their designs (as depicted in Figure 4.5).

The designs were often dependent on the children's experiences with aspects of the city centre especially experiences they had encountered recently, with family members often inspiring their designs. For example, one pupil often walked to school through a park with their Mother who had spoken to them about how walking instead of driving would reduce the volume of car emissions in the atmosphere. Therefore, the pupil designed a flying robot that could remove pollution from the air and convert it into nutrients to support tree growth (see Figure 4.6a). Furthermore, the students displayed a keen interest in developing technologies that seamlessly integrated into their existing routines, enhancing these routines in a manner that was both enjoyable and interactive. This pattern highlights the students' natural inclination to engage with technology in ways that harmonised with their lifestyles and interests, seeking solutions that felt like natural extensions of their world, augmenting their experiences without disrupting their established habits. This underscores the importance of designing technology with a keen understanding of user context and preferences, particularly when the users are children.

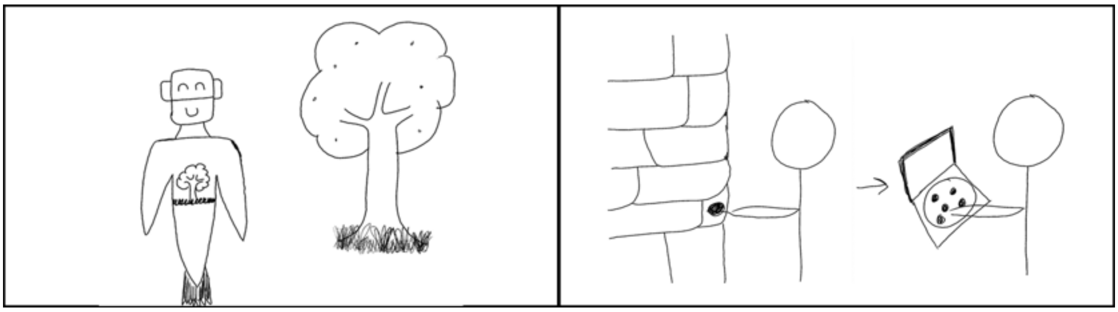

Figure 4.6: Pupils designs, redrawn to ensure anonymity. LEFT: An air-purifying flying robot that transforms pollution into nutrients, nurturing tree growth. RIGHT: A global network of buttons, deployable at various worldwide locations, capable of producing pizza upon activation to combat global hunger.

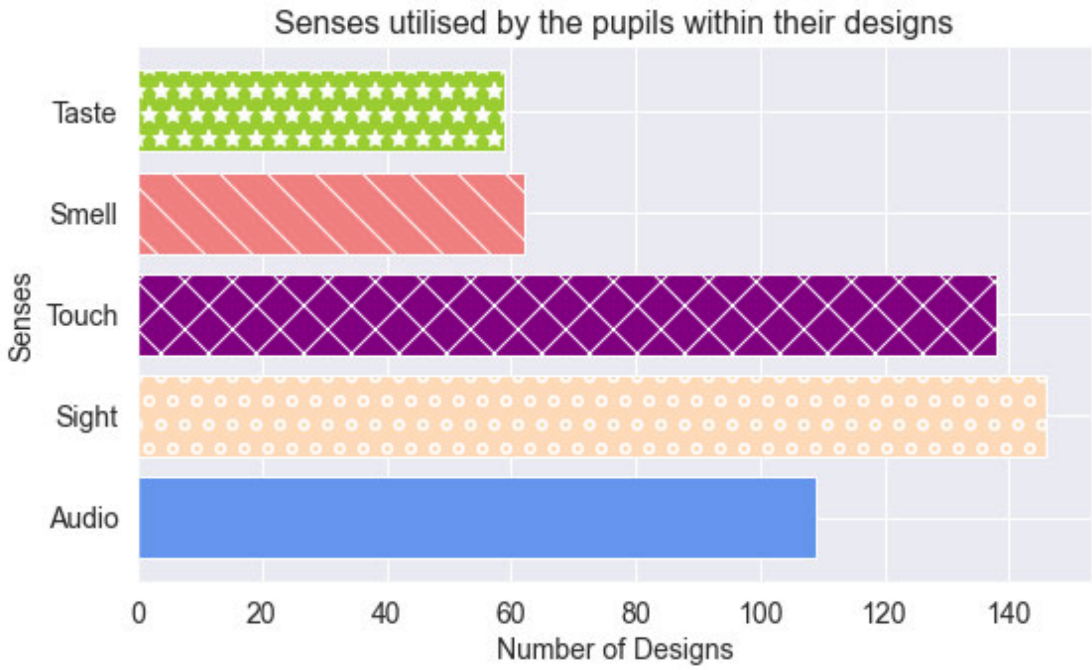

Figure 4.7: Classification of sensory inputs and outputs used, with each design earning a point for every potential technology placement.

Another trend to emerge were designs that focused on helping those less fortunate within the city. For instance, one student noticed people that were hungry in the city and in response designed: a button placed on buildings that, when pressed, produced pizza for free (see Figure 4.6b). This demonstrated how innovation prompting could help young minds to think about and address real-world problems.

Using multiple senses was popular, with 38% of pupils opting to design a multi-sensory technology using all five senses (see Figure 4.7). Although sight was a predominant sense to be used (95%), many of the designs were moving away from screen-based interactions, with a predominant number of shape changing vehicles and robots.

More unusual sensory outputs such as scent were also integrated (41% of designs) such as, smell-dispersing flying robots designed to combat littering. These robots would release pleasant scents into the air, thereby discouraging littering behaviours and fostering a cleaner and more environmentally friendly urban landscape. These ideas not only highlighted the pupils creative thinking but also shed light on the issues and concerns that mattered to them. These young minds viewed technology not just as a tool for convenience or entertainment but also as a potential solution to address real-world problems and make a positive impact on society.

In summary, in this section, a workshop plan overview has been provided to promote innovation and encourage out of the box thinking for designing new technologies with school pupils, specifically for cities of the future. However this procedure could be adapted and used for a variety of technology based creation workshops. The analysis of eight workshops with the 158 collected sketches demonstrated that children would like to see futuristic/novel technologies within the city that they had not had the opportunity to interact with before, as these would be the most fun and interesting to interact with. Most technologies had features that could incorporate and be associated with memorable experiences, especially with family members. Moreover, designing technologies that made use of a variety of senses and were novel often went hand in hand. This was intriguing because the children observed that a significant portion of the technology available in city centres consisted of large screens but were designing novel tangible installations with multiple sensory outputs. By completing these workshops it was possible to interact with children from a range of ages and discover the technologies they would hope to see in the future. The workshops uncovered three themes: the desire for new and uncommon technologies, technologies that make use of a variety of senses (not just sight) and finally a focus on technologies to aid social issues, such as pollution and mental health.

4.3 Exploring Possibilities for Multisensory Innovations in Urban Regeneration

In the previous section, design workshops were conducted with children, revealing that the children's design concepts prominently featured multiple sensory elements. Furthermore, after a recent visit to Disney [68], where the integration of some multisensory outputs was observed, discussions around the concept of multisensory experiences, particularly those involving olfactory designs, were initiated with the supervisory team.

To explore this area further, the author visited several immersive experiences, such as Shrek's Adventure in London [239] and the Harry Potter photography experience [293]. Additionally, a research placement with Professor Marianna Obrist at University College London (UCL), an expert in the field of multisensory experiences, was initiated. This placement spanned six months, as outlined in the thesis timeline, and aided towards the design thinking for the city-based prototype (Chapter 5) as well as the submission of a workshop to DIS 2023 about olfactory design within a variety of contexts [44].

Collectively, these experiences and insights inspired the idea of incorporating a form of multisensory experience into outdoor public spaces. This section outlines a two-fold approach: the development of a prototype for a multisensory installation through a collaborative focus group with urban regeneration experts, followed by a survey-based exploration of sensory cues.

4.3.1 Focus Group with Regeneration Experts

The next phase of the design process involved convening a focus group comprising experts in urban regeneration who were the stakeholders for the overall work completed within this thesis. This diverse group included a cultural developer, a regeneration specialist, a leader experienced in major events, and a project director. The primary objective of this focus group was to explore the potential of multisensory technologies within public spaces, with a specific focus on intergrating this type of technology into Swansea city centre. The focus group initiated the discussions by presenting the findings of the analysis conducted on the sketches generated during the innovation and sketching workshops with the children and by detailing existing immersive experiences, as detailed in the previous section. In addition, they were presented with a set of seven scenario-based prompts that encompassed various sensory elements, including visual, auditory, olfactory, and tactile components. The seven sensory scenarios were crafted by the researcher to centre around typical experiences grounded in Swansea, serving as foundational points for discussion and as prompts to ignite further exploration. The seven scenarios were inclusive of; Guy Fawkes Night, Seaside, Coffee Shop, Sweet Shop, Forest Walk, Rugby Match and Airshow, with the sensory output possibilities shown in Table 4.5. For example, Guy Fawkes night would be inclusive of flashing lights with the sound of the explosions slightly delayed representing firework explosions, the smell of gunpowder and smoke getting stronger as the experience continues, representing the volume of fireworks that had been released and a burst of air, representing, chilly wind. These prompts aimed to enhance an individual's experience within a central space, fostering a more immersive and engaging environment.

Table 4.1: The seven multisensory scenarios and corresponding multisensory cues: Visual, Auditory, Olfactory and Tactile.

Scenario	Visual	Auditory	Olfactory	Tactile
Guy Fawkes	Bright lights	Bang & Crackles	Gunpowder	Cold Wind
Seaside	Warm light	Beach waves	Seaweed	Warmth
Coffee Shop	Cosy lighting	Coffee grinder	Coffee	Cold to Warm
Sweet Shop	Multicoloured	Rattling Sweets	Strawberry	Cold to Warm
Forest Walk	Sparse green	Trees moving in the wind	Eucalyptus & fresh dirt	Wind
Rugby Game	Bright White lights	Cheering Fans	Hot Dogs & Beer	Cold
Airshow	Bright Yellow	Jet Planes	Petrol	Warmth

The experts unanimously shared the belief that incorporating a multisensory experience had the potential to significantly enhance user engagement with the city centre. Their focus was on ensuring the crafting of an unforgettable, innovative, and multisensory interaction that would create enduring and cherished experiences for visitors. They were particularly excited about the prospect of introducing an innovative technology that could offer something to captivate visitors in a way they had never seen before. The olfactory aspects piqued their interest, as it represented a distinct dimension of sensory engagement. Having discussed the variety of scenarios to recreate, a unanimous consensus was reached where experiences intricately tied to Swansea and the regeneration site held the experts' keenest interest. This came as no surprise, as the experts' work was centred within this location, and it was where the installation would ultimately be deployed. Their close connection to the city centre underscored their commitment to enhancing the local environment and creating a transformative experience for both residents and visitors. Furthermore, the regeneration experts considered that using a lower number of scenarios would prevent over stimulation and confusion, ensuring a more clear and effective approach. Hence, although the rugby game and airshow scenarios were indeed related to Swansea, they were not consistently accessible for participants to engage with.

Consequently, two of the experts raised concerns that including these scenarios might be confusing for visitors to the city centre. In contrast, the majority of participants would have likely experienced a Guy Fawkes night celebration somewhere, and they could directly engage with the scenarios related to the seaside, coffee shops, or sweet shops within the city. Additionally, it was suggested by one expert that the Forest Walk scenario closely paralleled the seaside experience. Therefore, the group unanimously decided to remove this option as well. They all agreed that the remaining scenarios offered the highest possibility of creating an immersive and engaging impact. As a result, the focus moving forward narrowed to four possible scenarios related to Swansea city centre:

1. Guy Fawkes Night - an annual crowd-pleaser on Swansea Beach with food stalls, a big bonfire on the beach and fireworks
2. Seaside - characterised by the city's proximity to a number of beautiful sandy beaches
3. A Coffee Shop - reflecting Swansea's array of independent cafes, including a sustainable cafe opening within the regeneration site
4. A Sweet Shop - mirroring Swansea's vibrant assortment of confectionery assortments, with a new shop also opening within the new site

During discussions with the experts, it became evident that the Guy Fawkes night experience held strong memories for them, albeit with differing recollections. For instance, one expert reminisced about standing on a chilly promenade in Scotland, eagerly awaiting the commencement of fireworks. In contrast, another expert's memory was centred around an event on Swansea beach, complete with food stalls, minimal wind, and a greater emphasis on the bonfire than the fireworks. This dialogue revealed the variations in sensory cues that held personal significance for different individuals. Recognising this diversity, it was concluded that conducting a comprehensive questionnaire would be beneficial. Such a questionnaire could yield a deeper insight into the diverse range of potential sensory cues that resonate with people, informing how the design could effectively cater to varying sensory associations.

4.3.2 Sensory Association Questionnaire

Following these initial exploration phases, a survey was conducted to understand which senses the members of the public associated with the four scenarios (Guy Fawkes Night, Seaside, Coffee Shop, and Sweet Shop). The questionnaire was structured into five sections. The first section collected participants' demographic information, while the following four sections focused on questions related to the four scenarios (see Appendix A). The questionnaire was distributed via a Google Forms link across various social media channels and community groups to gather responses from participants of diverse backgrounds and ages, resulting in a total of 62 responses. The demographic information for these 62 participants is summarised in Table 4.2, which includes data on Age Group, Gender Identity, Country of Origin, Employment Type, and Employment Sector, each of which also had a 'Prefer not to say' option. The demographics show a slight dominance of participants from the education sector, which could have introduced differences between the questionnaire users and the final user group. However, the focus of the questionnaire was on urban experiences which suggests that participants' feedback was still relevant for understanding broader user needs.

Before completing each scenario section, participants confirmed their prior experience with the scenario. The participants who answered *'no'* would pass to the next scenario. The distribution of participants with experience in each scenario is as follows: Guy Fawkes Night - 90%; Coffee Shop - 97%; Seaside - 97%; and Sweet Shop - 79%. Succeeding the confirmation of experience, the questionnaire asked the user to provide a minimum of one word that reminded them of the scenario for each sense; i.e. What words come to mind when you think of the Smell/Taste/Sounds/Lighting

Table 4.2: Demographic Data for Sensory Scenario Questionnaire Participants (n=62).

Demographic Information

Age Range		Gender Identity		Country of Origin	
18 – 29	21%	Female	55%	United Kingdom	92%
30 – 39	21%	Male	43%	India	4%
40 – 49	10%	Non-Binary	2%	USA	2%
50 – 59	19%	Transgender	0%	Belgium	2%
60+	29%	Other	0%		

Employment Type		Employment Sector	
Employed	39%	Education	35%
Full-Time Student	24%	Public Services & Administration	15%
Retired	23%	Engineering & Manufacturing	10%
Self-Employed	8%	Healthcare	9%
Homemaker	4%	Government	8%
Unemployment	1%	Creative Arts & Design	7%
Sick	1%	Charity & Voluntary Work	7%
		Business, Consulting & Management	5%
		Retail	2%
		Social Care	2%

and Colours/Physical Feelings/Emotional Feelings of Scenario X? (e.g., Seaside), with Physical and Emotional Feelings separated to help the participants to separate feelings such as warmth with feelings such as happiness. For each scenario and sense, the words were categorised using content analysis to determine the presence of certain words or themes for each sensory cue. Words with close resemblances would be grouped together, such as ‘Smoke’, ‘Smoky’ and ‘Smokiness’, into a single category (i.e. Smoke). After analysis, it was decided to keep the five most frequent words for each sense. This decision stemmed from the limited instances of other words, which hindered drawing conclusive findings from them. The results for the top five words of each scenario and sense are shown in Table 4.3. The results indicated that there were opportunities for combining olfactory, audio and visual (lights) experiences to present a particular scenario. The ‘physical feelings’ and ’taste’ aspects of the design would be more difficult to create due to the current digital tools that were available, so were not part of the prototype.

Table 4.3: The five most common words provided for each sense and scenario. The words were collected based on the questionnaire responses of 62 people.

Guy Fawkes Night		Coffee Shop		Seaside		Sweet Shop	
Number refers to times a *Scent* was mentioned							
Smoke	42	Coffee	38	Salt	32	Sweet	21
Burning Wood	12	Cakes	14	Sea	22	Sugar	20
Gunpowder	11	Tea	4	Fish and Chips	20	Chocolate	10
Hot Dogs	7	Pleasant	2	Seaweed	15	Liquorice	4
Fire	6	Chocolate	2	Fresh	12	Fruit	3
Number refers to times a *Sound* was mentioned							
Bang	49	Background Chatter	34	Waves	39	Sweet Weighing	13
Crackle	30	Foaming Milk	12	Seagulls	24	Children	12
Crowd Chatter	28	Clashing	12	Laughter	13	Laughter	9
Whizz/Whoosh	18	Loud	11	Children	10	Cash Register	5
Loud	17	Grinding Beans	6	Wind	8	Rustling	4
Number refers to times a *Light* was mentioned							
Bright	16	Bright	13	Blue	30	Bright	24
Red	15	Brown	13	Bright	27	Rainbow	18
Yellow	9	Dark	10	Yellow	14	Dark	4
White	8	Warm	8	Grey	12	Vibrant	4
Orange	7	Relaxing	8	Sunshine	8	Happy	2
Number refers to times a *Taste* was mentioned							
Hot Dogs	20	Coffee	24	Salt	29	Sweet	38
Smokey	12	Cakes	15	Ice Cream	26	Sour	13
Toffee Apples	11	Bitter	14	Fish and Chips	26	Chocolate	10
Fried Onions	10	Sweet	13	Candyfloss	5	Liquorice	6
Marshmallows	9	Chocolate	7	Vinegar	5	Strawberry	4
Number refers to times a *Physical Feeling* was mentioned							
Cold	32	Warmth	25	Warm	16	Excitement	7
Warm	17	Comforting	16	Cold	12	Hunger	6
Excitement	14	Relaxed	10	Relaxed	10	Happy	5
Cosy	4	Happy	3	Sand on Feet	6	Relaxed	4
Wet	2	Hunger	2	Wet	6	Sticky	2
Number refers to times a *Emotional Feeling* was mentioned							
Excitement	24	Relaxed	15	Happiness	28	Happy	14
Happiness	21	Happy	9	Relaxation	13	Excitement	11
Fun	7	Calm	8	Enjoyment	15	Enjoyment	5
Anxiety	5	Warmth	5	Peace	13	Childhood	4
Wonder	4	Comfort	4	Family	4	Nostalgia	4

Following initial motivations, this section explored the realm of multisensory interactions within urban regeneration, employing a two-fold approach. The exploration included a focus group session with regeneration experts using scenario-driven discussions. Through this collaborative session, a set of four scenarios emerged, which provided opportunities for multisensory exploration. Next, a comprehensive questionnaire involving 62 participants was administered, revealing trends in sensory cues related to olfactory, auditory, and visual possibilities. The analysis of these associations enabled the creation of a first iteration prototype, discussed within the next section.

4.4 Prototype for a Multisensory Rig

This section explores the aspects contributing to the design behind the hardware and software of the first multisensory prototype. These designs emerged following the cocreation sessions as outlined throughout the beginning of this chapter. The objective behind this prototype encompassed the construction of a multisensory rig, tailored for in-lab testing, with the overarching goal of substantiating a proof of concept, i.e. can multisensory cues be used to recreate the intended scenarios? The central aim was to create an easily modifiable prototype that would enable swift iteration and flexible adjustments to facilitate participant feedback.

4.4.1 Design Considerations

The process commenced by determining the types of sensory cues to be recreated and the devices to be employed for these scenarios. The sensory cue questionnaire revealed that visual, auditory, tactile, and olfactory cues would be the most effective moving forward with the design. Due to previous projects within the laboratory, existing resources were available, including a fan, LED lights, and a Bluetooth speaker, which could be adapted for the design. Consequently, there was a need to identify an accurate olfactory device and heaters for purchase, in order to incorporate olfactory elements and introduce heated aspects. Acquiring heaters was relatively easy as there was a wide range of options readily available. However, acquiring an olfactory device within budget constraints was a more challenging task due to the limited availability of on the market, pre-made devices due to them being such specialised equipment.

A number of devices were evaluated as possibilities for the olfactory aspect of the design (see Table 4.4). The choice was narrowed down to two options available on the market: the Olorama [262] and the Aromajoin [19], as these both had software development kits (SDK) to enable development. Although both devices exhibited similar qualities, the Aromajoin device stood out for several reasons. It offered a more compact design, the opportunity to collaborate with their research team for custom scent cartridges to align with the designed scenarios, compatibility with a broader range of software development kits (SDKs) for seamless integration, and a notably lower cost. In Figure 4.8, the Aromajoin device is depicted. This device has the capacity to accommodate up to six scent pods simultaneously. Its operational mechanism involves the propulsion of pressurised air through the scent cartridges, subsequently releasing the scent via the diffusion gate, covering a distance of approximately 60cm. The compact dimensions of this device permitted the inclusion of multiple units within a single installation, and its lightweight nature minimally impacted the overall rig's weight.

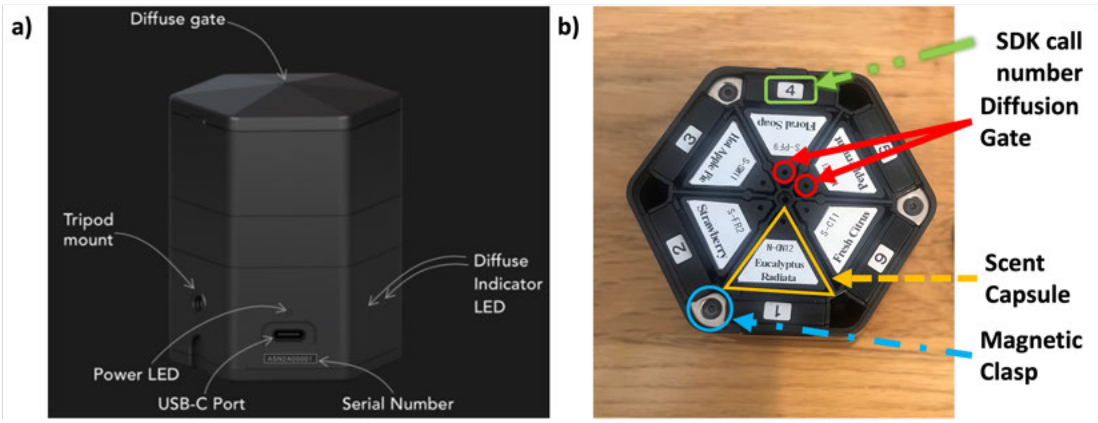

Figure 4.8: Aromajoin Device Overview - a) Labelled diagram of external features; b) Interior view with six scent capsules and magnetic lid clasps.

Upon testing the integration of heaters into the design, it was determined that they would not be feasible to integrate within the design because the adaptation of the heaters to enable them to be attached to the Arduino would involve bypassing safety features, presenting a potential safety hazard and fire risk. As a result, these elements were removed from the design to prevent any safety concerns.

Table 4.4: Product specifications for selecting the olfactory device in the multisensory rig design.

Device	Price (£)	Size (cm)	SDK	Custom Scent's	Scents per device
Olorama	2097.00	26.0x19.0x13.0	4	Y	10
Aromajoin	660.30	6.0x6.7x8.2	11	Y	6
AromaPrime	1439.99	26.0x13.6x34.5	1	Y	3
Ecoscent	699.00	20.0x17.0x55.0	0	N	1

Furthermore, tests were conducted with a fog machine which was integrated within the LED lights device, as an experiment to introduce smokiness to enhance the Guy Fawkes night experience. However, this addition was promptly removed from the design because controlling the volume of smoke emitted by the device proved challenging, resulting in excessive smoke clouds. This raised concerns about the potential impact on individuals with asthma. Moreover, due to the lab's limited ability to open windows, operating the fog machine triggered the fire alarm and led to a building evacuation. Additionally, the impracticality of using such a device in outdoor public areas was evident. As even brief operation of the fog machine for a few seconds would disperse substantial amounts of smoke over a wide area, making it incompatible with public spaces, due to the possible effect to those sensitive to air pollutants and the ability for smoke to degrade air quality possibly creating a hazard to people within the vicinity [67, 110, 203]. The potential ramifications of dispersing large quantities of smoke, both in terms of safety protocols and the potential distress it could cause to individuals, necessitated the elimination of this option from consideration.

4.4.2 First Iteration Prototype

The first prototype design consisted of two Aromajoin devices, one speaker, one fan, and a set of LED lights (see Figure 4.9). A laser-cut screen was used to minimise visual distractions, and participants sat roughly 0.5 metres from the table setup, with a typical study taking approximately 30 minutes. The chosen distance was a decision made for two key reasons. First, it aligned with the specified distribution area of the scent devices

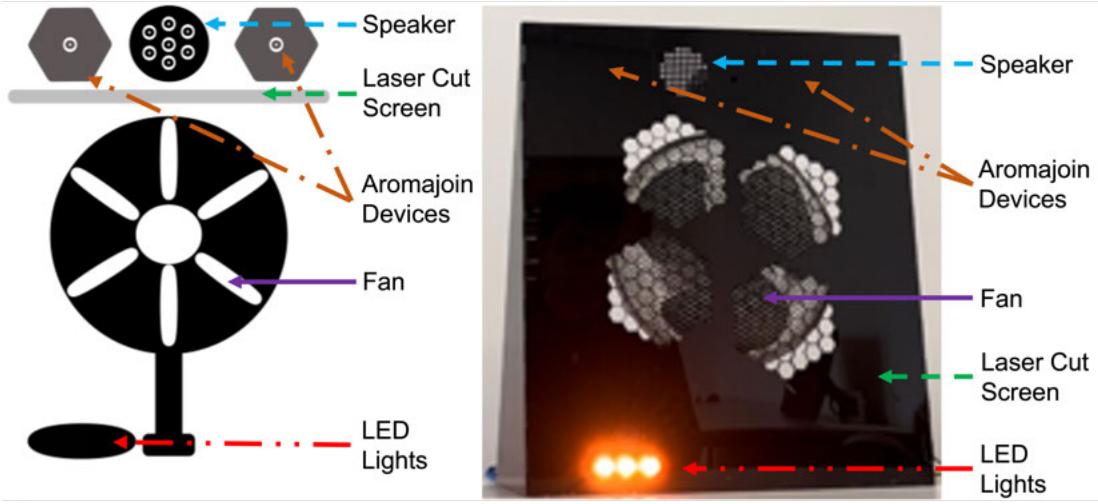

Figure 4.9: Pilot study multisensory device set-up, showing labelled device layout (LEFT) and the Coffee Shop experience in effect (RIGHT).

(60cm), as indicated by Aromajoin [19]. Second, it was essential to ensure participants' comfort. This distance not only allowed participants to effectively receive the sensory outputs from the olfactory, auditory, visual and tactile devices but also considered the need for personal space. It was crucial to acknowledge that participants might be interacting with a device they had not encountered before, and providing a comfortable space for this interaction was a priority.

The LED lights and fan were connected to an Arduino - a micro-controller board which could take inputs and create outputs. Control over the lights was established using an infrared transmitter - an electronic device that sends out pulses of infrared light. A full spectrum of colour combination codes were gathered using an infrared reader in conjunction with the LED lights controller. Subsequently, a binary infrared code sequence was created, transmitted via an Arduino infrared transmitter to the LED lights, resulting in a digital signal sent to the LED infrared reader to produce a specific light combination (e.g., blue). The fan featured three intensity levels and could be controlled for activation and deactivation using the Arduino device. Given the Aromajoin device's compatibility with multiple SDK languages, integration into the multisensory rig was streamlined. The selection was made to use the Java SDK, allowing for the passage of control through the Arduino and management of Java aspects (Olfactory and Audio).

In the initial prototype, the goal was to establish a Wizard of Oz setup with researcher-controlled outputs. The Java program could activate all devices to perform their respective functions upon case selection, (example in Appendix B). Each case had controls for visual, olfactory, auditory, and tactile outputs. The researcher selected a case from 1 to 4, triggering the corresponding output controls (1: Guy Fawkes Night, 2: Seaside, 3: Coffee Shop, 4: Sweet Shop). For example, Case 1: Guy Fawkes night generated smoky scents, firework sounds, strobe lighting, and a breeze for 5 seconds.

The sensory outputs were guided by the top five words linked to each cue from the questionnaire (Table 4.3). Compatibility with the employed devices was also taken into consideration. e.g., Guy Fawkes night featured premade scent 'Wood Smoke' and a custom 'Gunpowder' scent capsule. Additional scent capsules were tailored for the experiences, including 'Fishy Water' (evoking a salty fish water aroma) and 'Coffee' (evoking ground coffee). Lighting effects were based on the pre-existing options of the LED lights, aligning with the five most common lighting descriptors. Furthermore, the auditory elements were fashioned by the researcher using freely available sound effects and recordings captured at specific locations, such as Swansea Bay Beach.

Table 4.5: Pilot study sensory design for each scenario divided into the four deployment types: Olfactory, Auditory, Visual and Tactile.

	Guy Fawkes Night	Seaside	Coffee Shop	Sweet Shop
Olfactory	Wood Smoke, Gunpowder	Ocean, Fishy Water	Coffee	Peppermint, Chocolate Strawberry, Citrus, Hot Apple Pie
Auditory	Firework explosions and crackles	Beach waves & seagulls	Chatter & clattering of crockery	Old cashier till & children playing
Visual	Strobe of random colours	Yellow, orange, and blue	Dim orange	Strobe of random colours
Tactile	Fan on low	Fan on low	Fan on low	Fan on low

4.5 Pilot Study of a Multisensory Rig

The aim for the pilot study was three-fold, to (a) discover the types of digital sensory experiences the participants had taken part in before; (b) verify the efficacy of the formulated scenarios and corresponding sensory cues; and, (c) iterate the prototype based upon the feedback received from participants.

4.5.1 Procedure

Recruitment was accomplished through a combination of email distribution and social media outreach. Ethical approval was secured for the project with conditions including the disclosing of any allergens/breathing difficulties prior to attendance and the prevention of use by any children or vulnerable adults. Participants were advised not to partake if allergens or breathing difficulties were indicated. The study was conducted following a discussion aided by an information sheet, ensuring that informed consent was obtained from all participants. Additionally, participants were provided with the chance to participate in a prize draw for a £25 Amazon voucher as an expression of gratitude for their involvement. The study's primary objective was to ascertain the potential of a multisensory installation in eliciting sensory outputs that trigger the retrieval of past memories and its suitability as a public installation. The study was structured as follows:

1. Every participant engaged in a brief pre-study questionnaire (Appendix C) aimed at collecting demographic information. Furthermore, participants were asked to provide insights into any prior encounters they had with multisensory activities, encompassing both research-oriented and entertainment-driven experiences.

2. The participants were seated roughly 0.5 metres from the multisensory rig to ensure they could both smell the olfactory cues and see the visual outputs.

3. Participants were requested to observe three successive rounds of sensory output for four distinct scenarios (Guy Fawkes Night, Seaside, Coffee Shop, and Sweet Shop), with each deployment lasting a duration of five seconds. After the conclusion of the final round for each scenario, participants were presented with a series

of inquiries (see Appendix C) regarding the respective scenario. These inquiries encompassed aspects such as the degree of prominence associated with each scent and whether the sensory outputs had triggered any recollections or memories.

After completion, the participants were given the opportunity to discuss their experience and any further feedback they would like to provide regarding the device or overall experience.

4.5.2 Results

Pre-study Questionnaire

The pilot study included eight participants, aged 23 to 58, representing four work sectors, including two females and six males. Following the demographic retrieval questions, the participants were asked about their past experiences with multisensory activities. 38% of participants had experience with Virtual Reality (VR) studies, and 63% had been to a 4D experience (e.g., Heineken experience, Amsterdam [118]) or a 4D cinema viewing (e.g., Ironman 4D [82]). However, none of the participants had experience with interactions including olfactory outputs before.

Scenario Deployment

Following the questionnaire, the prototype deployed three rounds of output for each scenario, lasting five seconds per deployment. Participants were asked to share their perceptions of the stimulation's across the multiple sensory modalities, prompting them to identify any experiences or associations they recalled in relation to the specific scenarios. Additionally, they were asked to discern the relative prominence of each sense, ranking olfactory, audio, visual and tactile cues from the most to least prominent.

Weights were assigned to each level of prominence, with the highest rank receiving the greatest weight and the lowest rank receiving the least weight. A weighted average of participant-assigned ranks were calculated for each sense and scenario, resulting in the average prominence values illustrated in Figure 4.10. For instance, audio received the highest weighted average from 85% of participants. Consequently, audio held the highest prominence, closely trailed by light. During the course of the study, it became evident that the olfactory component of the design lacked sufficient intensity, making it challenging for the majority of participants to differentiate and perceive distinct olfactory cues. The tactile cue (wind) exhibited the lowest prominence. This observation was largely attributed to the participants' belief that the fan's purpose was to propel the scent forward, rather than providing tactile feedback. To determine whether or not there was a significant difference between the prominence of each scent the non-parametric statistical Friedman Test [95] was completed. This analysis aimed to understand whether the scenario deployments had any effect on the recognition's of the different sensory outputs. The results for testing the difference in each sensory cue across the four scenarios yielded the following statistics:

$$\textbf{Friedman Test Statistic (Q)} = 11.77;\ \textbf{p-value} = 0.0082;$$

Because the p-value for the prominence data is less than the significance level of 0.05, the analysis rejects the null hypothesis and concludes that at least one of the four senses had a significantly different sensory effect. In addition, whilst the median ranking for Olfactory (1.60) was close to the overall median (1.75), the median response for Audio (3.05) was substantially higher, at over double the overall median rank (see Table 4.6). These results indicated that the audio had a more effective prominence than other types of sensory cues across all four scenarios. In contrast, the results for testing the difference in scenarios provided a non-significant result of $p-value = 0.97$. Therefore, it can be concluded that, for the pilot study, the different scenarios had no effect on the sensory prominence as can be seen from the average weighted rankings in Figure 4.10 and insignificant Friedman's test results.

Table 4.6: Sum and Median Rank for each of the sensory cues (Pilot Study).

Sensory Cue	Sum of Rank	Median
Audio	12.30	3.05
Visual	8.90	2.30
Olfactory	6.40	1.60
Tactile	4.40	1.00

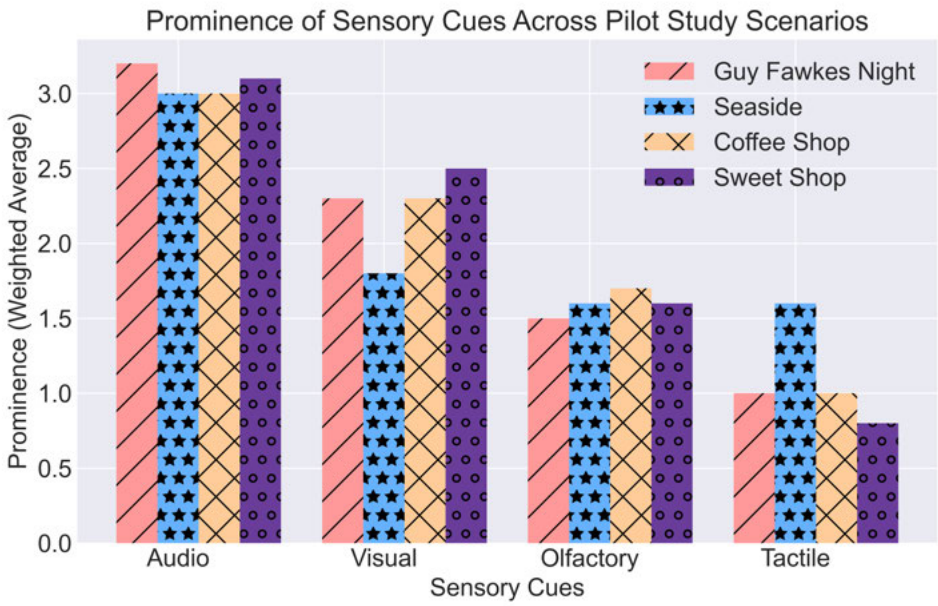

Figure 4.10: The average weighted ranking of multisensory cues (auditory, visual, olfactory and tactile) across four different scenarios.

In addition to evaluating the prominence of each sensory cue, the study also aimed to assess the effectiveness of the sensory outputs derived from the collaborative formulation based on the sensory cue questionnaire (see Section 4.3.2). The objective was to determine the extent to which these outputs successfully conveyed understandable experiences to the participants and elicited recollections of previous memories and experiences.

Guy Fawkes Night: All participants recalled some form of memory, with 75% describing experiences reminiscent of a Guy Fawkes night or Fireworks Display. Three participants specifically recounted a fireworks event held on a beach. For instance, one participant shared,

> "This reminds me of a Fireworks display a few years ago with my children on Swansea Beach where it was very cold but somebody had set fire to a sofa on the beach and it smelt really smokey."

The remaining participants evoked a diverse range of memories, including a military encounter in Bosnia. They associated the firework explosions with gunfire, while another was reminded of a monsoon during their childhood in India, where they engaged in a game of banging on tables until the rain ceased. Whilst, 90% of the participants accurately identified the olfactory output as a blend of smoke and gunpowder, some found the combination of audio and visual strobe lighting perplexing. They suggested that fireworks typically feature bursts of colour, whereas the prototype design had continuous strobe lighting prompting them to focus more on this aspect.

Seaside: The seaside experience successfully evoked memories for all participants, with 75% of participants recognising it as a seaside experience. Several provided personal anecdotes, for example, three participants who owned dogs recounted the joy of walking with their dogs along a beach during the warmer months of the year. Remarkably, the memories that diverged from the seaside theme, still exhibited parallels with a seaside experience, with the additional participants recounting experiences relating to local parks and leisurely walks along the cliffs with their partner, as the bird sounds within the audio and fresh sea scent reminded them more of a breezy walk under the trees than of waves.

Coffee Shop: In contrast, the coffee shop scenario encountered comparatively lower recognition among participants, with a mere 38% eliciting any recollections. Among these, only 25% related the experience to a coffee shop, while the remaining respondents drew parallels with a school cafeteria. The discrepancy in recognition might be attributed to the dominant sulfuric or eggy note in the coffee scent, which led to some discomfort. One participant remarked,

> "Oh gosh, it smells like (gone) off sandwiches. It's hard to focus on anything else."

Sweet Shop: The sweet shop scenario exhibited the lowest level of stimulation, as none of the participants were able to draw any reminiscent connections. This outcome might be attributed to the subtle nature of the scent, which participants struggled to identify, coupled with the challenge of deciphering the audio component. Several participants recognised the sound of a cashier bell but encountered difficulty discerning other elements. Another potential factor could be the potential over stimulation from previous experiences, potentially complicating the interpretation of the final scenario.

Post-Study Feedback

Following the conclusion of the study, participants were offered the opportunity to provide supplementary feedback, encompassing both the device itself and specific sensory outputs. Overall, the participants were intrigued as to how it could be utilised within public spaces. Several participants, suggested varying the lighting to intermittently illuminate and dim, to replicate natural sunlight. In addition, a unanimous consensus emerged among participants regarding the need for enhancement of the sensory aspects. Specifically, participants advocated for either intensifying the scents with stronger variations or increasing the volume of distributed scents. The same sentiment was echoed in the context of audio, where participants recommended increasing the volume.

The only scenario that received specific recommendations was Guy Fawkes night, where one participant recommended adapting the audio and visual lighting to have distinct gaps and crackling sounds to make it appear like a more authentic Firework display where lights would explode in the sky, disperse and then another would appear, instead of continuous lighting.

4.5.3 Pilot Study Overview

The pilot study provided insights for future prototype iterations, showing that participants found the experience novel and engaging, with a focus on memory stimulation, particularly for those concerned about memory loss. Additionally, accurate scenario recognition was perceived as enjoyable by some participants, contributing to their engagement with the study.

The results indicated scope for refining the accuracy of scenario recognition, fulfilling the second aim. The participants' engagement was most influenced by the audio component, with a substantial impact on their immersion, when the audio deviated from expectations it was harder for participants to engage with their other senses. This observation introduced an intriguing paradigm, contrasting with the assumption that the olfactory stimulation would take precedence over other sensory inputs. Instead, the study found that audio had the greatest impact on participants.

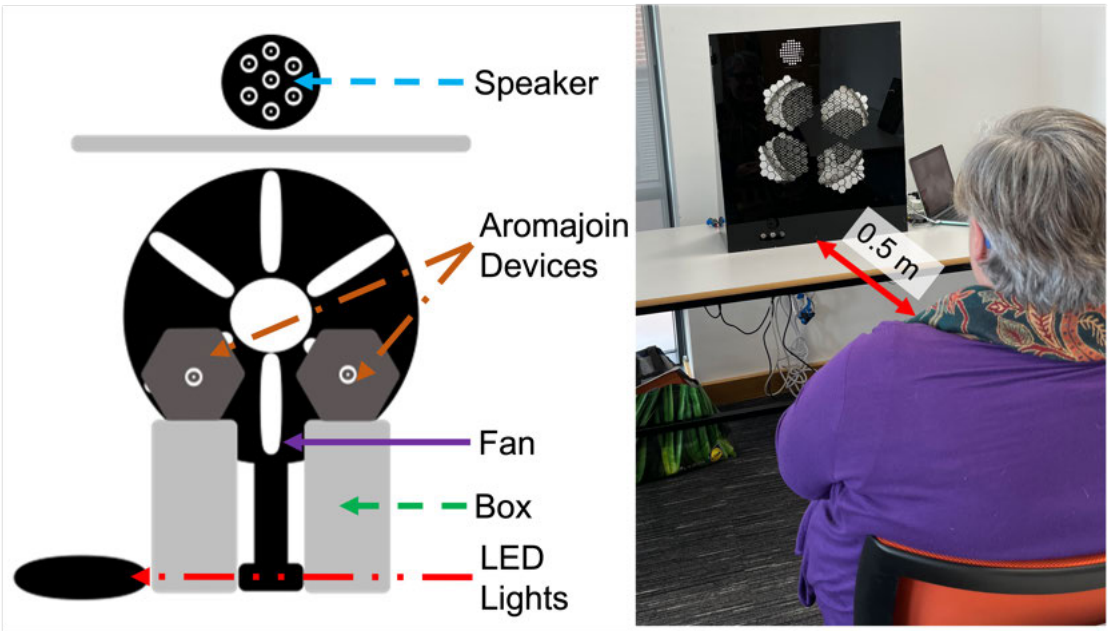

Figure 4.11: Lab study prototype device reconfiguration with scent devices at head height, and a participant seated 0.5 metres from the device.

Adaptations for the Second Iteration Prototype

Regarding the studies third aim, several adaptations were implemented in response to the feedback received from participants in the pilot study. To address the insufficient potency of olfactory outputs across the majority of scenarios, two adaptations were implemented. First, the olfactory devices were re-positioned to a height closer to head level and in front of the fan, in the hope of a more effective scent dispersion, (see Figure 4.11). Second, the quantity of scent capsules per scenario was increased from two to four capsules per scenario, with the fan intensity also being increased from low to high. These adjustments aimed to enhance the olfactory experience and its impact on sensory perception.

Furthermore, the scents were adjusted based on feedback to align more closely with the corresponding experiences. For instance, *'Hot Apple Pie*' was introduced to the *'Guy Fawkes Night'* scenario to emulate food stalls. It was also incorporated into the *'Coffee Shop'* scenario alongside chocolate to mitigate the strong coffee scent disliked by participants and to introduce sweeter aromas reminiscent of cakes. Additionally, the number of scents in the *'Sweet Shop'* scenario was reduced to two to facilitate easier scent discernment and prevent overstimulation. Given that all scents were created and supplied by Aromajoin in Japan, customising individual scents for greater accuracy, such as in the case of the coffee scent, within the timeframe was not feasible. Therefore, adjustments were made within the available options to align the scents as closely as possible with the intended experiences.

To attempt to solve the confusion arising from continuous lighting, adaptations were made to the Guy Fawkes night scenario by introducing synchronised flashing lights accompanied by delayed audio bangs. This modification aimed to enhance participants' comprehension of the scenario, addressing the specific feedback received. The sensory output that attracted the most feedback, likely due to its perceived prominence, was audio, resulting in requests for adjustments to be made for each scenario's audio components. To elaborate, the Guy Fawkes night scenario necessitated the inclusion of additional ambient noises such as sparklers, to compliment the explosions of individual fireworks. In the case of the coffee shop scenario, participant feedback prompted the addition of sounds associated with a coffee machine in operation, along with the omission of clattering crockery to reduce its similarity to a cafeteria. In contrast, the seaside audio evoked diverse feedback, reflective of the numerous beaches within the Swansea area each offering distinct sensory stimuli. To address this, the decision was made to amplify the crashing waves and seagull sounds, enhancing differentiation from a park environment. Finally, the sweet shop scenario required audio elements that would effectively distinguish it from a typical store. Consequently, sounds like rattling jars, pouring of sweets into scales, and the ringing of an old-fashioned till were integrated.

