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Advancing Women's Active Travel Safety through Technological Interventions

by

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Abstract

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The idea of feeling safe while travelling by foot or bike is inherently influenced by gender, and throughout history, women have adopted safety measures as a way to protect themselves. These practices are primarily undertaken in response to fear-based concerns for one's personal safety and are especially important for active travel (travel made under one's own steam such as walking, cycling and scooting) due to the need to enter public space. To address the need for safety work and to combat crime, a swathe of technological solutions has recently been advanced to make individuals 'safer', but do they in fact support women's safety?

The goal of this thesis is to investigate if technological progress can offer lasting protection for women by conducting a comprehensive study of the capabilities of technology in assisting them, while also identifying future potential areas for development and research.

This thesis examines the role of technology in supporting women's safety through the activities and social practices that women engage in while active travelling. The methodology is founded on a practice-oriented perspective. The reason for using a practice perspective is to include material or infrastructural (contextual) objects that are part of the practice of 'doing', and are frequently unaddressed by social-psychological approaches. It focuses on two distinct domains of 'practice' where technology is employed. The first, in the 'doing' of active travel and the second, in the reporting and campaigning undertaken via social media and the collective intelligence that this provides.

The findings show that the interplay between trust plays a key role in the adoption of safety technology. Technology is also unable to alter existing active travel safety strategies but does support their undertaking. It challenges rather than discredits the optimistic stance that technology can solve the issue of personal safety, requesting that development should centre on the availability of information rather than being used as a deterrent or weapon. This is of significance to developers, users, social science researchers, policymakers, urban planners and transport companies that constitute part of multi-modal active travel trips such as public transport and mobility as a service (MaaS) providers.

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To Sarah, Sabina, Ashling and Zara

Definitions and Abbreviations

AI	Artificial Intelligence
API	Application Processing Interface
BERT	Bidirectional Encoder Representations from Transformers
BoW	Bag of Words
CCTV	Closed-Circuit Television
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GPS	Global Positioning Systems
HCI	Human Computer Interaction
ICT	Information and communication technology
IPV	Intimate Partner Violence
LDA	Latent Dirichlet Allocation
LMIC	Low to Middle Income Countries
MaaS	Mobility as a Service
NLP	Natural Language Programming
PBC	Perceived Behavioral Control
PSD	Personal Safety Device
SMA	Social Media Analysis
SPT	Social Practice Theory
VAW	Violence Against Women

Chapter 1

Introduction

During the course of 2021 and 2022, a number of high-profile murder cases in the UK highlighted the everyday risks posed to women in effectively going about their daily lives in open spaces. Most notable was the case of Sarah Everard but within a year, Sabina Nessa, Ashling Murphy and Zara Aleena, had also been murdered. In all four cases, the individuals were walking or running, being active, on their way home or meeting with a friend — practicing everyday activities.

The response to these tragedies was vast, nowhere more so than on X (formerly known as Twitter), which saw an influx of dialogue about individual women's experiences of safety. The cases brought to light issues surrounding the under-reporting of harassment and sexual violence, and also likely influenced sporting companies to investigate the safety-related concerns of their users (Adidas, 2023). Out of these tragedies, new technological solutions were sparked into being (Torre, 2022).

At the time, media outlets repeatedly noted how Sarah Everard had employed strategies to try to increase her safety (walking a route along a main road that was well-lit, and calling her partner to keep them posted as to her whereabouts). These safety practices often employed by women have been extensively documented, with respect to both mobility (Bates, 2023, p. 64; d'Arbois de Jubainville & Vanier, 2017; Harumain et al., 2021; Z. Li et al., 2013; Orr et al., 2023) and violence against women (VAW), (L. Stark et al., 2021; Zedaker & Muftić, 2017) and form part of ingrained safety knowledge and 'routine strategies' that Kelly (2012) has conceptualized as women's 'safety work'.