In response to the feedback and analysis detailed above, the design of each scenario and physical location of the devices were adapted. The adapted device locations can be seen in Figure 4.11 and the final sensory outputs are summarised in Table 4.7.

Table 4.7: Lab based user study sensory design for each scenario divided into the four deployment types: Olfactory, Auditory, Visual and Tactile.

	Guy Fawkes Night	Seaside	Coffee Shop	Sweet Shop
Olfactory	Smoke, Gunpowder, Hot Apple Pie	Ocean, Fishy Water	Coffee, Chocolate, Hot Apple Pie	Strawberry, Citrus
Auditory	Whistle, Bang, Pause x2	Crashing waves & Seagulls	Espresso machine & chatter	Jars opening, pouring sweets, old-fashioned cash register
Visual	Red with Bang 1, Green with Bang 2	Blue	Dim orange	Dim orange
Tactile	Fan on high	Fan on high	Fan on high	Fan on high

4.6 Lab Study of a Multisensory Rig

The aim for the lab study was three-fold, to (a) discover the types of digital sensory experiences the participants had taken part in before; (b) verify that the adaptations made following the pilot study feedback were effective leading to a higher efficacy of the formulated scenarios and corresponding sensory cues; and, (c) discover the iterations necessary for the prototype to be adapted for a city based deployment.

4.6.1 Procedure

As described for the prototype testing, recruitment was accomplished through a combination of email distribution and social media outreach. Ethical approval was again secured for the project with conditions including the disclosing of any allergens/breathing difficulties prior to attendance and the prevention of use by any children or vulnerable adults. Again, as for the pilot study, participants were advised not to partake if allergens or breathing difficulties were indicated. The study was conducted following a discussion aided by an information sheet, ensuring that informed consent was obtained from all participants. Additionally, participants were provided with the chance to participate in a prize draw for a £25 Amazon voucher as an expression of gratitude for their involvement. The study's primary objective was to ascertain the potential of a multisensory installation in eliciting sensory outputs that trigger the retrieval of past memories and its suitability as a public installation. Confirmation of the improved efficacy based on adaptations made due to the pilot study was a central focus. The study followed the same structure as the pilot study outlined in section 4.5, except for one key difference: the duration of each scenario was extended from five to eight seconds to allow participants more time to fully experience the sensory outputs. Following the completion of the study, participants were offered the chance to engage in a discussion about their experiences. They were encouraged to share any additional feedback they had regarding the device and to suggest any modifications they believed would make it more suitable for deployment in a city setting.

4.6.2 Results

Pre-study Questionnaire

The lab study involved 18 new participants (8 females, 10 males), aged 23 to 57, from seven different work sectors, each dedicating roughly 30 minutes to the study. Following the demographic questions the participants' were asked about any prior experiences with multisensory activities. Two of the participants had previously participated in a VR research study that involved both audio and visual cues. Additionally, one participant had taken part in a taste test research study within the field of sport science. The majority of participants (73%) reported having encountered entertainment-based multisensory experiences. These experiences included attending 4D immersive experiences, such as the London Dungeons [77]. Furthermore, none of the participants had prior experience with multisensory activities in outdoor public spaces, or those involving olfactory outputs.

Scenario Deployment

After experiencing the three rounds of sensory output for each scenario the participants were asked to identify any experiences or associations they recalled in connection to the specific scenarios. Furthermore, participants were tasked with assessing the relative prominence of each sense by ranking olfactory, audio, visual, and tactile cues from the most prominent to the least prominent.

Within the lab study, each level of prominence was assigned a weight, with the highest rank being assigned the greatest weight and the lowest rank receiving the least weight. Participants' rankings were then used to calculate a weighted average for each sense and scenario (see Figure 4.12). As the same method was used for the pilot study experiments, the data can be directly compared. A comparable pattern emerges when examining the auditory cues, which maintained their position as the most prominent sensory elements, although at a slightly lower percentage of 68%. However, there was a shift in the ranking of olfactory cues, now occupying the second-highest position, compared to their third-place ranking in the pilot study. This shift signified a distinct trend in the significance of auditory cues and underscored the successful enhancement of olfactory output intensity, resulting in a more substantial impact during the user interactions.

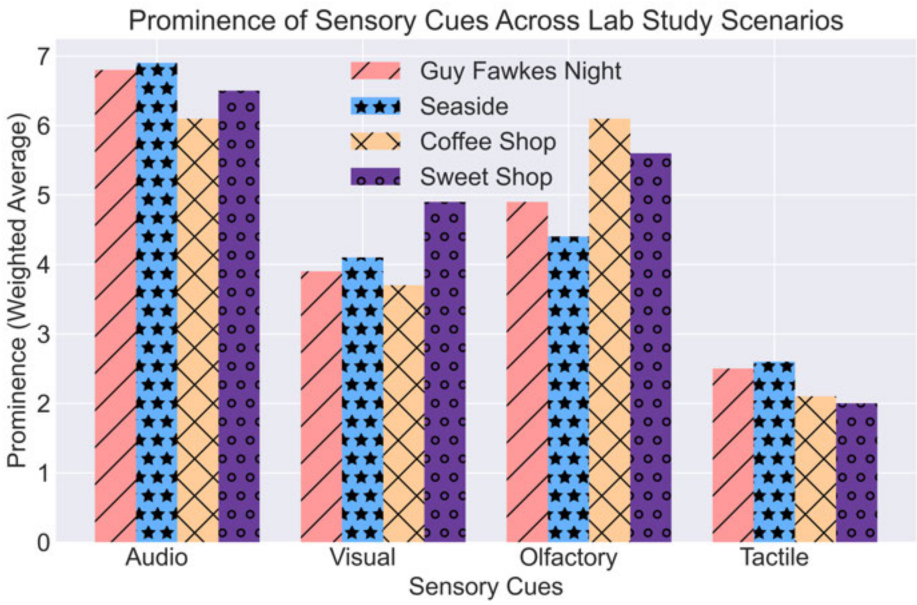

Figure 4.12: The average weighted ranking of multisensory cues (auditory, visual, olfactory and tactile) across four different scenarios.

Throughout the study, it became evident that while audio was consistently ranked as the most prominent sense, the olfactory component of the interaction held a particularly intriguing aspect. Many participants expressed a strong interest in knowing whether they had correctly identified the scents, highlighting the fascination associated with the olfactory experience during the study. Additionally, the tactile cue, consistently demonstrated the lowest prominence among participants. Several participants explicitly noted in the feedback section of the study that the tactile cue was a distraction and had a lesser impact on their sensory experience compared to other cues. In some cases, it was perceived as more of a hindrance than a meaningful sensory output.

As in the pilot study, the Friedman Test [95] was conducted to assess whether there were significant differences in prominence among the various senses. This analysis aimed to again ensure that the scenario deployments did not effect the recognition of the different sensory outputs. The results for testing the differences in each sensory cue across the four scenarios yielded the following statistics:

$$\textbf{Friedman Test Statistic (Q)} = 11.77; \ \textbf{p-value} = 0.0082;$$

With a p-value for the prominence data less than the significance level of 0.05, the null hypothesis was rejected, indicating that at least one of the four senses had a significantly different sensory effect on the overall experience. Moreover, although the median rankings for Olfactory (5.25) and Visual (4.00) were relatively close to the overall median (4.65), the median response for Audio (6.65) remained substantially higher (see Table 4.8). Consequently, the results suggest that auditory outputs continued to be the most effective and prominent sensory cue compared to the other types of sensory cues across all four scenarios.

Table 4.8: Sum and Median Rank for each of the sensory cues (Lab Study).

Sensory Cue	Sum of Rank	Median
Audio	26.30	6.65
Visual	16.60	4.00
Olfactory	21.00	5.25
Tactile	9.20	2.30

In contrast, the results for testing the differences between scenarios yielded non-significant results with a p-value of 0.75. Therefore, it was concluded that, in the context of the lab-based study, the scenarios had no discernible impact on sensory prominence, as evidenced by the prominence rankings in Figure 4.12 and the insignificant results of the Friedman Test.

In addition to evaluating the prominence of each sensory cue, the study also sought to assess whether there was any improvement in the effectiveness of the sensory outputs. These outputs were initially developed based on the sensory cue questionnaire (as outlined in Section 4.3.2) and were then refined based on the feedback from the pilot study. The primary objective was to determine to what extent these refined outputs successfully conveyed understandable experiences to the participants and triggered recollections of previous memories and experiences with increased accuracy compared to the pilot study.

Guy Fawkes Night: The Guy Fawkes night scenario demonstrated greater accuracy in the second study, with 89% of participants recalling memories of Guy Fawkes night. The remaining 11% (two participants) had never attended a fireworks display. One of these participants shared an experience of watching a James Bond movie in a cinema for the first time and related the audio in the movie to the sound of gunshots, with the smell reminding them of gunpowder. The scenarios adaptations, synchronising lights and audio so that lights flashed and paused with the audio bang, as opposed to continuous lighting in the previous iteration, which led to the participants focusing more on the olfactory outputs.

Seaside: The seaside recognition rose from 75% to 83%. Furthermore, 67% of the participants specifically recounted memories associated with a beach. For example, one participant shared,

> "It reminds me of walking along the beach towards the Mumbles on the bike path, ready for an ice cream"

Similar to the pilot study, participants who did not recognise the scenario as the seaside still recalled memories closely related to the seaside theme. For instance, one participant was reminded of a calming spa experience.

Coffee Shop: While the recognition accuracy for the coffee shop scenario did increase from 38% to 44%, the adaptations made were not notably successful in evoking a coffee shop environment. Among those who did recognise the scenario, it was primarily due to the sweet scent output reminding them of a franchise coffee house such as, Starbucks. Additionally, the adaptation of the audio output appeared to remind participants more of metal machinery than a coffee machine. The remaining 56% of participants had their memories triggered by the sensory outputs, but these memories were entirely distinct and unrelated to one another. For instance, one participant recalled:

> "I'm broken down on the motorway, there are red lights on the dashboard, something smells bad and the cars making funny noises"

Sweet Shop: The sweet shop scenario exhibited the most significant increase in recognition accuracy, increasing from no participant recognition to a 78% recognition rate. The significant improvement in accuracy could be attributed to the deployment of a higher number of scent capsules and the reduction in the variety of scent types. Although adjustments were made to the audio, it was the sweet scent, particularly the strawberry scent, that participants most frequently mentioned, with 65% specifically recalling moments of eating sweets with their grandparents, indicating its prominent role in enhancing the overall experience. Furthermore, this scenario emerged as one of the most popular among participants, further highlighting the effectiveness of scent in shaping user perception. For the remaining participants, the sensory cues brought to mind a country cafe or farm shop. The old-fashioned till in the scenario reminded them of a small local business, which was less likely to have a digital till.

Post-Study Feedback

Upon the conclusion of the study, participants were given the opportunity to provide additional feedback, including for the device itself, specific sensory outputs, and potential adaptations for deployment within a city setting. Overall, participants expressed great enthusiasm for their participation in the study and their interactions with the multisensory device. This time, feedback regarding adaptations to sensory outputs was more limited, possibly due to the improved recognition of sensory cues.

The tactile aspect of the experience was noted as being distracting for several users. As with the pilot study, some participants were again unsure whether the tactile component was intended to push the scent forward or serve as a standalone sensory cue.

In terms of lighting, it was rarely mentioned throughout the study, with approximately 70% of participants not referring to it unless prompted with specific questions. When suggesting adaptations for city-based deployments, all participants, recommended relocating the LED lights. They suggested that, in real environments, the lighting would typically be positioned above the participants' heads, shining downward, rather than below their eye line, as was the case in the study setup.

4.6.3 Lab study Overview

The laboratory study provided insights and highlighted potential adjustments necessary for the city-based deployment of this prototype. Regarding the studies first aim, participants' responses further confirmed that the experience was innovative, as none had previously engaged in a similar study. Furthermore, the accuracy recognition significantly improved, with an average recognition rate of 74% across all scenarios, compared to the 47% observed in the pilot study, completing the second aim.

The study results underscored the importance of auditory and olfactory cues working in harmony to stimulate memory recollections, with the increased olfactory output making it more prominent than visual cues. In addition, olfactory cues dominated in discussions among participants who wanted to identify scents accurately.

Looking ahead, it became evident that adaptations were necessary for the city-based deployment. The tactile cue, found to be distracting, and the lighting, which was challenging to perceive at its current height, both needed adjustments to enhance the overall experience rather than detract from it. These findings served as guidance for refining the prototype for real-world city deployments which will be explored in Chapter 5, completing the third aim.

4.7 Discussion

Whilst research has previously evaluated the creation of visual and speech based public displays (e.g., [87, 215, 229]), the process of cocreating a multisensory prototype offers new insights and contributions to the field. It represents a convergence of creative ideas from children, practical wisdom from regeneration experts, and feedback collected through extensive questionnaires, collectively leading to the creation of the initial prototype. The feedback received led to substantial changes and adaptations, ensuring that the prototype evolved in response to real-world experiences and user preferences.

The process of cocreation, as demonstrated in this chapter, played a central role in shaping a multisensory prototype developed as a proof of concept, laying the groundwork for its evaluation in the subsequent city-based deployment chapter. The iterative studies, commencing with a pilot study and evolving into a more comprehensive lab study, proved instrumental in the refinement and adaptation of the prototype. This multifaceted cocreation approach aligns with the principles of human-centred design and participatory urbanism (e.g., [148,185,186]), underscoring the value of diverse perspectives and active engagement in shaping technology for urban spaces. It contributes to the existing literature by showcasing the practical implementation of cocreation methodologies in the development of multisensory urban installations, highlighting the effectiveness of such an approach in creating technology that is both innovative and user-centric.

4.7.1 Diverse Perspectives to Foster Innovation

By actively engaging a diverse spectrum of contributors, as advocated by Bradbury [30], including children, regeneration experts, and community members, a multisensory rig could be made. Each group brought to the table a unique set of ideas, experiences, and solutions, contributing to the development of a prototype that was both innovative and effective.

This work underscores the importance of integrating children into design processes as previously advocated [76, 128, 237], introducing a comprehensive process for engaging children in workshops aimed at enhancing technology design for public spaces. Children, unburdened by conventional thinking, introduced a fresh and imaginative lens through which to view urban technology installations. Their boundless creativity led to ideas that pushed the boundaries of traditional design. However, it is worth noting that the children's involvement with the ongoing prototyping was constrained. Although the author aimed to have them involved throughout the entire process, ethical restrictions imposed by the university ethics restricted any scent-based research with participants under the age of 18 outdoors. Consequently, while children played a role in the initial stages of the prototype design, it was not possible to consult them throughout the subsequent phases of the prototyping studies. To address this gap, the final design was revisited and tested with pupils towards the conclusion of Chapter 5, where an alternate ethical review was completed.

In contrast, regeneration experts offered practical wisdom, rooted in their deep understanding of the specific context of Swansea's urban regeneration. Their insights ensured that innovative concepts could be translated into feasible and contextually relevant solutions. Their insights served as a bridge between imaginative ideation and pragmatic application. These exploratory workshops highlighted the differences in memory recollections associated with various sensory experiences. This revelation prompted the subsequent creation of a comprehensive questionnaire, which provided feedback to uncover variations in the words and phrases linked to different sensory experiences.

Community members, representing a diverse cross-section of end-users, provided critical feedback, aligning the prototype with the needs and preferences of the wider community. This collaborative approach highlighted the significance of integrating diverse facets to optimise the design of urban technology installations, making them more creative and practical.

The aggregation and analysis of these responses formed the basis for refining and validating the sensory cues intended for incorporation into the initial multisensory prototype. This contribution demonstrates the significance of incorporating user feedback, especially concerning multisensory experiences, to enhance the effectiveness and resonance of urban technology installations.

4.7.2 Measuring Effectiveness

The multifaceted evaluation of the multisensory prototype contributed to the understanding of its effectiveness and usability. The increase in average recognition accuracy (47% to 74%) across the four scenarios, demonstrated the impact of iterative development and user-centred design on enhancing the prototype's performance. In addition, it showcases the value of ongoing refinement based on user feedback [186].

Furthermore, the inclusion of users' recollections, and emotional responses in the evaluation process provided an understanding of the prototype's ability to create memorable experiences and engage the senses effectively. This holistic feedback not only measured the prototype's technical functionality but also its capacity to elicit emotional and sensory responses from users.

Moreover, users' voices were not only heard but also valued in the iterative development process. Overall, this multifaceted evaluation contributed to an understanding of the multisensory prototype's effectiveness and its potential to create engaging and memorable experiences in urban spaces, a process which could be adapted and integrated across multiple contexts.

4.7.3 Navigating Challenges in Multisensory Design

This research encountered several challenges, including the impact of the COVID-19 pandemic [88]. Conducting children's workshops online due to the pandemic presented obstacles, leading to a reduced collection of student designs (37% less) and limited in-person engagement. Additionally, the project encountered a diversity of perspectives on sensory cues and their associated triggers. The varying interpretations from different participants emphasised the intricate and sometimes subjective nature of sensory experiences. It highlighted that what one individual might associate with a particular sensory cue, another might perceive differently. Navigating these diverse perspectives was a balancing act, one that required careful consideration and adaptability to ensure that the prototype could resonate with a broad range of end-users. In summary, these challenges underscore the importance of flexibility and creativity in addressing unforeseen obstacles in research, enhancing our understanding of multisensory urban installations.

4.8 Conclusion

The cocreation process undertaken in this research described how diverse groups can influence the development and effectiveness of a prototype designed for multisensory engagement. By involving a wide range of users in the design process, it was acknowledged that urban technology should be inclusive, meeting the diverse needs and preferences of the entire community. In particular, children brought fresh perspectives, unbiased creativity, and a unique sense of curiosity to the table.

Furthermore, engagement with regeneration experts and participants from the wider community, steered the research towards a comprehensive and contextually relevant approach. This engagement facilitated a link between imaginative ideation, practical applicability, and a deeper understanding of the intricate relationship between sensory experiences and memory recollections in the context of urban regeneration. In essence, the process of cocreating the multisensory prototype encapsulated the essence of user-centric design, where the community's input and diverse perspectives were not only acknowledged but actively integrated into the development process. Which lead to the creation of a multisensory prototype with olfactory, visual, auditory and tactile outputs. Whilst recognition was low at first the feedback led to an increased recognition rate and a starting point for adaptations into a city-based prototype (Chapter 5).

In summary, the evaluation of the multisensory prototype extended beyond mere recognition accuracy. It embraced an understanding of how the prototype resonated with users, the emotional connections it fostered, and the valuable input users provided for continuous improvement. This multifaceted evaluation approach produced a prototype that not only performed well but also resonated deeply with the community members. In the upcoming chapter, these designs will undergo a transformation, evolving into a city centre-ready prototype.

4.8.1 Chapter Contributions

In this chapter, the impact of a diverse cocreation process on the development and effectiveness of a multisensory interactive prototype was explored, with a particular focus on fostering inclusive urban technology and influencing memory recollection and sense of space. Building upon insights from the Lookout deployment, where a desire for immersive experiences, especially for children, became evident, this chapter explored the cocreation of an interactive multisensory prototype. Motivated by the belief that such devices could enhance city centre engagement, particularly among young citizens, and inspired by the observation that children's interactions could inspire others to engage with urban technology, this chapter concentrated on testing a multisensory prototype incorporating olfactory, auditory, visual and tactile elements which could be adapted for city deployment (Chapter 5).

Chapter 5

Making Sense of Outdoor Public Places: Advancing Multisensory Design through Deployment, User Engagement, and Recommendations

5.1 Introduction

In the heart of bustling city centres, screens have long held sway as the primary medium through which people interact with technology, connecting people to a multitude of digital experiences [107, 130, 244]. While undeniably effective, these screens have often been accused of isolating us from the vibrant environments that surround us [184]. In response to this challenge, a journey was embarked upon to reimagine urban spaces, envisioning a cityscape where screens give way to immersive multisensory installations. This chapter marks a contribution to the understanding and exploration of multisensory installations within outdoor public spaces.

In the previous chapter, the process of cocreating a multisensory prototype using olfactory, auditory, visual and tactile outputs unfolded, involving regeneration experts, children, and the broader community. This collaborative process laid the foundation for the design and development of the multisensory rig explored here. While previous research has primarily focused on multisensory technologies within indoor settings (see [32, 165, 166, 200]), this work enters a new landscape in this context – i.e., multisensory technologies in the outdoor urban environment. This shift in focus provides a perspective into multisensory and urban installation design. This work highlights the potential of multisensory technology to transform public spaces and make cities more engaging and vibrant.

The combined efforts from the previous chapter culminated into the development of a multisensory prototype, which then underwent rigorous scenario testing in a controlled lab environment. In this chapter, the prototype will be refined and deployed in a city setting. To bring the process full circle, the young citizens who participated in the initial design phase were revisited. All of these phases contributed to the creation of a comprehensive set of recommendations for seamlessly integrating multisensory technologies into any outdoor public space.

In essence, this chapter provides a comprehensive guide for cities looking to leverage multisensory installations as a means of enhancing urban environments, fostering community engagement, and enriching overall city life. By embracing the lessons learnt outlined in this chapter, cities have the building blocks to create vibrant, inclusive, and immersive public spaces that resonate with the diverse preferences and needs of their citizens.

5.2 Multisensory Deployment Rig for a City Centre

This section describes the factors influencing the design of both the hardware and software components of a multisensory deployment rig intended for use in a city centre environment. These designs were formulated based on insights gathered from cocreation sessions and laboratory studies, as discussed in the previous chapter (Chapter 4). The primary goal of developing this prototype was to create a versatile multisensory rig tailored for urban deployments. The overarching objective was to establish the viability of engaging participants within city centre settings, answering the question of whether individuals would be interested in interacting with such a multisensory rig in a public space and its efficiency within that space.

5.2.1 Design Considerations

Deploying the prototype within an outdoor public space brought with it design considerations that played a role in shaping the final design. When designing interactive devices for outdoor environments, not only must the creation of an engaging experience be considered but also the intrinsic navigation of the complexities and challenges posed by deploying in outdoor urban settings. A description of the key design considerations are presented:

Addressing Overstimulation: The design took a comprehensive approach to mitigating overstimulation, by offering a diverse range of sensory experiences. Instead of overwhelming participants with intense sensations of one sense, such as blinding lights or deafening sounds, the rig incorporated a blend of visual, auditory, and olfactory elements. This diversity aimed to distribute sensory input evenly, preventing any one sense from becoming overloaded.

Guiding Interaction: Following the lessons learnt from the Lookout deployment (Chapter 3), clear and instructive auditory communication was integrated into the interaction design to guide participants through their multisensory experience. This approach set clear expectations and empowered individuals to make informed decisions about their level of engagement, reducing the likelihood of feeling overwhelmed (further details provided in Section 5.3).

User-centred Development: Extensive user testing and feedback collection were integral components of the design process, as discussed in Chapter 4. Diverse groups of participants including children, regeneration experts and community members provided valuable insights that helped refine the rig's design and functionality, narrowing down the number of scenarios and removal of tactile senses ensuring that it met the diverse needs of the community. This approach would remain central moving forward in assessing the compatibility of multisensory experiences for outdoor public spaces.

Accessibility: Accessibility was a fundamental principle throughout the design process. The multisensory rig was thoughtfully crafted to accommodate individuals with sensory sensitivities or disabilities. Features such as adjustable heights and a variety of multisensory elements were incorporated to ensure inclusivity and to accommodate users with sensory impairments. For example, for individuals with visual impairments, the inclusion of auditory and olfactory cues provided a more accessible experience, as the installation was not limited to a single sensory modality. This multisensory approach aimed to create a more inclusive urban environment, where individuals with diverse sensory capabilities could participate and enjoy the installation without the risk of sensory overload.

Foot Traffic Considerations: Collaborative discussions with Swansea Council resulted in a strategic positioning that enhanced rather than impeded foot traffic flow. Factors like pathway width, common walking routes, and congregation areas were considered. The rig's flexible and transportable design allowed for easy relocation, ensuring it did not disrupt pedestrian movement and would not be interacted with without a researcher present. This adaptability was crucial in maintaining harmony within the urban environment.

Weather Resistance: Considering Swansea's unpredictable weather [247], weather resistance became paramount. The design incorporated protective measures, including waterproof enclosures and covers, to shield sensitive components from rain. Stability mechanisms, such as weighted bases and secure anchoring, were implemented to ensure the rig remained steady during wind and precipitation fluctuations. Regular maintenance plans were established to monitor and address any weather-related wear and tear. This comprehensive approach guaranteed the rig's reliability, allowing it to operate effectively regardless of the prevailing weather conditions.

Simplistic Design: The decision to opt for a simplistic dressing for the rig was motivated by practical considerations. The selection of a grey outer box and the adherence to a minimalist design were deliberate choices made to enhance the ease of transport and ensure that the rig remained lightweight. This decision was particularly crucial due to the deployment site's distance of approximately 0.3 miles from the nearest available parking. Furthermore, the purposefully compact and slender dimensions of the rig further aided the transport of SALly.

Mitigating Bias: Keeping the design simple was also chosen to avoid biasing users' perceptions of the rig's purpose or contents and to maintain the rigs appearance as a prototype. This decision was informed by previous deployments, where users' comfort in providing feedback was observed to be influenced by their perception of prototypes completeness. By retaining a prototype-like aesthetic, the rig subtly communicated to users that it was a work in progress, encouraging them to engage and provide valuable feedback without reservations.

In summary, the design considerations for deploying the multisensory rig for the outdoor public space in Swansea was a multifaceted process that integrated user-centred principles, accessibility, weather resilience, and pedestrian flow considerations. The result was a design that aimed to enhance the city centre experience for a diverse range of participants while withstanding the challenges posed by the outdoor environment.

5.2.2 City Centre Rig

A number of adjustments were made to the multisensory rig design, driven by both the feedback obtained from the lab study, as detailed in Chapter 4, and the considerations highlighted in the previous section. These adaptations are detailed below:

1. **Fan Removal:** While the fan initially seemed beneficial for scent perception, it was found to introduce distracting noise during the lab study. Additionally, practical considerations emerged, as transporting a sufficiently powerful fan and the extra size that would need for outdoor deployment became impractical and outweighed any potential reduction in scent dispersion. Consequently, the final deployment design omitted the fan entirely. This decision was further supported by the presence of natural ambient wind outdoors. This strategic choice ensured the rig's functionality and ease of deployment in real-world settings.

2. **Repositioning of Lights:** Participant feedback revealed that having the lights positioned below head height was disorienting, as people are accustomed to overhead lighting, such as sunlight. To address this, the design was adapted to incorporate a longer set of LED lights placed above the other sensory devices. This new configuration aimed to create a more familiar lighting experience (see Figure 5.1).

3. **Colour Code Adaptations:** With the introduction of the new LED lights, a revised set of colour combination codes was developed using an infrared reader.

These codes were used to control the new lights, aligning them with the concept of sky or ceiling-based lighting, as suggested within the lab studies (Chapter 4).

4. **Refining Scenario Selection:** As the project transitioned to the city deployment phase, a re-evaluation of scenarios was completed. The *Coffee Shop* scenario exhibited accuracy issues during the lab studies, with some participants finding the scent unpleasant and not reflective of the intended experience. Similarly, the *Guy Fawkes* scenario, while achieving high recognition rates, raised concerns due to references to gunfire within the scenario, which could potentially cause distress in a public setting. In response to these concerns, the decision was made to exclude both of these scenarios from the city deployment to prioritise participant comfort and well-being. As a result, the city deployment focused exclusively on the *Seaside* and *Sweet Shop* scenarios.

5. **Enhanced Scent Capsules:** To account for the outdoor environment and natural wind, the number of scent capsules for each scenario was increased to six, with three scent capsules placed in the top and bottom olfactory devices for both scenarios (see Figure 5.1).

6. **Device Housing:** To enhance durability and protect the components from outdoor conditions, all the sensory devices were re-positioned within a waterproof, sealed box (see Figure 5.1). This box accommodated the two Aromajoin devices, one speaker, associated wiring, and the Arduino. The Arduino connected the infrared transmitter for the lights, and the Java SDK again allowed the passage of control through the Arduino and management of Java aspects (Olfactory and Audio) within the Java program (as described in the lab-based studies).

7. **Height Variability:** To accommodate individuals of varying heights, the design was adjusted to incorporate Aromajoin devices at two different heights, one at the top and one at the bottom of the installation box. Furthermore, the rig was attached to an *adjustable pole*, allowing for height adjustment to suit the preferences and needs of users (see Figure 5.2). This configuration aimed to provide effective scent dispersion for participants of different statures.

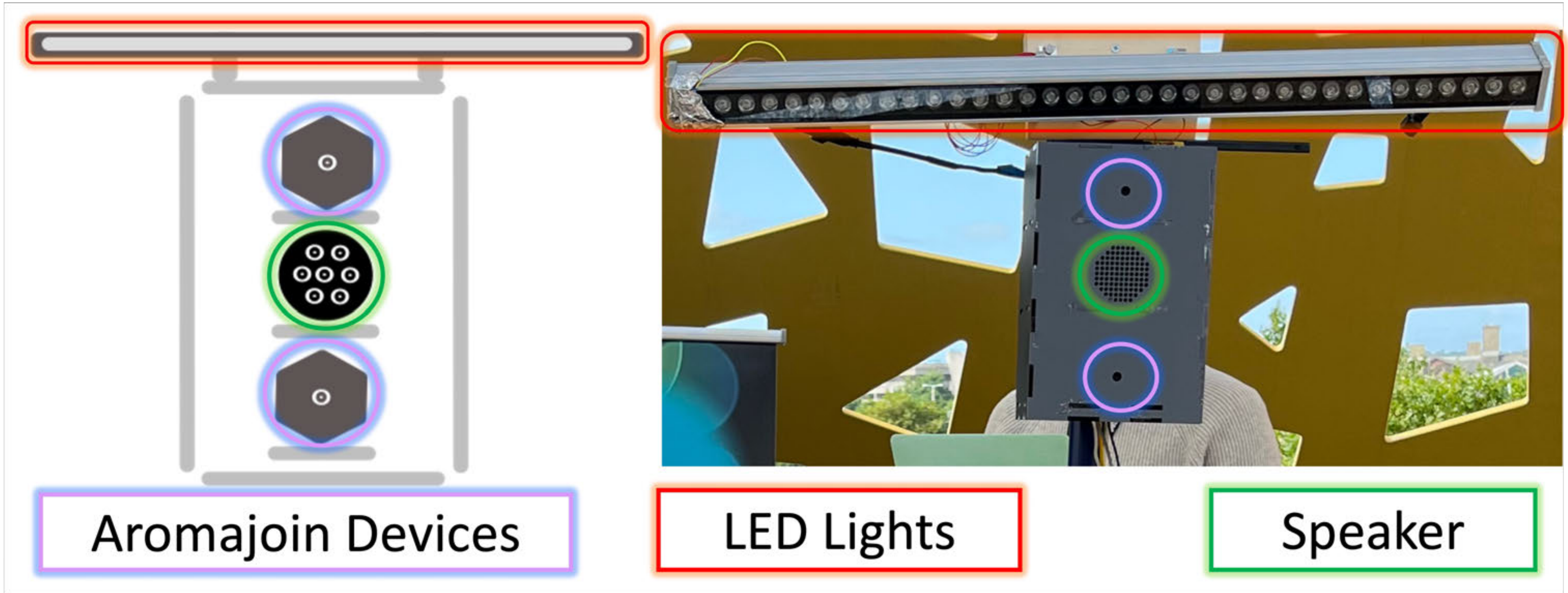

Figure 5.1: Reconfigured devices for city deployment: Two Aromajoin devices at different heights, a central speaker, and an LED light strip added. Left: Device Layout, Right: Final Deployment Housing.

8. **Stability and Mobility:**The height-adjustable pole was affixed to a weighted base housing a 12V caravan battery, ensuring device power and stability. The battery, enclosed in a waterproof casing to protect against environmental factors (see Figure 5.2), provided a 24-hour operational lifespan, eliminating the need for mains power during outdoor deployments, with daily recharging. Integrated rolling wheels ensured prototype stability and easy city centre transport, aided by the detachable pole design.

These adaptations collectively aimed to optimise the multisensory rig for outdoor deployment in a city centre setting. The goal was to address practical considerations, enhance user experience, and ensure the rig's accessibility and stability, with the aim of contributing to a more effective and user-friendly installation.

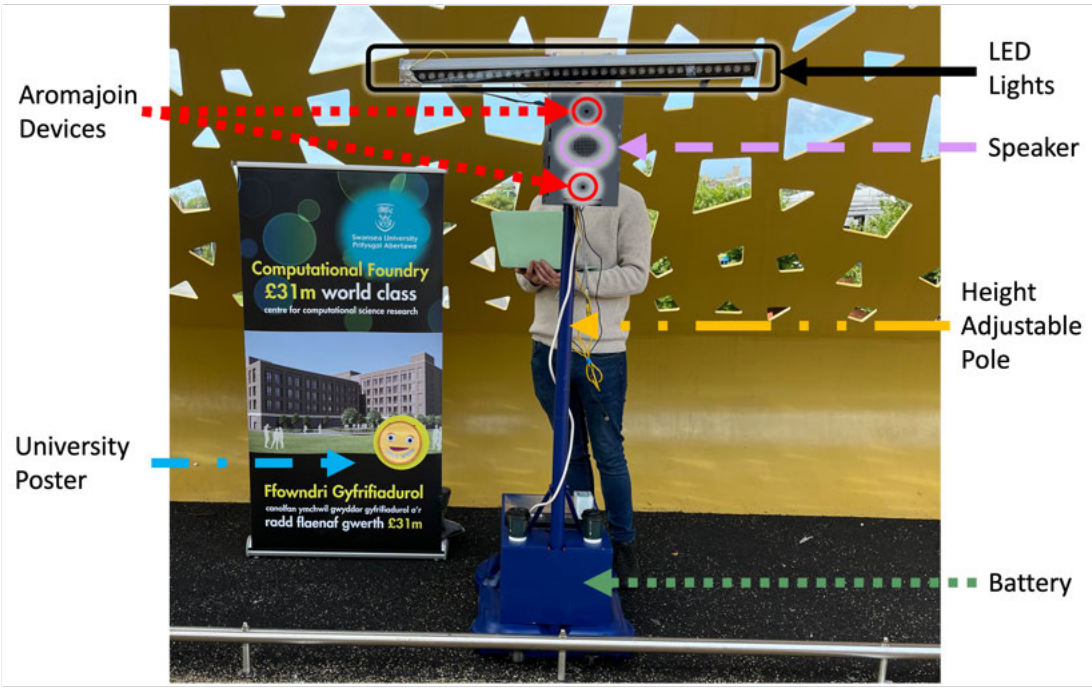

Figure 5.2: City deployment rig setup in designated location including: Two Aromajoin scent devices, a central speaker, an LED light strip on a height-adjustable pole and a battery. Next to it, a university poster informs passersby of the research study (as per ethics committee request).

Bringing all of these design adaptations together led to the creation of a new iteration of the prototype, nicknamed SALly (Scent, Audio, Lights). The final design adaptations for each sensory scenario output are shown within Table 5.3.

Table 5.1: City centre deployment sensory design for each scenario divided into the three deployment types: Olfactory, Auditory and Visual

	Seaside	Sweet Shop
Olfactory	Ocean, Fishy Water	Strawberry, Vanilla
Auditory	Crashing waves, children playing & seagulls	Jars opening, sweets pouring, scrunching of bags, happy children & an old fashioned till
Visual	Bright Yellow	Dim Yellow

5.3 City Deployment of a Multisensory Rig

The aim for the city-based deployment encompassed several objectives: (a) to ascertain whether individuals would engage with a multisensory installation in a public setting; (b) to assess the effectiveness of such an installation within a rengenerating city; (c) to examine its impact on participants' sense of comfort within the space; and, (d) to formulate a set of recommendations for the integration of multisensory installations into public spaces, informed by the feedback received from participants.

5.3.1 Implementation Guidelines and Constraints

The author secured approval from the University's ethical review and Council Risk Assessment, which granted the necessary permits. To obtain this approval, adherence to a set of limitations was required:

Participant Restrictions: The university ethics board expressed concerns about potential reactions to the olfactory element of the design, despite content assurances from Aromajoin. Consequently, deployment of the prototype for children or vulnerable adults within a city-based setting was prohibited to prevent potential discomfort. To gather feedback from young citizens, the prototype was introduced to schools in collaboration with Technocamps, aligning with the cocreation process's foundation in ideation workshops. Their insights into the installation will be detailed in Section 5.4.

Random Interaction: Spontaneous interaction with the device by passersby was prohibited due to the olfactory element. Consent forms and device explanations were required before any interaction. A designated area, marked on the floor, was also required to represent the region the scent device could disperse into (≈ 2.25 square metres). Only participants who completed the consent form could enter this area. This precaution aimed to mitigate the potential risk of passersby casthma or allergies. Additionally, a poster indicating that a study was being conducted as part of university research was displayed as an extra precaution to inform users that new technology was being tested within the space (see Figure 5.2). While this reduced the possibility of random interaction, it deviated from the typical practice of leaving installations for users to interact with freely.

Location: The council selected the pedestrian bridge as the deployment location to minimise the risk of disrupting pedestrian traffic (see Figure 5.3). The device was placed in an area with partial covering, slightly mitigating the influence of natural wind, which could have had a more pronounced impact on the deployment if located elsewhere. There were limited options to reduce the effects of the council's chosen location on the device's effectiveness.

This location, positioned in the centre of the new regeneration could have had an influence on the emotional responses to the rig. Being situated in a historically significant location for the city may have evoked feelings of nostalgia for participants. Additionally, the proximity to pedestrian traffic and the surrounding urban environment may have heightened the immersion and connection to the different sensory outputs presented by the multisensory rig.

Deployment Time: To secure a council permit, submission of preferred deployment dates for the device within the city centre, along with the desired duration of each deployment, was required. The permits duration was limited to weekends. However, due to project changes and a three-month ethical approval process, the council granted only one weekend for a permit.

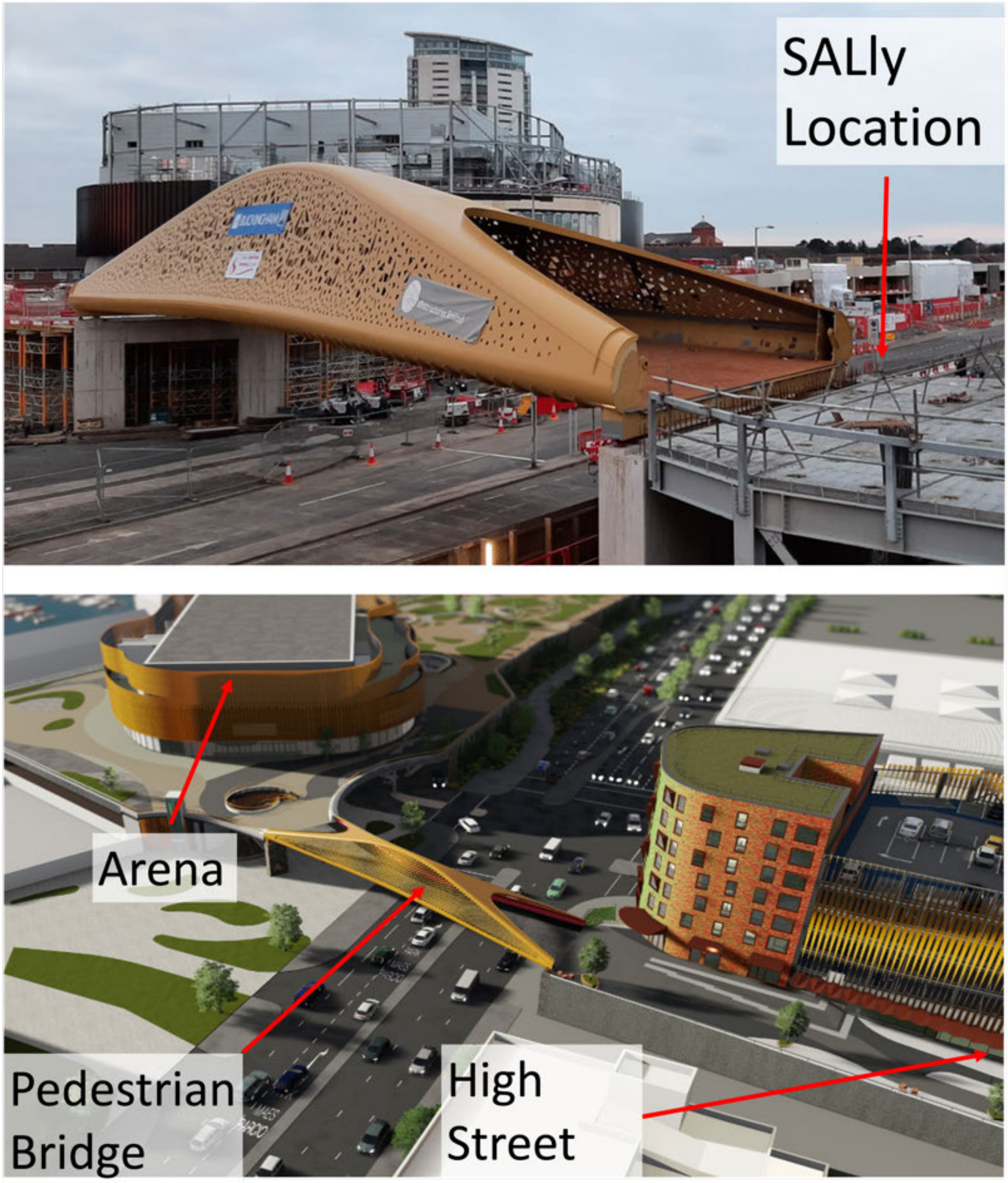

Figure 5.3: An overview of the SALly deployment location. On the left is the pedestrian bridge where the rig was deployed, while on the right is an overview of the regeneration area for comparison.

5.3.2 Procedure

The user journey within this project was mapped out in four stages (see Figure 5.4). In the initial stage (*Stage 1*), participants were encouraged to engage with the installation if they displayed interest. This interest could be expressed by either staring at the device or approaching it to inquire about its purpose. Moving on to *Stage 2*, each participant was provided with a brief explanation of the device and received a participant information sheet for additional context. Furthermore, individuals were advised not to participate if they indicated any allergies or breathing difficulties. After confirming their suitability, participants were requested to sign a consent form. *Stage 3* was dedicated to the interactive experience with the multisensory deployments of the installation, where participants could engage with SALly. Finally, in *Stage 4*, participants were asked to complete a post-study questionnaire. This questionnaire aimed to gather feedback and insights from the participants regarding their experience with the installation.

The multisensory rig was positioned at a location within the city centre that had received approval from Swansea Council. It was situated at the entrance to a new pedestrian bridge, placed behind a metal bar to prevent any disruptions caused by foot traffic. This location was outdoors and lacked upper rain cover, as it was positioned at the beginning of the bridge.

The entire study, from the initial explanation to sensory deployment, lasted ≈ 3 minutes. Subsequently, participants were given an additional 3 minutes to complete a questionnaire either in their own time (via QR code) or with the assistance of a researcher. The purpose of maintaining the interaction under 10 minutes was to allow participants to engage quickly and continue with their day, with flexibility for longer engagement as desired. For instance, if a participant wished to experience the deployment a second time, that option was available. Additionally, the brief interaction time-frame aimed to avoid queue formation, given that individuals rarely walked through the city alone, as observed during the Lookout study (see Chapter 3). As a gesture of gratitude for their participation, participants were offered the opportunity to enter a prize draw for one of four £25 Amazon vouchers. The study was structured as follows:

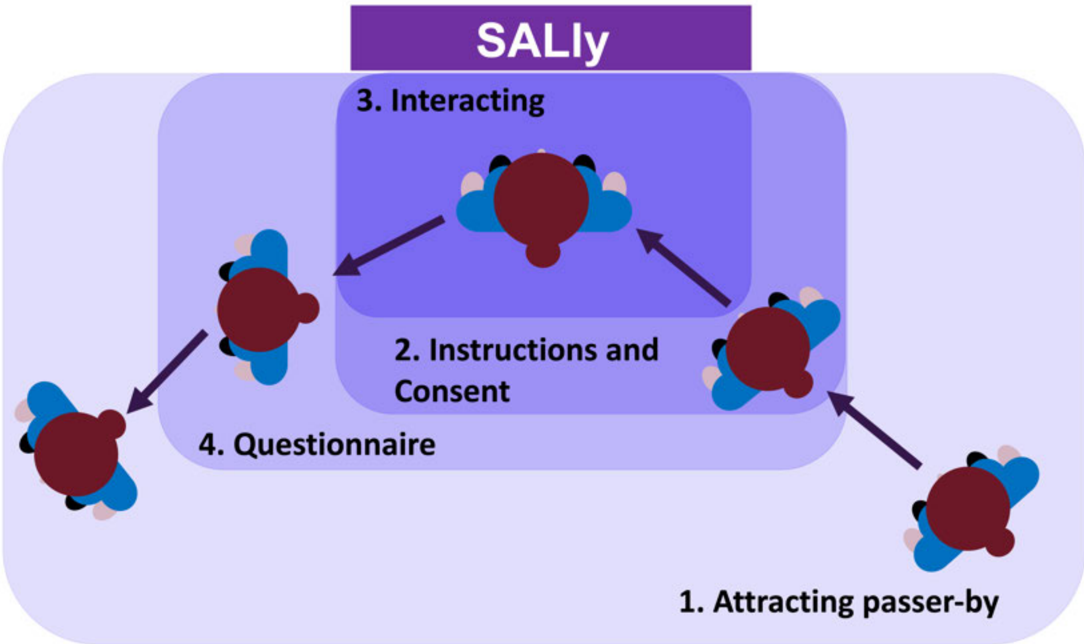

Figure 5.4: The Four Steps of the Interactive User Journey 1. Passersby are encouraged to interact with the multisensory rig. 2. Participants received detailed information and were asked to complete a consent form, ensuring no allergens or breathing difficulties existed. 3. The interaction commenced with two 8-second deployments of sensory cues. 4. Participants were invited to complete the post-study questionnaire, either with a researcher or via a QR code, with the chance to win an Amazon voucher.