A lack of awareness of this additional safety work was demonstrated in 2022 when a Samsung advertisement came under scrutiny for depicting a woman running in the early hours wearing in-ear headphones. After it was broadcast, there was a backlash focused on the audacity of the 'tech giant' for suggesting that running in this way was even possible for women. For instance, the practice of running alone during the twilight hours and wearing earbuds, that

may impair awareness, is entirely contrary to what are considered to be 'established' safety strategies (Orr et al., 2023).

Using technology is one possible way to tackle safety issues that affect women, as promoted by developers, governments (Letourneau, 2011; Topping, 2022), and media alike (Cardoso et al., 2019). Mobile applications form the largest percentage of personal safety devices. Their type and features are vast (Ford et al., 2022) and primarily developed for use in emergency situations to combat VAW, Intimate Partner Violence (IPV) and sexual violence (Eisenhut et al., 2020). The majority are targeted towards women (Eisenhut et al., 2020; Maxwell et al., 2020), but they have met with opposition from women's groups advocating for alternative approaches like educating men.

It became evident through the ongoing dialogue between women, the media, and developers, that the relationship between digital technologies, women's safety, and active travel was deserving of further investigation and thus, here I am. I will begin by defining what I mean by the terms active travel, safety, and technology.

1.1 Background

Active travel entails undertaking journeys through physically active methods, such as walking, scooting, or cycling. Active travelling is in itself a practice, although it is not always performed in isolation. It may be part of other social practices, such as commuting, or it may become part of a routinised leisure practice. As such, it integrates itself into other practices. This kind of practice is described as a 'dispersed practice' (Harries & Rettie, 2016). In this thesis, I consider active travel to include round trips, leisure trips, and multi-modal trips. This is perhaps a broader interpretation than is currently used within the literature, which usually identifies active travel in the context of commuting or performing movement from point A to point B, where in fact it could involve getting from point A to A or A to D to B to E (Jones & Spencer, 2024).

Safety has been defined as the absence of physical injury or threat of injury (Starr, 1985), and within mobilities, safety is frequently associated with this definition. Literature references reported road accidents and the likelihood of injury as their benchmark for safety (Bliš'anová et al., 2023), where safety is correlated to accidents (Amiour et al., 2022). Perceived safety is more nuanced and associated with the possibility of users experiencing criminal behaviour and harassment (J. Stark & Meschik, 2018). This is particularly pertinent for active travel modes, as they require users to enter a public space where experience is shaped by factors beyond their control (Ng & Acker, 2020). Safety in mobility is therefore a complex concept that extends beyond mere accident prevention. Vandeskog (2024, p. 106) defines safety as 'the material, emotional and mental state that obtains when it is highly probable that all relevant positive values will be preserved for a desired duration, and the knowledge

supporting this probability assessment is strong'. This description is much more applicable to this research, due to the potential harms that may occur whilst active travelling. The term safety within this thesis is used to describe both perceived and actual safety risks.

Safety is considered one of the main barriers to active travel uptake, and whilst it affects all genders, it disproportionately affects women (Basu et al., 2021; Department for Transport, 2020). Women are more likely to experience harassment or suffer assault in public spaces (Gekoski et al., 2017), are twice as likely to be subjected to harassment than men whilst cycling (Aldred et al., 2017), and are more likely to be close-passed (Evans et al., 2018). The prevalence of harassment towards women and the extent of their safety fears have been extensively documented. For example, 71% of women in the UK reported that they had experienced public sexual harassment (UN Women, 2024) and 32% of women in the UK fear walking alone in the dark (European Social Survey, 2018). Researchers have discovered that fears related to activity (Ravensbergen et al., 2020) and environmental responses are also gendered (Basu et al., 2021; Pelclová et al., 2014). For example, Rišová and Sládeková Madajová (2020) investigated the spatial-temporal considerations of adolescents while walking. The study found that, in general, women are more fearful, but also that they are more fearful when there is a low level of lighting or a lack of activity or people in areas such as parks, alleyways, or spaces near pubs and bars. Research consistently shows that women's perceptions of safety significantly influence their mobility patterns.