1. Participants were instructed to stand within a defined area on the floor, which was marked out with silver tape and measured 1.5 metres from the rig. Only individuals who had completed a consent form were allowed to participate in the study. This area is illustrated in Figure 5.5.

2. Participants were asked to observe two consecutive rounds of sensory output from one of two distinct scenarios, labelled as *Seaside* and *Sweet Shop*. Each deployment of these scenarios lasted for eight seconds. Participants were given the choice to select which scenario they wanted to experience by asking whether they preferred scenario one or two. After each scenario deployment, participants were requested to describe what they believed the scenario represented.

3. Following the sensory experience, participants were tasked with completing a post-deployment questionnaire, which is detailed in Appendix C. They had the option to complete this questionnaire either with the assistance of the researcher (if they had the time) or independently using a Google Form. To facilitate this, printed cards containing a QR code linking to the questionnaire were provided (see Figure 5.6). The questionnaire encompassed multiple-choice questions to gather demographic information and assess the prominence of different sensory elements (e.g., olfactory, visual, auditory). Additionally, it included free-form questions that allowed participants to provide more detailed insights about the memories triggered by the scenarios and the potential future applications of SALly.

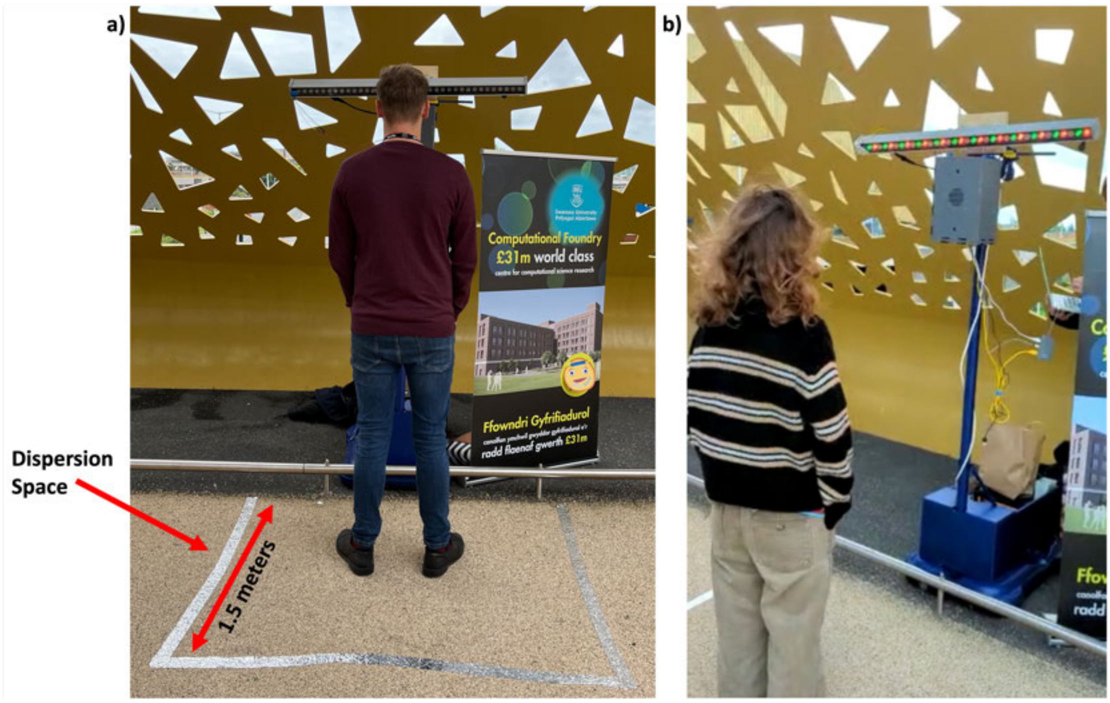

Figure 5.5: Participant interactions with SALly. a) A participant standing within the marked 1.5-metre box, facing the device for interaction. b) Participant engaging with the device, featuring the deployment of the seaside experience.

Figure 5.6: Cards distributed with QR codes for the city deployment post-study questionnaire. LEFT: Back of the card, which contains contact information for researchers in case participants need to reach out. RIGHT: Front of the card featuring a QR code that directs users to the Google Form link and provides details about incentives for participation.

5.3.3 Results

The city deployment was held across a weekend, with approximately 5 hours per day. Over the two day period 55 participants (26 females and 29 males) interacted with SALly, with an additional four participants wanting to take part but were prevented due to epilepsy or severe allergies.

Scenario Deployment

Following the signing of a consent form, participants were guided to stand within a designated area where SALly would initiate the participants selected scenario twice, each lasting for 8 seconds. The *Seaside* experience was deployed 28 times, while the *Sweet Shop* experience occurred 27 times. After these deployments, participants were prompted to provide brief descriptions of the scenario they believed SALly was delivering and whether it had triggered any associations.

The *seaside* scenario was recognised by 79% of participants, with one individual recalling visiting their Grandfather in Ireland. The remaining participants predominantly associated it with a children's swimming pool, citing audio cues resembling a children's party and a scent reminiscent of chlorine rather than the ocean.

The *sweet shop* experience yielded a recognition rate of 67%. Some participants struggled to identify the scent, possibly due to environmental factors such as wind, which was unusual as the sweet shop scents had been quite distinct during the second lab study. Many of the participants who did not recognise it thought the experience represented a children's playground, likely influenced by the cheerful sounds of children enjoying sweets. Interestingly, there seemed to be some overlap between the sweet shop and seaside scents, with participants occasionally detecting seaside scents during the sweet shop scenario dispersal.

Post-Study Questionnaire

In this study involving 55 participants, 34 individuals, comprising 11 females and 23 males, completed the post-study questionnaire. 88% of the respondents chose to complete the questionnaire on the day with the researcher, while the remaining 12% opted for the convenience of a QR code. The participants covered a wide spectrum of age, ranging from 18 to 85 years, with an average age deviation (σ) of 2.67. These participants were from three countries, with the majority (94%) originating from the UK, while 3% each represented Canada and Nigeria.

Scenario Relation

Following demographics, the participants were asked to write down in more detail about what they believed the scenario to be and if it had reminded them of a particular memory. The responses from the 34 participants were then classified into three categories: Seaside Related, Sweet Shop Related and Broader Theme Related.

Within the *Seaside Related*, which included 50% of the responses, participants frequently recalled their strong connections to coastal settings, where the olfactory and auditory cues had an ability to stir nostalgia, particularly for residents from Swansea. For many, the sensory experience of the seaside transported them to a place of profound longing and belonging. A participant's remark, such as,

> "It made me think of home as that's what the beach represents for me"

showcased that the scenario was more than just sensory stimulation. It could act as a gateway to a deeper connection—a sense of home and self. In this context, the seaside ceased to be merely a physical location; it symbolised cherished memories and a portal to one's personal history.

These responses shed light on the remarkable influence of olfactory and auditory cues as pathways to the past, and the potential to ignite place-based nostalgia. They demonstrated how our senses serve as powerful triggers, capable of transporting us to another time and place, where moments can be relived that hold deep sentimental value. Furthermore, they underscored the ability of sensory experiences to establish profound emotional bonds, offering participants a means to revisit and rekindle their most beloved memories.

For the *sweet shop* category, which included 41% of responses, participants frequently mentioned cherished memories with loved ones, and in particular Grandparents. For example, one participant wrote

> "Going to old sweet shops with granny as a child"

The olfactory and auditory cues of this scenario were able to rekindle, multi-generational bonds for the majority of participants. This was particularly interesting in the context of a public city centre deployment, as it suggested that sensory experiences could evoke not only personal memories but also a sense of collective nostalgia, specific to a place (e.g., Swansea).

This aspect of the study showed that sensory experiences could unite residents in shared memories of loved ones and cherished traditions, enriching the city's emotional fabric. It emphasised that public spaces could be enriched not only by the sensory engagement themselves but also by the profound connections they foster, making city centres not just vibrant hubs of activity, but also repositories of collective memory.

The remaining 9% of comments fell into the *Broader Themes* category. These participants went beyond the immediate scenarios and delved into broader themes related to sensory perception, offering insights like,

> "It makes me think about how our smell and sound feelings can transport us to another place"

Their comments reflected a more indepth level of engagement with the multisensory installation, indicating that such installations have the potential to stimulate deeper philosophical and contemplative discussions. In a city centre, where diverse populations congregate, installations that encourage reflection on sensory perception could serve as focal points for public engagement and intellectual discourse. This concept aligns with the research of Spence [248], who explored the cognitive and emotional evolution of multisensory approaches within architecture. They provide possibilities for inviting people to pause, think, and share their thoughts with others, thereby fostering a sense of community.

In essence, the *Broader Themes* category underscored the capacity of multisensory installations in city centres to engage individuals on a deeper level, fostering intellectual discussions, and contributing to the overall cultural and artistic landscape of the urban environment. It shows a potential to transform city centres into spaces where sensory experiences are not just enjoyed but also contemplated, encouraging a richer and more meaningful interaction between residents and their surroundings.

The classification of participants' interpretations of sensory outputs, not only within specific scenarios but also within broader considerations, provided valuable insights into the depth to which sensory stimuli could evoke thought and exploration. It illuminated the intricate interplay between sensory perception, memory, and the process of personal meaning-making. It emphasised the importance of considering the broader context and individual differences in interpreting sensory inputs, offering valuable insights for fields such as psychology, neuroscience, and human-computer interaction.

Sensory Cue Prominence

Following the scenario-related questions, participants were asked to assess the prominence of sensory cues within the scenarios. Initially, they were queried about which senses they had perceived in the scenarios, yielding the following observations: 94% noted the presence of audio cues, 74% noted the presence of visual cues, and 62% noted the presence of olfactory cues (see Figure 5.7).

Next, participants were tasked with evaluating the relative prominence of each sense by ranking olfactory, auditory, and visual cues from most to least prominent. Each rank level was assigned a corresponding weight, with the highest rank receiving the greatest weight and the lowest rank the least weight. A weighted average of the ranks, as assigned by participants, was then calculated for each sense and category: ‘Seaside’, ‘Sweet Shop’ and ‘Broader Themes’ (represented as ‘Other’ in Figure 5.7) as the scenario that the ‘Broader Themes’ category had experienced could not be discerned. To account for unequal sample sizes in each scenario, weights were further applied based on the proportion of participants in each group. Each weight was divided by the total number of responses. For each scenario, the ranks were adjusted according to their respective weights to compute the weighted ranks. For example, for the seaside theme:

$$\text{weight\_seaside} = \frac{\text{Number of ‘Seaside’ responses}}{\text{Total number of responses}} \tag{5.1}$$

$$\text{new\_seaside\_weight} = (\text{sensory\_cue}) * (\text{weight\_seaside}) \tag{5.2}$$

Here, the *‘sensory_cue’* represents each sense within the list (e.g., Auditory, Olfactory, Visual), and the *‘weight_seaside’* signifies the weight factor assigned to each theme.

As in the lab studies, the Friedman Test [95] was conducted to assess whether there were significant differences in prominence among the sensory outputs. This analysis aimed to understand whether the scenario deployment had any effect on the recognition’s of the different sensory outputs and in this case specifically if that changed when deployed outdoors. By employing this statistical test, we sought to ensure reproducibility for others who may wish to adopt and adapt the designs for their own cities.

The results across the three categories for each sensory cue yielded the following statistics:

Friedman Test Statistic (Q) $= 6.00$; **p-value:** $= 0.0498$

The analysis of the data yielded a p-value below the significance level of 0.05, leading to the rejection of the null hypothesis. This finding indicated that at least one of the sensory cues investigated had a discernible impact on the overall participant experience.

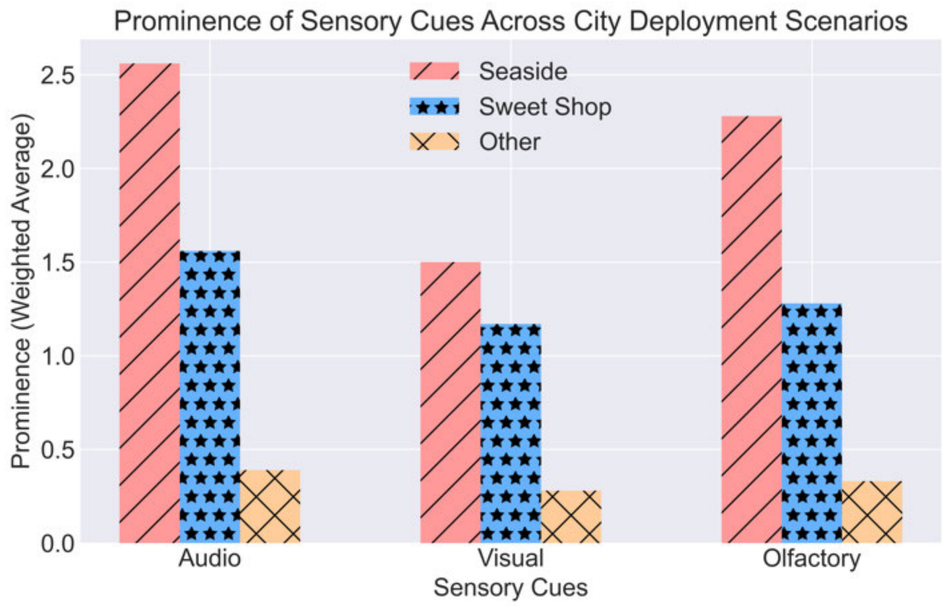

Figure 5.7: The ranking of multisensory cues (auditory, visual, and olfactory) across three categories: Seaside, Sweet Shop, and Other, denoting Broad Themes.

However, it is worth noting that the result was in close proximity to the significance threshold (≈ 0.05), suggesting that the observed differences were not substantial.

Further examination of the data revealed intriguing insights into the role of sensory cues. In the study, Visual cues had a median ranking of 1.17, Olfactory cues matched the overall median ranking at 1.28, and Auditory cues had a median ranking of 1.56. While Auditory cues still held the highest ranking, the difference was not as pronounced as the lab studies (see Table 5.2). This variation in the influence of sensory cues becomes particularly apparent when comparing outdoor environments to a controlled indoor laboratory setting. This was not surprising, considering the presence of background noise and outdoor elements such as, wind that differ from the quiet, controlled environment indoors.

An interesting finding was the resilience of Olfactory cues, which maintained their impact even within the outdoor setting. This suggests that the increase in scent capsules introduced was effective, reinforcing that the fan was unnecessary in this context.

Due to only two scenarios being deployed within this study, the statistical T-test

Table 5.2: Sum and Median Rank for each sensory cue (City Deployment).

Sensory Cue	Sum of Rank	Median
Audio	4.51	1.56
Visual	2.95	1.17
Olfactory	3.89	1.28

[254] was conducted to assess whether there were significant differences in prominence among the two scenarios, compared to the Friedmans test previously used, which requires four or more. The results for testing the differences yielded the following statistics:

$$\textbf{T-Test Statistic } = 3.48; \textbf{ p-value: } = 0.0737$$

In contrast to the sensory results for testing the differences, the scenarios yielded non-significant results. Therefore, it was concluded that within the context of the city-based study, the scenarios had no discernible impact on sensory prominence.

Comfort and Wellbeing

Furthermore, it was important to understand how the experience affected participants' emotional states within the public setting. To assess this, participants were asked to rate their comfort levels during the scenarios using a multiple-choice answer format, which included the options: 'Very Uncomfortable,' 'Uncomfortable,' 'No Change,' 'Comfortable,' and 'Very Comfortable.' The results indicated that the experience had no negative effects on the participants, with 15% reporting feeling 'Very Comfortable,' 64% feeling 'Comfortable,' and 21% experiencing 'No Change' in their comfort levels.

In a public setting, assuring participant comfort was important, re-emphasising why the *Guy Fawkes* and *Coffee Shop* scenarios were removed from city deployment. The absence of negative emotional impact, with many participants reporting comfort and even very high comfort levels, indicated that the multisensory experience was well-received. These findings suggested that the design and execution of the experience were successful in creating a positive and enjoyable atmosphere for participants. Additionally, they implied that the multisensory experience was accessible and inclusive, with none of the participants feeling alienated or uncomfortable—crucial considerations when designing experiences for diverse audiences in public spaces.

Ensuring that participants' emotional well-being was safeguarded within a public setting was not just a matter of enjoyment but also one of safety. The absence of adverse emotional effects suggests that the experience did not induce psychological discomfort or distress in participants, highlighting its inherent suitability for public installations and aligning with the examination of passive and active engagement in public spaces conducted by Memarovic et al. [176]. This suggests that a multisensory experience is likely to be embraced by the public, especially in scenarios where such experiences are intended to enhance public spaces or events.

Exploring the Potential Applications of Multisensory Experiences in Public Spaces
In this deployment, a key objective was to understand the feasibility and desirability of implementing multisensory experiences within public spaces. To achieve this, a dialogue was initiated with participants to discern their perspectives on the potential applications of this technology within public realms. SALly served as a technology probe, acting as a starting point for exploring possibilities for future technologies. The use of SALly as a probe to initiate discovery discussions was based on the concept defined by Boehner et al. [27]. The responses were collated and categorised using content analysis by highlighting phrases throughout and grouping them into common themes, revealing three distinct categories.

18% of participants envisioned the use of these experiences to create comforting havens within public spaces, catering to individuals who may find the environment overwhelming. A participant suggested the concept of *"relaxation pods in busier areas"*, highlighting the potential for these sensory installations to serve as sanctuaries of tranquillity amid the hustle and bustle of public settings.

A further 15% of participants regarded these experiences as valuable informational and promotional tools for the city. Their suggestions included employing this technology to spotlight new visitor experiences, offering directional guidance to local landmarks, and stimulate tourism. This underscores the versatility of multisensory installations in enhancing a city's identity and engaging both residents and tourists.

In the final category, 12% of participants envisioned the technology as a source of amusement and engagement for children. One imaginative idea involved using the device in a treasure hunt-style game, where it would serve as a set of clues. This inventive response underscores the capacity of multisensory experiences to captivate and entertain younger audiences, potentially transforming public spaces into interactive playgrounds.

In addition to understanding potential applications, the aim was to assess how SALly could enhance participants' city-visiting experiences. The responses to this query were once more categorised using content analysis, revealing three prominent themes:

Memories, Mood, and Comfort, were prominently featured in combination within participants' feedback, emphasising SALly's potential to offer tranquility in bustling cityscapes. Moreover, participants believed it could evoke nostalgic memories relating to the city, elevate moods, and foster a deeper sense of connection within the community.

Behavioural Change, unveiled the perception of SALly as an agent for positive change within the city centre. Participants envisaged its use in deterring littering through immersive experiences simulating the sights and sounds of rubbish dumps. Additionally, they believed SALly could contribute to the reduction of anti-social behaviour by promoting positive messaging and using scent as a means of influence.

Information Prompts, centred on the notion of dispersing SALly across the city centre to serve as interactive hubs for information dissemination. Participants saw this as an exciting and engaging way to provide local information, with potential experiences ranging from guided information sessions to directional advertisements for tourist attractions, wherein participants could follow sensory trails to their destinations.

5.3.4 Overview of Multisensory Rig City Centre Deployment

The multisensory deployment demonstrated that there is a significant interest in public interactions facilitated by systems like SALly. It not only piqued the curiosity of the community but also exhibited effectiveness, achieving recognition rates of 73% on average for the two scenarios deployed. These scenarios, deployed within Swansea city centre, provided a sense of comfort to participants and spurred contemplation about future deployment possibilities for the system.

The city-based study yielded insights into the potential of multisensory deployments in outdoor public spaces. Participants' responses indicated a prevalence of comfort and satisfaction, indicators of the experience's success. These outcomes not only elevated the quality of the interactions but also have broader implications for acceptance, accessibility, and the overall well-being of individuals within the public sphere.

The data underscored how sensory experiences, even in a controlled urban environment, could elicit strong emotions and a sense of belonging. This emotional resonance could be harnessed to establish a deeper and more meaningful connection between city residents and their urban surroundings, due to its abilities to prompt nostalgia.

Just as participants associated specific scents and sounds with their personal history and identity, urban sensory elements can become synonymous with a city's identity. In addition, it showed the ability of the sensory cues to evoke nostalgia and emotions with possibilities to be used for enhanced public engagement initiatives of the future.

In the city context, the data suggests that multisensory installations hold the potential to cultivate a sense of shared heritage and community. e.g., the deployment replicating the sensory ambiance of old sweet shops, served as a reminder of the city's history and its inhabitants' shared experiences. It emphasised the ability of sensory engagement to transcend individual encounters and become a communal narrative, celebrating the significance of loved ones and cherished traditions.

In summary, although limitations were encountered, helpful insights emerged regarding the potential of multisensory experiences within public spaces. This comprehensive exploration not only aides the understanding of the versatility of multisensory experiences in public spaces but also underscores their potential to enhance comfort, encourage positive behavioural change, and serve as interactive information hubs within urban environments, something that has not been explored before within the literature. To further explore the device's efficiency and possibilities, and considering the limited deployment time, workshops were organised with 99 school children.

5.4 Engaging Pupils in Exploring SALly's Potential and Inspiring Future City Technologies

Following the deployment of SALly within the city centre, the aim was to introduce the rig to the pupils who had contributed to its initial design. These workshops aimed to observe the children's interactions and engagement with the device, assessing its appeal to a younger audience. Moreover, the workshops aimed to pinpoint areas for enhancing SALly's appeal and interactivity. As only a limited number of pupils could interact with SALly at any one time, an additional sketching exercise was conducted with the students, enabling them to envision and design their own multisensory technology.

Due to the timing, which coincided with the end of the school year, there were limited dates availabile to complete workshops. Consequently, the team could only work with two schools and four classes. Technocamps (an organisation working with schools to improve STEM enagement) again liaised with the schools to determine suitable dates and timings for each session. Meanwhile, the content and structure of the workshops was created and hosted by the author. To ensure the smooth execution of these workshops, a Technocamps assistant was on hand to provide support and manage any logistical challenges that might arise.

Crucially, at the time of these workshops, COVID-19 restrictions had been lifted, enabling the team to conduct in-person workshops directly within the classrooms, as opposed to the previous online format. This in-person interaction allowed for real-time feedback and hands-on engagement, crucial in evaluating SALly's potential for engaging with children.

5.4.1 Structured Workshop Format

In each class, a 1.5-hour workshop was designed to be completed in person in the classroom. The workshop comprised four distinct stages, occurring simultaneously, where pupils would complete the sketching exercise (*Stage Two*) until requested to interact with SALly (*Stage Three*) which was completed table by table. An outline of the procedure is provided:

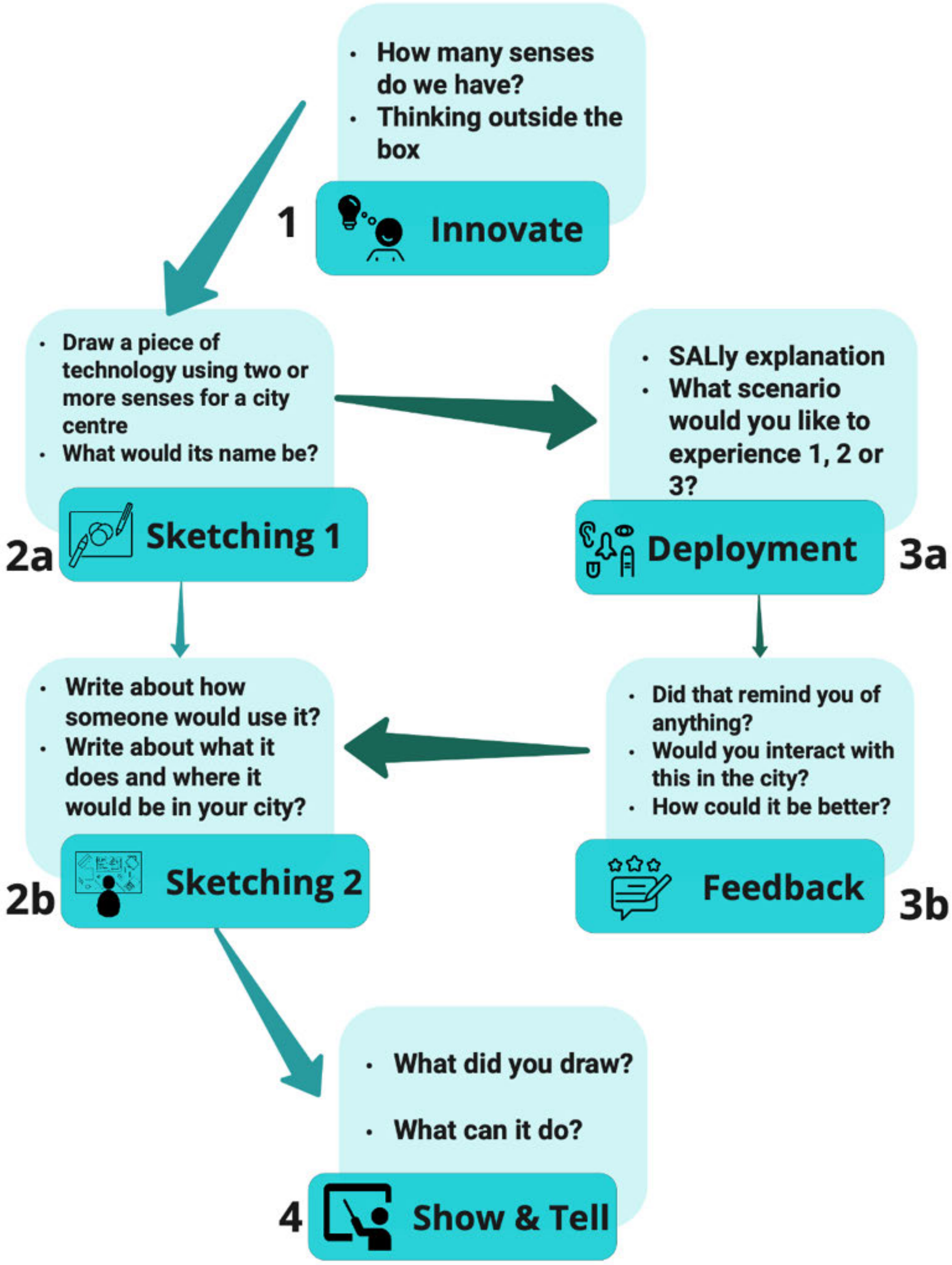

Figure 5.8: Schematic diagram illustrating the session overview for the 1.5-hour Technocamps workshop, comprising Innovation, Sketching, Deployment, and Feedback of the Multisensory Rig, along with a Show and Tell session.

1. **Innovation** (10 minutes): Encouraging out-of-the-box thinking and excitement about multisensory technologies

2a. **Sketching 1** (40 minutes): Focusing on multisensory technology sketches

2b. **Sketching 2** (20 minutes): Exploring the contextual considerations for these concepts.

3a. **Deployment** (1 minute per pupil): Explanation and deployment of two SALly scenarios with pupils selected to come forward table by table

3b. **Feedback** (1 minute per pupil): Questions and feedback from the pupils about the deployments (assuming 30 students per class)

4. **Show and Tell** (10 minutes): Providing a platform for the pupils to present their ideas to the class

This structured workshop format was designed to not only engage and stimulate creative thinking among participants but also to foster collaborative discussions about multisensory engagement and idea sharing. Responding to the schools' request for longer sessions of 1.5 hours (compared to the previous 1-hour sessions), the plan was adapted accordingly. During these extended workshops, approximately one hour was dedicated to the combined activities of sketching and multisensory deployment. In this phase, the researcher took charge of deploying the sensory device placed at the front of each classroom, while the Technocamps representative handled any sketching-related queries that arose.

The timing for multisensory deployments was based on the information provided by Technocamps, which indicated that each class would have approximately 30 pupils. If fewer students were in attendance, more time would be available for each student. For a more detailed breakdown of the workshop stages, refer to Figure 5.8, which provides an overview of each of the four stages.

Stage One aimed to provide students with a solid foundation for feeling comfortable in the process of innovation and thinking creatively. The innovation section began with a brief introduction to the researcher and an overview of the workshop agenda. During this stage, students were reminded of the sketches they had previously created in workshops with the researcher in 2021, emphasising the value of their input in shaping the design presented during the workshop. A discussion about the participants' senses, highlighting how many senses they had, and prompting them to consider sensory experiences they might have noticed in the city centre was conducted. The objective here was to encourage participants to think outside-the-box, introduce them to the possibilities of sensory technologies, and prompt ideas about the technologies they could design using their senses. It was explained that two activities, sketching and SALly interaction, would run concurrently throughout the workshop.

Stage Two transitioned students into the sketching phase, where they were tasked with designing their own multisensory technology for deployment in a city centre. Given that only one or pairs of pupils could interact with SALly at any given time, sketching provided a productive way to occupy the rest of the class and provide insights into the multisensory technologies the students would like to see in the city. The sketching requirements included labelling the main features of their designs, specifying which senses were involved, giving their creations names, and keeping all designs on a single A4 sheet of paper. Students were encouraged to generate as many designs as they wished (on seperate sheets). After 40 minutes of sketching, students were prompted to add explanations detailing how their designs could be used and where they would be located within the city centre.

While the sketching phase was underway, *Stage Three* unfolded simultaneously, inviting students to interact with SALly either in pairs (to reduce issues with shyness) or individually, table by table. Students with asthma or allergies had previously been identified in coordination with the teacher and were advised not to participate. Those engaging with SALly received a brief explanation about the device, including its olfactory, auditory, and visual outputs, which represented different scenarios.

During the interactive experience, students were instructed to position themselves approximately 0.5 metres away from the device. They were then presented with a choice of scenarios: (1) Seaside, (2) Sweet Shop, or (3) Forest. The forest scenario was added to complement the sustainability lessons being conducted in the classes. The inclusion of this forest scenario was intended to provide a thought-provoking resource that teachers could use to inspire students to reflect on critical topics related to environmental sustainability, conservation, and the importance of safeguarding natural habitats. Each of these scenarios were created to offer unique sensory outputs, creating distinct and immersive experiences for the students. The specific sensory output designs corresponding to each scenario are outlined in the Table 5.3.

Table 5.3: Sensory deployment design for the Technocamps workshops with each scenario divided into the three deployment types: Olfactory, Auditory and Visual

	Seaside	Sweet Shop	Forest
Olfactory	Ocean, Fishy Water	Strawberry, Vanilla	Eucalyptus, Forest
Auditory	Crashing waves, children playing and seagulls	Jars opening, sweets pouring, bags scrunching, happy children and old fashioned till	Wind moving through the trees and birds chirping
Visual	Bright Yellow	Dim Yellow	Dim Yellow

The students were then prompted to describe their sensory perceptions in response to the scenarios and how they would react if they encountered such a device in the city and what, if anything, it would require to facilitate interaction if a researcher were not present to explain its purpose.

Finally, *Stage Four* of the workshop concluded the design phase. During this segment, students had the opportunity to present their favourite design to the rest of the class and explain its functionality. The sketches were then collected and handed over to the researcher for further evaluation and analysis.

5.4.2 Insights from School Workshop

This section provides a comprehensive overview of the analysis conducted, drawing from the four workshops that took place in two primary schools in South Wales in July 2023. These workshops were structured according to the detailed plan outlined in the previous section, with one exception. The final workshop was shortened by 20 minutes as the teacher needed to prepare the students for sports day. Consequently, the *'Show and Tell'* stage (Stage Four) was omitted for this session, while the remaining activities could be continued, due to the smaller class size of 23 pupils.

In total, these workshops engaged 99 pupils (52 females and 47 males), with ages ranging from 9 to 11 years old. On average, each workshop involved 25 students (W1: 23, W2: 27, W3: 26, W4: 23). The lower student turnout was influenced by the end of the term, as some students were absent due to their schools hosting sports day events during the researcher's visit.

Insights from Multisensory Rig Deployments with Children

The analysis of the multisensory rig deployments within the set of four workshops with school pupils revealed intriguing insights into their perceptions and reactions:

Enjoyment and Engagement: 44 pupils found the multisensory rig experience to be 'fun' or 'cool', indicating a positive and enjoyable experience. In a city centre, where there are numerous distractions and competing activities, having technology that can captivate the attention and interest of a passersby is highly valuable, especially children bearing in mind the observations at the Lookout (Chapter 3) showing their importance in producing a space of acceptance within public spaces. Hence, this data suggests that the interaction could serve as an attraction point, drawing people into the experience and making them more likely to engage with it.

Fun and enjoyable experiences tend to be memorable. In the context of a city centre, where people come for diverse experiences, a positive memory associated with a multisensory deployment can linger in the minds of those who interacted with it, contributing to the city's overall reputation as an exciting and engaging destination. Furthermore, this shows the potential to revitalise city centres, making them more appealing and 'cool' destinations, particularly for young people, by offering innovative and captivating urban experiences - something established as a major positive for cities [94].

Desire to Share: Twelve students expressed a desire to share their experience with friends or siblings who were not present in the class. The desire to share, was a testament to the technology's appeal and the impact it had on the students. It went beyond personal enjoyment and reflected a desire to extend the positive experience to others, allowing them to partake in the excitement and wonder that the multisensory rig offered. It also hinted at the multisensory rig's ability to foster a sense of community and connectedness, by providing a shared experience that could bond individuals.

Mixed Reactions to Novelty: Six students described the technology as 'weird' or 'unusual' highlighting its innovative design, with four of the six, while finding it odd, still liking it. In a city centre, where the urban landscape is often characterised by familiarity [83], the presence of something perceived as new and different can be intriguing and attention-grabbing.

A further six students mentioned that they would not initially walk up to the multisensory rig within a public space but two said they were open to interaction upon a second encounter, indicating that familiarity may encourage participation. In contrast, the enthusiasm of 88 students to engage with the technology in a city setting signified a strong inclination for interactive and participatory experiences in the urban landscape.

Scenario Recognition: To evaluate how effectively the pupils recognised different scenarios presented by the multisensory rig, the recognition rate was calculated across the four workshops with an average of 74% as depicted in Figure 5.9. This analysis considered the total number of pupils who experienced each scenario: Seaside (55), Sweet Shop (71), and Forest (64). The pupils were given the choice of which two scenarios they would like to experience to provide an added element of anticipation and to help them feel in control with this new technology.

It is important to acknowledge that there existed variance in the abilities, ages and circumstances among the pupils. This variance may have influenced the recognition levels of the scenarios, potentially resulting in differing levels of recognition among the workshop groups. Factors such as prior experience with similar environments, individual interests, and events ongoing at the schools on the day (such as sports day) which pulled several students in and out of the workshops, especially in the first workshop, could have contributed to this variability.

In addition to these quantitative findings, qualitative comments from students provided deeper insights into their perceptions of the multisensory scenarios:

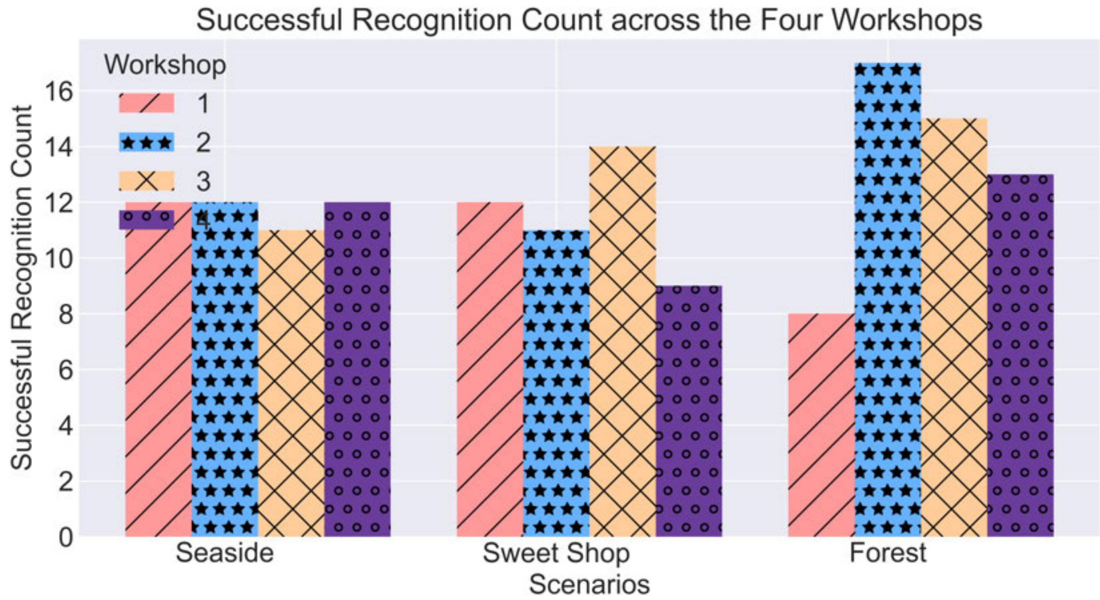

Figure 5.9: The distribution of participants who correctly recognised the scenarios across four workshops.

Forest: Among the presented scenarios, the forest scenario emerged as the most easily recognisable, with 82% of pupils recognising the scenario. This high recognition rate underscored the effectiveness of the multisensory rig in conveying the essence of the forest scenario to the pupils, allowing them to readily identify it. The pupils' fondness for this scenario was evident, with several drawing connections to Plantasia - a tropical rainforest zoo with a variety of tropical plants and animals to experience in Swansea's city centre [218]. One pupil described it by saying,

> "It's a flowery forest, like Plantasia in town"

Sweet Shop: The sweet shop scenario demonstrated a lowest recognition rate of 69%, with one pupil offering a vivid description, stating,

> "Its like I'm going to buy sweets with granny before watching movies at her house"

Some participants who did not immediately recognise this as the sweet shop experience likened it to the festive atmosphere of Christmas. Pupils in Workshop 3, in particular, referenced Christmas time, noting that the LED lights reminded them of Christmas lights rather than dim yellow lights (these workshops were completed in the summer, making these recollections even more surprising). This could be attributed to the use of LED lights that alternated between orange and green to produce the overall dim yellow hue. This alternating lighting scheme may have led some pupils to associate it more with Christmas rather than identifying it as a sweet shop experience.

Seaside: The seaside scenario also achieved a strong recognition rate, with 71% of pupils accurately identifying it. One participant expressed their perception, saying,

> "It was like listening into a seashell"

These descriptions and recognition rates underscore the multisensory rig's ability to effectively immerse pupils in diverse scenarios. The pupils' ability to connect these experiences to real-world settings and their detailed descriptions highlight the rig's capacity to convey sensory elements convincingly to the pupils as well as the adults within the city deployment. These scenarios not only engaged the senses but also triggered nostalgic memories and associations, enhancing the overall impact of the multisensory rig within the city centre.

Overall Experience: The pupils' overall experience with the multisensory rig was positive, and they expressed enjoyment during their interactions. They were particularly enthusiastic about experiencing it with their friends in pairs. In fact, 42 students, opted to interact in pairs. This choice not only provided an enjoyable social aspect but also allowed ample time for students to have another turn if they wished.

In Workshop 1, where the class size was smaller (23 pupils), all pupils had the opportunity for a second interaction, further enhancing their overall experience. Workshops 2 and 3 accommodated 6 and 8 pupils, respectively, who had the chance for a second interaction. Due to the reduced time frame in Workshop 4 imposed by the teacher, pupils there were required to interact in pairs, and additional interactions were not possible. It is difficult to determine the exact impact this had on the students, but it is worth noting that they still expressed great joy and engagement during their interactions.

Feedback from the pupils regarding the device was overwhelmingly positive. Some students even offered valuable suggestions on how to adapt the design for city use. For instance, they recommended adding a large 'X'/sign on the floor to indicate where to stand if no one was available to guide them. They also suggested incorporating pictograms to illustrate what would happen during the interaction, or including a small information box that they could read for context. The following section will evaluate the pupils sketches, which were created simultaneously to SALly deployments.

5.4.3 Insights from Multisensory Sketching Analysis

During the sketching sessions, innovation proved highly engaging for the pupils, who enthusiastically crafted their multisensory technology designs, sharing their creations with their peers and the researcher. The resulting sketches were collated and categorised into three distinct groups using content analysis, with each sketch often spanning multiple classifications (1 point per classification). For example, a sketch depicting a candy maze (see Figure 5.10) with varying scents to follow, leading to specific sweets, received a point each for 'Game,' 'Shape Changing', 'Transportation', 'Olfactory', 'Visual' and 'Tactile'. Additionally, 20 students designed multiple technologies, contributing to a total of 119 designs. The categories include:

1. **Sensory Outputs:** The types of sensory outputs created by the technology, with one point for each sense used, inclusive of: Taste, Smell, Touch, Sight and Audio. The overall points for each sense are shown in Figure 5.11
2. **Technology Functionality:** Classifying the emerging functionality of the technology, with designs able to be classified into multiple types, inclusive of: Culinary, Health, Scenario Creation, Socialising, Game, Shape Changing and Teleport. The overall points for each technology type are shown in Figure 5.12
3. **Technology Type:** Classifying the emerging technology type, with designs able to be classified into multiple types, inclusive of: Transportation, Virtual Reality, Wearable, Hologram, Mobile Application, Robot, Public Installation and Automation. The overall points for each technology type are shown in Figure 5.13

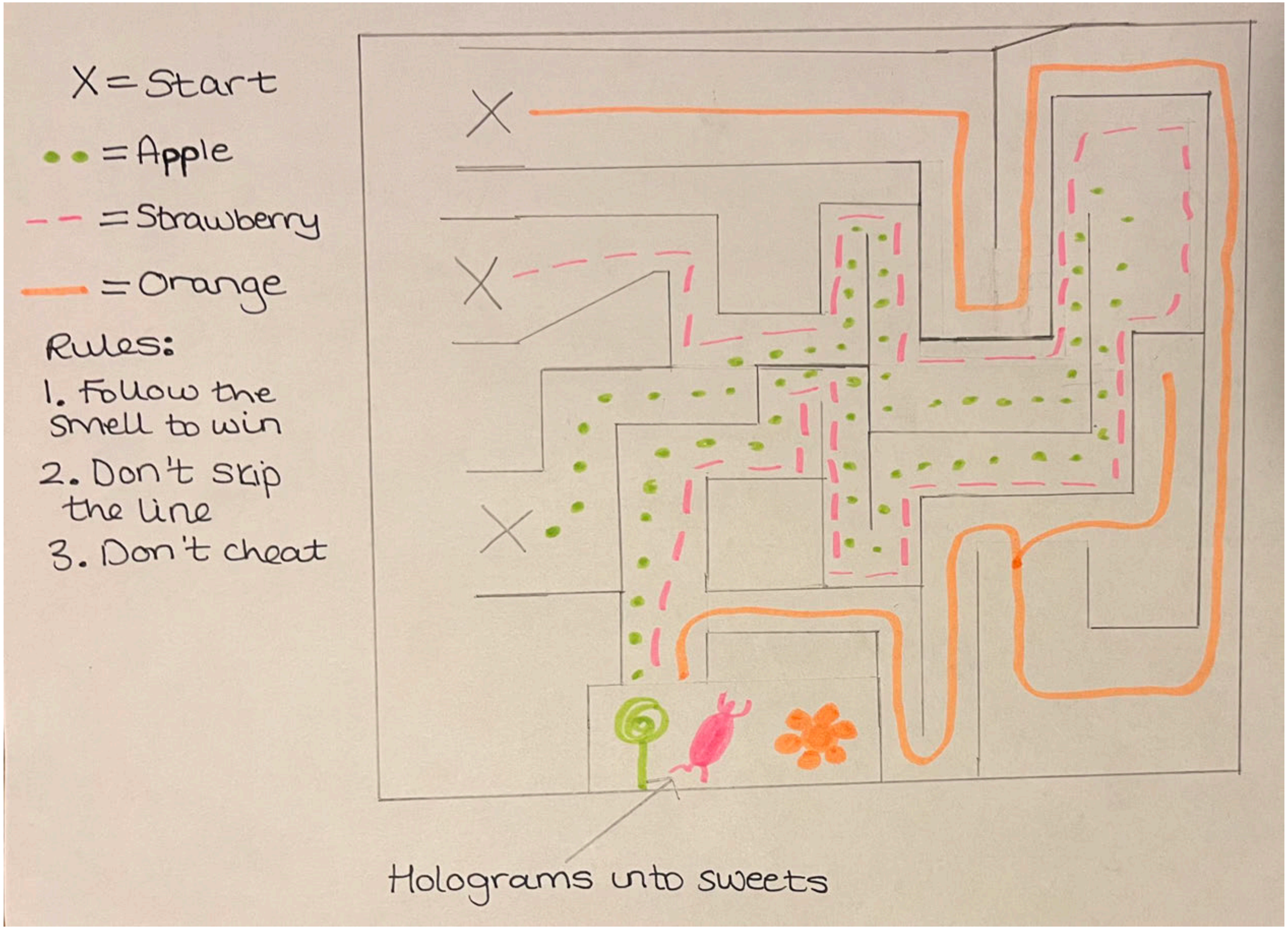

Figure 5.10: Redrawn pupils' design for a candy maze with various olfactory outputs, enabling participants to gamify the search for their favorite sweet. Upon locating it, the sweet transforms from a hologram into physical sweets.

As shown in Figure 5.11, students primarily incorporated tactile and visual elements into their sketches. Approximately 85% integrated tactile cues, while 71% included visual cues. This aligns with expectations, as real-world technologies often require both visual and tactile aspects for user interaction. Additionally, only 13% of the designs featured screen-based interfaces, with visual elements focusing on dynamic transformations and robotic movements. This trend aligns with previous findings (see Chapter 4), emphasising the importance of innovative, non-screen-based interfaces for public spaces to engage users in novel ways.

Moreover, the presence of the multisensory device may have had an impact on the students' design choices. For instance, sketches, such as a memory calendar designed by one student, were specifically tailored to use the features of the multisensory device. The calendar enabled users to experience various events happening in the city for a given month by clicking on specific dates. The immersive experience included elements such as dynamic lighting, audio enhancements, and scents, creating a multi-dimensional encounter that enriched the calendar's content. This exemplifies how the introduction of multisensory interactivity not only influenced the students' designs but also inspired innovative and imaginative concepts that leverage the full potential of such technology.

Whilst used less often, the olfactory and auditory cues were still used by 65% and 64% consecutively, with a major focus for these cues occurring within workshop 2 (see Figure 5.11). This workshop also saw the highest number of additional sketches, with 12 of the 27 pupils in this session creating more than one design. These designs were some of the most outside-the-box ideas ranging from culinary integration's to socialising abilities. For example, one pupil designed a real time hologram that could be produced from their watch to speak to their friend who had moved far away, they would not only be able to see them but also smell and hear them. Another example featured a Virtual Reality Headset design, allowing participants to select food items from a restaurant menu, experience their preparation through sensory cues, and make their dining choices.

Among the emerging functionalities of the designed technologies, culinary experiences stood out as particularly intriguing to the participants (see Figure 5.12). However, as evident in Figure 5.11, taste-related output was the least used among the sensory elements. Instead, the focus shifted toward harnessing other senses to craft items that

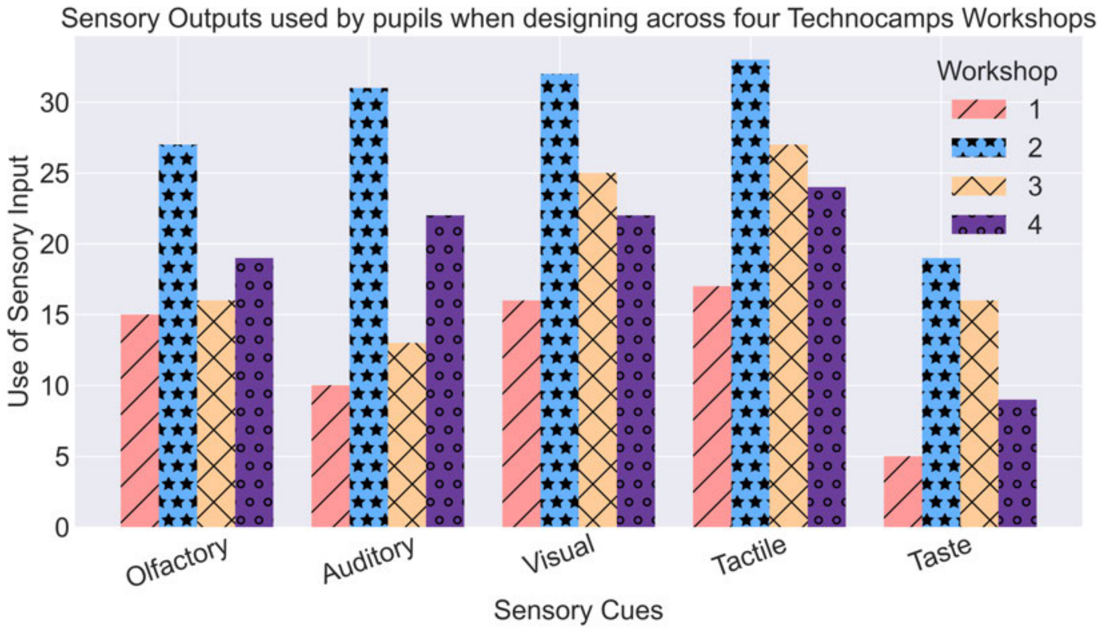

Figure 5.11: The sensory cues used by pupils in their designs across each workshop, with Olfactory, Auditory, Visual, Tactile, and Taste modalities.

could be consumed later. This preference may result from the close link between the senses of smell and taste, both of which can strongly trigger autobiographical and collective memories [281]. It is noteworthy that this workshop took place shortly before lunchtime, likely influencing the culinary themes in the designs.

Sensory vending machines emerged as a prevalent and innovative theme within this context, with approximately 80% of the culinary designs centring on some form of culinary vending machine. For instance, one design envisioned a 'make your own chocolate machine', where users could select the colour and scent of the chocolate, with audio cues facilitating a touchless interaction. Subsequently, the machine would craft the desired chocolate bar to the user's specifications. Similarly concepts included vending machines for crafting candles, pizzas, Lego, and various types of sweets.

It is worth noting that over the past year, the city of Swansea has witnessed the emergence of interactive vending machines that dispense milk and milkshakes. Initially introduced during the lockdown period to minimise the need for on-site cashiers, these machines have gained popularity and continue to be in high demand. It is possible

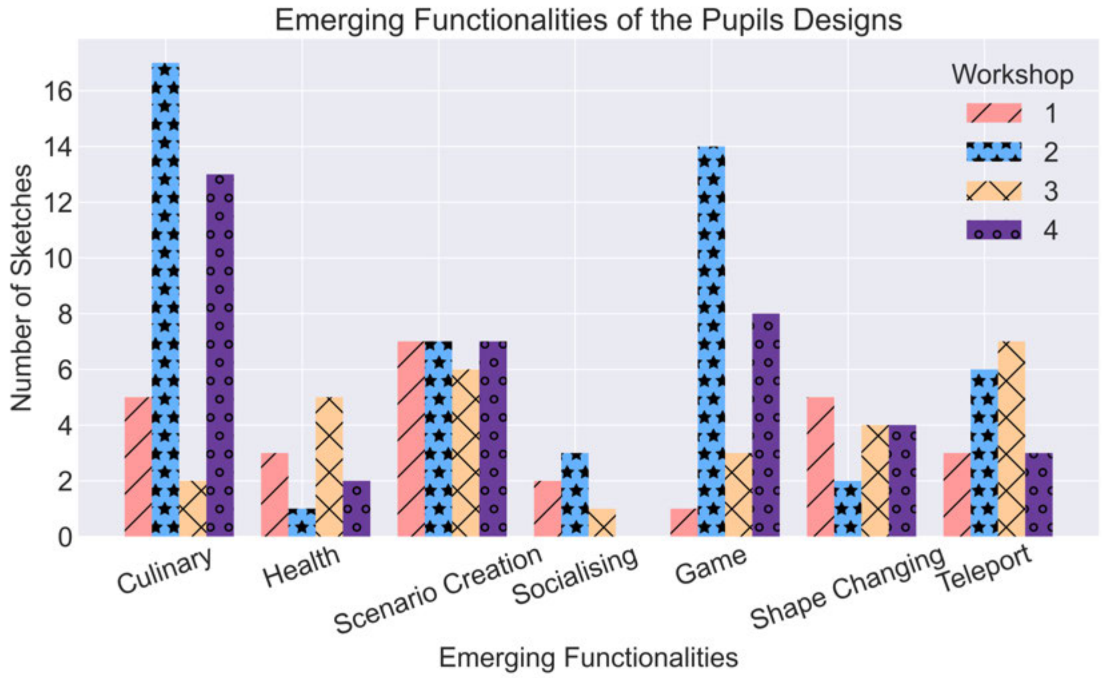

Figure 5.12: The emerging functionalities for the designs across the four workshops, with culinary designs emerging as the most commonly used.

that the presence and success of these interactive vending machines may have exerted some influence on the design concepts generated by the students during the workshops. Their exposure to these real-world examples of interactive vending machines could have sparked their creativity and prompted them to explore similar concepts, such as culinary vending machines, within the context of the workshops.

Additionally, the participants expressed a strong affinity for scenario-based technologies, which allowed them to explore and interact with immersive narratives and experiences. For example, the interactive calendar, as mentioned earlier, would provide visitors with information about events and activities happening in the city on specific dates. Moreover, interactive scenario-based games were popular among the pupils. These games, often offered users the opportunity to participate in interactive story-lines and adventures. The students' preference for scenario creation technologies underscores the value of multisensory interactivity in enhancing engagement and immersion, whether for informational purposes or entertainment, as demonstrated in Figure 5.12.

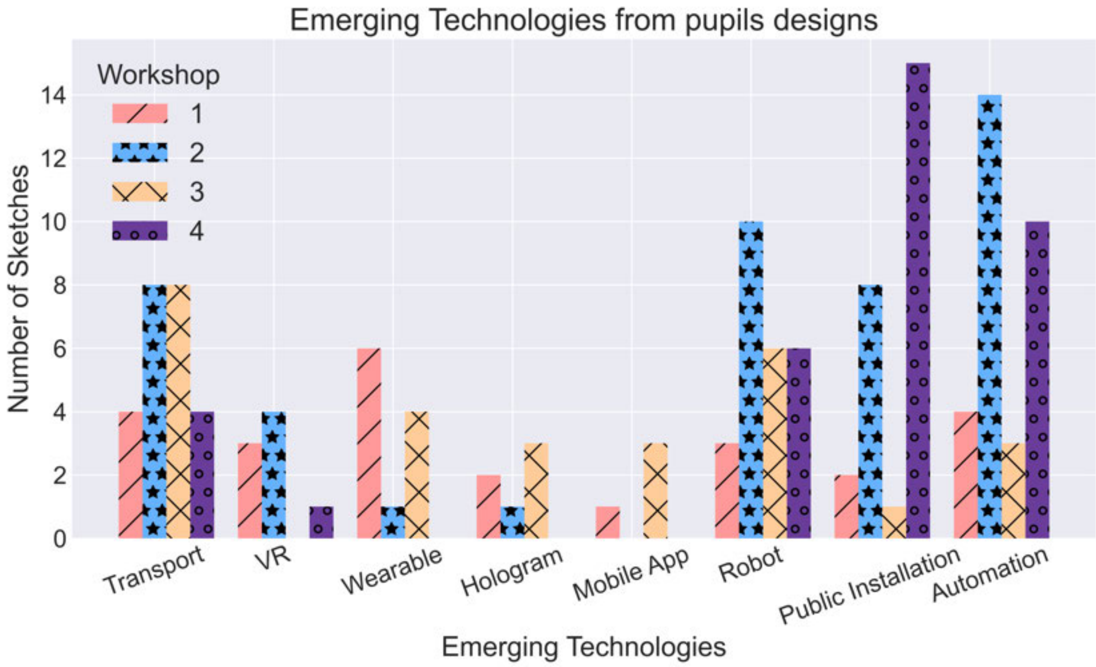

Figure 5.13: The emerging technologies for the designs across the four workshops, with automation and public displays leading as the most frequently employed technologies.

The final group focused on the emerging technology type, with vending machines and automated machines being the most popular, followed by public displays (see Figure 5.13). Transportation was again popular with the pupils but mainly focused around transporting through game environments compared to the flying cars designed within the initial design workshops.

In the few instances where screens or mobile apps were incorporated, participants integrated scent and audio cues to enhance the functionality and engagement of these existing technologies. This underscores the students' aptitude for re-imagining and improving upon traditional screen-based experiences. This trend could be due to students seeking more innovative sensory design.

5.4.4 Summary

In summary, this section has provided a comprehensive overview of the workshop plan, designed to integrate prototype deployment, feedback collection, innovation, and design sessions. The outcomes of four workshops involving 99 pupils have been analysed, encompassing both multisensory rig deployments, feedback collection and multisensory sketching analysis.

The analysis of the multisensory rig deployments unveiled a positive response from the participants. Many students eagerly embraced the opportunity to interact with the device, often opting for repeated engagements when time permitted. The pupils demonstrated a keen understanding of the presented scenarios, with an average recognition rate of 74% across the three scenarios. Their expressions of joy and the desire to share their experiences with friends underscored the device's potential for intrigue and novelty in its design. Furthermore, the participants contributed valuable insights for the placement of the device in the city on a more permanent basis, suggesting the addition of informational prompts or pictograms to facilitate user interaction.

The multisensory sketches continued to showcase the students' enthusiasm for multisensory technologies, yielding imaginative and unconventional ideas. These concepts ranged from visual and tactile cues to the integration of olfactory and auditory elements, illustrating the students' broad creativity. Public displays and culinary experiences emerged as prominent themes within the sketches, with real-life prompts and experiences serving as inspiration for many of the students' designs.

Collectively, these findings highlight the potential and promise of multisensory technologies, not only as sources of engagement and enjoyment for users but also as catalysts for innovative installations in the cities of the future. The workshops gathered insights and fostered creativity, laying the foundation for the continued exploration and development of multisensory experiences in public spaces.

5.5 Lessons learnt from from Multisensory Integration into Public Spaces

Based upon the comprehensive analysis of design sessions, discussions with city regeneration experts, sensory discovery questionnaires and the lab studies explored in Chapter 4 and the city centre deployments and school-based deployments, here are eight lessons learnt from the integration of multisensory installations into public spaces:

User-Centric Design: Involving citizens in the design process, especially young individuals, proved to be effective in gaining insights into their preferences and requirements. This approach not only fostered a sense of ownership but also ensured that the multisensory installations were custom-tailored to meet the expectations and desires of the target audience. Consequently, the installations delivered an enhanced and more engaging experience for users.

By embracing these user-centric design principles, cities can proactively engage their communities and align their efforts with the needs of their residents. This not only fosters a sense of belonging but also contributes significantly to urban revitalisation endeavours, resonating with the community and fostering a stronger connection between citizens and their cityscape. This discovery underscores the impact of incorporating multisensory installations in future urban development, where user engagement and satisfaction are paramount.

Expert Collaborations: Drawing upon insights gathered from discussions with city regeneration experts, the importance of fostering close collaboration between urban planners and specialists in the field when deploying within urban areas was underscored. A multidisciplinary approach, combining perspectives from both the research side, focused on user research and innovative installations, and the regeneration side, focused on urban development, led to a realistic and innovative deployment. This lesson emphasises the pivotal role of collaboration in ensuring the successful incorporation of multisensory installations in urban development, wherein expert perspectives align installations with the broader goals of urban revitalisation and enhancement.

Diversifying Public Displays: The value of offering a wide array of sensory experiences to cater to diverse preferences and age groups has been highlighted within this work. These data-driven insights hold potential to enhance the urban experience. By incorporating sensory elements into a wider range of public displays, cities can create multisensory installations that are inclusive and multifaceted, engaging multiple senses, from sight and sound to touch, smell, and even taste. In future work it would be intriguing to understand how these displays could render public spaces to be more inclusive and enjoyable for individuals of all abilities. Thus, this lesson underscores the possibilities for inclusivity and diverse sensory engagement in elevating the overall allure and accessibility of public spaces.

Scenario Testing: The deployments of multisensory installations offered insights into users' recognition and emotional responses when encountering various scenarios. Through testing and evaluation within controlled lab settings, scenarios effectively conveyed the intended sensory experiences to users. This systematic and methodical approach allowed for the fine-tuning and optimisation of the installation, resulting in the creation of more immersive, engaging, and impactful sensory encounters within public spaces.

Moreover, this testing and evaluation process served as a bridge between the initial design concepts and the final implementations within the city. It played a role in aligning the installations with the city's broader goals and objectives for urban development, ensuring that they seamlessly integrated into the urban fabric and resonated with the local community. Consequently, the research not only contributed to the enhancement of sensory experiences but also played a role in elevating the overall urban environment.

Public Awareness: Multisensory installations hold the potential to serve as a marketing assets for promoting upcoming events and attractions within cities. By integrating these installations into promotional campaigns and city branding efforts, cities could leverage multisensory experiences to generate heightened interest and anticipation. These installations could become captivating focal points that draw the attention of both residents and tourists. Whether it is an art installation, a sensory teaser for an upcoming event, or an interactive landmark, multisensory installations can pique curiosity and create a buzz.

Community Engagement & Nostalgia: Multisensory installations present an opportunity for fostering community engagement and strengthening their sense of place through nostalgia. By actively encouraging users to share their multisensory experiences and stories related to these installations, cities could initiate a narrative that weaves together the diverse threads of community life. These installations, designed to be interactive and thought-provoking, have the ability to spark conversations and curiosity. They could become conversation starters, drawing people from different backgrounds and walks of life into a shared sensory journey. By actively promoting user engagement and storytelling, cities can create a sense of shared heritage and community identity. This not only fosters a sense of nostalgia but also highlights the richness and diversity of the community's experiences.

Ethical Compliance and Regulatory Adherence: The successful implementation of multisensory installations within urban landscapes hinges on strict adherence to ethical standards and regulations. Safety and regulatory compliance require the consideration of electrical, structural, fire, and accessibility standards. By ensuring these installations meet or surpass these requirements, ensures that the safety and well-being of all participants is a priority. Furthermore, ethical approval and regulatory compliance are vital in installations involving data collection or human interaction. Obtaining ethical clearance guarantees ethical data handling and user privacy, while addressing legal and permit requirements ensures smooth integration into public spaces. This commitment fosters trust, signaling a dedication to creating an engaging and secure urban environment.

5.6 Discussion

Typically, research in this domain has predominantly concentrated on single-sensory or visual-centric installations within public spaces (see [7,104,126,135]). Conversely, multisensory research has primarily focused on indoor installations, examining their impact and applications in controlled environments (see [32, 165, 166, 200]). The contribution of this work emerges from its exploration of multisensory experiences in outdoor public spaces, an area that has remained relatively uncharted in the existing body of literature. This research transcends the boundaries of conventional sensory installations, pushing the boundaries of design and engagement in urban environments.

5.6.1 Designing a Multisensory Rig Fit for City Deployment

The process of designing a multisensory rig fit for deployment in a city presented a series of complex challenges. These challenges encompassed various factors, including user-centred design principles, accessibility, resilience to adverse weather conditions, and considerations related to pedestrian flow in the outdoor public space of Swansea.

The design changes implemented in response to these considerations addressed several critical aspects, ultimately resulting in a more practical, user-friendly, and resilient installation. Some of the key design enhancements included the removal of a fan, repositioning of lights, modifications to the device housing to enhance weather resistance, and the implementation of accessibility features such as an adjustable height pole and devices placed at different heights. These adaptations not only addressed practical considerations but also contributed to an improved user experience, making the multisensory rig more inclusive and accommodating to participants of varying statures and needs.

5.6.2 Insights from the City-Based Study

The deployment of SALly garnered public interest, sparking curiosity and achieving a 73% average recognition rate across the deployed scenarios. This success raises the opportunity for future deployments in similar settings. In addition, the participants' comfort and satisfaction indicated a positive experience, with broader implications for acceptance, accessibility, and overall well-being in public environments. These sensory cues also demonstrated their ability to trigger nostalgia and emotions, offering opportunities for enhanced public engagement initiatives. e.g., memories of eating sweets with Grandparents. Therefore, this work provides a new possibility for the growing interest in enhancing urban engagement and revitalising public spaces. Existing research often emphasises the importance of technology in transforming urban environments [13,38,190], but the multisensory properties of the installation evaluated here add another dimension by appealing to multiple senses simultaneously. This could lead to more immersive and memorable urban experiences.

5.6.3 Fostering a Sense of Shared Heritage and Community

Whilst exploring the possible roles of multisensory outputs for shared heritage within Augmented Reality [12, 81, 270], such as memory mapping [265] and museum exhibits [264] has been explored, this work provides an exploration of its role within public spaces. This discovery serves as a foundation for cities worldwide to integrate multisensory installations specific to their urban landscapes. This exploration demonstrates multisensory installations potential to enhance comfort, promote positive behaviours, and function as interactive information hubs within urban environments.

Furthermore, the exploration of multisensory installations in urban contexts unveiled their potential to foster a shared heritage and a sense of community with scenario relation showing strong emotions and revealing the ability to build a sense of belonging. For example, by recreating the sensory atmosphere of historic sweet shops, this research has evoked reminders of the city's rich history and the collective experiences shared by its inhabitants. Highlighting the power of sensory engagement, transcending individual encounters to weave a communal narrative that celebrates traditions and cherished memories. This emotional resonance has the capacity to forge deeper connections between city residents and their urban surroundings.

5.6.4 Engaging Youthful Perspectives: Interactive Workshops with School Children

Incorporating interactive workshops to involve school children in the process of urban design aligns with the user-centred design principles advocated in the existing literature (e.g., [29, 134, 260]). This approach not only underscores the importance of involving diverse user groups in the design and evaluation of multisensory technologies within public spaces but also places a particular emphasis on the role of younger generations in shaping the future of urban technology. By actively seeking the perspectives of these young participants, this chapter contributes to the existing body of literature by showcasing how multisensory installations can engage and inspire the next generation of technology users and innovators.

Having both the pupils and researcher within the classroom facilitated a highly interactive and collaborative environment throughout the sessions. This setup allowed for easier creation of designs and enabled pupils to seek feedback throughout their creative process, if they desired. This was in contrast to the workshops conducted over COVID-19, where remote interactions were less conducive to such real-time collaboration. Conducting these workshops also provided the opportunity to interact with pupils spanning a range of ages, gathering their feedback not only on SALly but also on the types of multisensory technologies that would pique their interest in an urban setting.

Furthermore, the feedback received from the school children not only highlighted their enthusiasm for the SALly rig but also revealed their imaginative ideas and expectations for multisensory technologies in the future. This enthusiasm and creativity underscored the potential of multisensory technologies to capture the imagination of the younger demographic, fostering an early interest in interactive and tactile experiences within urban environments.

5.7 Conclusion

Prior to this research, the exploration of multisensory installations in urban environments remained largely unexplored. Through evaluations detailed in the previous chapter, the design was refined to ensure optimal performance in an outdoor public space. The journey continued with the deployment of SALly into Swansea city centre, where the device was not only implemented but also a set of considerations and limitations for its effective operation were established. e.g., indepth scenario testing and the incorporation of a range of users including experts, children and community members. The procedures employed in this deployment were documented, facilitating comprehensive analysis and ensuring reproducibility and adaptability for future multisensory rigs. This real-world application highlighted the adaptability and versatility of multisensory installations in engaging urban communities with their surroundings.

While this chapter has emphasised the prominence of audio as a dominant sensory cue, it is vital to highlight the broader value of a multisensory approach. The potential sequential absorption of audio and olfactory cues by the brain, influencing their perceived dominance, is a captivating aspect. Acknowledging the synergy among multisensory cues allows for the development of more immersive and effective memory-triggering experiences (nostalgia), enhancing the overall impact of audio-visual interactions. Therefore, although audio is undeniably significant, adopting a comprehensive sensory approach, including olfaction, holds great promise for crafting more engaging and memorable experiences.

Engaging with pupils to evaluate SALly revealed its potential and appeal to a younger generation. Their innovative ideas and excitement for multisensory technologies underscored the possibilities for future advancements in the field.

Collectively, these efforts have paved the way for a wide range of new and exciting multisensory installations that can be seamlessly incorporated into public spaces, enriching community engagement and enhancing urban environments. The comprehensive nature of this research — from design and deployment, positions it as a new contribution in the realm of multisensory technology integration in public spaces. This approach has implications for the future of cities worldwide, offering opportunities for multisensory engagement in urban settings.

Additionally, this chapter has demonstrated that multisensory installations provide a distinctive method for nurturing community engagement and enriching residents' perception of their surroundings by evoking nostalgic sentiments. By encouraging individuals to share their multisensory encounters and interactions with these installations and environments, cities could initiate a narrative that interweaves the diverse aspects and experiences of communities. It has been illustrated here that these installations have the potential to spark discussions and generate interest in urban transformations and multisensory design. Through actively promoting user participation and narrative exchange, cities could leverage the insights gained to foster a collective heritage and communal identity through multisensory installations. These installations not only have the ability to evoke nostalgia but also to strengthen the bonds of shared heritage.

In conclusion, this chapter has undertaken a comprehensive exploration of multisensory installations in outdoor public spaces, drawing insights from city centre deployments and workshops with pupils. This multifaceted approach along with the cocreative process completed within Chapter 4 has yielded recommendations for the seamless integration of multisensory installations into urban environments.

5.7.1 Chapter Contributions

Chapter 5 explored the deployment of a multisensory rig in an outdoor public space for two days, as well as a set of interactive workshops with 99 children, informing a comprehensive set of lessons for seamlessly integrating multisensory technologies into any outdoor public space. These lessons endeavour to guide cities in harnessing the potential of multisensory installations to enhance urban environments, promote community engagement, and enrich the overall quality of city life. By embracing these recommendations, cities can create more vibrant, inclusive, and immersive public spaces that resonate with the diverse preferences and needs of their citizens.

Chapter 6

Exploring New Paradigms in User Design Tools

6.1 Introduction

When designing the Lookout, explored in Chapter 3, several aspects of the design were highly situation specific, and custom hardware had to be developed alongside the screen content. Physical actions on the device had an impact on the screen display, and there were no point-and-press interactions due to COVID-19 safety concerns. Crucially, communication with stakeholders regarding the physical situation was vital, including establishing the need for a second 'child and wheelchair-friendly' device. Visual mock-ups were created through hand drawing and photo-editing tools, but this was not supported by UX tools. This issue resonated with educators questioned in an EduCHI focus group (beyond the scope of this thesis) [70], where they detailed difficulties in encouraging their students to consider the broader context of their designs: who is using the device?, where are they?, and what are they doing? This challenge is less pronounced when designing desktop applications like spreadsheets but becomes apparent with mobile applications that might be used while walking or in a car.

Therefore, the overarching goal was to realign user-experience design tools with the latest developments in interface and application design. This was achieved through collaborative efforts involving designers, researchers, educators, and students to explore, catalogue, and critique existing public-facing design tools. The discoveries can be used to inform future features and changes to existing technology. Collaboration with industry and academic users has also been explored to gain insights into the state-of-the-art and the needs of both commercial and 'future' groups, at the forefront of digital development and design.

Digital technology exists within a continually evolving landscape of innovation and use. UX design tools encompass everything from pen and paper to programmed offerings, but none appear to support the entire process, or developing technology which suggests multisensory, contextual, and environmental interactions. It is uncertain whether the existing paradigms of user experience design [234] and their tools can keep up with the fast-moving, contextual and often multisensory world of technology. Therefore, if existing user-experience design tools do not serve the purpose of an evolving digital landscape, then their future must be considered.

In this chapter, a two-fold exploration is undertaken. First, a series of workshops will evaluate the current landscape of tool use across various design needs. These workshops scrutinise prevailing practices, dissect tool strengths and limitations, and reveal unmet needs of designers within this domain. Concurrently, a suite of proof-of-concept prototyping tools will be introduced as potential solutions to identify challenges, infusing innovation into the design process.

6.1.1 Motivations Leading from Previous Chapters

Throughout the previous chapters, experiences were gained which led to motivations to further explore the works within this chapter. In Chapter 3, complexities arose whilst sharing designs with stakeholders and communities, especially amidst the challenges posed by the COVID-19 pandemic. The inability to physically demonstrate prototypes and gather feedback through direct interactions, was challenging and could not be rectified through online tool usage as design tools predominantly focused on screen-based interactions only. Therefore, demonstrating a non-screen based interactive design to stakeholders was not possible through currently available design tools. Additionally, the Lookout's design and surrounding area design was influenced and needed to be tailored to Swansea's environmental context, something that was not possible to design through

UX design tools. This spurred a motivation to investigate how others approached similar design processes for both multimodal interactive designs and contextually-based designs using different tools and methodologies.

Furthermore, the process of demonstrating low-fidelity/wireframe multisensory prototypes, which inherently require tangible demonstrations rather than conventional methods, was not possible. Traditional design tools, often centred around software and screens, were not suitable to effectively represent the different outputs of a multsensory device like SALly or an elbow-based interactive device like the Lookout, designed specifically for interactions within Swansea city. In the absence of tools for scent-based or unconventionally shaped interactive device prototyping, traditional design phases often were not possible to complete. Consequently, essential stages like low-fidelity prototyping were often bypassed, resulting in simple errors or adaptations that could have been addressed in these phases needing to be rectified later on. This process was both time consuming and cost-ineffective for completing iterative prototyping and further motivated the author to discover the different work around other designers and researchers had found to complete similar prototypes.

Through these experiences of designing interactive multisensory displays, while considering the contextual nuances of their interactions across various projects, fueled a desire to explore deeper into how industry professionals and researchers navigated such spaces, and how mutual support and collaboration could be fostered. Discussions with Prof. Alan Dix (Cardiff Met University) and Dr. Miriam Sturdee (St Andrews University) further highlighted the limitations of existing design tools in capturing the context of use. This realisation, combined with the challenges amplified by the pandemic, underscored the urgency for innovative approaches in the HCI design field [46].

To address these challenges and expand the project's scope, a collaboration was formed and supported by additional funding by the Cherish-DE project. While consulting support was provided by Prof. Dix and Dr. Sturdee, the author took the lead in the majority of the project's work. Throughout this process, acknowledgments were included where necessary to recognise the contributions of collaborators and stakeholders.

6.2 Procedure: Navigating the Future of UX Design Tools

Four online workshops were hosted online to explore the present and potential future of user experience (UX) design tools. The prototypes were used during these workshops as probes to inspire ideation. The workshops were designed to engage with a diverse group of participants, including practitioners, educators, students, and academics. The primary objectives were to gather insights into their current usage of UX tools and to inspire discussions and innovative thinking within the field.

These workshops were conducted on Zoom due to the COVID-19 pandemic, with live transcription. A dedicated Miro board was created to enable collaborative innovations. For example, Figure 6.1 provides an overview of *Workshop 3* with different task areas highlighted. To accommodate participants from various time zones, the workshops were conducted over two hours and offered at four different times. This approach aimed to ensure that designers, researchers, and industry members worldwide had the opportunity to engage with the workshops. The workshop schedule was presented on each Miro board, facilitating participant navigation through for key phases: (1) Pre-study Questionnaire; (2) Preliminary Tasks: Current Tool Use; (3) Demonstration of Prototypes; and (4) Tools of the Future (see Figure 6.1). Each phase was carefully designed to collect insights, share current practices, showcase prototypes, and explore innovative concepts for future design tools. Further details on each phase will be provided in the subsequent sections.

6.2.1 Phase One: Pre-Study Questionnaire

The demographic study encompassed a range of questions aimed at gaining a comprehensive understanding of the participants' backgrounds and roles within the field of design and were based upon the design tool survey [209]. Key questions included:

1. **Profession Description:** Participants were asked to describe their profession, enabling the categorisation based on professional design responsibilities, helping to

ensure that the respondents were from a diverse range of groups within the design community.

2. **Experience in Design:** The number of years of experience each participant had in the design field, providing valuable context for understanding the participants expertise and seniority levels.

3. **Types of Designed Experiences:** To capture the diversity of design work, participants were asked to specify the types of experiences they typically designed. e.g., digital interfaces or physical products.

4. **Primary Design Platforms:** The respondents were asked to specify their preferred design platforms, shedding light on the software and technologies used in the design community.

5. **Tool Preference:** The participants were asked to detail the software tools they used across the design process to provide an overview of participants' software preferences and workflows. The questions were divided into design phases including:

    a. Brainstorming and Ideation;
    b. User flows and site maps;
    c. Interface Design;
    d. UI Prototyping;
    e. Developer Handoff;
    f. Managing Design Systems
    g. User Testing;
    h. Versioning and File Management

The participants were required to complete this pre-study questionnaire before attending to the workshop, in order to provide an opportunity to adapt the workshops to participant preferences if necessary and to save in-workshop time.

6.2.2 Phase Two: Preliminary Tasks - Current Tool Use

Following the completion of the pre-study questionnaire and consent forms, which were also sent and returned prior to the workshop (via email), each workshop began with a short introduction to the project rationale, during which the schedule was outlined. Designated areas were provided within the Miro board for all workshop tasks to guide participants through the process (see Figure 6.1). Participants were encouraged to explore the board and share their thoughts throughout the session, engaging in discussions with fellow participants. The *Phase Two* tasks were designed as follows:

Task 1: Current Tool Use and Tool Sorting into Types/Activities The first task built upon the question about current design tool use from the demographic and UX Design Tools Survey [209]. Each participant was asked to select an area at the top of the board (*Task 1*), label it with their initials, and list all UX tools (software and tangible) they were currently using or had used within their UX or HCI work on sticky notes. Sticky notes were made available next to *Task 1* for ease of use. Following this, each participant was tasked with identifying at what point in their process they used each tool and duplicating sticky notes if they were used at multiple stages of their work (i.e. Brainstorming and User Testing).

Task 2: Evaluation of Existing Design Tools After identifying which tools were used at each stage, participants were given the opportunity to assess the best and worst features (pain points) of each tool and provide reasons for their choices. These insights were again added as sticky notes to the Miro board and could be duplicated for the next task.

Task 3: Pain Point Categorisation Participants sorted the pain points into three 'swim lanes' (a diagram used to illustrate steps in a process [86]): *High-Level Design*, *Low-Level Design* and *Sharing and Collaboration*, through discussion and collaboration with other participants.

Task 4: Group Evaluation of Existing Design Tools Following this, the participants were asked to work together to clarify how the pain points could be mitigated/removed, and if there were any global improvements that tools could implement for better usability tool wide.

Figure 6.1: Overview of design workshop board 3, with task sections highlighted and numbered from 1-7.

6.2.3 Phase Three: Demonstration of Prototypes

After a ten-minute break, participants returned to the workshop for a demonstration of two proof-of-concept prototypes, 'Scenario Viewer' and 'PhysProto', created by Prof. Dix. These prototypes aided issue understanding and acted as technology probes, as described by Hutchinson et al. [131], bridging the gap between currently available tools and possible futures. Initially, they were developed as throw-away prototypes for exploring design possibilities, with a specific focus on UX tool design [45].

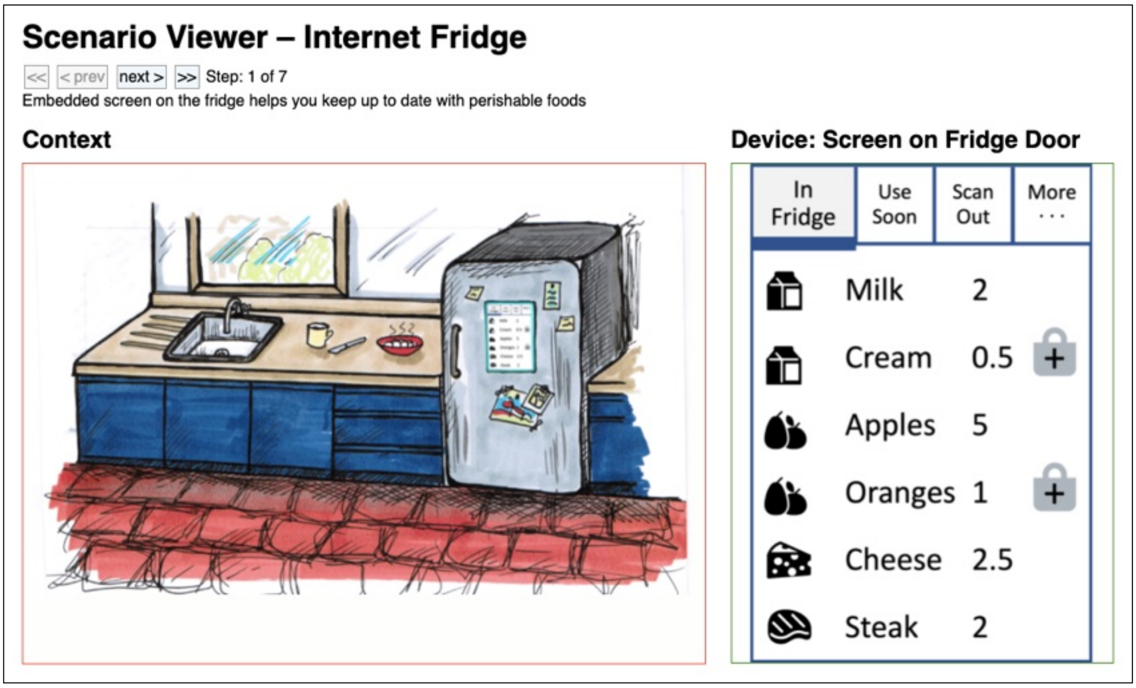

Figure 6.2: The Scenario Viewer showcases the use of a smart screen fridge door within the context of the user's kitchen, featuring sketches by Miriam Sturdee, implemented by Alan Dix.

Scenario Viewer

The *Scenario Viewer* (Figure 6.2) was designed to envision how a tool could be integrated into storyboard-style views of context with Figma-like screen mock-ups.

Funcitonality: Figure 6.2 shows a stage in a scenario depicting the use of an internet-enabled fridge. The beginning of the scenario is shown, with the fridge located in the kitchen and an image of the screen that would be displayed on the fridge. Subsequent stages portray the process of ordering items through a mobile app connected to the fridge while sitting in an armchair, using the app in a supermarket, and reviewing purchases at home via the fridge app on a smart TV. This design scenario transitioned across different physical devices (fridge display, phone, smart TV) accessing the same system, as well as using the same device (phone) in various physical settings (home and supermarket). Additionally, the screen mock-ups in Figure 6.2 are presented in miniature within the respective context scenes, emphasising their presence *within* the context.

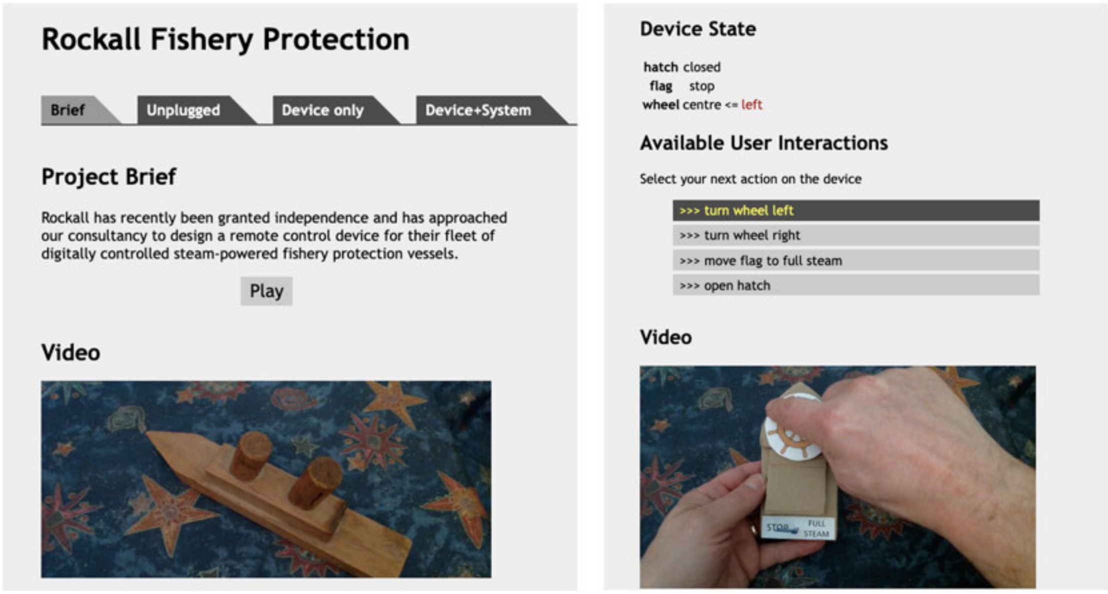

Figure 6.3: Overview page for *PhysProto*. A model boat represents the remote-controlled fishery protection ship. The user is shown a physical boat-shaped prototype of a control device with a closed hatch. The user selects to open the hatch.

Physical Design Prototype (PhysProto)

PhysProto was developed to assist users in creating interactive physical prototypes virtually, a task that posed challenges during the Lookout project (Chapter 3). It initially arose out of a workshop on the use of video in HCI education during the early part of the COVID-19 pandemic [292]. While it was possible to create a simple demonstration video, this did not allow stakeholders to experiment or ask questions like, "What happens when I move this?". In the process of creating a video-based prototype tool to partially address this issue, it became clear that this tool could also serve as a means to share early prototype concepts for physical devices in a professional setting.

Functionality: The *PhysProto* (Figure 6.3) tool was used in addition to the low-fidelity physical prototype, such as a small corrugated card controller shown in Figure 6.3. The example resembles a boat-shaped remote controller for a semi-autonomous ship, with various controls like a miniature steering wheel, a switch-like flag, and a red button under a flap. In this design tool, it is possible for designers to produce a demonstration video and short clips of potential device actions. Designers can then create a physical behaviour model based on physigram notation [71], describing the device's states and behaviours without electronic effects. The completed PhysProto can be shared with users who can interact with the device virtually by simulating physical actions. Video clips corresponding to physically possible actions are shown, considering device states (e.g., flap open). Designers can also include videos showing the effects on other systems, like the remote-controlled ship. This provides remote demonstration and experimentation capabilities, especially useful for fragile prototypes.

6.2.4 Phase Four: Tools of the Future

After providing an overview and demonstrating the concept prototypes as described above, the remainder of the workshop was structured as follows:

Task 5: Ideation for Combination Approach *Task 5* Participants collaborated as a group to explore how inspiration and feedback from the prototypes could be integrated with solutions to current tool issues, with a specific focus on identifying valuable features from existing tools. The Miro board included screenshots of the design-context prototypes (detailed within the previous section) to facilitate feedback and comments.

Task 6: Feature Brainstorming and Paper prototyping Following this, participants completed a solo brainstorming activity aimed at generating individual features considered as *essential* for a new UX design tool (i.e. functionalities). Participants were encouraged to sketch their ideas to convey complex concepts effectively.

Task 7: Group Discussion To complete the workshop the resulting features were collectively discussed, and any supplementary notes were added to the board in the *Task 7* section (see Figure 6.1).

This four-phase workshop structure allowed valuable insights and input from a diverse group of participants to be gathered, facilitating an exploration of the future of UX design tools. Fundamentally, this approach navigates a path that blends innovation and empirical investigation, resulting in the exploration of the future direction of UX design tools. This journey combines the tangible with the conceptual, the analytical with the creative, ultimately providing a road-map for the development of tools that will shape the future of UX design.

6.3 Results

A website (https://hcibook.net/incontext/) was created providing up to date information on the project. In addition, mailing lists and social media were used to promote the workshops to a diverse audience. Following their workshop participation, each participant received a £20 incentive, which they could choose to receive in the form of an Amazon voucher or as a donation to a charity of their choice. Except for the thematic analysis, which is detailed in Section 6.3.4, all the described analyses were conducted by the author.

6.3.1 Pre-Study Questionnaire

In total, 28 participants were recruited, and 24 of them actively engaged in one of the four design workshops ($W1:7, W2:5, W3:6, W4:6$). Out of the initial 28 participants, the age ranged between 18-60 ($18-25:3$, $26-36:13$, $37-47:5$, $48-60:7$) with a standard deviation $\sigma = 4.36$.

The participants significantly represented academia and experienced designers with over 10 years of experience across diverse company sizes (see Table 6.1). The participants were completing work on a variety of projects with a high number of web/app designs and study designs. Furthermore, Mac emerged as the dominant platform. All the collected data exhibited patterns that closely mirrored those observed in the UX Design Tools survey.

From the initial 28 participants, four were unable to take part in the workshops after completing the demographic questionnaire. Consequently, the data analysis and insights beyond here were derived from the responses of the remaining 24 participants.

Table 6.1: Participant Demographics and Current Focus

Demographic Information

Participant Role		Sector	
Researcher	12	Higher Education	16
UI/UX Designer	6	Tech Industry	4
Student	4	Government	2
Design Product Manager	3	Freelance	2
Design/Interaction Researcher	1	Media	2
UX Founder	1	E-commerce	1
Professor	1		
Current Work		**Years of Experience**	
Web/Apps Design	8	<1yr	6
UX Study Design	8	1-2yrs	3
User Interfaces (UI)	5	3-5yrs	7
Tangible Interfaces	4	6-10yrs	2
Product Design	3	10+yrs	12
Social Media Content	2		
VR/AR	2		
Conversational UI	2		
Escape Room/Immersive Entertainment	1		
Company Size		**Number of Designers**	
1	2	1	5
1-10	4	2-10	7
11-100	1	11-20	6
101-500	4	21-50	6
501-1000	2	51-100	0
1000+	15	100+	4
Primary Platform		**Gender Identity**	
Mac	17	Female	14
Windows	9	Male	9
Linux	2	Prefer Not to Say	1

6.3.2 Participant Design Tool Survey

This section presents a comprehensive analysis of the design tools used by the 24 participants, offering insights into the diverse tool preferences and usage patterns within the study cohort. In *Task 1*, participants were instructed to list all the tools they used throughout their entire design process. After the workshops, the frequency of tool mentions was aggregated and ranked from most to least used. Subsequently, the accessibility of each tool was assessed by gathering information regarding the necessity of a subscription, annual pricing, educational pricing, free trial duration, and compatibility with both Mac and Windows platforms.

Collectively, participants used a total of 164 distinct tools throughout their design process, averaging seven tools per person. This count includes a research tool named DENIM, which is unavailable for open access use, making its inclusion unusual. Consequently, freelance and industry designers would, on average, incur an annual cost of £954.27, while educational licenses would incur a lower average annual expense of £209.39.

Table 6.2: Top ten UX design tools used by the participant sample, showing annual price, educational price, whether there is a free trial, if it has cross-platform compatibility, and the number of participants who use it.

Tool	Subscription Required	Annual Price (£)	Educational Price (£)	Free Trial Duration	Cross Platform Compatibility	Users
Paper	–	–	–	–	–	19
Miro	Y	79.00+	–	∞	Y	12
Figma	Y	132.00	–	30 Days	Y	9
Adobe XD	Y	623.76+	194.88+	7 Days	Y	7
Balsamiq	Y	105.00+	Request	30 Days	Y	6
Post-it Notes	–	–	–	–	–	4
ProCreate	Y	10.51	10.51	0 Days	N	4
Sketch	Y	87.42+	–	30 Days	Y	4
Axure RP	Y	246.00	Request	30 Days	Y	3
Google Docs	Y	–	–	∞	Y	3

The ten most popular tools used, which include two non-digital tools (out of a total of five non-digital tools), are shown in Table 6.2. A full overview of the 78 tools is provided in Appendix E. Among the top ten digital tools, 88% were compatible with both Mac and Windows and offered some form of a free trial, with 75% of them providing trial periods of 30 days or more.

Tangible tools emerged as the most popular category of tools, with 79% of the participants incorporating paper into their design process, often using it across several stages. Moreover, 71% of the participants stated that they used at least one other tangible tool, such as sticky notes. This suggests a demand for tangible tools and processes to facilitate and enhance the design process.

6.3.3 Affinity Diagramming

As noted in Section 6.2.2, participants were asked to specify at what stage of their design process they used each tool and duplicated these sticky notes to represent their use across different design stages. Following this initial data collection, the author performed Affinity Diagramming - a qualitative content analysis process. The aim of this process was to condense the raw data into categories or themes through valid inference and interpretation. Affinity Diagramming uses inductive reasoning, allowing themes and categories to emerge from the data through careful examination and constant comparison. An example of best practice for using Affinity Diagramming in HCI was described by Lucero [162], the analysis and results were completed following a similar methodology to provide a comprehensive overview of the data. The diagramming process was carried out in four stages on a Miro board:

1. **Creating Initial Notes:** Initially, notes were created by extracting the processes from each user's sticky notes along with the respective tools used. Each participant's contributions were colour-coded for clarity.

2. **Clustering:** In this stage, common themes and trends that emerged throughout the processes were identified and grouped together. This clustering helped in identifying overarching patterns in which tools were used across which processes.

3. **Re-clustering:** During this phase, process categories were re-analysed, and sticky notes were re-categorised as needed. The goal was to ensure that the themes and subcategories within those themes were accurately identified and represented. This iterative process allowed for a deeper understanding of the data and was completed in a separate sitting to ensure no previous bias of categorisation.

4. **Colour Classification:** An additional step was included which involved assigning specific colours to tools based on their types. This approach was adopted to gain insights into the variety of tools used throughout the design processes.

5. **Documentation:** The final stage involved documenting the results of the Affinity Diagramming process. This documentation included creating visual representations of the clustered data, summarising key findings, and providing insights into the identified themes and subcategories, as described below.

Results

As a result of the Affinity Diagramming process, four overarching themes were identified: (1) Ideation, (2) Design and Development, (3) Prototyping, and (4) Demonstration and Feedback. These themes encompassed various subcategories, such as Wireframing and Problem Definition, providing a detailed understanding of how participants used tools in their design processes. The tools within these subcategories were then colour coded based on tool type, with each code serving a specific purpose for designing, helping to address the different types of tools used across their design processes. Here are classifications for each colour code:

Orange: Development and Programming *Orange* tools included software development tools and programming environments used to implement design solutions. e.g., Microsoft Visual Studio [178] - an integrated development environment (IDE) used for software development and programming tasks.

Pink: Animation and Multimedia *Pink* tools focused on tools for creating animations, graphics, and multimedia content, to enhance the visual appeal and engagement of user interfaces. e.g., Adobe After Effects [3] - used for creating motion graphics, animations, and visual effects.

Blue: Design and Planning *Blue* tools focused on tools for creating visual representations, diagrams, and layouts to structure and organise ideas. e.g., Miro [181] - an online collaborative whiteboarding platform that enables teams to brainstorm, plan, and visually organise their ideas with diagrams, flowcharts and mind maps.

Green: Prototyping and Interface Design Green tools focused on developing interactive prototypes and designing user interfaces. Designers use these tools to create mockups, wireframes, and visual elements that define the user experience. e.g., Figma [85] - a cloud-based design and prototyping tool that allows designers to create interactive prototypes and design user interfaces collaboratively.

Purple: Communication and Collaboration *Purple* tools supported team communication, collaboration, management, task coordination, and effective teamwork during the design process. e.g., Slack [243] - a team collaboration platform that facilitates communication, file sharing, and project management.

Yellow: Research and Documentation *Yellow* tools helped designers document their findings, manage data, and maintain project-related documentation. e.g., Zotero [300] - a reference management tool designed for collecting, organising, and citing research materials.

Theme 1: Ideation

The first theme, labelled *Ideation*, encompassed a variety of activities aimed at fostering and refining ideas for design projects. This theme provided the foundation for the subsequent stages of the design process. Within this theme, activities were geared toward nurturing creativity, problem-solving, and idea generation to shape the early phases of design concepts. The resulting affinity diagram for this theme was subsequently divided into two additional subcategories, as elaborated below:

1. **Problem Definition:** This category involved activities related to defining the problem statement, its context, and the challenges that needed to be addressed. Participants frequently mentioned using design and planning tools (14 out of 30) for activities such as, mind mapping and brainstorming, with particular emphasis on idea generation tools such as Paper, Pinterest, and Miro.

2. **Context Building:** In this category, participants focused on outlining the basic design structures, layouts, and functionalities. Sketching and drawing played a dominant role, with designers relying on visual representations to clarify and communicate their design concepts effectively across 18 sketching/drawing tools.

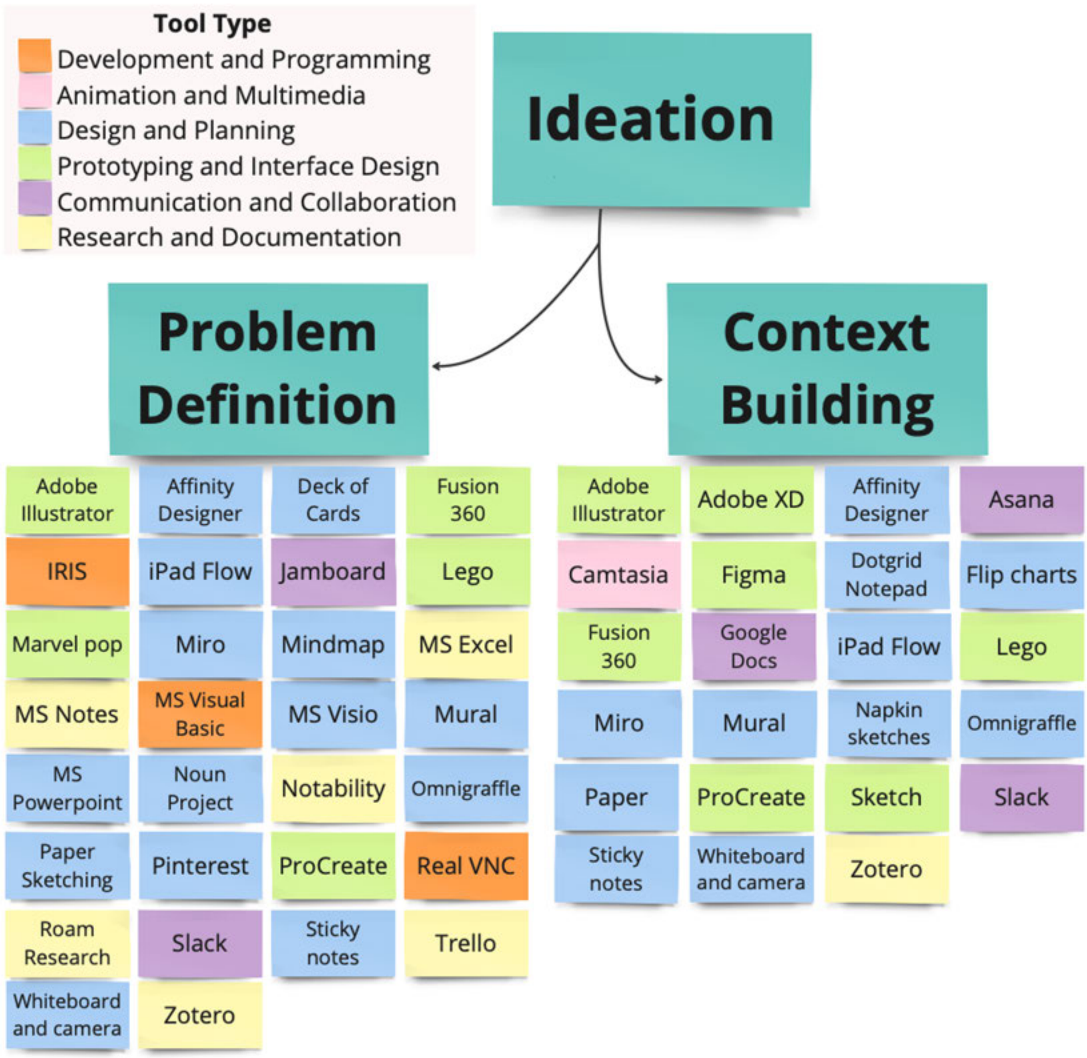

Figure 6.4: Affinity Diagram for *Ideation* Phase Showing Tools Categorised into Problem Definition and Context Building Themes, with tools colour coded by type.

The resulting affinity diagram can be seen within Figure 6.4. Among the 39 tools used by participants in this phase, 17 were categorised as design and planning tools, with seven of them being non-digital tools like paper and post-it notes. This observation underscores the importance of quick and tangible creation during the ideation phase, with a particular emphasis on sketching. Iterative design, occurring often during ideation, benefits from the ease and low cost of non-digital tools.

In this theme, designers engaged in activities that fostered creativity, problem-solving, and idea generation. Two main categories, *Problem Definition* and *Context Building*, emerged, emphasising the importance of defining problem statements and creating visual representations of design concepts during ideation. The dominance of sketching and tangible tools in this phase highlighted the preference for quick and tangible creation, often using non-digital tools like paper and post-it notes. Overall, the design ideation phase was characterised by an interplay between problem definition and context building, with designers using a diverse set of tools to nurture creativity and innovation, ultimately driving the development of user-centred design solutions.

Theme 2: Design and Development

The *Design and Development* phase bridged the gap between the ideation phase (*Theme 1*) and the prototyping phase (*Theme 3*) in the participants' design process. It involved a transition from conceptual ideas to detailed design concepts. The process entailed creating low-fidelity prototypes for issue identification and resolution before progressing to higher-fidelity prototypes. Key activities in this phase included storyboarding, wireframing, and the application of the Wizard of Oz (WoZ) technique. A total of 27 tools were used with a shift in tool usage towards prototyping and interface design tools, marking the transition from initial ideas to the early stages of prototype development. The resulting affinity diagrams from this phase can be seen within Figure 6.5. The *Design and Development* phase was further divided into three subcategories:

1. **General:** This category encompassed general design and development activities that did not specify particular techniques. There was an emergence of animation and multimedia tools and documentation tools within this phase, indicating a transition to more robust and comprehensive designs.

Figure 6.5: Affinity Diagram for *Design and Development* Phase Showing Tools Categorised into General, Storyboards/Wireframing and Wizard of Oz Themes, with tools colour coded by type.

2. **Storyboarding/Wireframing:** This category focused on context based designing and functionalities with storyboarding tools for creating designs with fictional users interacting and wireframing tools helping to visualise the possibilities for screen based designs. Within this phase the move away from tangible tools such as paper into digital tools such as Figma begins to show.

3. **Wizard of Oz (WoZ):** This category focused on the application of the WoZ technique, simulating automated system responses through manual task execution for rapid iterative design. It involved a return to tangible tools like Arduinos, highlighting the need for testing user experiences before full-scale development.

This phase acted as a bridge between ideation and prototyping, focusing on refining initial ideas into concrete design concepts. The subcategories emphasised context-based design and functionalities and quick iterative design and functionality testing. Tool usage shifted from the predominantly sketch-based designs and planning tools observed in the *Ideation* phase to an increasing reliance on prototyping and interface design tools. This shift indicated the transition from initial ideation to the early stages of prototype development, ensuring that designs aligned with user needs and expectations before building high fidelity prototypes.

Theme 3: Prototyping

In the *Prototyping* phase design process, where designers shifted their focus towards creating robust prototypes ready for user interaction and feedback (*Theme 4*). This phase built upon the foundations laid in the earlier phases and introduced subcategories that reflected the diverse range of prototypes being developed. Across the 42 tools used, this phase exhibited a noticeable shift in tool usage patterns, with an increase in the adoption of development and programming tools (10 tools), which were more time-intensive and geared towards creating functional and interactive prototypes. Additionally, communication and collaboration tools became more prominent (7 tools), emphasising the importance of team collaboration and sharing among participants during this phase. The resulting affinity diagrams from this phase can be seen within Figure 6.6. The *Prototyping* phase was further divided into four main categories:

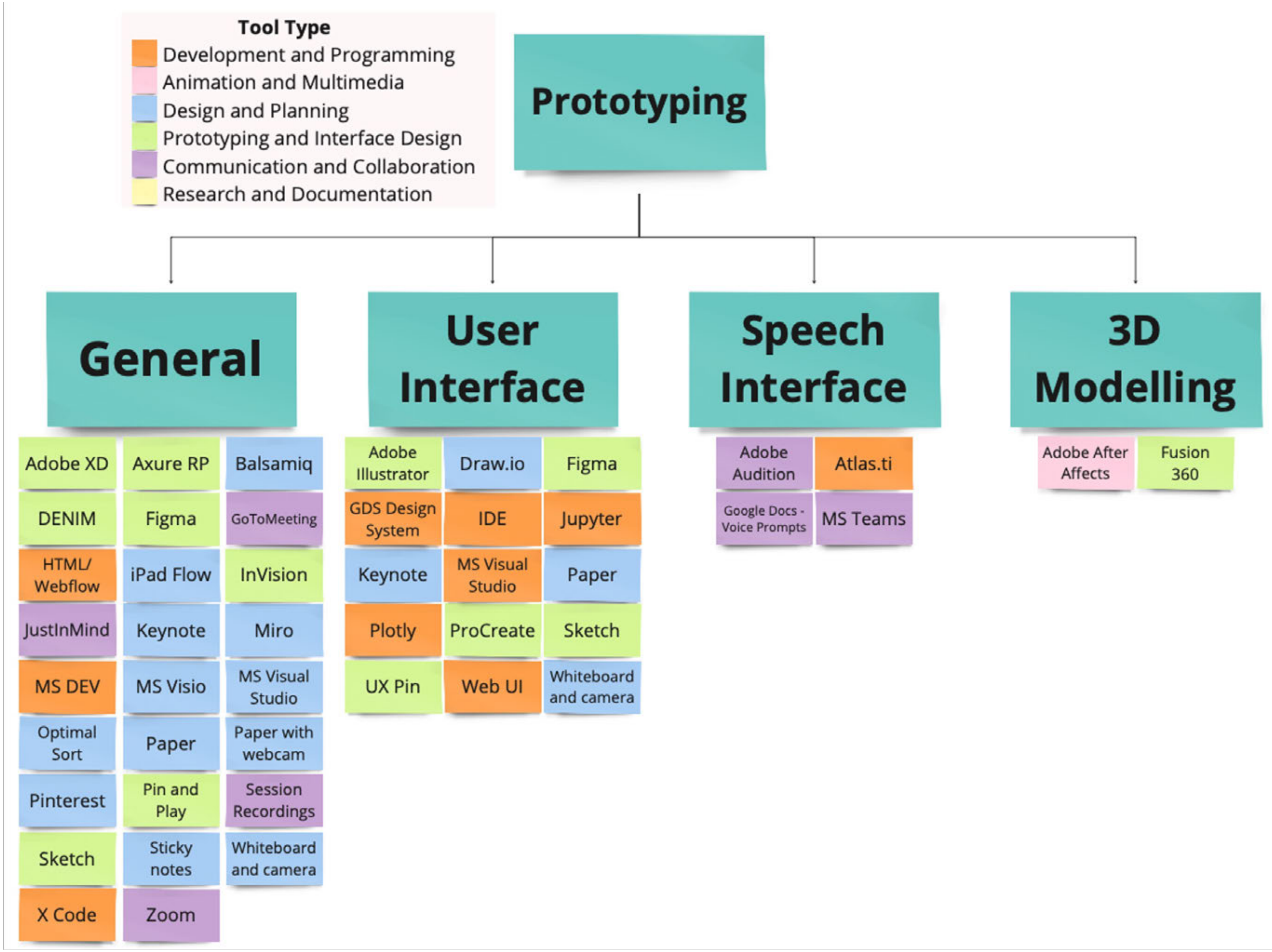

Figure 6.6: Affinity Diagram for *Prototyping* Phase Showing Tools Categorised into General, User Interfaces, Speech Interfaces and 3D Modelling Themes, with tools colour coded by type.

1. **General:** This category encompassed a broad spectrum of prototyping activities where the type of design being created was not mentioned. The prototypes created in this category served as the final representations of their design concepts, with a dominance of tools returning back to design and planning tools (12 tools) which could display the prototypes created.

2. **User Interfaces (UI):** Within this subcategory, designers concentrated on crafting prototypes that specifically addressed UI aspects. These prototypes aimed to fine-tune the visual and interactive elements of their designs, ensuring a user-friendly experience, with development and programming tools to achieve these functional designs being the dominant tools (6 tools).

3. **Speech Interfaces:** The emergence of *Speech Interfaces* as a distinct subcategory in the Prototyping phase signified a noteworthy shift in design projects. Designers in this category concentrated on developing prototypes that introduced voice interaction elements, allowing users to interact with the system through spoken commands or incorporating auditory outputs as part of the user experience. Limited tools are available for incorporating speech interfaces of this kind and the tools that are available are collaboratively oriented.

4. **3D Modelling:** In this subcategory, creating prototypes that provided tangible and immersive user experiences, particularly projects involving physical products or virtual reality applications.

Overall, the prototyping phase showed the diverse nature of prototypes created across UX design and highlighted the adaptability and innovation demonstrated by designers in preparing their designs for user testing and refinement. The four subcategories focused on covering various prototyping activities, fine-tuning visual and interactive elements, introducing voice interaction and, exploring three-dimensional and immersive experiences. There was a significant increase in the use of development and programming tools, highlighting the shift towards functional and interactive prototypes.

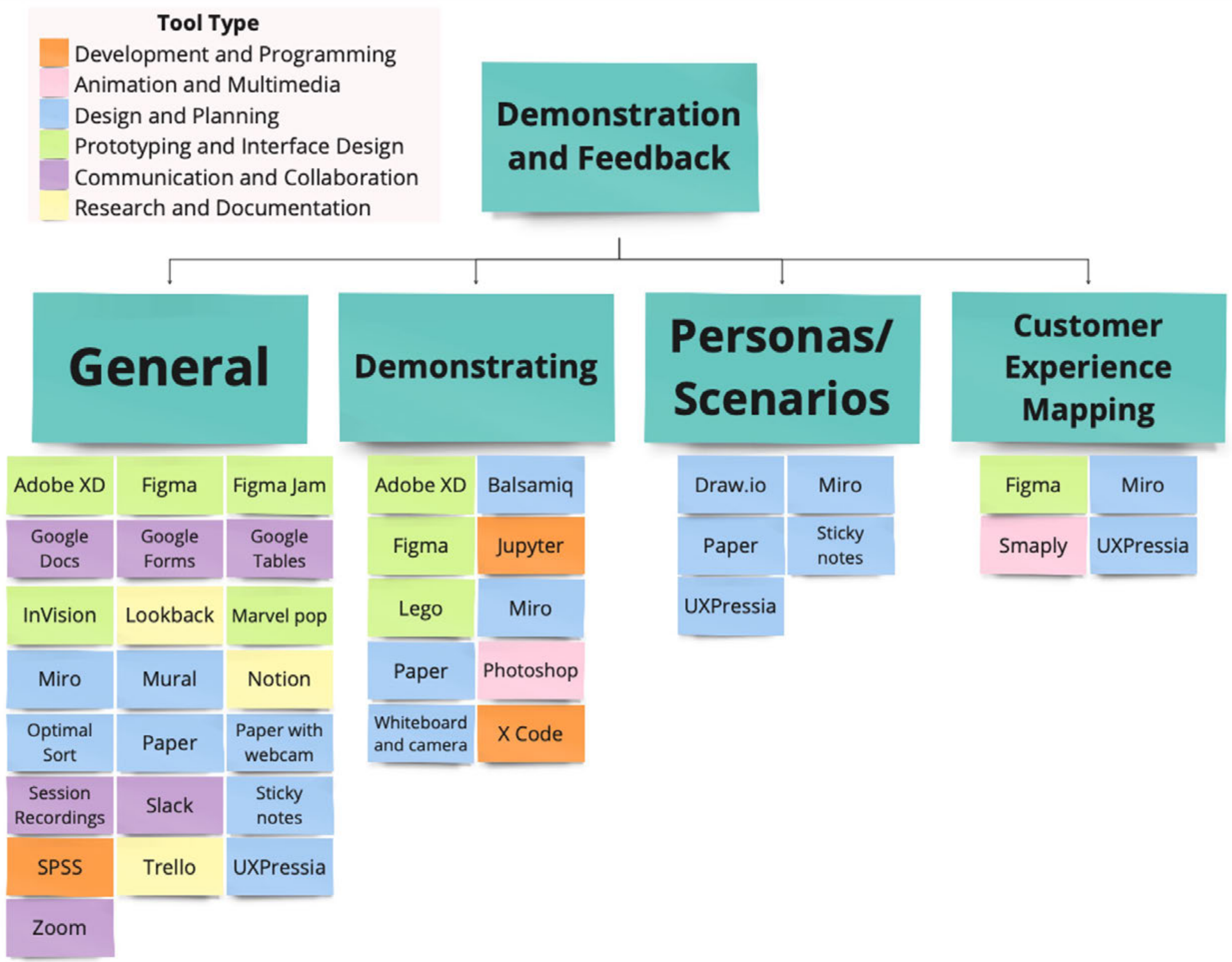

Figure 6.7: Affinity Diagram for *Demonstration and Feedback* Phase Showing Tools Categorised into General, Demonstrating, Personas/Scenarios and Customer Experience Mapping, with tools colour coded by type.

Theme 4: Demonstration and Feedback

The *Demonstration and Feedback* theme marks the final stage in the design process, concentrating on the tools used within user feedback sessions. e.g., interviews and focus groups. Additionally, this phase encompassed the tools used to demonstrate any prototypes created within the previous phase. Overall 30 tools were used in this phase, returning to the dominant use of design and planning tools (18 tools), which were intrinsic to the designers user feedback sessions. There was also an increase in collaborative design tools (6 tools) like Miro with several mentions of their increased use in the context of the COVID-19 pandemic when these design workshops were conducted. The resulting affinity diagrams from this phase can be seen within Figure 6.7. The *Demonstration and Feedback* theme was divided into four subcategories:

1. **General:** A wide range of tools used in various aspects of user feedback sessions and prototype demonstrations. Whilst there was an emphasis on design and planning tools, many of these tools were also collaborative tools, with collaborative tools also in high use within this section (e.g., Miro).

2. **Demonstration:** Designers focused on tools that aided them in the demonstration of their prototypes and design concepts to stakeholders, users, or team members, with tools used to create the prototypes within the previous phase (*Theme 3*) commonly used to also demonstrate those designs within this phase. e.g., Figma.

3. **Personas/Scenarios:** Designers emphasised the importance of providing contextual help when describing prototypes. They used tools that helped create and present user personas and scenarios, enabling a deeper understanding of the user experience, all of which were design and planning tools, with emphasis on paper based sketching.

4. **Customer Experience Mapping:** This subcategory was centred around tools used to visualise and map the customer experience, providing insights into how users interact with products or services, with animations mentioned consistently throughout this subcategory as the most useful in providing these for participants.

The *Demonstration and Feedback* theme underscores the importance of effective communication and collaboration with stakeholders and users to gather valuable feedback and insights. It highlights the role of collaborative design tools, especially in a remote or socially distant working environment, where tools like Miro played a crucial role in facilitating these activities.

Affinity Diagramming Summary

Completing affinity diagramming provided insights into the diverse and dynamic landscape of tool usage within the UX design process for the 24 participants. Through in depth analysis, four main themes emerged, providing the following insights:

1. **Diverse Tool Ecosystem:** The findings underscore the diverse set of tools used throughout the UX design process, emphasising the need for designers to be proficient in various tool categories, including design and development, prototyping, and collaboration tools and also emphasising the lack of one tool for all processes.

2. **Iterative Nature of Design:** The prevalence of iterative design practices, especially in the *Design and Development* and *Prototyping phases*, highlighted the importance of tools that enabled the refining and iterating design concepts to enhance usability and effectiveness.

3. **Remote Collaboration:** The COVID-19 pandemic's influence on tool usage was evident, with collaborative and remote-friendly tools like Miro playing a pivotal role in maintaining effective communication and collaboration during remote work scenarios.

4. **Emerging Trends:** The emergence of speech interfaces and 3D modelling tools indicated a shift towards incorporating more novel interactions with multimodality and immersive experiences into UX design projects.

Overall, the analysis of tool usage within the UX design process offered valuable insights into the evolving landscape of design tools, iterative design practices, and the role of collaborative tools, which can inform and enrich the existing literature in the field of human-computer interaction and UX design.

6.3.4 Thematic Analysis

This section focuses on the third stage of analysis, which focuses on thematic analysis and qualitative requirement creation. Through meticulous analysis of the data harvested from the online workshops, themes, trends, and unmet needs were discovered. This qualitative exploration provides a comprehensive understanding of the evolving demands and expectations of UX designers. This is where the blueprints for the future of design tools starts to form, guided by insights and experiences of designers navigating this ever-evolving space.

Thematic Analysis (TA) was chosen to analyse the transcriptions recorded during the four workshop sessions due to its user centred approach and compatability with workshop data. Braun et al. [51] recommend conducting "four or five" in-depth interviews or data samples for this process. After exploring best practices for applying thematic analysis in an HCI context [250], the subsequent analysis and results are presented in a similar manner, offering a comprehensive overview of the findings. Moreover, collaborative analysis is often recommended for thematic analysis to incorporate diverse perspectives, mitigate researcher bias, and improve the validity and reliability of identified themes and patterns in qualitative data [66, 119]. Therefore, the author conducted the analysis collaboratively with Prof. Dix and Dr. Sturdee during two in-person sessions to ensure a comprehensive approach. The coding was completed manually with print-outs of the transcriptions and highlighters, where the highlighted sections were converted into post-it notes and then codes for sorting and discussion.

Below, the six stages followed for thematic analysis are outlined, with an additional sub-stage* in the process that involved coding and sorting information from *Workshop 1* as an initial standalone step to consolidate the thematic analysis process in the minds of the researchers. This was done before returning to *Stage 1* to complete the final coding and theme development.

1. **Familiarisation:** The full transcription for all workshops were printed and bound, and each researcher conducted a careful read through, making notes if needed.

2. **Initial Coding:** This exercise was done inductively. On an individual basis, each researcher highlighted potential items of interest, and noted down ideas for codes.

The transcriptions and notes were then discussed, line by line, and codes generated collaboratively. These were transcribed onto post-it notes during the process. Examples include items such as: *use of pen and paper*, *screen bias*, *hacking existing software*, *experience design*, or *multimodal support*.

3. **Theme Search:** The codes on post-it notes were spread out in a large room and an initial card-sorting of codes into affinities was conducted. Initial themes were then generated,(e.g., *Complex World*) with photographs then taken of the result.

4. ****Sub-stage:*** Here, a break was taken, with the researchers returning to the transcripts to complete the note-taking and code discussion phase in a second sitting (see Thesis timeline 1.1), having become more confident in the process. Codes from the remaining three transcripts were generated, and merged with the initial codes, having de-linked the initial theme headings. A second Theme Search was then conducted.

5. **Theme Review:** The themes were reviewed within the context of the transcriptions, to consolidate thoughts, avoid 'bucket themes' and check the background of each code to ensure it had been interpreted correctly. The themes were adjusted if needed (including the addition of sub-themes), to better reflect the contained codes, and any outliers discussed until consensus was reached.

6. **Naming & Definition:** The codes, themes and sub-themes were transcribed into a spreadsheet, and further refinement took place (e.g. merging duplicated codes, making connections between themes, and considering the bigger picture).

7. **Report:** Writing up and any final development and refinement of the themes was completed.

In the sections below five themes and corresponding sub-themes, in line with examples from the transcription data are described. In addition, the inclusion of a separate subsection on *Requirements* in Theme 5 (One Tool To Rule Them All) is provided, as during the Theme Review it was identified that a 'bucket theme' (Wishlist) had been formed where participants simply stated what they wanted from a new interface. This was not picked up upon in the initial coding, but was realised during sorting and discussions, as whilst of interest, it does not provide the same qualitative and analytical depth compared to the other themes and sub themes. Following its separation from the main themes, the review stage was continued, of which the results are described below. The requirements/wishlist codes were then subject to a second review and sorting process and are reported at the end of the results section for Theme 5.

This thematic analysis resulted in five themes: (1) *Complex Process, Complex People*, (2) *Growing Pains*, (3) *Barriers to Access*, (4) *Supporting a Multimodal World* and (5) *One Tool to Rule Them All*. The theme and sub-category names were created collaboratively. The 'One Tool' theme also includes tables of requirements which elaborate on the needs of the user base that were interrogated. In Figure 6.8, an overview of the final grouped post-its, as well as a specific example illustrating the 'Pain Points' group can be seen showing how the final post its were congregated into groups which could be easily adapted. These visual representations help convey the structure and content of the thematic analysis findings, offering a glimpse into the key themes and patterns that emerged from the workshop discussions.

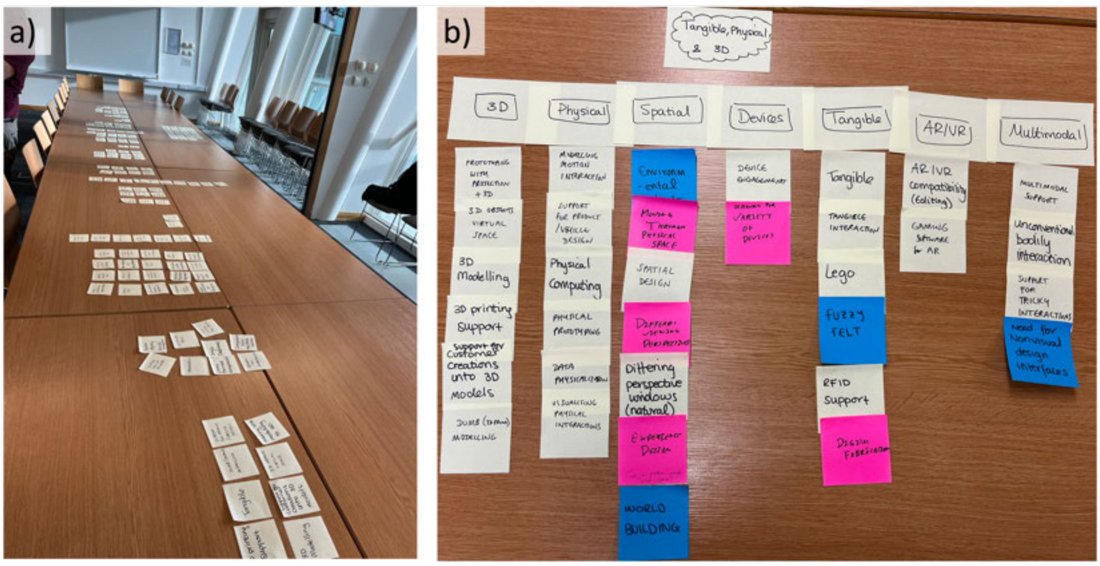

Figure 6.8: Overview of Final Grouped Post-its from the first thematic analysis session (Left) and Specific Example of “Tangible, Physical & 3D” (Right).

Theme 1: Complex Process, Complex People

UX processes are well documented but increasingly complex, and can incorporate many designers and developers, stakeholders and user groups, all with different expectations and needs. The diversity of participants in terms of role and experience illuminated the range of use cases and applications and the tensions between stages and stakeholders.

Who Does What & How (1a)

> "A lot of the **pain points are people issues**, how to manage people, how to take data from one place to another place and analyse it there" *P4, W1*

> "I do all of the diagramming in the same tool, and then the designers use different tools, and **basically everyone uses different tools**." *P3, W1*

When working with design tools, different people have specific preferences and methods of working that are often ingrained – such as the preference of some users to go 'the long way around' rather than learning a new technique or tool (mindlessness trumps efficiency). Furthermore, beyond tool use, there are often problems with communication, conversion between stages, and commentary, and some participants stressed the difficulty with both people management and data transfer.

> "... working with a big team of designers and using lots of different tools for different stages of the design process, but **it's hard to move from one to another**" *P1, W3*

> "When you work with projects, [we] **don't like to tell people what they have to use** which is why they use so many tools." *P5, W4*

The issues appeared to be either person centred, or tool centred, with the UX process appearing to be a free-for-all when working across teams, sites and stages. These issues could be solved in theory, with a *Master Design Suite* (Theme 5) but only if all stakeholders adopted it, which presents its challenges. People have diverse needs, wants, and desires, and the UX process is intricate, leading to a complex interaction.

The Collaboration Conundrum (1b)

> "When collaborating it's a pain to **join the different tools you use together**." *P3, W4*

Collaboration was consistently discussed during the workshops, in differing contexts. Showing that the UX process is not an insular one, and incorporating multiple points of view, allowing feedback, and communicating requires careful management and organisation of time and resource. Participants often found themselves using unrelated tools at the same time to support collaboration (e.g., using Miro, Zoom and Google Docs simultaneously), which could then cause issues with documentation and integration for the next stage, or when producing client reports.

The mismatch between online and in-person can also produce different results, with no clear path to a solution. The COVID-19 pandemic led to an "emergency response" (*P2, W4*) in the UX world:

> "...we use zoom, teams, and miro but its so **different to in person** user experience" *P2, W4*

This forced response however led to the rapid development and iteration of tools such as Zoom and Miro, as well as remote conferencing and interaction spaces such as Gathertown, which are now still in regular use despite the gradual return to an 'in person' environment, with the factor of the rise in remote working: "Design teams [are] **dispersed across the world!**" *P6, W2*. There is an increasing need to rely on digital collaboration within the UX process, both for client and team interaction, but also for user research and testing.

Theme 2: Growing Pains

Due to the nature of the workshop and its tasks, many of the attendees used the discussions to complain about the existing design tools. One reason for the expansion of UX design tools is the gaps in the market for specialised offerings that tailor to the niche, to be used alongside more 'all-round' tools such as, Figma. However, this has already led to a bloat in the market, and the creation of tools that are not fit for purpose.

Hacking for Functionality (2a)

> "... the [Balsamiq] scroll function **must be hacked to use**, but is just about good enough to show wireframes but nothing more" *P3, W3*

> "I **Hacked Denim** to let you add buttons and the ability to link things across and add in the RFID... " *P4, W4*

Some users either used their proficiency in coding to make workarounds, re-appropriated non-UX tools for their specific purposes, or used multiple UX tools for small, specific parts of their workflow. This increases the time taken to complete projects, and also does not always provide a complete solution.

There is also a barrier to most users taking advantage of hacking, as it requires a high level of proficiency in code and sometimes complex knowledge of hardware capabilities (in the physical prototyping space). In the latter quote, P4, W4 is not only hacking a system, but the system itself is experimental (DENIM [192]).

There, and Back Again (2b)

> "[I] start off with pens and paper, [with] a huge piece of paper [it] is easier to capture things. Working on multiple projects at the same time and **having a big piece of paper means being able to cross over and have multiple ideas at the same time**." *P6, W3*

Some UX innovation and design processes were supported by low-fidelity approaches such as sketching and paper prototyping which do not require complex tools or functionality. However, there are still issues with the physical/digital divide however, and despite advances in digital sketching, and image conversion, many practitioners frequently return to paper – especially for paper prototyping, which gives a tangible sense to moving through a user pathway.

Paper-based interactions were used as a timeless offline method for designers. The tangible act of sketching on paper can *bridge the gap* between designers and stakeholders, facilitating communication during the design process (a concept the author regularly used themselves with their stakeholders). Sketching on paper is known for its speed, accessibility, affordability, and ease of use. Furthermore, it can be applied across various stages of the design process, both in industry and academia continuously [158]. Nevertheless, as mentioned by participant seven in *Workshop 3* and questioned by participant four in *Workshop 4*:

> " How to **turn paper into something online** or photograph for scanning **is hard**" *P7, W3*

> " Paper prototyping, how do you move from that more **smoothly into the next stage?**" *P4, W4*

These tangible paper-based processes were well liked, and behaved in an expected fashion due to their non-digital nature. However, there are issues when it comes to integrating offline resources with online functionality, especially when working remotely. Some paper based tools (e.g. dotted notebooks which can be easily converted) and digital 'paper-like' tools (e.g. *Remarkable* [223]) attempt to bridge this divide, but are still stand-alone offerings in a digital world. In an ideal world, paper-based and offline approaches would be seamlessly integrated into the digital world (see Theme 5 *One Tool to Rule Them All*), enabling users to switch between approaches at will. The need to interact with the physical and tangible world not only with paper, but with objects and environments is also integral to future UX design (see Theme 4 *Supporting a MultiModal World*).

Cognitive Load (2c)

> "[I] **Don't want to be worrying** about which project is where and whether the project is in the correct place." *P5, W4*

> "...you don't want to have to use **two different apps at the same time**." *P3, W4*

The intricacy of certain multifunctional tools, such as Figma, can result not only in a steep learning curve but also in a substantial cognitive load, as users need to recall how each feature functions and how they integrate with one another. This heightened mental burden is exacerbated when designers are required to use multiple tools to accomplish their objectives. This problem is interconnected with sub-theme 1*b*, where multiple users collaborate across various tools, and the hand-off between these tools can introduce additional complexity.

> "An **easy tool that does not require registration or steps** to get onto collaboration would be good." *P2, W2*

> "[Use] lots of beta meeting, zoom, teams but [there are] **struggles with letting people view** at the time and **not making them feel overwhelmed**." *P4, W1*

Associated with the necessity of using multiple tools was the challenge of managing numerous subscriptions, handling various log-ins, and keeping track of file formats and storage locations (whether in the cloud or on local drives). Usability principles are typically aimed at minimising cognitive load (*"Don't make me think!"* [150]), but ensuring usability *across* different tools is not a priority for companies primarily focused on their individual products.

Moreover, the internal intricacies of these tools and their demanding hardware prerequisites can pose challenges for individuals lacking high-end equipment, such as someone attempting to run Adobe Premiere Pro on an older computer. The strain placed on the machine's processing capacity can also be considered a form of cognitive load. This complexity-related issue further extends to the time required to accomplish tasks, as indicated by one participant who noted:

> "it requires a **significant amount of time** to export a design into Miro" (P1, W4)

Theme 3: Barriers to Access

Accessibility is a critical concern within the realm of digital UX design tools. Historically, users could obtain single licenses by purchasing physical disks and a license key. However, the landscape has evolved to include digital subscription models, which may deactivate access if the user fails to log in regularly. For individual users, particularly those in self-employment, this subscription-based model can be cost-prohibitive, especially when multiple tools with specific functionalities are required.

Moreover, accessibility issues extend beyond economic considerations. Many complex UX design tools are not developed with the needs of all users in mind, rendering them incompatible with assistive devices such as screen-readers or voice activation. Designing for the inclusivity of all users also necessitates addressing the learning curve associated with software, recognising that not all users possess expertise or programming skills (see 2a).

The Cost of Doing Business (3a)

> "Miro is quite expensive, **lots of the tools are expensive for start ups**" *P3, W4*

Individual freelancers and small businesses often operate within constrained software budgets. While some software providers offer *free trials* or limited-functionality free versions, these options typically come with short expiration dates or restricted features (see Appendix E for an overview of free trials by tool). Additionally, some larger enterprises may mandate specific tools that they expect contractors and freelancers to use. This requirement can create a high barrier to entry for pitching new jobs and maintaining multiple clients.

> "...OptimalSort **is overpriced for what it offers**" *P5, W4*

Users often face a trade-off between cost and functionality when choosing software and tools. They must weigh the price of a tool against the features it offers, evaluating whether the investment justifies the cost. Additionally, users need to consider whether they can sustain a subscription over time or if a one-time purchase can be reused for future projects. This decision-making process requires users to assess the value they receive from their chosen software and its long-term viability for their needs. For example, Adobe XD [4], required for adding ALT text to conference submissions, costs 623.76 annually but may not be needed for other projects.

Design for ALL and ALL for Design (3b)

> "[We need] **voice activation and annotation**. Making sure that the tools aren't just focused around expensive equipment." *P7, W3*

Ensuring usability for all users goes beyond just providing accessibility support; it involves making the tool easy to learn and use without requiring extensive commitment or causing unnecessary difficulty. Usability principles emphasise the importance of creating user-friendly software, and these principles should extend to the tools used by designers and developers.

> "Using Miro at first there is a **high entry bar** for people who are not designers. People who have not used it before **requiring a bit of training**."
> *P4, W1*

The learning curve associated with some UX design tools can be a significant barrier. Tools that have steep or lengthy learning curves may not be practical for short-term projects, students, or individuals who do not have coding skills. While tools with broader appeal, like Miro, may take these factors into account, specialist tools such as D3 [61] for data visualisation often have a high barrier to entry for users outside their specific domain of expertise. It is essential to address these challenges to make UX design tools more inclusive and accessible to a wider range of users.

Many UX design tools, including both free and paid ones like Miro and Adobe, lack support for screen readers. This deficiency, which may be attributed to the complexity of these tools, creates a significant barrier to use for individuals who rely on screen readers for accessibility. Additionally, despite advancements in Conversational User Interfaces (CUIs), voice activation remains an under used interaction method in these tools.

> "[I] want a master design centre ... also supporting non-visual like audio and brail, **more focused around accessibility**." *P2, W1*

To ensure true accessibility, it is not enough to just provide support for access; UX design tools should be designed with accessibility in mind from the outset. This approach involves considering the needs of all users, including those with disabilities, and implementing features and interactions that accommodate a wide range of users, including those who rely on assistive technologies. Designing for accessibility is a crucial step in making these tools more inclusive and usable for everyone.

Theme 4: Supporting a MultiModal World

> "[We] Need some more help focusing on **multimodal design tools**". P4,W2

The emergence of novel interfaces such as, VR, AR, large-format surfaces, conversational user interfaces (CUIs), tangibles, shape-changing interfaces, interactive surfaces and environments, and even brain-computer interfaces has expanded the design landscape far beyond the traditional $2D$, planar screen-based experience design. This evolution necessitates a shift in thinking, moving from a focus on designing for $2D$ screens to considering the diverse needs of humans as multimodal beings.

While there are already commercialised offerings in some of these domains, such as Amazon Alexa [9] as a CUI or various medical innovations like the SecondSight eye implants [253] (despite their discontinuation), many of these developments have occurred without adequate support from UX design tools. Even sound design, a fundamental aspect of many user experiences, is inadequately supported by current tools. As Participant 4, in Workshop 2 points out:

> "Sound design is a **critical component of user experience**, and it's surprising that there are so few tools that cater to this aspect of design." P4, W2

This underscored the pressing need for UX design tools to evolve and adapt to the changing landscape of user interactions, encompassing both traditional and emerging modalities. This finding is in line with the design work explored within the previous chapters where new approaches had to be sought to build multimodal rigs.

You Can't Touch This! (4a)

> "combining customer blueprints with 3D objects, inspired about modelling interactions with **physical objects in a virtual space...**" *P2, W3*

Tangible interfaces are a prominent and evolving area of interest in Human-Computer Interaction. In numerous instances, tangible interfaces have been deployed in public spaces, and some of these installations continue to be operational long after the conclusion of their initial research projects [42]. Additionally, there are tangible interfaces being developed within various industries, often without the aid of dedicated commercial UX design tools. The pursuit of bridging the gap between the physical and digital realms is a highly relevant and widely discussed theme. This bridging can extend to the realm of prototyping, encompassing both on-screen and 'in-hand' interactions simultaneously.

The Sound of Silence (4b)

> "I have not come across any low-level **design tool for speech interfaces**" *P5, W1*

> There's **nothing to represent conversational technology** which is mainly what were working on. P4, W2

Considering the widespread adoption of voice assistants and Conversational User Interfaces (CUIs) in today's digital landscape, it is somewhat surprising that commonly available design tools do not provide adequate support for vocal and audio interactions. This deficiency could be attributed to the use of proprietary technology by some companies or, perhaps, the fact that the demand for such features is not yet widespread, potentially limited to academic and niche circles. Nevertheless, it is noteworthy that audio support and sound design emerged as recurring topics of discussion during the workshops, with relevance to both accessibility concerns (as discussed in 3b) and speech output functionalities.

> "Everything is tailored to visual design; **sound is not considered at all**." *P1, W3*

It is important to recognise that designing for speech interfaces and addressing sound design for music or environmental audio output are distinct yet interconnected aspects of UX design. As the design landscape evolves to accommodate multimodal interactions, comprehensive UX design tools should incorporate support for both of these facets. This would ensure that designers could effectively craft experiences that involve not only vocal interactions but also the broader auditory context, which includes music, sound effects, and environmental audio elements.

Designing Experiences, Not Screens (4c)

> "...there are multi-channel ways of making a prototype, but **only to make a screen**" *P2, W4*

The evolving landscape of technology and user interactions calls for a broader perspective on design, moving beyond the traditional screen-based interfaces. The future of design encompasses a holistic approach to experience design, integrating various interfaces and modalities seamlessly. This includes transitioning between screens, VR environments, audio interactions, and tangible interfaces to craft immersive and engaging user experiences that transcend the limitations of any single medium [208]. Designers must adapt to this dynamic environment by leveraging versatile UX design tools capable of accommodating these diverse modalities and fostering creativity in multimodal experience design.

> "...idea, prototyping sound in 3D: **how to prototype a whole environment** not just a string." *P1, W3*

Immersive experiences present unique challenges in the design process. The inability to effectively prototype and test these complex interactions can hinder iteration and innovation. However, as technology continues to advance, designers must explore new frontiers, including sensory dimensions like smell [44], and emerging technologies such as Brain Computer Interfaces (BCI) [116]. Incorporating these elements into the design process requires innovative tools that can support the ideation, prototyping, and testing of multisensory and brain-computer interactions. By developing such tools, designers can unlock new possibilities for creating truly immersive and inclusive user experiences in the digital realm.

> "[Need] Lots of items with a range of different tools so that you can do **lots of different environments** that **don't just focus on web based or app-based things**." *P3, W4*

A case study involving Participant 4 from *Workshop 1* provides a compelling example of the challenges faced by designers working in innovative and multi-dimensional environments like escape rooms. In such contexts, designers must seamlessly integrate digital interactions with physical objects within a physical space. This integration requires consideration of various interaction modalities, including tangible, sound-based, and screen-based interactions. Additionally, there is the potential to incorporate AR and VR functionality into the overall experience. This case underscores the need for design tools that can accommodate the complexity of such multimodal, environmental interactions, enabling designers to create cohesive and immersive experiences that blend the digital and physical realms seamlessly.

Theme 5: One Tool to Rule Them All

> " ... a digital tool that as a team you can log in and **all the tools are in the same place, everyone can access everyone's stuff** in a streamline, not having to log into different applications." *P1, W3*

The workshops clearly highlighted the demand within the design community for a comprehensive, user-friendly, and cost-effective tool that addressed a wide range of needs. This tool should offer a seamless experience, support both current and future requirements, facilitate digital-to-physical and vice versa interactions, consider context and environment, provide open-source options, and include extensive libraries for diverse situations. While theoretically, such a tool seems feasible, the question that arises is whether it is plausible to develop and implement such a tool given the complexity of these requirements and the evolving nature of design technology.

Magical Realities (5a)

> "There is **no single tool or device that can do all the processes**. Move from paper, to iPad, to computer, to laser cutter/ 3D printer." *P5, W2*

The aspirations and criteria for a *Master Design Suite* are theoretically achievable given the current state of technology. However, bringing such a tool to life would demand an unprecedented level of resources, time, and collaboration between industry and academia. While existing multi-function tools like Figma and suites such as Adobe Creative Cloud are making strides in this direction, there are still gaps to be filled, especially in accommodating novel technologies and innovative design approaches, as well as addressing the challenges of bridging the physical and digital realms. Whether such a suite or tool will become a reality is another matter, despite the anticipated demand.

Viewing the Big(ger) Picture (5b)

> "**Branching narratives at different levels**, surface map to storyboards to wireframes." *P3, W1*

In addition to the environmental design discussed previously, there are other supporting processes that involve discrete interaction modalities and presentation methods. Through the use of contextual prototypes, it is possible to explore the possibility of extending design thinking beyond a mere storyboard. This envisions a tool that could seamlessly transition from storyboards to the libraries supporting them and the scenarios that inspired them. The UX design process is inherently interconnected rather than strictly linear (as shown within the Affinity Diagramming analysis), and an ideal master tool should facilitate communication between these different facets, providing a top-level view that allows designers to navigate between various levels of detail with ease.

The integration and consideration of the *big picture* must also encompass people and their diverse perspectives. Visual storytelling is a significant aspect of the UX process, and while there are numerous tools available (including traditional paper-based methods) to support this, there is a growing demand for seamless integration that connects the narrative with all the intermediate steps in the design journey.

> "In a complex world of different modes of interaction, **the context of the user should be central to the software that we are using with everything else surrounding around that**." *P5, W1*

This final quote underscores the idea that the user remains central to the design process. Consequently, a tool that revolves around the central concept of a *user node*, mapping interactions, environments, and narratives, could be a viable approach for the envisioned master tool.

6.3.5 Requirements for the Master Design Suite

The outlined requirements for the Master Design Suite represent the collective aspirations and needs expressed by the participants across the four workshops. These requirements span from high-level ideals to more specific desires, reflecting the participants' vision for an ideal design suite.

At the highest level, participants hope for features such as a unified dashboard, seamless cross-platform access, and the capability to work offline, providing support for participants' diverse work environments - of particular interest as these workshops were completed during the COVID-19 pandemic where participants had less ability to vary their working spaces.

On the mid-level, participants requested features such as integrated video calls, version management across multiple stages, and linked note-taking tools to enhance collaboration and communication among diverse teams.

At the lowest level of granularity, participants requested features such as layer support and version tracking history, where designs could be re-evaluated from the initial to final stages of the process. These requirements collectively reflect the participants' hopes and expectations for a comprehensive Master Design Suite that caters to their interdisciplinary needs. The overall requirements for the Master Design Suite are provided within Table 6.3.

Table 6.3: General feature requirements for a Master Design Suite UX design tool showing different levels of granularity from top level features to in-program interactions.

Master Design Suite

Top Level	Mid Level	Low Level (Granular Details)
Single dashboard	Integration of video call software	Layers
Open any file type	Different version downloads	Merge
Master log in	Note-taking tool (linked)	Adaptable top level map
Share without registering	Multimodal support	Annotation and feedback
Personalisation	Multi-device designs	Jump between design level
Cloud usability	Low to high fidelity continuity	Version History
Open source	Analysis tools for design data	Dynamic panel choice
Offline availability	Easy data transfer	Code alongside visual
Preset Component library	Support for secure design	Multi-person spotlighting
Legacy management	Device/software conversion	
Easy to use	Backend analysis	
Constantly evolving interface	AI: Text to multiple formats	
Cross device compatibility	AI: Adjustment for user testing	
Customisable element bank	Converting paper to digital	
Links to software repositories	Screen share	
Individual library purchase	Multiple editor feedback	
	Tool for sharing ideas	
	Collaborative sketching	
	Link databases to designs	

Multimodal Support

A prominent theme that emerged from the requirements analysis centred on the extensive demand for multimodal support within the envisioned Master Design Suite, categorising it into three key areas: *3D/Physical*, *Voice & Sound*, and *Animation & Video*.

Within the *3D/Physical* category, participants expressed a strong emphasis on physical prototyping and modelling. They highlighted the need for tools that support physical interactions, including the ability to conduct Wizard of Oz (WOZ) studies. This requirement reflects the importance of bridging the gap between digital and physical design, enabling designers to explore and test ideas that involve tangible and spatial elements.

Table 6.4: Specific design features relating to 3D and physical interactions, voice and sound, and animation and video, suggesting major areas of focus needed for the Master Design Suite.

Multimodal Support

3D/Physical	Voice & Sound	Animation & Video
3D Modelling & Printing Support	3D sound environment	Animation capability
Physical prototyping	Voice/Audio annotation	Quick video examples
Data physicalisation	Transcription automation	Out of scene modelling
Support for product/vehicle design	Regional accent support	Multiple state viewing
Different viewing perspectives	Speech to prototype	Modelling motion interaction
Support for superimposing objects	Speech activation	Hypermedia comics
RFID support	Support for CUI	
Premade environments templates	Speech interaction	
AR/VR compatibility (editing)		
Environmental contexts		
WOZ support		

The *Voice & Sound* discussions were a major point of focus during the workshops, particularly in *Workshop 2*. Participants emphasised critical requirements such as transcription automation and speech activation. These features were deemed essential by several participants, underlining the significance of integrating voice and sound interactions into the design process. This aligns with the growing importance of voice-activated interfaces and the need for designers to create and test such interactions effectively.

The requirement for *Animation capabilities* highlighted participants' desire for advanced features related to animation and video. This included the need for out-of-scene modelling to prevent contamination of perfected models. Designers expressed the need for tools that support rich animations and video integration, enabling them to create more dynamic and interactive user experiences.

These requirements collectively underscore the importance of incorporating diverse modalities and designing abilities within the *Master Design Suite*. Currently, there is a gap in design tools that offer comprehensive support for these various modes of interaction and expression. Addressing these needs is essential to ensure that designers have the tools and capabilities required to meet the evolving demands of the field, where multimodal experiences are becoming increasingly prevalent and important.

Summary

The detailed layout of requirements for the Master Design Suite represents contribution to the research in several ways. First, it provides a comprehensive and granular insight into the specific needs and aspirations of UX designers, which has not been done in such depth and detail before. This level of specificity is crucial for guiding the development of future UX design tools and ensuring that they align with the real-world demands of professionals in the field.

Second, the layout of requirements serves as a valuable resource for both academia and industry. Academically, it contributes to the growing body of knowledge in the field of Human-Computer Interaction (HCI) by offering a structured and empirically derived set of requirements that can inform future research and development efforts. This can help researchers explore new avenues for creating more effective and user-centric design tools.

From an industry perspective, this detailed requirements layout provides a clear roadmap for tool developers and companies looking to create or improve UX design software. It offers insights into the features and functionalities that are highly sought after by UX professionals, potentially leading to the development of more competitive and user-friendly tools. In an increasingly competitive market, having a detailed understanding of user needs can be a significant advantage.

Furthermore, this contribution demonstrates the importance of incorporating user feedback and perspectives into the design and development process of UX tools. By actively involving UX designers in the workshops and eliciting their input, this research highlights the value of user-centred design practices, emphasising that the best tools are those that directly address the challenges and requirements identified by the end-users themselves.

In addition to the detailed layout of requirements, another significant emphasis that emerges from this research is the pressing need for incorporating multimodal support within the Master Design Suite. This represents a crucial aspect of the contribution to the research. The participants consistently highlighted the evolving landscape of user interactions, moving beyond traditional 2D, screen-based interfaces. The emergence of novel modalities such as Virtual Reality (VR), Augmented Reality (AR), conversational user interfaces (CUIs) and tangibles, underscored the importance of designing tools that cater to these diverse interaction modes.

Furthermore, participants stressed the significance of seamless integration between these modalities within a single design suite. Designing for multimodal experiences often involves integrating elements like physical objects, audio, and spatial interactions. Therefore, a tool that could seamlessly bridge the gap between these different modalities and provide designers with the means to ideate, prototype, and test across these varied interfaces is highly desired.

This emphasis on multimodal support represents a forward-looking perspective that acknowledges the rapid advancements in technology and the increasing demand for user experiences that transcend traditional screen-based interactions. It underscores the need for UX design tools to evolve and adapt to this changing landscape, offering designers the capabilities to craft holistic, multisensory experiences.

In summary, the detailed requirements layout is a contribution that advances the field of HCI research by providing a comprehensive understanding of UX designers' needs and expectations. It bridges the gap between academia and industry by offering valuable insights for both researchers and tool developers, ultimately aiming to enhance the quality and effectiveness of UX design tools in the future.

6.4 Discussion

The field of technology is on the brink of another technological leap, which, hopefully, will create a renewed interest in the development and adoption of new guidelines, tools, and ongoing research in User Experience Design. Within HCI, the UX community is large and dynamic, constantly generating novel prototypes and methodologies to assist designers in innovative ways. Many of these tools are developed and rigorously tested, yet they often fail to transition into widespread commercial adoption, despite offering excellent ideas and interactions (such as the case of *Longboard* [137]). This suggests that the pipeline from research to end-use requires better support and facilitation.

In the early stages of user interface development, Myers et al. [188] recognised the impending need for tools to support the evolution of user interfaces. Although their primary focus was on software development rather than design tools, it is worth revisiting the UI trends they foresaw at that time. These trends encompassed a widening array of devices beyond the conventional screen, keyboard, and mouse interfaces. This expansion included grappling with the physical challenges posed by large screens, the proliferation of ubiquitous computing devices in various environments, the advent of recognition-based interfaces, and the imperative to rapidly prototype not just software but also physical devices. Of particular note is the attention they paid to issues related to the physical context, such as interacting with large screens, as well as the emergence of diverse physical devices. While some of their observations align with contemporary software development toolkits and frameworks, the realm of UX design tools, especially those implemented at scale, has yet to fully embrace these insights.

Through the analysis of this work, a notable theme emerged: for many of the participants, their needs and wishes for future design tools lay more in the realm of interaction design than in the intricacies of system design, echoing the principles advocated by Beaudouin [24]. Tactile, auditory, and alternative modality interactions were at the forefront with traditional interface design, while undeniably crucial, often only focusing on visual elements of user-system interaction. This approach, at times, results in interfaces that are overly intricate or inflexible, failing to resonate with end-users or adapt to evolving requirements and technologies. Consequently, the data suggested the need for a shift in perspective, one that elevates the context of interactions above the narrow focus on visual aspects alone.

Prioritising the contextual dimension of interactions underscores the importance of creating intuitive, responsive, and natural designs that transcend the confines of specific interface elements [24]. This shift encourages the development of systems that not only fulfill functional requirements but also consider where and how users engage with these systems. For instance, a participant expressed the desire for their design students to not only envision the aesthetics of a washing machine but also contemplate the context in which it operates — whether within a student's cramped apartment, or a hotel laundry room, a difficult task with current tools.

In practice, designing interactions entails a holistic approach, encompassing factors like user context, workflow, feedback mechanisms, and the integration of innovative interaction modalities such as voice, touch, or gestures. It calls upon design tools to help designers to anticipate and accommodate diverse user preferences, abilities, and needs, fostering inclusivity and accessibility. By shifting the focus towards interactions rather than rigid interfaces, designers gain the flexibility needed to adapt to evolving user behaviours and emerging technologies, thereby enhancing the prospects of commercial adoption.

6.4.1 Accessibility & Education

Prioritising accessibility is paramount. It is essential for both the designs being created and the designers themselves that accessibility is incorporated. Accessible software means usable by anyone, and this is not the case with much of the current software in this design space. Accessible design is intrinsically linked to multimodal design, in terms of offering a range of interaction modalities to support a diverse user base [194]. However, this is very much a situation where one is needed to help design the other – there is a gap in the market to design and develop accessible technologies such as CUIs, tangibles and interactive surfaces and spaces. Many who experience differing abilities in using computers have to use hacks or work-arounds, get bespoke support, or suffer via systems that are not fit for purpose. If design tools could be developed to support both the interaction itself and the design *for* that interaction, then this would be a great leap forward for usability.

In terms of education, focus should be placed not only on the designs being created but also on nurturing designers who understand the importance of accessibility, which can have far-reaching effects across all disciplines [70]. Unfortunately, the current tool landscape falls short of the necessary features to enable educators to effectively emphasise the significance of inclusive design, potentially limiting their capacity to cater to the diverse needs of all their students. Furthermore, cost-effectiveness is a pressing concern, given the substantial financial barriers associated with existing design tools, even with educational discounts. Despite reduced prices, affordability remains an issue. Moreover, improving the learning curve for these tools is vital for effective education [70], emphasising intuitive, user-friendly options that cater to a diverse range of users. This is particularly crucial as students may enter industries where collaborative stakeholders have limited knowledge of HCI and UX processes. Integrating these implications will enrich HCI and UX education fostering inclusivity, affordability and ethical responsibility among students.

6.4.2 Collaboration

The analysis highlighted that the concept of a single, all-encompassing master tool would be ideal – but had its impracticalities. However, a potential alternative solution lies within encouraging UX tool companies to explore ways of promoting cross-compatibility while protecting their intellectual property and unique selling points (USPs). This approach could facilitate a more seamless integration of diverse tools, accommodating the needs of interdisciplinary collaboration within the community. It was discovered that, interdisciplinary collaboration has become and integral part of this community, necessitating the incorporation of collaborative tools into the design process. Design teams frequently comprise professionals from various fields, which can pose significant challenges if each stakeholder relies on different, potentially less intuitive tools for their work.

Moreover, the recent surge in remote work [282] has further emphasised the importance of tools that enable global accessibility and collaboration. Such tools would engage designers, researchers, industry professionals, and students from diverse backgrounds to collaborate effectively across various design platforms. This adaptability is crucial in addressing the evolving needs of the community and promoting efficient, inclusive and innovative design practices.

6.4.3 Novel Interactions

The initial motivation for this author stemmed from the realisation that existing design tools were ill-equipped to handle the creation of multimodal devices and interfaces, which were encountered while developing a series of such devices (see Chapters 3,4,5). This limitation was further corroborated by discussions during the workshops, where participants frequently highlighted the absence of support for tangible, environmental, or unconventional interfaces that extended beyond traditional screens and incorporated various modalities.

These novel interfaces, originally conceived in research settings, are gradually making their way into public and commercial applications [42, 215]. They are also appearing in community spaces as potential permanent fixtures [43] and even finding utility in industrial contexts like factory production lines [112]. This evolving landscape of interactive technology underscores the need for more flexible and adaptable design tools capable of accommodating these emerging and innovative interaction types.

Looking to the future, it becomes apparent that the current list of requirements, while comprehensive, is not exhaustive. Nonetheless, it offers invaluable insights into the work practices and requirements of a diverse user base. It is worth recalling Vannevar Bush's concept of the *Memex* [35], which might have seemed like wishful thinking at the time but is now a reality. In a world where data can be offloaded onto devices and machines, it prompts the pondering of what else might be possible in the realm of UX design tools. This chapter aims to contribute to the blueprint for the future of these tools, ensuring they evolve in step with the dynamic landscape of interactive technology and continue to empower designers to create exceptional user experiences across a wide spectrum of modalities and interfaces.

6.5 Conclusion

In conclusion, this exploratory chapter has explored the current landscape of practices, usage patterns, and interactions with UX design tools. It has revealed a diverse user base comprising researchers, practitioners, educators, and students, each with their unique interests and objectives. These users used a hybrid approach to digital design for user experience, adapting available tools to meet their specific needs.

Two proof-of-concept prototypes were created by Prof. Dix to demonstrate both the idea of contextual or environmental cues, and also integrating physicality into UX prototyping tools. These tools were presented during four exploratory online workshops where the futuring of UX design tools was explored. A detailed qualitative analysis of the data revealed that needs of the UX community are complex, but that advances are needed to support novel technologies and interactions, such as integrated software, and support for full context and environment design.

The findings suggested that the needs of the design community are changing, moving away from screen-based and application design, to designing whole experiences, environments, accessible technology, and pinpointing the needs of the individual user and designer. Demonstrating the need to consider the context and deployment of technology, in order to design better futures. The contributions centre around the evolving needs of the user base, and the identification of novel features and methods to improve UX design tools to benefit their community of users.

An overarching message from this work is the evident market gap. There is a clear demand for a comprehensive *Master Design Suite* that can effectively support the multifaceted and intricate requirements of both the people involved in the UX design process and the process itself. However, the realisation of such a tool remains a significant undertaking and is yet to be translated into actionable steps.

Nonetheless, this exploration has highlighted tangible opportunities for immediate improvement in the realm of UX design tools. These concrete steps can be taken to enhance the accessibility, collaboration, and multimodal capabilities of existing tools. By doing so, these tools can be better aligned with the evolving technology landscape and the changing needs of the user base, which, in turn, benefits the end users themselves.

Presenting these areas—accessibility, collaboration, and multimodality—as vital focal points for the future development of UX design tools underscores the potential for immediate improvement. This exploration can serve as a catalyst for interest and action within the research community. Researchers can further investigate and recommend interventions that will drive the evolution of UX design tools towards greater usability, effectiveness, and user-centredness.

The core message remains constant: the user should always be the focal point of our design efforts. While acknowledging that modern users engage with the world in diverse ways, extending beyond traditional screens, the commitment to prioritising the user in UX design remains unwavering. This commitment drives the evolution of tools, practices, and methodologies to adapt to the changing landscape of human-computer interaction and user experience design.

6.5.1 Chapter Contributions

Chapter 6 explored the evolving paradigms of User Experience (UX) design, emphasising the adaptation to individual user capabilities and the dynamic technology landscape. Rooted in prior chapters' challenges, it presented workshop findings that assessed the alignment of UX design tools with recent interface advancements and navigated the challenges of contextual, multisensory, and rapidly evolving digital design. Additionally, it investigated integrating multimodal elements into design practices. To summarise the contributions of this chapter began by identifying the shifting needs of the UX design community, moving from screen-based design to holistic, user-centred experiences. Followed by the introduction of the two proof-of-concept prototypes, demonstrating the incorporation of physicality into UX prototyping tools and enabling support for novel technologies and interactions. Furthermore, through in-depth qualitative analysis of workshop data, valuable insights into the future of UX design tools were provided, benefiting industry professionals, researchers, and students in navigating the evolving UX landscape. Finally, the chapter underscored the importance of addressing the evolving needs of the UX design community and advocated for user-centric advancements in UX design tools, aligning them with evolving technology and user expectations.

Chapter 7

Conclusion & Future Work

This thesis presents research which has been conducted to investigate how collaborative design can be employed to create installations in partnership with communities, fostering long-lasting engagement opportunities. This concluding chapter revisits the aims and objectives laid out in Chapter 1, reaffirming the contributions of this work to the field of urban planning, design and HCI. Additionally, it offers a contextual discussion of key points from Chapters 3, 4, 5, and 6 and possibilities for future work.

7.1 Revisiting Aims and Objectives

The *Introduction* states four research objectives for this work. Below, a description of how the work contained within Chapters 2-6 complete these objectives.

1. ***To investigate and demonstrate the pivotal role of user feedback and active participation in the cocreation process of urban regeneration projects***

   Throughout this research journey, the objective of investigating and demonstrating the role of user feedback and active participation in the cocreation process of urban regeneration projects has been thoroughly addressed. The cocreative approach detailed throughout this thesis, involving a diverse range of participants, including children, regeneration experts, and the wider community, exemplified the significance of user feedback and active involvement. Insights from participants played a central role in shaping the design and development of interactive public installations. This dedication to cocreation fostered a sense of ownership and empowerment, which, in turn, enriched the final deployments. This approach also ensured inclusivity, with careful consideration given to marginalised voices in urban design. The outcomes of this thesis illustrates the power of user-centricity, resulting in technologies that are not only advanced but also resonate with the needs and desires of the communities they serve. In essence, this work underscores the importance of user feedback and active participation in cocreation processes, reaffirming their role in creating more inclusive, culturally relevant, and impactful technologies within the realm of urban regeneration projects.

2. ***To conceptualise and design, and deploy novel interactive installations that leverage diverse sensory modalities to create immersive and captivating experiences***

   The overarching objective of redefining public engagement in city centres through immersive interactive installations using diverse sensory modalities has been realised through a comprehensive research journey. This journey began with the development and deployment of the Lookout installation in Swansea's city centre, illustrating the transformative role of technology in urban regeneration. An analysis of over $10,000$ sessions underscored the pandemic's impact and the critical importance of inclusive design and user-centricity. The inclusion of children in the design process marked a shift towards inclusivity, while stakeholder engagement guided a holistic approach. Furthermore, the multisensory prototype, assessed for emotional impact and user feedback, exemplified the potential of inclusive design and community involvement in urban technology. Simultaneously, Chapter 5 successfully tackled the goal of designing and deploying innovative interactive installations in city centres, reshaping public engagement through diverse sensory modalities. This contribution addressed a void in evaluating multisensory displays in outdoor public spaces, commencing with the design of a city-centred multisensory rig, followed by its refinement through thorough evaluations. Its deployment in a city centre provided practical insights and operational guidelines, while engagement with young citizens illuminated its appeal and inspired innovative possibilities.

3. ***To assess the real-world impact and effectiveness of alternate modality urban installations in city centre environments***

   By actively involving a diverse range of stakeholders, including children, community members, and experts, in the cocreation and evaluation processes, this thesis ensured that user feedback played a role in shaping the multimodal installations. Through extensive data collection, including an extensive dataset of over $10,000$ sessions from the Lookout installation, this research gathered empirical evidence that formed the foundation for assessing their impact. Additionally, data from the multisensory installation provided insights into recognition rates, comfort, and memory recollection. These comprehensive dataset offered valuable insights into user behaviours, preferences, and patterns, providing a comprehensive understanding of how these installations were perceived and interacted with in real-world urban settings. These insights, coupled with the collaborative efforts of various stakeholders, allowed for a refined assessment of both the positive aspects and challenges associated with alternate modality urban installations. Moreover, the research translated these findings into practical recommendations and best practices, enriching the field with actionable insights for future deployments. In essence, this research represents a holistic and robust approach to assessing the real-world impact of alternate modality installations, firmly establishing their role in reshaping urban environments and community engagement.

4. ***To address the lack of accessible tools for designing alternate modality technologies***

   This thesis effectively addresses the objective of tackling the lack of accessible tools for designing alternate modality technologies. Throughout the multi-chapter journey, the work not only conceptualised and developed innovative multimodal installations but also emphasised the importance of creating tools and guidelines to enable their design and deployment. The comprehensive exploration of multimodal technologies in urban environments, as demonstrated in Chapter 5, involved design considerations and practical evaluations, which served as the foundation for accessible and user-friendly tools. In Chapter 6, the current landscape of UX design tools was scrutinised, revealing gaps and opportunities for improvement. The findings underscored the demand for a comprehensive "Master Design Suite" to support the multifaceted requirements of UX design, addressing the lack of accessible tools. While acknowledging the complexity of such an endeavour, this research lays the groundwork for future tool development, ensuring that the creation of alternate modality technologies is made accessible to a broader range of designers and developers, ultimately fostering innovation in urban regeneration projects and beyond.

In summary, this research journey has effectively achieved a set of interconnected objectives aimed at advancing the field of urban regeneration and interactive technology design. It has demonstrated the role of user feedback and active participation in the cocreation process, emphasising inclusivity and community involvement. The work has conceptualised, designed, and deployed immersive interactive installations, a novelty for public engagement in city centres, leveraging diverse sensory modalities to create captivating experiences. Furthermore, it has filled a gap in the literature by evaluating multisensory displays in outdoor public spaces, contributing insights and guidelines. Additionally, the research has addressed the lack of accessible tools for designing alternate modality technologies, paving the way for future inclusive and user-centric design practices. Lastly, it has assessed the real-world impact and effectiveness of two multimodal urban installations, unveiling insights, challenges, and best practices through empirical data and user feedback. These achievements collectively position this research as a contribution to the fields of urban regeneration, multimodal technology integration, and user-centric design.

7.2 Chapter Summaries

From the development of immersive installations in city centres to the cocreation process involving diverse stakeholders, the exploration of multisensory displays, and an investigation into the landscape of UX design tools, each chapter contributes to the overarching goal of reshaping urban spaces, fostering community engagement, and advancing user-centric technology in urban regeneration projects. Together, these chapters form a comprehensive narrative that underscores the potential of inclusive and innovative approaches to urban development and can be summarised as follows:

Chapter 3: In this nine-month journey, marked by COVID-19 challenges and opportunities, the development and deployment of the interactive Lookout installation in Swansea's city centre exemplifies technology's role in reshaping urban regeneration. Collaborative workshops with diverse stakeholders resulted in a beacon of community engagement, reconnecting the public with their evolving urban space. Analysis of over $10,000$ sessions revealed the pandemic's impact on public engagement and the importance of inclusive design, wheelchair accessibility, and personalised experiences. Children and families infused energy into public spaces, while the overlooked demographic of elderly users highlighted the need for clear instructions in technology deployment. Real-life content like drone footage aided users' understanding of Swansea's transformation. This work emphasises involving diverse demographics in public display design and the Lookout's potential to enhance civic projects. Integrating technology into urban regeneration holds promise for reshaping community engagement in urban spaces, marking a paradigm shift born from unique challenges and opportunities.

Chapter 4: This research highlighted the power of a cocreative process involving diverse groups in shaping an urban technology prototype designed for city deployment. Inclusion of children in the design process marked a shift towards user-centric and community-involved development, recognising the need for inclusivity to address diverse community needs. Stakeholder engagement, including regeneration experts and community members, played a crucial role in guiding the research towards a comprehensive approach bridging creative ideation, practical applicability, and the interplay of sensory experiences and memory in urban regeneration. This cocreative effort not only embraced diverse perspectives but actively integrated them, exemplifying a commitment to technology resonating with and serving the entire community. The evaluation of the multisensory prototype went beyond mere accuracy, considering its emotional resonance, fostering connections, and user feedback for ongoing improvement. This multifaceted approach was instrumental in shaping a prototype connected to the community it aimed to serve. These designs then evolved in the preceding chapter into a city-ready prototype, deployed in a real urban setting to assess its effectiveness and impact, reaffirming the promise of inclusive design and community involvement in urban technology development.

Chapter 5: This chapter filled a gap in the use and evaluation of multisensory displays in outdoor public spaces. It commenced by thoroughly designing a multisensory rig tailored for city centres, refining it through comprehensive evaluations. The deployment of this rig into a city centre established operational guidelines and constraints, offering real-world insights into multisensory installations' adaptability. It highlighted the possibilities for multisensory technologies to evoke nostalgia and in doing so re-engage people with these spaces. Engagement with pupils highlighted its appeal to the younger generation, paving the way for innovative advancements. This research's holistic approach positions it as a contribution in multisensory technology integration in public spaces, with implications for urban environments worldwide.

Chapter 6: This exploratory chapter surveyed the current landscape of UX design tools, revealing a diverse user base with unique needs and objectives, ranging from researchers and practitioners to educators and students. It has underscored the demand for a comprehensive *Master Design Suite* to support the multifaceted requirements of UX design, though its realisation remains a significant undertaking. However, this exploration has highlighted immediate opportunities for improvement in existing UX design tools, particularly in the areas of accessibility, collaboration, and multimodality. These areas have been identified as focal points for future development, offering the potential for immediate enhancement. This chapter serves as a catalyst for further research and interventions within the UX design community, emphasising the enduring commitment to placing the user at the forefront of design endeavours in an ever-evolving landscape of human-computer interaction and user experience design.

7.3 Major Insights and Themes

By analysing the discussion points from Chapters 2–6 it was possible to identify the insights for the future of cocreation for community engagement in public spaces. These insights underscore the exploration of how cocreation, specifically tailored to the context, can enhance the design of interactive technology, ultimately fostering engagement and inclusivity within urban communities in public spaces. These insights incorporate the core focus of the thesis, unravelling the relationship between technology, community involvement, and the design of public spaces, with a particular emphasis on cocreation as a catalyst for positive change and innovation.

From the tangible interfaces deployed for extended periods to the cocreation of multisensory prototypes, and from the deployment of a multisensory rigs in city centre to the exploration of possibilities for future design tools, the following discussion will delve into the major overarching themes that have surfaced in this journey of research and discovery. These insights explore the practical aspects of urban technology deployment but also contribute to our understanding of how technology can be harnessed to foster community engagement, inclusivity, and resilience in urban contexts.

7.3.1 Sense of Place, Nostalgia and Interactive Public Displays

Throughout this research journey, a recurring theme was the impact of public installations on the sense of place (topophilia) and nostalgia within urban environments. With nostalgia referring to memories and recollections participants had due to the experience, often related to Swansea, and then topophilia relating to their feelings with that space following the experience. The deployment of a tangible embedded interface (Lookout) and multisensory rig (SALly) into real-world settings shed light onto how these technologies can both enhance the physical environment but also contribute to the intangible, but crucial, concept of *sense of place, through nostalgia*.

The deployment of the *Lookout* not only improved the users knowledge of the regeneration space but also enhanced their topophilia and engagement through nostalgia. In addition, the multisensory installation revealed comforting abilities and was described by some individuals as evoking a feeling of homecoming and a sense of familiarity. These insights underscore how public installations, when designed and integrated through cocreation, can become a cornerstone for enhancing topophilia, nostalgia and community identity in urban spaces.

Importance of Cultural Heritage

A notable finding from this work has been the recognition of the importance of cultural heritage in the design of interactive installations for urban environments. Whilst cultural heritage has been explored online and within indoor settings [240, 264, 284], this thesis explored cultural heritage through alternate modality outdoor public installations. The incorporation of cultural cues that resonated with the local community and evoked nostalgia was seen in both the Lookout (featuring a slideshow of images from Swansea's past) and SALly (depicting a nostalgic sweet shop scenario), fostered deeper and more meaningful connections with users.

This emphasis on cultural local heritage shows the powerful nature of the personalised designs for local *contexts*. Underscoring the importance of designing installations that are culturally relevant. Such an approach can ensure that installations appeal to a diverse range of users, enhancing their topophilia and cultural connection with the urban environment.

To summarise, the real-world deployments explored within this work, have not only provided insights into the role of public installation in enhancing topophilia and nostalgia but also underscored the significance of cultural heritage in design of context-specific urban deployments. These contributions have the potential to be incorporated across future of urban technology designs, promoting a deeper sense of community engagement in public spaces.

7.3.2 Advances in Multisensory Design

The transition from the initial multisensory prototype to the deployment of the SALly rig showcased the success of the project but also its implications for enhancing user engagement and interaction within future city centres. Through numerous iterations and collaborative efforts with a diverse range of stakeholders, the data demonstrated the possibility of creating a dynamic, immersive, and sensory-rich urban experience that transcended traditional forms of engagement. This accomplishment establishes a solid foundation for future initiatives aiming to transform public spaces into hubs of multisensory interaction and community engagement. Although, there are ongoing discussions that are needed to enhance the viability of these installations, including the regulation of scent distributions and the advancement of technologies to meet the demands of outdoor deployments.

Furthermore, this research advanced the field of multisensory design by exploring the integration of olfactory, auditory, and visual cues within the urban environment. These insights not only expand the boundaries of traditional design but also provided valuable principles for future endeavours in this domain. The findings extend beyond the immediate scope of this research and hold the potential to inform broader discussions about the integration of sensory experiences in urban spaces worldwide. As cities continue to evolve to meet the changing needs and expectations of their residents, the outcomes of this project offer a compelling vision of creating vibrant, engaging, and inclusive urban environments that cater to the diverse sensory preferences of their inhabitants. While the SALly rig may not be immediately ready for in-situ deployment, it has laid the groundwork, and the recommendations provided offer a clear path for realising this vision when technology and infrastructure align to make it a reality.

7.3.3 Looking towards the installations of the future

As far back as 2000, Myers et al. began the process of evaluating the need for tools to support a next generation of user interfaces [188]. The work undertaken in Chapter 6 not only sheds light on the possibilities of tools for designing multisensory installations but also underscores the future of the design process itself. While the journey of crafting these installations posed its challenges and limitations, the insights provided from this endeavour have implications for the future of design in various contexts. The need for tools that facilitate the design of alternate modality displays, as outlined in Chapter 6, has the potential to spark the introduction of new design tools and methodologies. These tools, if implicated, could revolutionise the way we approach design in online and interactive spaces, offering a more inclusive and immersive experience for all users, even if this is across a variety of tools rather than one master design suite.

Furthermore, the importance of resilience and adaptability in design became paramount. The process of creating alternate modality installations demanded flexibility and an openness to iteration and adaptation. This lesson extends beyond the realm of multisensory displays and serves as a reminder for all designers. In a rapidly changing technological landscape, the ability to create designs that work with and for the user, rather than against them, is imperative. The insights gained from this project emphasise the need for designs that can evolve, respond to user feedback, and remain relevant in dynamic environments both for tools to design and designs themselves. As we look towards the future of design, these principles of resilience and adaptability will be essential in crafting user-centred experiences that stand the test of time and continue to engage and delight audiences.

7.4 Future Directions for HCI Research and Practice

In this section, we will explore two key future directions for research in the multisensory field, alongside adaptations for shaping inclusive and innovative design practices, and an overview of future directions for the broader HCI community.

7.4.1 Multisensory Installations for Future Urban Environments

Following the deployment of the multisensory rig in the city centre and the workshops with school pupils, two directions could be explored. The first direction involves evaluating the feasibility of modifying the SALly rig's design to enable independent user interaction, eliminating the need for a researcher's physical presence. This adjustment could empower individuals to engage with the installation autonomously, whether for accessing information or deepening their connection with the city centre, potentially transforming it into a more enduring and self-sustaining installation for extended deployment. The second direction entails investigating SALly's versatility and its potential applications in various contexts.

Exploring Possibilities for Stand-Alone Deployment of the Rig

The technologies and approaches considered to achieve this goal could be explored, along with the potential for SALly to become a more permanent installation for extended deployment. Exploratory work in this area was initiated during this thesis. However, given the current technological limitations, certain aspects remain open for future investigation. Based on this, three different approaches could be considered for future integrations:

Proximity Sensors: One approach could be to integrate proximity sensors into the installation. These sensors could detect people within a specific radius, triggering interactions when someone enters that zone. However, this approach presents potential issues, as it does not consider individuals with allergies or respiratory problems. Since there is no viable way to address this concern currently, this approach may not be the most immediate choice for future exploration.

Bluetooth: A second approach could involve integrating Bluetooth technology into the design, offering two interaction methods: a) passersby could directly connect via their own devices; and b) the installation could scan for open Bluetooth connections, prompting users to download an app or visit a website for connection.

This concept has considerable potential. Future research in this domain may encounter challenges, such as the necessity for significant promotional efforts to encourage participation, which could prove impractical when requiring participants to engage through QR codes or Bluetooth sign-up in public spaces can be in-practical [149]. Additionally, future investigations may need to scrutinise the reliability of Wi-Fi and internet connections with these devices, as their performance could impact tracking accuracy and user accessibility. An exploration into accessibility concerns is important as it cannot be assumed that every person has a smartphone, potentially excluding certain demographics from participation. Furthermore, considerations would be required to factors such as allergens or breathing difficulties among nearby participants. Ethical concerns, specifically regarding GDPR compliance in tracking participants' locations through their smartphones, should also need be acknowledged. Hence, this approach may also not be the most suitable choice for all contexts.

Radio Frequency Identification (RFID): A third approach to be considered could involve integrating RFID technology into the design, which appears to be the most viable option among the three, aiming to address personal device tracking concerns. RFID systems use special tags with transponders that communicate with RFID readers, typically containing ID numbers. These readers are more reliable than Bluetooth for further development.

Initial work completed within this thesis highlighted that a group of users who had confirmed the absence of allergies/breathing difficulties could be equipped with RFID tags and explore a predefined area. They could encounter various installations triggering different sensory cues and audio prompts to navigate the city, potentially reaching an endpoint. This concept could be valuable during city centre events, such as a comedy performance at an arena. To achieve this, at each installation, audio prompts, scents, and lighting could guide users through the city, evoking experiences enjoying lights, hearing jokes, and smelling beer/food aromas, and concluding with warm wishes for a great time. The mapped route could guide users through these sensory installations, offering an engaging multisensory journey through the city.

The initial work carried out in this thesis highlighted the possibilities for future work integrating RFID readers into the machine and using an RFID reader to monitor RDIF tags carried by participants. This could allow participants to provide consent and ensure that they were not negatively affected by the device. However, the following challenges would need to be addressed for this approach to be viable. First, addressing the challenge of people in proximity to the device who might have allergies or sensitivities, necessitating careful environmental design around the device. Creating a booth-like interaction, where only one participant could enter at a time, could possibly mitigate this issue, but this would require testing. Nonetheless, this approach could limit the possibility of paired or group-based interactions, which had previously shown benefits for participants and still poses ethical concerns surrounding olfactory output.

While it is possible to consider an approach that would rely solely on audio and visual cues for crafting engaging and memorable experiences going forward, projects and technologies have been successfully deployed using these two sensory cues within public displays to engage users already [151, 173, 255]. Furthermore, this research in this thesis has shown that the inclusion of olfactory cues, in addition to audio and visual elements, can provide a unique and enhanced level of engagement and memory-triggering. The synergy among multisensory cues, including olfaction, allows for a more comprehensive and immersive experience. Olfactory cues, in particular, have shown a strong connection to memory and emotion, making them a valuable addition to the sensory mix. So, while an approach using only audio and visual cues could be effective, the data suggests that incorporating olfaction as well can further elevate the overall impact of audio-visual interactions and create richer, more memorable experiences.

In other future work, an exploration of the ethical dilemmas associated with integrating olfactory devices into public spaces would also be required. This issue could perhaps be resolved by using alternate scent dispersion types, such as essential oils. However, these alternatives may also pose potential challenges. As a response to this concern, the author organised a workshop hosted at DIS 2023, titled *Scent InContext: Design and Development around Smell in Public and Private Spaces* [44]. This workshop will aim to explore the roles of scent technologies within alternate contexts of the future and explore potential solutions to the ethical and health-related challenges posed by scent dispersion in public spaces. The in-depth analysis of this workshop, however, falls outside the scope of this thesis and will be explored in future publications.

Versatility of SALly: Adapting Olfactory, Auditory, and Visual outputs for Diverse Experiences

The second direction of research could explore the adaptability of SALly's design for diverse urban contexts. This could include assessing how SALly could be tailored to meet the unique requirements of various cities and their inhabitants. The sensory outputs could be fine-tuned to capture the essence of the chosen city, using distinctive aromas, sounds, or visual characteristics.

The customisation of sensory outputs could help to capture the unique essence of each selected city. Whether through the infusion of distinct aromas which could evoke the city's character, the harmonious symphony of sounds that could resonate with its spirit, or the visual components that could mirror its visual identity.

This future exploration could showcase SALly's potential to transcend traditional boundaries, offering innovative sensory interactions that resonate with diverse audiences and settings. These endeavors may harness SALly's capacity to enhance urban experiences, unveiling new dimensions and establishing it as a transformative tool for cities seeking unforgettable and engaging environments.

7.4.2 Envisioning the Future: Shaping Inclusive and Innovative Design Practices

The outlined principles for creating inclusive and accessible design tools have the potential to reshape the very landscape of design. By moving away from an exclusive focus on screen-based interactions, designers could leverage alternate modalities to craft more immersive, engaging, and user-centric experiences. This shift not only addresses the evolving needs of users but also opens up new avenues for creativity and innovation in the design process.

The data collection completed within Chapter 6 was conducted before the release of tools such as ChatGPT, Dall-E and Midjourney. There is already evidence that UX researchers are incorporating these tools and other AI processes into their workflow, as time saving devices, or to generate ideas. This could be widely problematic for any public facing constructs due to the ongoing copyright issues, but could save designers time in early stage activities, where communicating with stakeholders or brainstorming is the focus. Despite the current popularity of AI tools, it was interesting that there was only two mentions of AI during the workshops and currently AI 'refinement' is not widely practiced to my knowledge, although current media suggests that AI can develop logos, storyboards, and scripts.

Whilst it is anticipated that AI will be incorporated into many tools and become part of professional practice, it is possible that the requirements, sketches and other ideas generated throughout the course of the work described within Chapter 6 could inform the design space. The next step for this particular body of work might be to start imagining the practicalities of the *Master Design Suite*, to elaborate upon the contextual prototypes, and instill features and layers of functionality to further explore the concepts presented in the chapter. It may also be possible to use speculative design and design fiction to model some of these concepts, as a method to explore not only interactive potential, but the tool's place in the world [57].

Alongside designing for the future, it is possible to expand the remit to give insights as to future usability guidelines. Current ISO standards for Human Centred Design rely on the current status quo of screen and web usability, unable to integrate tangible, multimodal processes directly. It should be possible to work together with industry on 'future proofing' novel interaction, and help build instinctive, accessible, and universal standards to guide future technology and its development.

7.4.3 Future Directions for the Broader HCI Community

These future directions serve as broader impacts and calls to action for the HCI community:

Digital Interventions and Urban Regeneration's: This research highlights both the potential and the necessity for digital interventions to assist communities in re-engaging with evolving public spaces, such as Swansea's regeneration project. By offering interactive and informative installations, communities can access crucial information to maintain their connection to spaces undergoing significant changes. Despite the necessity of these changes for the area, they can still disrupt emotional ties that individuals have with these spaces. Therefore, integrating interactive information technologies into changing spaces should become a standard practice globally. This serves as a call to action to prioritise the implementation of such technologies to support communities in adapting to and remaining connected with their evolving environments.

Sense of Place and Nostalgia: The exploration of sense of place and nostalgia as triggers in interactive designs has unveiled promising possibilities. These insight holds significant potential for adaptation and exploration within various contexts across the HCI community. Integrating multisensory elements into interactive designs to evoke nostalgia could facilitate deeper connections within a variety of spaces and/or relationships, enabling its application in diverse projects seeking to evoke nostalgia or foster a sense of connection with a particular environment or social interaction. Furthermore this work has laid out a clear framework for building effective multisensory installations that can be adapted and deployed into a variety of contexts.

Cultural Heritage: Acknowledging cultural heritage and its influence on both sense of place and nostalgia is essential. Cultural heritage is integral to community identity and can significantly impact the quality of interactions within a space when it has been acknowledged. Evaluating how cultural heritage and nostalgia can be incorporated into different contexts would be intriguing and could further advocate for designing within specific cultural and historical contexts. This exploration could lead to more culturally sensitive and contextually relevant designs that resonate deeply with individuals and communities across a range of spaces, from public to private to fully virtual.

Policy and Regulatory Engagement: Integrating scent-based technologies into outdoor deployments, whether for commercial or research purposes, currently lacks regulation. As this research has revealed, scent is highly emotive and can be used within interactive installations to evoke positive emotions and foster positive impacts. However, its emotive abilities mean it is equally susceptible to manipulate and potentially have negative impacts. Therefore, it is imperative to continue the discourse on the necessity of policy and regulatory engagement regarding the future of scent-based deployments. This discussion should include ethical considerations surrounding allergens, as well as concerns related to manipulation and behavioral change possibilities of scent-based interactions. By fostering dialogue and collaboration among stakeholders, including policymakers, researchers, and industry professionals, we can develop frameworks that ensure the responsible and ethical use of scent-based technologies in outdoor deployments. This proactive approach will help safeguard against potential misuse while maximising the positive impacts of these technologies on individuals and communities.

Evolving Space of Design: The design landscape is continually evolving, driven by the emergence of new technologies and interaction paradigms. It is crucial that our design tools evolve alongside these advancements to ensure that we can create experiences that remain relevant and impactful. In this work, a framework with key features and requirements to guide the development of future multisensory and contextual tools has been established. This call to action urges the HCI community to collaborate and innovate, striving to create designs that are not only technologically advanced but also contextually relevant. By fostering a culture of continuous learning, exploration, and collaboration, we can ensure that our designs meet the evolving needs and expectations of users in an ever-changing world.

7.5 Concluding Remarks

In conclusion, this thesis has embarked on a journey through the realm of interactive technology design for community engagement in public spaces. With a focus on cocreation, alternate modality experiences, and the integration of diverse perspectives, the research has uncovered insights that hold the potential to reshape the way we approach urban regeneration, technology design, and community engagement.

The deployment of the Lookout over nine months provided vast data and highlighted the resilience and inclusivity of such installations. It emphasised the importance of accessibility, user behaviour, and the profound impact of integrating aspects of cultural heritage into interactive installations can have on the sense of place and community identity. These insights lay the groundwork for designing technology that truly resonates with the communities it serves.

The creation of a multisensory prototype (SALly) through cocreation further underscored the significance of involving diverse stakeholders, including children and urban development experts. This collaborative approach not only led to innovative solutions but also demonstrated the power of diverse perspectives in fostering creativity. The deployment of SALly in a city centre unveiled the potential for enhancing shared heritage and community engagement. Recommendations based on this real-world deployment provide a roadmap for future multisensory installations in urban settings and beyond.

Finally, exploring the possibilities for future design tools, the research emphasises the importance of incorporating accessibility, collaboration, and novel interaction types into design tools. Further illustrating the need for tools that can adapt to the evolving landscape of technology and user needs.

Looking ahead, the insights gained from this thesis have far-reaching implications.

They offer a blueprint for enhancing city planning, technology design, and community engagement on a broader scale. By prioritising inclusivity, alternate modality experiences, and cocreation, future projects can create vibrant and user-centric city environments that resonate with the communities they serve.

In conclusion, this thesis has contributed to the evolving landscape of interactive technology design, emphasising the importance of cocreation, multisensory experiences, and inclusive design. It is this author's hope that these insights will continue to inspire innovative approaches to urban regeneration and technology design, ultimately fostering more vibrant, inclusive, and engaging public spaces for all for generations to come.

Bibliography

[1] A Acedo, T Oliveira, M Naranjo-Zolotov, and M Painho. 2019. Place and city: toward a geography of engagement. *Heliyon* 5, 8 (2019). DOI:http://dx.doi.org/10.1016/j.heliyon.2019.e02261

[2] David Adams and Peter Larkham. 2016. Walking with the ghosts of the past: Unearthing the value of residents' urban nostalgias. *Urban Studies* 53, 10 (2016), 2004–2022. DOI:http://dx.doi.org/10.1177/0042098015588683

[3] Adobe. 2021. Adobe XD: Design Like you always imagined. (2021). https://www.adobe.com/uk/products/xd.html?sdid=88X75SKR&mv=search&ef_id=Cj0KCQjw-4SLBhCVARIsACrhWLVcasfQFIq9LiAbt_sAOhK1br5v3BIItKZm1bJMeGcT6Vz-HAjtfhEaAhAbEALw_wcB:G:s&s_kwcid=AL!3085!3!529101237965!e!!g!!adobe%20xd!1642716928!71269819668

[4] Adobe. 2023. Adobe Creative Cloud. (2023). https://www.adobe.com/uk/creativecloud.html

[5] Y Afacan and S O Afacan. 2011. Rethinking social inclusivity: design strategies for cities. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning* 164, 2 (2011), 93–105.

[6] N H Ahmad, F Olugbenga, and G Taylor. 2020. A Quest on the Role of Aesthetics in Enhancing Functionality of Urban Planning. *Civil Engineering and Architecture* 8 (10 2020), 873–879. DOI:http://dx.doi.org/10.13189/cea.2020.080514

[7] I Akpan, P Marshall, J Bird, and D Harrison. 2013. Exploring the effects of space and place on engagement with an interactive installation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '13, 2213–2222. DOI:http://dx.doi.org/10.1145/2470654.2481306

[8] I Altman and S M Low. 2012. *Place Attachment*. Springer. DOI:http://dx.doi.org/10.1007/978-1-4684-8753-4

[9] Amazon. 2021. Amazon Alexa: Learn what Alexa can do. (2021). https://www.amazon.com/b?ie=UTF8&node=21576558011

[10] A Amin, B Kersten, O Kulyk, P Pelgrim, C Wang, and P Markopoulos. 2005. SenseMS: a user-centered approach to enrich the messaging experience for teens by non-verbal means.. In *Proceedings of the 7th international conference on Human Computer Interaction with Mobile Devices and Services*. MobileHCI '05, 161–166. DOI:http://dx.doi.org/10.1145/1085777.1085804

[11] J Amores and P Maes. 2017. Essence: Olfactory Interfaces for Unconscious Influence of Mood and Cognitive Performance. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. CHI '17, 6–11. DOI:http://dx.doi.org/10.1145/3025453.3026004

[12] M Anabela, M Melo, A Gonçalves, and M Bessa. 2020. Multisensory Augmented Reality in Cultural Heritage: Impact of Different Stimuli on Presence, Enjoyment, Knowledge and Value of the Experience. *IEEE Access* 8 (10 2020), 193744 – 193756. DOI:http://dx.doi.org/10.1109/ACCESS.2020.3032379

[13] M Angelidou. 2015. Smart cities: A conjuncture of four forces. *Cities* 47 (2015), 95–106. DOI:http://dx.doi.org/10.1016/j.cities.2015.05.004

[14] A N Antle. 2008. Child-Based Personas: Need, Ability and Experience. *Cognition, Technology and Work* 10, 2 (2008), 155–166. DOI:http://dx.doi.org/10.1007/s10111-007-0071-2

[15] K Aradhna. 2009. *Sensory Marketing: Research on the Sensuality of Products*. Routledge. DOI:http://dx.doi.org/10.4324/9780203892060

[16] Arch20. 2020. The Impressive Role of Public Spaces in Fostering a Sense of Community. (2020).

[17] N M Ardoin. 2014. Exploring Sense of Place and Environmental Behavior at an Ecoregional Scale in Three Sites. *Hum Ecol* 42 (2014), 425–441. DOI:http://dx.doi.org/10.1007/s10745-014-9652-x

[18] S R Arnstein. 1969. A Ladder Of Citizen Participation. *Journal of the American Institute of Planners* 35, 4 (1969), 216–224. DOI:http://dx.doi.org/10.1080/01944366908977225

[19] Aromajoin. 2022. Welcome to the digital scent technology era. (2022). https://aromajoin.com

[20] J Assmann and J Czaplicka. 1995. Collective memory and cultural identity. *New german critique* 65 (1995), 125–133. DOI:http://dx.doi.org/10.2307/488538

[21] Land's End Attractions. 2019. Arthurs Quest: Experience the Legend. (2019). https://landsend-landmark.co.uk/attractions/arthurs-quest/

[22] Kendall Barnes, Gordon Waitt, Nicholas Gill, and Chris Gibson. 2006. Community and nostalgia in urban revitalisation: A critique of urban village and creative class strategies as remedies for social 'problems'. *Australian Geographer* 37, 3 (2006), 335–354. DOI:http://dx.doi.org/10.1080/00049180600954773

[23] P Barry. 2019. Context-Centred Design. *The Startup* (2019). https://medium.com/swlh/context-centred-design-ce095aa39e8b

[24] M Beaudouin-Lafon. 2004. Designing interaction, not interfaces. In *Proceedings of the working conference on Advanced visual interfaces*. 15–22.

[25] N C Benda, E Montague, and R S Valdez. 2020. Design for Inclusivity. In *Design for Health*. Elsevier, 305–322.

[26] P Bilkstein. 2013. Digital Fabrication and 'Making' in Education:The Democratization of Invention. In *FabLabs: Of Machines, Makers and Inventors*, J. Walter-Hermann and C. Büching (Eds.). Bielefeld: Transcript Publishers.

[27] K Boehner, J Vertesi, P Sengers, and P Dourish. 2007. How HCI interprets the probes.. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '07, 1077–1086. DOI:http://dx.doi.org/10.1145/1240624.1240789

[28] A Jr Bokolo. 2023. The Role of Community Engagement in Urban Innovation Towards the Co-Creation of Smart Sustainable Cities. *J Knowl Econ* (2023). DOI: http://dx.doi.org/10.1007/s13132-023-01176-1

[29] Fondation Botnar. 2020. Future Cities Challenge celebrates young people's role in urban planning. (2020). https://www.fondationbotnar.org/future-cities-challenge-celebrates-young-peoples-role-in-urban-planning/

[30] H Bradbury. 2015. *The SAGE Handbook of Action Research.* SAGE.

[31] E V Bramley. 2021. Therapists report huge rise in cases of anxiety as England ends Covid rules. *The Guardian* (11 Jul 2021). https://www.theguardian.com/world/2021/jul/11/therapists-report-huge-rise-in-cases-of-anxiety-as-england-ends-covid-rules

[32] S Brewster, D McGookin, and C Miller. 2006. Olfoto: designing a smell-based interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '06, 653–662. DOI:http://dx.doi.org/10.1145/1124772.1124869

[33] H Brignull and Y Rogers. 2003. Enticing people to interact with large public displays in public spaces. In *Proceedings of the IFIP International Conference on Human-Computer Interaction*. INTERACT '03. https://rauterberg.employee.id.tue.nl/conferences/INTERACT2003/INTERACT2003-p17.pdf

[34] J Brooks, S Nagels, and P Lopes. 2020. Trigeminal-based Temperature Illusions. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. CHI '20, 1–12. DOI:http://dx.doi.org/10.1145/3313831.3376806

[35] V Bush. 1945. As we may think. *The atlantic monthly* 176, 1 (1945), 101–108.

[36] C Bushdid, M Magnasco, L Vosshall, and A Keller. 2014. Humans Can Discriminate More than 1 Trillion Olfactory Stimuli. 343, 6177 (2014), 1370–1372. DOI: http://dx.doi.org/10.1126/science.1249168

[37] E Cameron-Blake, H Tatlow, A Wood, T Hale, B Kira, A Petherick, and T Phillips. 2020. *Variation in the response to COVID-19 across the four nations of the United Kingdom*. University of Oxford.

[38] A Caragliu, C Del Bo, and P Nijkamp. 2011. Smart Cities in Europe. *Journal of Urban Technology* 18, 2 (2011), 65–82. DOI:http://dx.doi.org/10.1080/10630732.2011.601117

[39] M Carmona. 2021. *Public Places Urban Spaces: The Dimensions of Urban Design (3rd ed.)*. Routledge. DOI:http://dx.doi.org/10.4324/9781315158457

[40] G F Carolien de Kovel, C Amaia, and F Clyde. 2019. A large-scale population study of early life factors influencing left-handedness. *Sci Rep* 584, 9 (2019). DOI:http://dx.doi.org/10.1038/s41598-018-37423-8

[41] S Carr, M Francis, L Rivlin, and A Stone. 2009. *Public Space*. Cambridge, Cambridge Universty Press.

[42] A R L Carter. 2020. *Cocreation of the Lookout*. MSc. Swansea University. https://www.swansea.ac.uk/media/Anna-Carter_Thesis_resized.pdf

[43] A R L Carter, G Bailey, J Pearson, M Jones, S Robinson, D K Raju, S Winter, and J L Hicks. 2022. Designing and Embedding a Tangible Public Interface in the COVID Era. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22)*. Association for Computing Machinery, New York, NY, USA, Article 26, 7 pages. DOI:http://dx.doi.org/10.1145/3491101.3503556

[44] A R L Carter, M Obrist, C Dawes, A Dix, J Pearson, M Jones, D Zampelis, and C Becsevli. 2023. Scent InContext: Design and Development around Smell in Public and Private Spaces. In *Companion Publication of the 2023 ACM Designing*

Interactive Systems Conference (DIS '23 Companion). Association for Computing Machinery, 138–141. DOI:http://dx.doi.org/10.1145/3563703.3591455

[45] A R L Carter, M Sturdee, and A Dix. 2022a. Prototyping InContext: Exploring New Paradigms in User Experience Tools. In *Proceedings of the 2022 International Conference on Advanced Visual Interfaces (AVI 2022)*. Association for Computing Machinery, Article 22. DOI:http://dx.doi.org/10.1145/3531073.3531175

[46] A R L Carter, M Sturdee, A Dix, D K Raju, M Aldridge, E Sari, W Mackay, and E Churchill. 2022b. InContext: Futuring User-Experience Design Tools. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22)*. Association for Computing Machinery, Article 95. DOI:http://dx.doi.org/10.1145/3491101.3503739

[47] F S Chapin III and C Knapp. 2015. Sense of place: A process for identifying and negotiating potentially contested visions of sustainability. *Environmental Science Policy* 53 (05 2015). DOI:http://dx.doi.org/10.1016/j.envsci.2015.04.012

[48] Y Chen and M E Atwood. 2007. Context-Centered Design: Bridging the Gap Between Understanding and Designing. *Jacko, J.A. (eds) Human-Computer Interaction. Interaction Design and Usability. HCI 2007. Lecture Notes in Computer Science* 4550 (2007). DOI:http://dx.doi.org/10.1007/978-3-540-73105-4_5

[49] G Choi, D Stettler, B Kallman, S Bhaskar, A Fleischmann, and R Axel. 2011. Driving Opposing Behaviors with Ensembles of Piriform Neurons. 146, 6 (2011), 1004–1015. DOI:http://dx.doi.org/10.1016/j.cell.2011.07.041

[50] Core Cities. 2021. *The Future of Urban Centres: An Agenda for post-pandemic Inclusive City Renewal*. Core Cities.

[51] V Clarke, V Braun, and N Hayfield. 2015. Thematic analysis. *Qualitative psychology: A practical guide to research methods* 3 (2015), 222–248.

[52] E G Clary and M Snyder. 2020. Community involvement: Opportunities and challenger in socializing adults to participate in society. *Journal of Social Issues* 3 (2020), 581–592. DOI:http://dx.doi.org/10.1111/1540-4560.00277

[53] R Coleman, J Clarkson, and J Cassim. 2016. *Design for inclusivity: A practical guide to accessible, innovative and user-centred design.* crc Press.

[54] Collins. 2024. Definition of Nostalgia. (2024). https://www.collinsdictionary.com/dictionary/english/nostalgia

[55] Mischief Comedy. 2021. Mischief Movie Night. (2021). https://www.mischiefcomedy.com/our-work/mischief-movie-night/about

[56] European Commision. 2023. Smart cities. (2023).

[57] P Coulton, J G Lindley, M Sturdee, and M Stead. 2017. Design fiction as world building. (2017).

[58] Exeter City Council. 2021. Empty city centre shops transformed with amazing new artworks. (2021). https://news.exeter.gov.uk/empty-city-centre-shops-transformed-with-amazing-new-artworks/

[59] Swansea Council. 2023. Swansea Bay City Deal: About. (2023).

[60] T Creswell. 2015. *Place: An Introduction.* John Wiley and Sons.

[61] D3. 2023. The JavaScript library for bespoke data visualization. (2023). https://d3js.org

[62] C Dameria, R Akbar, P N Indradjati, and D S Tjokropandojo. 2020. A conceptual framework for understanding sense of place dimensions in the heritage context. *Journal of Regional and City Planning* 31, 2 (2020), 139–163.

[63] P Datta. 2022. Community Engagement: Building a Sense of Belonging. *Apna Complex* (2022).

[64] N Davis. 2015. Don't just look – smell, feel, and hear art. Tate's new way of experiencing paintings. (2015). https://www.theguardian.com/artanddesign/2015/aug/22/tate-sensorium-art-soundscapes-chocolates-invisible-rain

[65] M de Sa, L Carricco, L Duarte, and T Reis. 2008. A mixed-fidelity prototyping tool for mobile devices. In *Proceedings of the working conference on Advanced visual interfaces*. 225–232.

[66] H L Delve. 2023. Collaborative Thematic Analysis in Qualitative Research. (2023). https://delvetool.com/blog/collaborative-thematic-analysis

[67] Environment Department of Agriculture and Rural Affairs. 2019. Air pollution and smoke control. (2019). https://www.daera-ni.gov.uk/articles/air-pollution

[68] Disney. 2023. Disney California Adventure Park. (2023). https://disneyland.disney.go.com/destinations/disney-california-adventure/

[69] C Distasio. 2016. Giant interactive wheels light up Montreal. (2016). https://inhabitat.com/giant-interactive-wheels-light-up-montreal/

[70] A Dix, A R L Carter, and M Sturdee. 2021. Where, Who, Why? Tools to Encourage Design In Context. In *3rd Annual ACM SIGCHI Symposium on HCI Education*. EduCHI '21. https://educhi2021.hcilivingcurriculum.org/wp-content/uploads/2021/04/educhi2021-final90.pdf

[71] A Dix and M Ghazali. 2017. Physigrams: Modelling Physical Device Characteristics Interaction. In *The Handbook of Formal Methods in Human-Computer Interaction*. Springer, Chapter 9, 247–271. DOI:http://dx.doi.org/10.1007/978-3-319-51838-1_9

[72] P Dourish. 2006. Re-Space-Ing Place: "Place" and "Space" Ten Years On. In *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work*. Association for Computing Machinery, New York, NY, USA, 299–308. DOI:http://dx.doi.org/10.1145/1180875.1180921

[73] S Dredge. 2016. The complete guide to virtual reality – everything you need to get started. (2016). https://www.theguardian.com/technology/2016/nov/10/virtual-reality-guide-headsets-apps-games-vr

[74] E Drewes, V Roos, and K Puren. 2008. A sense of place and spatial planning in the Vredefort Dome, South Africa. *South African Geographical Journal* 90 (09 2008). DOI:http://dx.doi.org/10.1080/03736245.2008.9725320

[75] J Driver and C Spence. 2000. Multisensory perception: Beyond modularity and convergence. *Current Biology* 10, 20 (2000), 731–735. DOI:http://dx.doi.org/10.1016/S0960-9822(00)00740-5

[76] A Druin. 2001. The Role of Children in the Design of New Technology. *Behaviour and Information Technology* 21 (2001). DOI:http://dx.doi.org/10.1080/01449290110108659

[77] London Dungeon. 2022. What is the Dungeon? (2022). https://www.thedungeons.com/london/whats-inside/what-is-the-dungeon/

[78] Irish Government Economic and Evaluation Service. 2022. *An Evaluation of the Impacts of Remote Working*. Department of Enterprise, Trade and Employment.

[79] Enrigue. 2018. The World's Future In 2100 - An Amazing Future For Humans. (2018). https://www.youtube.com/watch?v=qNq2TLuQZSQ

[80] K Falkingham. 2021. Wimbledon 2021: Masks, social distancing and smaller crowds - yet it still feels the same. *The Guardian* (2021).

[81] B Fanini, A Pagano, E Pietroni, D Ferdani, E Demetrescu, and A Palombini. 2023. *Augmented Reality for Cultural Heritage*. Springer International Publishing, 391–411. DOI:http://dx.doi.org/10.1007/978-3-030-67822-7_16

[82] D Feit. 2013. Multisensory Version of Iron Man 3 in Japan Is a Gimmicky Waste of $28. (2013). https://www.wired.com/2013/04/iron-man-4dx-japan/

[83] M Felder. 2021. Familiarity as a Practical Sense of Place. 39, 3 (2021). DOI:http://dx.doi.org/10.1177/07352751211037724

[84] Fever. 2022. Dopamine Land. (2022). https://dopaminelandexperience.com/london/

[85] Figma. 2021. Figma: The collaborative interface design tool. (2021). https://www.figma.com/

[86] Figma. 2023. Whate is a swimlane diagram? (2023). https://www.figma.com/resource-library/what-is-a-swimlane-diagram/

[87] Centre for Cities. 2021. Cities Outlook 2021: Covid and the City. (2021). https://www.centreforcities.org/reader/cities-outlook-2021/covid-and-the-city/

[88] Insitute for Government. 2020. *The cost of Covid-19: The impact of coronavirus on the UK's public finances*. Whitehall Monitor 2020 Snapshot.

[89] Project for Public Spaces. 2022. Placemaking: What If We Built Our Cities Around Places?: A Placemaking Primer. (2022).

[90] L Forlano. 2013. Making waves: Urban technology and the co–production of place. *First Monday* (2013). DOI:http://dx.doi.org/10.5210/fm.v18i11.4968

[91] M Foth. 2017. Participation, co-creation, and public space. *The Journal of Public Space* 2, 4 (2017), 21–36. DOI:http://dx.doi.org/10.5204/jps.v2i4.139

[92] N Frantzeskaki, F Van Steenbergen, and R C Stedman. 2018. Sense of place and experimentation in urban sustainability transitions: The Resilience Lab in Carnisse, Rotterdam, The Netherlands. *Sustainability science* 13 (2018), 1045–1059. DOI:http://dx.doi.org/10.1007/s11625-018-0562-5

[93] C Frayling. 1994. Research in art and design (Royal College of Art Research Papers, vol 1, no 1, 1993/4). (1994).

[94] J Fredericks. 2020. From smart city to smart engagement: Exploring digital and physical interactions for playful city-making. *Making Smart Cities More Playable: Exploring Playable Cities* (2020), 107–128.

[95] M Friedman. 1940. A Comparison of Alternative Tests of Significance for the Problem of *m* Rankings. *The Annals of Mathematical Statistics* 11, 1 (1940), 86 – 92. DOI:http://dx.doi.org/10.1214/aoms/1177731944

[96] D Frohlich, D Rachovides, K Riga, R Bhat, M Frank, E Edirisinghe, D Wickramanayaka, M Jones, and W Harwood. 2009. StoryBank: Mobile Digital Storytelling in a Development Context. In *Proceedings of the 2009 conference on Mobile Applications*. CHI '09, 1761–1770. DOI:http://dx.doi.org/10.1145/1518701.1518972

[97] M Fullilove. 1996. Psychiatric Implications of Displacement: Contribution from The Psychology of Place. *American Journal of Psychiatry* 153 (1996), 1516–1523. http://ajp.psychiatryonline.org/cgi/content/abstract/153/12/1516

[98] A Galaktionova. 2021. Emotional boundaries of public involvement in city improvement. *Cities* 115 (2021), 103254. DOI:http://dx.doi.org/10.1016/j.cities.2021.103254

[99] Quan Gao, Duo Yin, and Hong Zhu. 2020. Urban regeneration and emotional politics of place in Liede Village, Guangzhou, China. *Habitat International* 103 (2020), 102199. DOI:http://dx.doi.org/10.1016/j.habitatint.2020.102199

[100] V Gentile, M Khamis, F Milazzo, S Sorce, A Malizia, and F Alt. 2020. Predicting mid-air gestural interaction with public displays based on audience behaviour. *International Journal of Human-Computer Studies* 144 (2020). DOI:http://dx.doi.org/10.1016/j.ijhcs.2020.102497

[101] E L Glaeser. 2022. Reflections on the post-Covid city. *Cambridge Journal of Regions, Economy and Society* 15, 3 (10 2022), 747–755. DOI:http://dx.doi.org/10.1093/cjres/rsac039

[102] L Glavan, N Nenad, F Branislav, V Biljana, M Aleksandra, and K Saja. 2022. COVID-19 and City Space: Impact and Perspectives. *Sustainability* 3 (2022). DOI:http://dx.doi.org/10.3390/su14031885

[103] GOV.UK. 2021. Policy paper Roadmap Reviews: Update. (2021). https://www.gov.uk/government/publications/covid-19-response-spring-2021-reviews-terms-of-reference/roadmap-reviews-update

[104] C Graham and M Rouncefield. 2008. Probes and Participation. In *Proceedings of the Tenth Anniversary Conference on Participatory Design*. PDC '08, 194–197. DOI:http://dx.doi.org/10.5555/1795234.1795272

[105] E Gratian. 2023. Bilingualism in 2023: US, UK Global Statistics. (2023).

[106] M J Greenberg. 2017. Relax with lavender: Learn how lavender can reduce anxiety and improve sleep. 12, 6 (2017), 1695–1707. link.gale.com/apps/doc/A499494538/HRCA?u=anon~88d775d5&sid=googleScholar&xid=622280a1

[107] A Greenfield. 2006. *Everyware: The Dawning Age of Ubiquitous Computing*. AIGA. DOI:http://dx.doi.org/10.5555/1199246

[108] R Gregory. 2020. Digital technology gives view of future as part of £1bn Swansea regeneration. *Wales 247* (2020). https://www.wales247.co.uk/digital-technology-gives-view-of-future-as-part-of-1bn-swansea-regeneration

[109] Groundwork. 2023. Co-Creation: The Key To Building Inclusive, Socially Cohesive Communities. (2023). https://www.groundwork.org.uk/co-creation-the-key-to-building-inclusive-socially-cohesive-communities/

[110] M Guarnieri and J R Balmes. 2014. Outdoor air pollution and asthma. *The Lancet* 383, 9928 (2014), 1581–1592. DOI:http://dx.doi.org/10.1016/S0140-6736(14)60617-6

[111] V Gutiérrez, D Amaxilatis, G Mylonas, and L Muñoz. 2018. Empowering Citizens Toward the Co-Creation of Sustainable Cities. *IEEE Internet of Things Journal* 5, 2 (2018), 668–676. DOI:http://dx.doi.org/10.1109/JIOT.2017.2743783

[112] J Hardy, C Ellis, J Alexander, and N Davies. 2013. Ubi displays: A toolkit for the rapid creation of interactive projected displays. In *The International Symposium on Pervasive Displays*.

[113] J Hare, S Gill, G Loudon, and A Lewis. 2014. Active and passive physicality: making the most of low-fidelity physical interactive prototypes. *International Journal of Design Research* 12, 4 (2014), 330–348. DOI:http://dx.doi.org/10.1504/JDR.2014.065847

[114] S Harrison and P Dourish. 1996. Re-Place-Ing Space: The Roles of Place and Space in Collaborative Systems. In *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work*. Association for Computing Machinery, New York, NY, USA, 67–76. DOI:http://dx.doi.org/10.1145/240080.240193

[115] R Hay. 1998. Sense of Place: Cross-Cultural Perspectives from Banks Peninsula, New Zealand. *The Canadian Geographer* 42 (1998), 245–266. DOI:http://dx.doi.org/10.26021/5973

[116] B He, H Yuan, J Meng, and S Gao. 2020. Brain–computer interfaces. *Neural engineering* (2020), 131–183.

[117] M Heeley and L Damodaran. 2009. *Digital Inclusion: a review of international policy and practice*. Loughborough Univeristy.

[118] Heineken. 2022. The Heineken Experience. (2022). https://www.heinekenexperience.com/en/about-the-experience/

[119] M A Hemphill and A R Richards. 2018. A practical guide to collaborative qualitative data analysis. *Journal of Teaching in Physical Education* 37, 2 (2018), 225–231. DOI:http://dx.doi.org/10.1123/jtpe.2017-0084

[120] R Herz and T Engen. 1996. Odor memory: Review and analysis. 3 (1996), 300–313. DOI:http://dx.doi.org/10.3758/BF03210754

[121] H Hofstad, E Sorensen, J Torfing, and T Vedeld. 2022. Designing and leading collaborative urban climate governance: Comparative experiences of co-creation

from Copenhagen and Oslo. *Environmental Policy and Governance* 32, 3 (2022), 203–216.

[122] Universal Studios Hollywood. 2022. The World-Famous Studio Tour. (2022). https://www.universalstudioshollywood.com/web/en/us/things-to-do/rides-and-attractions/the-world-famous-studio-tour

[123] Computer Hope. 2020. iPhone. (2020). https://www.computerhope.com/jargon/i/iphone.html

[124] J Hosagrahar, J Soule, L F Girard, and A Potts. 2016. Cultural heritage, the UN sustainable development goals, and the new urban agenda. *BDC. Bollettino Del Centro Calza Bini* 16, 1 (2016), 37–54.

[125] S Hosio, J Goncalves, V Kostakos, and J Riekki. 2014. Exploring Civic Engagement on Public Displays. In *Public Administration and Information Technology. User-Centric Technology Design for Nonprofit and Civic Engagements.*, S. Saeed (Ed.). Vol. 9. Springer, 91–111. DOI:http://dx.doi.org/10.1007/978-3-319-05963-1_7

[126] S Hosio, V Kostakos, H Kukka, M Jurmu, J Riekki, and T Ojala. 2012. From School Food to Skate Parks in a Few Clicks: Using Public Displays to Bootstrap Civic Engagement of the Young. In *Pervasive Computing. Pervasive 2012. Lecture Notes in Computer Science*, Tokuda H. Olivier P. Krüger A. Kay J., Lukowicz P. (Ed.). Vol. 7319. Springer, Berlin, Heidelberg, 425–442. DOI:http://dx.doi.org/10.1007/978-3-642-31205-2_26

[127] K Houghton, E Miller, and M Foth. 2014. Integrating ICT into the planning process: impacts, opportunities and challenges. *Australian Planner* 51, 1 (2014), 24–33.

[128] J P Hourcade. 2008. *Interaction Design and Children.* Now Publishers Inc.

[129] J W Hsieh, A Keller, M Wong, R Jiang, and L B Vosshall. 2017. SMELL-S and SMELL-R: Olfactory tests not influenced by odor-specific insensitivity or prior

olfactory experience. *Proceedings of the National Academy of Sciences* 114, 43 (2017), 11275–11284. DOI:http://dx.doi.org/10.1073/pnas.1711415114

[130] E Huang, A Koster, and J Borchers. 2008. Overcoming Assumptions and Uncovering Practices: When Does the Public Really Look at Public Displays? 5013 (2008), 228–243. DOI:http://dx.doi.org/10.1007/978-3-540-79576-6_14

[131] H Hutchinson, W Mackay, B Westerlund, B B Bederson, A Druin, C Plaisant, M Beaudouin-Lafon, S Conversy, H Evans, H Hansen, N Roussel, and B Eiderback. 2003. Technology Probes: Inspiring Design for and with Families. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, 17–24. DOI:http://dx.doi.org/10.1145/642611.642616

[132] T Hwang, K Rabheru, C Peisah, W Reichman, and M Ikeda. 2020. Loneliness and social isolation during the COVID-19 pandemic. *Int Psychogeriatr* 32, 10 (2020), 1217–1220. DOI:http://dx.doi.org/10.1017/S1041610220000988

[133] M Ibrahim, A El-Zaart, and C Adams. 2017. Stakeholders engagement in smart sustainable cities: a proposed model. In *2017 International Conference on Computer and Applications (ICCA)*. IEEE, 342–347.

[134] Child in the City. 2023. Giving young people a say in the future of our cities. (2023). https://www.childinthecity.org/2023/05/30/giving-young-people-a-say-in-the-future-of-our-cities/?gdpr=deny

[135] G Jacucci, A Morrison, G T Richard, J Kleimola, P Peltonen, L Parisi, and T Laitinen. 2010. Worlds of Information: Designing for Engagement at a Public Multi-Touch Display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '10, 2267–2276. DOI:http://dx.doi.org/10.1145/1753326.1753669

[136] J J Jensen and M B Skov. 2005. A Review of Research Methods in Children's Technology Design. In *Proceedings of the 2005 Conference on Interaction Design*

and Children. Association for Computing Machinery, 80–87. DOI:http://dx.doi.org/10.1145/1109540.1109551

[137] A Jhala, C Rawls, S Munilla, and R M Young. 2008. Longboard: A Sketch Based Intelligent Storyboarding Tool for Creating Machinima.. In *FLAIRS Conference*. Citeseer, 386–390.

[138] G Jiven and P J Larkham. 2003. Sense of Place, Authenticity and Character: A Commentary. *Journal of Urban Design* 8, 1 (2003), 67–81. DOI:http://dx.doi.org/10.1080/1357480032000064773

[139] B S Jorgensen and R C Stedman. 2001. Sense of place as an attitude: Lakeshore owners attitudes toward their properties. *Journal of Environmental Psychology* 21, 3 (2001), 233–248. DOI:http://dx.doi.org/10.1006/jevp.2001.0226

[140] A Jutraz and T Zupancic. 2015. Virtual Worlds as Support Tools for Public Engagement in Urban Design. In *Planning Support Systems and Smart Cities. Lecture Notes in Geoinformation and Cartography.*, S. Geertman, J. Ferreira, R. Goodspeed, and J. Stillwell (Eds.). Springer, 391–408. DOI:http://dx.doi.org/10.1007/978-3-319-18368-8_21

[141] P Kavilanz. 2021. Vaccination megasites pop up in empty malls. (2021). https://edition.cnn.com/2021/01/15/business/malls-vaccination-sites/index.html

[142] L Kay. 2011. Olfactory Coding: Random Scents Make Sense. 21, 22 (2011), 928–929. DOI:http://dx.doi.org/10.1016/j.cub.2011.10.008

[143] A H Khan, S Snow, and B Matthews. 2023. Participatory Design Tools: Leveraging Materiality and Familiarity to Adapt Unconventional Materials into Design Tools. In *Proceedings of the 15th Conference on Creativity and Cognition*. 399–412.

[144] S Kianicka, M Buchecker, M Hunziker, and U Müller-Böker. 2006. Locals' and tourists' sense of place: A case study of a Swiss Alpine village. *Mountain Research and Development* 26 (02 2006). DOI:http://dx.doi.org/10.5167/uzh-2621

[145] M Kinnula and N Iivari. 2019. Empowered to Make a Change: Guidelines for Empowering the Young Generation in and through Digital Technology Design. In *Proceedings of the FabLearn Europe 2019 Conference*. FabLearn Europe '19, 1–8. DOI:http://dx.doi.org/10.1145/3335055.3335071

[146] S R Klemmer, A K Sinha, J Chen, J A Landay, N Aboobaker, and A Wang. 2000. Suede: a wizard of oz prototyping tool for speech user interfaces. In *Proceedings of the 13th annual ACM symposium on User interface software and technology*. 1–10.

[147] S Konsti-Laakso and T Rantala. 2018. Managing community engagement: A process model for urban planning. *European Journal of Operational Research* 268, 3 (2018), 1040–1049. DOI:http://dx.doi.org/10.1016/j.ejor.2017.12.002

[148] K M Korpela. 1989. Place-identity as a product of environmental self-regulation. *Journal of Environmental Psychology* 9, 3 (1989), 241–256. DOI:http://dx.doi.org/10.1016/S0272-4944(89)80038-6

[149] M Koszko. Acceptance of New Bar Codes (QR codes) in Poland-Not Just yet. *Knowledge Management and Challenges in Education* (????), 21. https://www.researchgate.net/profile/Lucyna-Wilinkiewicz-Gorniak/publication/337647181_TECHNOLOGY_IN_EDUCATION_LWG_in_Knowledge_Management_and_Challenges_in_Education/links/5de1be15a6fdcc2837f6c94b/TECHNOLOGY-IN-EDUCATION-LWG-in-Knowledge-Management-and-Challenges-in-Educatio pdf#page=22

[150] S Krug. 2000. *Don't make me think!: a common sense approach to Web usability*. Pearson Education India.

[151] H Kukka, J Goncalves, K Wang, T Puolamaa, J Louis, M Mazouzi, and L Roa Barco. 2016. Utilizing Audio Cues to Raise Awareness and Entice Interaction on Public Displays *(DIS '16)*. Association for Computing Machinery, 807–811. DOI:http://dx.doi.org/10.1145/2901790.2901856

[152] Cassidy I-Chih Lan and Jianglong Chen. 2022. Urban Nostalgia, Regeneration, and Cultural Monopoly Rent:'Nanjing 1912'and Its Branding Bubbles. *International Journal of Urban and Regional Research* 46, 6 (2022), 954–972. DOI: http://dx.doi.org/10.1111/1468-2427.13126

[153] J Lazar. 2007. *Universal Usability: Designing Computer Interfaces for Diverse User Populations*. John Wiley and Sons.

[154] S Leasca. 2020. 'The Wave' May Be the Coolest Art Installation on Earth Right Now (Video). (2020). https://www.travelandleisure.com/culture-design/visual-arts/the-wave-public-art-display-seoul

[155] F K Lehnert, J Niess, C Lallemand, P Markopoulos, A Fischbach, and V Koenig. 2022. Child–Computer Interaction: From a systematic review towards an integrated understanding of interaction design methods for children. *International Journal of Child-Computer Interaction* 32 (2022), 100398. DOI: http://dx.doi.org/10.1016/j.ijcci.2021.100398

[156] H Leino and E Puumala. 2021. What can co-creation do for the citizens? Applying co-creation for the promotion of participation in cities. *Environment and Planning C: Politics and Space* 39, 4 (2021), 781–799.

[157] N Levent and A Pascual-Leone. 2014. *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space*. Rowman and Littlefield.

[158] M Lewis and M Sturdee. 2022. Curricula design & pedagogy for sketching within HCI & UX education. *Frontiers in Computer Science* 4 (2022), 826445.

[159] Sight Life. 2021. Sight Life, Local sight loss support. (2021). https://sightlife.wales/

[160] Y Lin, S Guan, Y Yao, W Cheng, and J Wu. 2012. U-Drumwave: An Interactive Performance System for Drumming. In *International Conference on Multimedia Modeling*. MMM 2012, 609–620. DOI:http://dx.doi.org/10.1007/978-3-642-27355-1_56

[161] T Lowdermilk. 2013. *User-centered design: a developer's guide to building user-friendly applications*. O'Reilly Media, Inc.

[162] A Lucero. 2015. Using Affinity Diagrams to Evaluate Interactive Prototypes. *Human-Computer Interaction – INTERACT 2015* 9297 (2015). DOI:http://dx.doi.org/10.1007/978-3-319-22668-2_19

[163] R Macefield. 2007. Usability Studies and the Hawthorne Effect. *Journal of Usability Studies* 2, 3 (2007), 145–154. https://orion2020.org/archivo/TO/h_hawthorne-effect.pdf

[164] K E MacLean, O S Schneider, and H Seifi. 2017. Multisensory haptic interactions: understanding the sense and designing for it. In *The Handbook of Multimodal-Multisensor Interfaces: Foundations, User Modeling, and Common Modality Combinations-Volume 1*. 97–142. DOI:http://dx.doi.org/10.1145/3015783.3015788

[165] E Maggioni, R Cobden, D Dmitrenko, K Hornbaek, and M Obrist. 2020. SMELL SPACE: Mapping out the Olfactory Design Space for Novel Interactions. *ACM Trans. Comput.-Hum. Interact.* 27, 5, Article 36 (2020), 26 pages. DOI:http://dx.doi.org/10.1145/3402449

[166] E Maggioni, R Cobden, and M Obrist. 2019. OWidgets: A Toolkit To Enable Smell-based Experience Design. *International Journal of Human-Computer Studies* 130 (06 2019). DOI:http://dx.doi.org/10.1016/j.ijhcs.2019.06.014

[167] T Malone. 1981. Toward a Theory of Intrinsically Motivating Instruction. *Cognitive Science* 4 (1981), 333–369. DOI:http://dx.doi.org/10.1207/s15516709cog0504_2

[168] S Marginson, R Tytler, B Freeman, and K Roberts. 2013. *STEM: Country Comparisons*. Report for the Australian Council of Learned Academies. www.acola.org.au

[169] I Mariën and J A Prodnik. 2014. Digital inclusion and user (dis)empowerment: a critical perspective. *Info* 16 (2014), 35–47. DOI:http://dx.doi.org/10.1108/info-07-2014-0030

[170] B Marques, J McIntosh, C Muthuveerappan, and K Herman. 2022. From smart city to smart engagement: Exploring digital and physical interactions for playful city-making. *Sustainability* 14, 7308 (2022). DOI:http://dx.doi.org/10.3390/su14127308

[171] T Mattelmaki. 2006. *Design Probes*. Gummerus Printing.

[172] A Matthews. 2022. The Girl Puzzle Monument honoring Nellie Bly. (2022). https://www.prometheusart.com/the-girl-puzzle-nyc

[173] J McCarthy. 2002. Using public displays to create conversation opportunities. In *Workshop at CSCW*.

[174] J McCarthy and P Wright. 2004. Technology as Experience. *Interactions* 11, 5 (2004), 42–43. DOI:http://dx.doi.org/10.1145/1015530.1015549

[175] S Mehrotra, A Brocker, M Obrist, and J Borchers. 2022. The Scent of Collaboration: Exploring the Effect of Smell on Social Interactions. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22)*. Association for Computing Machinery, Article 303, 7 pages. DOI:http://dx.doi.org/10.1145/3491101.3519632

[176] N Memarovic, M Langheinrich, F Alt, I Elhart, S Hosio, and E Rubegni. 2012. Using public displays to stimulate passive engagement, active engagement, and discovery in public spaces. In *Proceedings of the 4th Media Architecture Biennale Conference*. MAB '12, 55–64. DOI:http://dx.doi.org/10.1145/2421076.2421086

[177] H Michels and C Michels. 2020. Can Copper Help Fight Covid-19? Experts on copper and microbiology recomment the expanded use of copper in public spaces to recude the spread of COVID-19 and minimize future pandemics. *Advanced Materials and Processes* (2020).

https://www.asminternational.org/documents/10192/1630346/20_CopperCorona_Digital_First.pdf/6bca29a0-fe6d-cb09-a8bc-a2dbaff4db11

[178] Microsoft. 2023. Microsoft Visual Studio. (2023). https://visualstudio.microsoft.com/

[179] A Minton. 2020. Coronavirus has emptied public spaces – but it could reinvent the high street. *The Guardian* (2020).

[180] Miraikan. 2021. Living with a robot: Paro. (2021). https://www.miraikan.jst.go.jp/exhibitions/future/robotworld/

[181] Miro. 2023. Miro. (2023). https://miro.com

[182] J Montgomery. 1998. Making a city: Urbanity, vitality and urban design. *Journal of Urban Design* 3, 1 (1998), 93–116. DOI:http://dx.doi.org/10.1080/13574809808724418

[183] C Moser. 2013. Children Ideation Workshop. In *Advances in Computer Entertainment*, Dennis Reidsma, Haruhiro Katayose, and Anton Nijholt (Eds.). Springer International Publishing, 592–599. DOI:http://dx.doi.org/10.1007/978-3-319-03161-3_61

[184] J Muller, F Alt, D Michelis, and A Schmidt. 2010. Requirements and design space for interactive public displays.. In *International Conference on Multimedia*. MM '10. DOI:http://dx.doi.org/10.1145/1873951.1874203

[185] J Muller, R Walter, G Bailly, M Nischt, and F Alt. 2012. Looking glass: a field study on noticing interactivity of a shop window. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '12, 297–306. DOI:http://dx.doi.org/10.1145/2207676.2207718

[186] M J Muller and S Kuhn. 1993. Participatory design. *Commun. ACM* 36, 6 (1993), 24–28.

[187] Mumbler. 2018. Digital technology gives view of future as part of £1bn Swansea regeneration. (2018). https://northleeds.mumbler.co.uk/bright-ideas-to-keep-little-ones-busy-on-leeds-light-night/

[188] B Myers, S E Hudson, and R Pausch. 2000. Past, present, and future of user interface software tools. *ACM Transactions on Computer-Human Interaction (TOCHI)* 7, 1 (2000), 3–28.

[189] M Myllymaki, P Impio, and I Hakala. 2021. Collaboration network for inspiring children and youth into science, mathematics and technology in Finland. In *30th Annual Conference of the European Association for Education in Electrical and Information Engineering*. EAEEIE, 1–5. DOI:http://dx.doi.org/10.1109/EAEEIE50507.2021.9530931

[190] T Nam and T A Pardo. 2011. Conceptualizing Smart City with Dimensions of Technology, People, and Institutions. In *Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times*. Association for Computing Machinery, 282–291. DOI:http://dx.doi.org/10.1145/2037556.2037602

[191] V Nesset and A Large. 2004. Children in the information technology design process: A review of theories and their applications. *Library and Information Science Research* 26, 2 (2004), 140–161. DOI:http://dx.doi.org/10.1016/j.lisr.2003.12.002

[192] M W Newman, J Lin, J I Hong, and J A Landay. 2003. DENIM: An informal web site design tool inspired by observations of practice. *Human-computer interaction* 18, 3 (2003), 259–324.

[193] M Newton and J Sinner. 2017. Considering Sense of Place in Freshwater Planning. (2017). DOI:http://dx.doi.org/10.13140/RG.2.2.32214.86082

[194] Z Obrenovic, J Abascal, and D Starčević. 2007. Universal accessibility as a multimodal design issue. *Commun* (2007), 83–88. DOI:http://dx.doi.org/10.1145/1230819.1241668

[195] M Obrist, E Gatti, E Maggioni, C Vi, and C Velasco. 2017. Multisensory Experiences in HCI. 24, 2 (2017), 9–13. DOI:http://dx.doi.org/10.1109/MMUL.2017.33

[196] M Obrist, A Tuch, and K Hornbaek. 2014. Opportunities for odor: experiences with smell and implications for technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '14. DOI:http://dx.doi.org/10.1145/2556288.2557008

[197] R O'Connor. 2021. Pandemic can be a catalyst for changing future cities. (2021). http://www.infrastructure-intelligence.com/article/feb-2021/pandemic-can-be-catalyst-changing-future-cities

[198] School of Art and Design. 2021. Student uses empty Mall as art gallery during lockdown. (2021). https://www.beds.ac.uk/news/2020/july/student-uses-empty-mall-as-art-gallery-during-lockdown/

[199] E Oh, M Lee, and S Lee. 2011. How 4D effects cause different types of presence experience?. In *Proceedings of the 10th International Conference on Virtual Reality Continuum and Its Applications in Industry*. VRCAI '11, 375–378. DOI:http://dx.doi.org/10.1145/2087756.2087819

[200] J Ohene-Djan and R Begum. 2008. Multisensory Games for Dyslexic Children. In *2008 Eighth IEEE International Conference on Advanced Learning Technologies*. 1040–1041. DOI:http://dx.doi.org/10.1109/ICALT.2008.98

[201] T Ojala, H Kukka, T Lindén, T Heikkinen, M Jurmu, S Hosio, and F Kruger. 2010. UBI-Hotspot 1.0: Large-Scale Long-Term Deployment of Interactive Public Displays in a City Centre. In *Fifth International Conference on Internet and Web Applications and Services*. IEEE Computer Society, 285–294. DOI:http://dx.doi.org/10.1109/ICIW.2010.49

[202] World Health Organisation. 2020. 'One World: Together At Home' Global Special. (2020). https://www.who.int/news-room/events/detail/2020/04/18/default-calendar/one-world-together-at-home-global-special

[203] World Health Organisation. 2023. Air Pollution. (2023). https://www.who.int/health-topics/air-pollution#tab=tab_1

[204] C Ortiz. 2022. Cultivating urban storytellers: A radical co-creation to enact cognitive justice for/in self-built neighbourhoods. *Urban Planning* 7, 3 (2022), 405–417.

[205] A Ouf. 2001. Authenticity and the Sense of Place in Urban Design. *Journal of Urban Design* 6, 1 (2001), 73–86. DOI:http://dx.doi.org/10.1080/13574800120032914

[206] S Oviatt, P Cohen, L Wu, L Duncan, B Suhm, J Bers, T Holzman, T Winograd, J Landay, and J Larson. 2000. Designing the user interface for multimodal speech and pen-based gesture applications: State-of-the-art systems and future research directions. *Human-computer interaction* 15, 4 (2000), 263–322. DOI:http://dx.doi.org/10.1207/S15327051HCI1504_1

[207] C Owen. 2022. Striking art installation transforms street in Cardiff city centre. (2022). https://www.walesonline.co.uk/news/wales-news/striking-art-installation-transforms-street-24353979

[208] B O'Keefe, T Flint, M Sturdee, A Resmini, A R L Carter, M Mastermaker, and A Chirico. 2023. Towards a Choreography of Blended Experiences: Dancing with Technology. In *ACM International Conference on Interactive Media Experiences (IMX)*. IMX'23. https://blendedexperiences.com

[209] T Palmer and J Bowman. 2022. The 2022 Design Tools Survey. (2022). https://uxtools.co/survey/2022/

[210] H Papagiannis. 2020. How AR Is Redefining Retail in the Pandemic. *Technology and Analytics* (2020). https://hbr.org/2020/10/how-ar-is-redefining-retail-in-the-pandemic

[211] R M Parsa and Z Torabi. 2015. Explaining the Concept of Identity and Sense of Place in Residential Environment and Lifestyle. *Kuwait chapter of Arabian*

Journal of Business & Management Review 4 (2015), 27–43. DOI:http://dx.doi.org/10.12816/0018961

[212] E Paulos, R J Honicky, and B Hooker. 2009. *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*. IGI Global, Chapter Citizen Science: Enabling Participatory Urbanism. DOI:http://dx.doi.org/10.4018/978-1-60566-152-0.ch028

[213] E Paulos and T Jenkins. 2005. Urban probes: encountering our emerging urban atmospheres.. In *Proceedings of the 2005 CHI Conference on Human Factors in Computing Systems*. CHI '05, 341–350. DOI:http://dx.doi.org/10.1145/1054972.1055020

[214] J Pearson, G Bailey, S Robinson, M Jones, T Owen, C Zhang, T Reitmaier, C Steer, A R L Carter, D R Sahoo, and D K Raju. 2022. Can't Touch This: Rethinking Public Technology in a COVID-19 Era. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*. Association for Computing Machinery. DOI:http://dx.doi.org/10.1145/3491102.3501980

[215] J Pearson, S Robinson, T Reitmaier, M Jones, J A Anirudha, D Sahoo, M Nimish, and B Bhakti. 2019. StreetWise: Smart Speakers vs Human Help in Public Slum Settings. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. CHI '19. DOI:http://dx.doi.org/10.1145/3290605.3300326

[216] P Peltonen, E Kurvinen, A Salovaara, G Lacucci, T Ilmonen, J Evans, A Oulasvirta, and P Saarikko. 2008. It's Mine, Don't Touch!: interactions at a large multi-touch display in a city centre. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI'08, 1285–1294. DOI:http://dx.doi.org/10.1145/1357054.1357255

[217] C Pisano. 2020. Strategies for Post-COVID Cities: An Insight to Paris En Commun and Milano 2020. *Sustainability* 5883 (2020). DOI:http://dx.doi.org/10.3390/su12155883

[218] Plantasia. 2023. Plantasia Tropical Zoo. (2023). https://www.plantasiaswansea.co.uk

[219] D Powell, P Gyory, R Roque, and A Bruns. 2018. The Telling Board: An Interactive Storyboarding Tool for Children. In *Proceedings of the 17th ACM Conference on Interaction Design and Children (IDC '18)*. Association for Computing Machinery, New York, NY, USA, 575–580. DOI:http://dx.doi.org/10.1145/3202185.3210778

[220] I P S Qamar, K Stawarz, S Robinson, A Goguey, C Coutrix, and A Roudaut. 2020. Morphino: a nature-inspired tool for the design of shape-changing interfaces. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*. 1943–1958.

[221] V Quinio. 2021. Is online shopping threatening the future of our high streets? (2021). https://www.centreforcities.org/blog/is-online-shopping-threatening-the-future-of-our-high-streets/

[222] G Rakesh, D Whitney, and D Zeltzer. 2015. Prototyping and design for assembly analysis using multimodal virtual environments. 29, 8 (2015), 585–597. DOI:http://dx.doi.org/10.1016/S0010-4485(96)00093-0

[223] ReMarkable. 2023. ReMarkable: The Paper Tablet. (2023). https://remarkable.com/

[224] C Remy, O Bates, A Dix, V Thomas, M Hazas, A Friday, and E M Huang. 2018. Evaluation beyond usability: Validating sustainable HCI research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–14.

[225] Make Retail. 2022. Internet shopping and the effect on cities. (2022). https://www.makearchitects.com/thinking/internet-shopping-and-the-effect-on-cities/

[226] Reuters. 2019. Police robot to patrol the streets in California neighborhood. (2019). https://www.wtvy.com/content/news/Police-robot-to-patrol-the-streets-in-California-neighborhood\-511502901.html

[227] C Rigby. 2022. How online growth has reshaped the UK's high streets – and the effect on retail jobs. (2022). https://internetretailing.net/how-online-growth-has-reshaped-the-uks-high-streets-and-the-effect-on-retail-jobs-24430/

[228] D Roselli, J Matthews, and N Talagala. 2019. Managing bias in AI. In *Companion Proceedings of The 2019 World Wide Web Conference*. 539–544.

[229] M Roussou. 1999. Incorporating Immersive Projection-based Virtual Reality in Public Spaces. In *Proceedings of 3rd International Immerse Projection Technology Workshop*. INTERACT '03, 33–39. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.102.1703&rep=rep1&type=pdf

[230] E Sanders and J Stappers. 2008. Co-creation and the new landscapes of design. *CoDesign* (2008). DOI:http://dx.doi.org/10.1080/15710880701875068

[231] L Scannell and R Gifford. 2010. Defining place attachment: A tripartite organizing framework. *Journal of Environmental Psychology* 30, 1 (2010), 1–10. DOI: http://dx.doi.org/10.1016/j.jenvp.2009.09.006

[232] H Schnadelbach, B Koleva, M Flintham, M Fraser, I Shahram, P Chandler, M Foster, S Benford, C Greenhalgh, and T Rodden. 2002. The Augurscope: A mixed reality interface for outdoors. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI'02, 9–16. DOI:http://dx.doi.org/10.1145/503376.503379

[233] J Scholz and A Smith. 2016. Augmented reality: Designing immersive experiences that maximize consumer engagement. *Business Horizons* 59 (2016), 149–161. Issue 2. DOI:http://dx.doi.org/10.1016/j.bushor.2015.10.003

[234] ISO Central Secretary. 2019. *Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems*. Standard ISO 9241-210:2019. International Organization for Standardization. https://www.iso.org/standard/77520.html

[235] A Sharma and A Shruti. 2022. *COVID-19 and the Tourism Industry*. Taylor & Francis, Chapter The Effect of COVID-19 Pandemic on Tourism and Hospitality Industry - A Review.

[236] M Shepard. 2009. Sentient city survival kit: archaeology of the near future. *Digital Arts and Culture* (2009). https://escholarship.org/uc/item/4zp0c4x2

[237] E B Shlesinger. 1982. An Untapped Resource of Inventors: Gifted and Talented Children. *The Elementary School Journal* 82, 3 (1982), 215–220. http://www.jstor.org/stable/1001571

[238] E Shokeen, N Katirci, C Williams-Pierce, and E Bonsignore. 2022. Children learning to sketch: sketching to learn. *Information and Learning Sciences* 123, 7/8 (2022), 482–499.

[239] DreamWorks Shrek. 2021. Shrek Adventure London: An interactive Fairytale Experience. (2021). https://www.shreksadventure.com/

[240] N Silberman, M Purser, and E Giaccardi. 2012. Collective memory as affirmation. *Heritage and social media: Understanding heritage in a participatory culture* (2012), 13–30.

[241] A K Sinha and J A Landay. 2001. Visually prototyping perceptual user interfaces through multimodal storyboarding. In *Proceedings of the 2001 workshop on Perceptive user interfaces*. 1–4.

[242] A K Sinha and J A Landay. 2003. Capturing user tests in a multimodal, multidevice informal prototyping tool. In *Proceedings of the 5th international conference on multimodal interfaces*. 117–124.

[243] Slack. 2023. Slack. (2023). https://slack.com

[244] Smartkem. 2023. City of Screens. (2023). https://www.smartkem.com/blog/city-of-screens/

[245] L Smith. 2006. *Uses of Heritage*. Routledge. DOI:http://dx.doi.org/10.4324/9780203602263

[246] L Smith, M Wetherell, and G Campbell. 2018. *Emotion, Affective Practices, and the Past in the Present*. Routledge.

[247] Weather Spark. 2023. Climate and Average Weather Year Round in Swansea. (2023). https://weatherspark.com/y/37763/Average-Weather-in-Swansea-United-Kingdom-Year-Round

[248] C Spence. 2020. Senses of place: architectural design for the multisensory mind. *Cognitive Research: Principles and Implications* 5, 1 (2020), 46. DOI:http://dx.doi.org/10.1186/s41235-020-00243-4

[249] Sphero. 2023. Sphero BOLT Coding Robot. (2023). https://sphero.com/products/sphero-bolt

[250] K Spiel, S A Alharthi, A J Cen, J Hammer, L E Nacke, Z O Toups, and T J Tanenbaum. 2019. It Started as a Joke" On the Design of Idle Games. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. 495–508.

[251] R Stedman. 2003. Is It Really Just a Social Construction?: The Contribution of the Physical Environment to Sense of Place. *Society Natural Resources* 16 (2003), 671–685. DOI:http://dx.doi.org/10.1080/08941920309189

[252] P Stojicic. 2018. The Importance of Residents' Sense of Belonging, Trust, and Power. *ReThink Health* (2018). https://rethinkhealth.org/blog/Resource/the-importance-of-residents-sense-of-belonging-trust-and-power/

[253] E Strickl and M Harris. 2022. Their Bionic Eyes are now Obsolete and Unsupported: Second Sight left users of its retinal implants in the dark. (2022). https://spectrum.ieee.org/bionic-eye-obsolete

[254] Student. 1908. The probable error of a mean. *Biometrika* (1908), 1–25.

[255] B Sullivan, C Ware, and M Plumlee. 2006. Linking audio and visual information while navigating in a virtual reality kiosk display. *Journal of Educational Multimedia and Hypermedia* 15, 2 (2006), 217–241. https://www.learntechlib.org/primary/p/6171/

[256] A Sutcliffe, S Thew, O De Bruijn, I Buchan, P Jarvis, J McNaught, and R Procter. 2010. User engagement by user-centred design in e-Health. *Philosophical Transactions of the Royal Society* (2010). DOI:http://dx.doi.org/10.1098/rsta.2010.0141

[257] Y Suzuki. 2022a. About. (2022). https://www.yurisuzuki.com/about

[258] Y Suzuki. 2022b. Sonic Bloom. (2022). https://www.yurisuzuki.com/projects/sonic-bloom

[259] Taliesin. 2018. Star Wars: Episode IV - A New Hope at the Taliesin Art Centre. (2018). https://www.taliesinartscentre.co.uk/en/cinema?id=59665

[260] R Tapio and L Antti. 2020. Multisensory Augmented Reality in Cultural Heritage: Impact of Different Stimuli on Presence, Enjoyment, Knowledge and Value of the Experience. *IEEE Access* 8 (10 2020), 193744 – 193756. DOI:http://dx.doi.org/10.1109/ACCESS.2020.3032379

[261] Technocamps. 2021. What is Technocamps? (2021). https://www.technocamps.com/en/

[262] Olorama Technologies. 2023. Digital Scent Synthesizer. (2023). https://www.olorama.com/scent-software

[263] Talk Technologies. 2020. STENOMASK / PRIVACY MICROPHONES. (2020). https://talktech.com/stenomask-steno-sr/

[264] A Terracciano. 2020. *Mapping Memory Routes: A Multisensory Digital Approach to Art, Migration, and Critical Heritage Studies*. 275–292. DOI:http://dx.doi.org/10.1007/978-3-030-39915-3_15

[265] A Terracciano, M Dima, M Carulli, and M Bordegoni. 2017. Mapping Memory Routes: A Multisensory Interface for Sensorial Urbanism and Critical Heritage Studies. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. Association for Computing Machinery, 353–356. DOI:http://dx.doi.org/10.1145/3027063.3052958

[266] L Terrenghi, A Quigley, and A Dix. 2009. A taxonomy for and analysis of multi-person-display ecosystems. *Personal and Ubiquitous Computing* 13 (2009), 583–598. DOI:http://dx.doi.org/10.1007/s00779-009-0244-5

[267] J Tillotson. 2021. eScent Personalised Scent Bubble. (2021). https://www.escent.ai/

[268] R Trotta, D Hajas, J Camargo-Molina, R Cobden, E Maggioni, and M Obrist. 2020. Communicating cosmology with multisensory metaphorical experiences. 19, 2 (2020). DOI:http://dx.doi.org/10.22323/2.19020801

[269] York Archaeological Trust. 2021. The original viking encounter. (2021). https://www.jorvikvikingcentre.co.uk/

[270] F Tscheu and D Buhalis. 2016. Augmented Reality at Cultural Heritage sites. In *Information and Communication Technologies in Tourism 2016*, Alessandro Inversini and Roland Schegg (Eds.). Springer International Publishing, 607–619.

[271] Y F Tuan. 1990. *Topophilia: A Study of Ennvironmental Attitudes and Values*. New York, Columbia Universty Press.

[272] K Tufts. 2014. Why sketching is an important part of the design process. (2014).

[273] UD/MH. 2022. How the city affects mental health. (2022). https://www.urbandesignmentalhealth.com/how-the-city-affects-mental-health.html

[274] Age UK and Britain Thinks. 2015. Life Offline | What life is like for older people who don't use the internet. *Britain Thinks* (2015). https://www.ageuk.org.uk/globalassets/age-uk/documents/reports-and-publications/reports-and-briefings/active-communities/life_offline.pdf

[275] London South Bank University. 2021. The pandemic's mental toll: new survey finds one in five suffer from Covid-19 Anxiety Syndrome. (Jul 2021). https://www.lsbu.ac.uk/about-us/news/the-pandemics-mental-toll-new-survey-finds-one-in-five-suffer-from-covid-19-anxiety-syndrome

[276] Swansea University. 2023. EPSRC Centre for Doctoral Training in Enhancing Human Interactions and Collaborations with Data and Intelligence Driven Systems. (2023). https://www.swansea.ac.uk/computational-foundry/epsrc-centre-for-doctoral-training/

[277] D L Uzzell. 1996. Creating place identity through heritage interpretation. *International Journal of Heritage Studies* 1, 4 (1996), 219–228.

[278] M Veenstra, N Wouters, M Kanis, S Brandenburg, K Raa, B Wigger, and A V Moere. 2015. Should Public Displays be Interactive? Evaluating the Impact of Interactivity on Audience Engagement. In *Proceedings of the 4th International Symposium on Pervasive Displays*. PerDis'15, 15–21. DOI:http://dx.doi.org/10.1145/2757710.2757727

[279] C Velasco, C Michel, J Youssef, X Gamez, A D Cheok, and C Spence. 2016. Colour–taste correspondences: Designing food experiences to meet expectations or to surprise. *International Journal of Food Design* 1, 2 (2016), 83–102. DOI:http://dx.doi.org/10.1386/ijfd.1.2.83_1

[280] C Velasco and M Obrist. 2020. *Multisensory Experiences: Where the senses meet technology*. DOI:http://dx.doi.org/10.1093/oso/9780198849629.001.0001

[281] C Verbeek and C Van Campen. 2013. Inhaling memories: Smell and taste memories in art, science, and practice. *The Senses and Society* 8, 2 (2013), 133–148.

[282] S Vicaria. 2023. The Rise Of Remote Work And How To Handle A Remote-First Team. *Forbes Communications Council* (2023). https://www.forbes.com/sites/forbescommunicationscouncil/2023/03/14/the-rise-of-remote-work-and-how-to-handle-a-remote-first-team/#

[283] Victoria and Albert Museum. 2021. Alice: Curiouser and Curiouser Exhibition. (2021). https://www.vam.ac.uk/exhibitions/alice-curiouser-and-curiouser

[284] L Vong. 2013. An investigation of the influence of heritage tourism on local people's sense of place: the Macau youth's experience. *Journal of Heritage Tourism* 8 (02 2013), 292–302. DOI:http://dx.doi.org/10.1080/1743873X.2013.787084

[285] Senedd Wales. 2023. Coronavirus timeline: the response in Wales. (2023). https://research.senedd.wales/research-articles/coronavirus-timeline-the-response-in-wales/

[286] Technology News Wales. 2020. Technology Gives view of future as part of £1bn Swansea Regeneration. *Business News Wales* (2020). https://businessnewswales.com/technology-gives-view-of-future-as-part-of-1bn-swansea-regeneration/

[287] A Watkins. 2015. 4D: Next Evolution in Film or Bust? (2015). http://www.cinemablography.org/blog/4d-next-evolution-in-film-or-bust

[288] K Wiedmann, N Hennigs, C Klarmann, and S Behrens. 2013. Creating Multi-Sensory Experiences in Luxury Marketing. 30 (2013), 60–69. DOI:http://dx.doi.org/10.1365/s11621-013-0300-4

[289] J Willander and M Larsson. 2006. Smell your way back to childhood: autobiographical odor memory. 13, 2 (2006), 240–244. DOI:http://dx.doi.org/10.3758/bf03193837

[290] D R Williams. 2014. Making sense of 'place': Reflections on pluralism and positionality in place research. *Landscape and Urban Planning* 131 (2014), 74–82.

[291] T Winograd. 1996. *Bringing Design to Software*. ACM DL. DOI:http://dx.doi.org/10.1145/229868

[292] A Wlide and A Dix. 2020. Navigating Challenges on Wide-scale Adoption of Video for HCI Education: The HCIvideoW Experience. (2020). http://alandix.com/academic/papers/LatS-hcivideow-exp-2020/

[293] Wizarding World. 2023. The Harry Potter Photographic Exhibition. (2023). https://www.wizardingworld.com/discover/experiences/harry-potter-photographic-exhibition

[294] Z Xiao and Y Deling. 2019. The "hyper-presence" of cultural heritage in shaping collective memory. *Presence* 27, 1 (2019), 107–135. DOI:http://dx.doi.org/10.1162/pres_a_00321

[295] Mill New York. 2019. Nike Unveils Giant Immersive Joyride Experience at NYC's House of Innovation. (2019). https://www.lbbonline.com/news/nike-unveils-giant-immersive-joyride-experience-at-nycs-house\-of-innovationNikeUnveilsGiantImmersiveJoyrideExperienceatNYC'sHouseofInnovation

[296] J Youssef and C Spence. 2021. Nattura by Kitchen Theory: An immersive multisensory dining concept. *International Journal of Gastronomy and Food Science* 24 (2021), 100354. DOI:http://dx.doi.org/10.1016/j.ijgfs.2021.100354

[297] W Yuli, C Kepu, Y Yuting, Z Tao, and Z Wen. 2020. Humans navigate with stereo olfaction. *Proceedings of the National Academy of Sciences* 117, 27 (2020), 16065–16071. DOI:http://dx.doi.org/10.1073/pnas.2004642117

[298] S Zhang, Y Feng, and N Sadeh. 2021. Facial Recognition: Understanding Privacy Concerns and Attitudes Across Increasingly Diverse Deployment Scenarios. In *Seventeenth Symposium on Usable Privacy and Security (SOUPS 2021)*. 243–262.

[299] J Zimmerman, J Forlizzi, and S Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '07, 493–502. DOI:http://dx.doi.org/10.1145/1240624.1240704

[300] Zotero. 2023. Your personal research assistant. (2023). https://www.zotero.org/

Appendix A

Sensory Cue Questionnaire

The appendix presented in this section served as a tool for collecting participant demographics and their associations with sensory cues for four specific scenarios: Guy Fawkes Night, Coffee Shop, Seaside, and Sweet Shop. The survey commenced by gathering demographic information from participants and then provided a brief explanation for each scenario. Subsequently, participants were asked whether they had prior experience with a given scenario. If they had not encountered the scenario, they would proceed to the next section, while those with experience would continue to answer sensory-related questions. Additionally, participants had the opportunity to enter a draw for a £25 Amazon voucher as an incentive for their participation. This data was used to gain a deeper understanding of potential sensory outputs for each scenario, with the results shown in Chapter 4.

Demographic survey questions capturing participant information:

- Which age group describes you?
  - 18-29
  - 30-39
  - 40-49
  - 50-59
  - 60-69
  - 70+
  - Prefer not to say

- Which of the following most accurately describe(s) you?
  - Female
  - Male
  - Non-binary
  - Transgender
  - Prefer not to say
  - Other
- Country of Residence (258 Country Options)
- Please select the Employment Type most relevant to you?
  - Employed
  - Self-Employed
  - Homemaker
  - Retired
  - Full Time Student
  - Part Time Student
  - Prefer not to say
  - Other
- Please select the sector most relevant to you
  - Accountancy, banking and finance
  - Business, consulting and management
  - Charity and voluntary work
  - Education
  - Creative arts and design
  - Engineering and manufacturing
  - Healthcare
  - Law
  - Public services and administration
  - Recruitment and HR
  - Retail and Sales
  - Social Care
  - Transport and logisitcs
  - Prefer not to say
  - Other

Scenario One: Bonfire Night Questions

Bonfire Night also known as Guy Fawkes Night/Fireworks Night is an annual event on the 5th November in the UK. In Swansea, the event is held on the beach and prom and can attract over 30,000 spectators every year. Many people will attend in groups to experience the event together. Please envisage bonfire night and provide an answer to the following questions.

- Have you been to a Bonfire Night before?
  - Yes
  - No
- What words come to mind when you think of the **Smell** of Bonfire Night? Please separate words by a comma
- What words come to mind when you think of the **Sounds** of Bonfire Night? Please separate words by a comma
- What words come to mind when you think of the **Tastes** of Bonfire Night? Please separate words by a comma
- What words come to mind when you think of the **Colour/Lighting** of Bonfire Night? Please separate words by a comma
- What words come to mind when you think of the **Physical Feelings** of Bonfire Night? Please separate words by a comma
- What words come to mind when you think of the **Emotional Feelings** of Bonfire Night? Please separate words by a comma
- Any other words that come to mind that do not fit into the above categories?

Scenario Two: Coffee Shop Questions

There are a number of local coffee shops within Swansea which enable a space for social interactions. The community is able to congregate in groups to socialise over a beverage or can sit and work with their laptop absorbing the background noise. Please envisage your favourite coffee shop and provide an answer to the following questions.

- Have you been to a Coffee Shop before?
  - Yes
  - No
- What words come to mind when you think of the **Smell** of Coffee Shop? Please separate words by a comma

- What words come to mind when you think of the **Sounds** of Coffee Shop? Please separate words by a comma
- What words come to mind when you think of the **Tastes** of Coffee Shop? Please separate words by a comma
- What words come to mind when you think of the **Colour/Lighting** of Coffee Shop? Please separate words by a comma
- What words come to mind when you think of the **Physical Feelings** of Coffee Shop? Please separate words by a comma
- What words come to mind when you think of the **Emotional Feelings** of Coffee Shop? Please separate words by a comma
- Any other words that come to mind that do not fit into the above categories?

Scenario Three: Seaside Questions

Seaside towns and cities such as Swansea enable communities to take trips to the seaside. Many will take trips down to the beach to enjoy stunning views, fresh air, walks on the beach or even BBQ's in warmer months. The beach can enable people to join together in a scenic place and interact by walking together, completing activities. Please envisage your favourite coffee shop and provide an answer to the following questions.

- Have you visited the Seaside?
  - Yes
  - No
- What words come to mind when you think of the **Smell** of Seaside? Please separate words by a comma
- What words come to mind when you think of the **Sounds** of Seaside? Please separate words by a comma

- What words come to mind when you think of the **Tastes** of Seaside? Please separate words by a comma
- What words come to mind when you think of the **Colour/Lighting** of Seaside? Please separate words by a comma
- What words come to mind when you think of the **Physical Feelings** of Seaside? Please separate words by a comma
- What words come to mind when you think of the **Emotional Feelings** of Seaside? Please separate words by a comma
- Any other words that come to mind that do not fit into the above categories?

Scenario Four: Sweet Shop Questions

A trip to the sweet shop can enable a person to buy their favourite confectionery within a layout that is unlikely to have changed over the years creating a warm and nostalgic feel across a range of ages. The shops often have an assortment of different sweets sometimes causing an aversion of the senses. They are often frequented by family groups and couples who look forward to going together. Please envisage your favourite coffee shop and provide an answer to the following questions.

- Have you visited the Sweet Shop?
  - Yes
  - No
- What words come to mind when you think of the **Smell** of Sweet Shop? Please separate words by a comma
- What words come to mind when you think of the **Sounds** of Sweet Shop? Please separate words by a comma
- What words come to mind when you think of the **Tastes** of Sweet Shop? Please separate words by a comma

- What words come to mind when you think of the **Colour/Lighting** of Sweet Shop? Please separate words by a comma
- What words come to mind when you think of the **Physical Feelings** of Sweet Shop? Please separate words by a comma
- What words come to mind when you think of the **Emotional Feelings** of Sweet Shop? Please separate words by a comma
- Any other words that come to mind that do not fit into the above categories?

Appendix B

Java Program Example: Activation of Multisensory Devices for Case-Based Outputs

Appendix B provides a snippet of the Java program used to activate the multisensory devices, triggering their respective outputs (olfactory, auditory, visual, and tactile) based on specific scenarios. The program operates on a case-by-case basis, and the example presented here focuses on the first case, which corresponds to the seaside scenario. Navigating through the code, three distinct cases are configured, each corresponding to a particular scenario: (1) Seaside, (2) Sweet Shop, and (3) Forest. Within a loop, detailed instructions for each case are established. The Aromajoin (Aromashooter) code actively monitors device connections by identifying the serial port. It then determines the number of ports containing scents and sets the percentage strength, with 100 representing the maximum pressure. Subsequently, the code specifies the diffusion process for the Aromajoin devices, including the diffusion time (set at 15 seconds). Finally, the audio outputs are configured to play for the same duration.

```java
@Override
protected void loop() {


    int choice;

    do {
    Scanner keyboard = new Scanner(System.in);
    System.out.println("Chose a Scenario");
    System.out.println("1");
    System.out.println("2");
    System.out.println("3");

    choice = keyboard.nextInt();

    }while(!(choice <= 3 || choice >= 1));
    if (choice == 1) {
        System.out.println("Seaside");

            if (!a.getConnectedDevices().isEmpty()) {

                for(AromaShooter b : a.getConnectedDevices()) {
                    System.out.println("AromaShooter: " + b.getSerial());
                }
                // Ocean and Ocean Fishy Water
                Port port1 = new Port(1,100);
                Port port2 = new Port(2,100);

                a.diffuseAll(15000,  100,  100, port1, port2);

                try {
                    AudioInputStream ais = AudioSystem.getAudioInputStream(seasidesound);
                    Clip c = AudioSystem.getClip();
                    c.open(ais);
                    c.start();
                    Thread.sleep((int)(c.getMicrosecondLength()*0.001));
                }catch(Exception e) {
                    System.out.println(e.getMessage());
                }
```

Figure B.1: Java program snippet illustrating case-based configuration for three scenarios (Seaside, Sweet Shop, Forest) with Aromajoin device setup and synchronised audio outputs.

Appendix C

Multisensory Study Questions

The appendix presented in this section was used to obtain participant demographics, prior experiences with multisensory studies and 4D experiences, and detailed perceptions and recognition of various scenarios for the multisensory lab studies. This data, collected through the survey, was instrumental in shaping the analysis and understanding of participants' sensory experiences and associations with the scenarios under investigation as explored in Chapter 4.

Demographic survey questions capturing participant information and previous sensory experiences:

- Gender Identity:
- Age:
- Job Title:
- Have you ever been part of a multisensory study before?
- If so, what was it?
- Have you ever been to a 4D experience?
- If so, what was it?

Questions from the sensory perception assessment survey, probing participants' sensory experiences, emotions, associations, and sensory prominence ranking:

- What do you sense?
- What do these sensory stimuli evoke?
- What do you think it represents?
- Does it make you think of an event scenario?
- What made you think of that scenario?
- Rank the senses from most to least prominent and what they were:
- Is there anything you think could represent this scenario in a better way?

Appendix D

City Centre Sensory Experience Questionnaire

The appendix included in this section served as a critical component of the city-based questionnaire, offering insights into participant demographics, sensory scenario experiences related to Seaside and Sweet Shop, comfort assessments, and prospects for future use. The survey encompassed a range of aspects, including participants' personal characteristics, their sensory perceptions during specific scenarios, their comfort levels, and their visions for potential future applications. This data collection process, featuring questions and responses related to the Seaside and Sweet Shop experiences, was instrumental in shaping the analysis and understanding of participants' perspectives and contributions to the research and is explored in Chapter 5.

Demographic survey questions capturing participant information:

- Which age group describes you best?
  - 18-29
  - 30-39
  - 40-49
  - 50-59
  - 60-69
  - 70+
  - Prefer not to say
- Which of the following most accurately describe(s) you?

  - Female
  - Male
  - Non-binary
  - Transgender
  - Prefer not to say

- Country of Residence:

Questions from the sensory perception assessment survey, probing participants' sensory experiences, emotions, associations, and sensory prominence ranking:

- What do you think the experience on the bridge was trying to represent?
- Was there a particular scenario/memory it made you think of?
- Which was the most prominent sense?
  - Scent
  - Sound
  - Light
- Which was the least prominent sense?
  - Scent
  - Sound
  - Light
- Where else do you think this could be used within city centres?
- How could these experiences improve you visitor experience to the city?
- How did it make you feel?
  - Very Comforted
  - Comforted
  - No Change
  - Uncomforted
  - Very Uncomforted

Appendix E

UX Design Tool Data: Prices and Compatability

Appendix E provides a comprehensive overview of the 78 UX design tools employed by the participant sample. This includes information on annual pricing, availability of educational discounts, the existence of free trial options, cross-platform compatibility, and the extent of user adoption. This compilation of tools and their associated attributes serves as a valuable reference point, offering insights into the landscape of UX design tool usage among the participants.

Tool	Subscription Required	Annual Price (£)	Education Price (£)	Free Trial	Mac	Windows	Users
Adobe After Affects	Y	239.64	194.88	7 Days	Y	Y	1
Adobe Audition	Y	239.64	194.88	7 Days	Y	Y	1
Adobe Illustrator	Y	239.64	194.88	7 Days	Y	Y	2
Adobe Photoshop	Y	239.64	194.88	7 Days	Y	Y	1
Adobe XD	Y	623.76	194.88	7 Days	Y	Y	7
Affinity Designer	Y	69.99	Request	30 Days	Y	Y	2
Arduino (starter kit)	N	84.50	84.50	0 Days	Y	Y	1
Asana	Y	–	–	0 Days	Y	Y	1
Atlas.ti	Y	420.00	115.20	5 Days	Y	Y	1

Axure RP	Y	246.00	Request	30 Days	Y	Y	3
Balsamiq	Y	105	Request	30 Days	Y	Y	6
Camtasia	Y	295.91	105.04	30 Days	Y	Y	1
Deck of Cards	N	Up to £160	Up to £160	0 Days	N	N	1
DENIM	N	–	–	0 Days	Y	Y	1
Draw.io	Y	–	–	0 Days	Y	Y	1
Figma	Y	132.00+	–	30 Days	Y	Y	9
Figma Jam	Y	132.00+	–	30 Days	Y	Y	1
Flip Charts	N	25.00+	25.00+	0 Days	N	N	2
Fusion 360	Y	510.00	–	30 Days	Y	Y	2
Google Docs	Y	–	–	Unlimited	Y	Y	3
Google Drawings	Y	–	–	Unlimited	Y	Y	1
Google Jamboard	Y	–	–	Unlimited	Y	Y	1
Google Tables/Forms	Y	–	–	Unlimited	Y	Y	1
GoToMeeting	Y	114.00	114.00	14 Days	Y	Y	1
HTML/WEbflow	Y	137.81+	–	30 Days	Y	Y	1
IDE	Y	–	–	Unlimited	Y	Y	1
InVision	Y	39.99	–	30 Days	Y	Y	3
iPad 'Flow'	Y	13.99	13.99	14 Days	Y	N	2
IRIS	Y	Request	Request	0 Days	Y	Y	1
Jupyter	N	–	–	Unlimited	Y	Y	1
Keynote	N	–	–	Unlimited	Y	N	1
Lego	N	35.00+	35.00+	0 Days	N	N	1
Lookback	Y	246.00	246.00	60 Days	Y	Y	1
Miro	Y	79.00	–	Unlimited	Y	Y	12
MS Dev	Y	59.99	59.99	30 Days	Y	Y	1
MS Excel	Y	59.99	59.99	30 Days	Y	Y	1
MS Notes	Y	59.99	59.99	30 Days	Y	Y	1
MS Powerpoint	Y	59.99	59.99	30 Days	Y	Y	2
MS Stream	Y	59.99	59.99	30 Days	Y	Y	1
MS Teams	Y	–	–	Unlimited	Y	Y	2
MS VBA	Y	59.99	59.99	30 Days	Y	Y	2
MS Visio	Y	59.99	59.99	30 Days	Y	Y	2

MS Visual Studio	Y	59.99	59.99	30 Days	Y	Y	2
Mural	Y	99.99	–	30 Days	Y	Y	2
Notability	Y	–	–	Unlimited	Y	Y	3
Notion	Y	–	–	Unlimited	Y	Y	1
Noun Project	N	–	–	Unlimited	Y	Y	4
OmniGraffle	Y	205.00	205.00	14 Days	Y	N	2
Optimal Sort	Y	136.00	–	60 Days	Y	Y	2
Paper	N	2.00+	2.00+	0 Days	N	N	19
Pin and Play	N	£5.00+	£5.00+	0 Days	N	N	1
Pinterest	Y	–	–	Unlimited	Y	Y	1
Plex	Y	Request	Request	0 Days	Y	Y	1
Plotly	Y	Request	Request	0 Days	Y	Y	1
POP Marvel	Y	96.00	–	30 Days	Y	Y	1
Post it notes	N	2.00+	2.00+	0 Days	N	N	4
Principle	Y	104.42	104.42	14 Days	Y	N	1
ProCreate	Y	10.51	10.51	0 Days	Y	N	4
Proto.io	Y	281.69	140.85	14 Days	Y	Y	1
Real VNC	Y	78.00	78.00	14 Days	Y	Y	1
Roam Research	Y	133.56	133.56	30 Days	Y	Y	1
Sketch	Y	87.42	–	30 Days	Y	Y	4
Slack	Y	–	–	Unlimited	Y	Y	1
Smaply	Y	175.02	–	30 Days	Y	Y	1
Smoke and Mirrors	N	£5.00+	£5.00+	0 Days	N	N	1
Speech interfaces	Y	£20.00+	£20.00+	0 Days	Y	Y	1
SPSS	Y	962.65	32.33	30 Days	Y	Y	1
Stick IT	N	–	–	0 Days	Y	Y	1
Trello	Y	48.50	–	30 Days	Y	Y	3
UXPin	Y	228.64+	–	14 Days	Y	Y	1
UXpressia	Y	12.50+	–	30 Days	Y	Y	1
Webcam	N	13.00	13.00	0 Days	N	N	3
Whiteboard	N	30.00	30.00	0 Days	N	N	2
Written Sys	N	–	-	0 Days	N	N	1
Xcode	Y	–	–	Unlimited	Y	N	1

Zigbee	Y	–	–	Unlimited	Y	Y	1
Zoom	Y	–	–	Unlimited	Y	Y	3
Zotero	Y	–	–	Unlimited	Y	Y	1

Appendix F

UX Design Tool Usage throughout the Design Process

Appendix F offers a comprehensive overview of how the 78 UX design tools were used by the participants throughout various stages, including ideation, design and development, prototyping, demonstration, and feedback. This compilation sheds light on the landscape of UX design tool usage among the participants, providing valuable insights for the future.

Tool	Ideation	Design and Development	Prototyping	Demonstration and Feedback
Adobe After Affects	–	Y	Y	–
Adobe Audition	–	–	Y	–
Adobe Illustrator	Y	Y	Y	–
Adobe Photoshop	–	Y	–	Y
Adobe XD	Y	Y	Y	Y
Affinity Designer	Y	Y	–	–
Arduino (starter kit)	–	Y	–	–
Asana	Y	–	–	–
Atlas.ti	–	–	–	Y
Axure RP	–	Y	Y	–

Balsamiq	–	Y	Y	Y
Camtasia	Y	–	–	–
Deck of Cards	Y	–	–	–
DENIM	–	–	Y	–
Draw.io	–	Y	Y	Y
Figma	Y	Y	Y	Y
Figma Jam	–	–	–	Y
Flip Charts	Y	–	–	–
Fusion 360	Y	–	Y	–
Google Docs	Y	–	Y	Y
Google Drawings	–	Y	–	–
Google Jamboard	Y	–	–	–
Google Tables/Forms	–	–	–	Y
GoToMeeting	–	–	Y	–
HTML/WEbflow	–	–	Y	–
IDE	–	–	Y	–
InVision	–	Y	Y	Y
iPad 'Flow'	Y	–	–	–
IRIS	Y	–	–	–
Jupyter	–	–	Y	Y
Keynote	–	–	–	–
Lego	Y	–	–	Y
Lookback	Y	–	–	Y
Miro	Y	Y	Y	Y
MS Dev	–	Y	Y	–
MS Excel	Y	–	–	–
MS Notes	Y	–	–	–
MS Powerpoint	Y	Y	–	–
MS Stream	–	–	–	–
MS Teams	Y	–	–	Y
MS VBA	Y	–	–	–

MS Visio	Y	Y	Y	–
MS Visual Studio	–	–	Y	–
Mural	Y	Y	–	Y
Notability	Y	Y	–	–
Notion	–	–	–	Y
Noun Project	Y	–	–	–
OmniGraffle	Y	–	–	–
Optimal Sort	–	–	Y	Y
Paper	Y	Y	Y	Y
Pin and Play	–	–	Y	–
Pinterest	Y	–	Y	–
Plex	–	–	–	–
Plotly	–	–	–	–
POP Marvel	Y	–	–	–
Post it notes	Y	–	Y	Y
Principle	–	Y	–	–
ProCreate	Y	Y	Y	–
Proto.io	–	Y	–	–
Real VNC	Y	–	–	–
Roam Research	Y	–	–	–
Sketch	Y	Y	Y	–
Slack	–	–	–	–
Smaply	–	–	–	Y
Smoke and Mirrors	–	Y	–	–
Speech interfaces	–	–	–	–
SPSS	–	–	–	Y
Stick IT	–	–	–	–
Trello	Y	–	–	Y
UXPin	–	–	–	–
UXpressia	–	–	–	Y
Webcam	Y	Y	Y	Y

Whiteboard	Y	Y	Y	Y
Written Sys	–	–	Y	–
Xcode	–	–	Y	Y
Zigbee	–	Y	–	–
Zoom	–	–	Y	Y
Zotero	Y	–	–	–