Women make substantial adjustments to their daily behaviours and spatial practices to maintain their safety (Cherif & Wahdan, 2023; Pucci et al., 2023), such as seeking out safer routes, even if this means travelling greater distances or active travelling at different times of the day (Aldred et al., 2017; Loukaitou-Sideris, 2014). These 'safety work' strategies are carried out in various contexts, but are especially common when they are in what are considered to be risky situations (Vera-Gray & Kelly, 2020). Education, previous experiences, and self-declared perception of safety all correlate with avoidance behaviours. However, avoidance behaviours cannot be implemented by those with existing transport habits that cannot be changed and are considered necessary (d'Arbois de Jubainville & Vanier, 2017). Ultimately, J. Stark and Meschik (2018) highlight that if the journey is considered unfeasible due to safety concerns, women feel captive by their travel options.

Alongside these existing and longstanding safety strategies, there is increasing evidence to suggest that humans are creating relationships with technology, such as mobile phones, in response to their perception of safety (Cumiskey & Brewster, 2012; Orr et al., 2023). An individual's perception of safety has been found to be improved by the presence of a mobile phone (Line et al., 2011), and phenomenological research has revealed that more specific embodiment behaviours, such as holding a mobile phone in a particular way, increase the user's sense of safety and that this changes depending on the user's sense of place and requirements (keeping it in a bag rather than in your hand depending on the situation) (Hardley & Richardson, 2019). There have also been cases of nascent use of technology for criminal convictions from the data they generate, as was the case for Jill Meagher and Ashling

Murphy (Anderson, 2013; Ní Aodha, 2023). The data from Ashling Murphy's Fitbit was used to track her physical movements, and the rapid fluctuation of her heart rate prior to her death (which was pinpointed at exactly 3.31 pm). There is a blurring of lines between technology and safety that extends to active travel because it is where women feel vulnerable.

Following the trend of technology use in mobility, newer digital 'personal safety devices' are also being developed and marketed as a high-tech solution addressing the safety concerns of women (Cardoso et al., 2019). Despite their perceived benefits, there remains no established proof of them reducing the risk of harm (Eisenhut et al., 2020) or preventing criminal activity. Whilst these devices have been shown to increase feelings of safety, (Ford et al., 2022) they can also be detrimental, leading to risky behaviours (Ishikawa, 2019; Line et al., 2011; Nasar et al., 2007) or adverse psychological effects (Carleton et al., 2019; Nasar et al., 2007). Promises of efficacy paired with increasing fear and uncertainty suggest the necessity of utilising these tools. Therefore, it is just as, if not more, crucial to inquire about the 'suitable' timing for creating technologies as remedies. While technology has shown success in various aspects of society, it is important to question if we are being too hasty in relying on it as a simple solution to complex issues like VAW.

Current studies on how technology influences women' safety have mainly focused on content analysis and creating individual tools, and whilst important, this is a limited perspective. Content analysis does not detail how women use and interact with this technology in daily life and assessment of a mobile application, without specifying its individual features, makes the findings less applicable to future research and development. Whilst it is understood that being specific about a technology is of scientific importance, so is being more 'general' in its definition, such that it can be applied in more ways to future studies. The Collingridge Dilemma (Worthington, 1982) highlights this reciprocal trope in the design and development of technology, where social impacts cannot be predicted until introduced, and once introduced it becomes difficult to change, control or influence (Genus & Stirling, 2018). Given that development requires constant attention to keep pace with its introduction, this general approach is favoured in this thesis, as a means of addressing the problem of pacing in technological development.

McOmber (1999) defines technology as an instrument, industrialisation, and innovation. These three notions hold technology to be purely functional. Yet, technology can mediate tasks through both functional and knowledge-based components (Fox, 2019; Matthewman, 2011). Benson and Magee (2015) consider using these two components to facilitate the objective analysis of technological domains. To approach this study in a similar way, these two components have been adopted for this research, proposing that investigations consider technology as a functional device in the 'doing' of active travel, but also in the understanding of how to use technology to harness knowledge. I further deviate from existing studies by splitting the research into two streams to account for the variance in technological accommodation in this domain. Firstly, in the 'doing' of active travel (women's technology-related practice) which considers a 'newer' swathe of small portable personal

safety devices that use tools such as global positioning systems (GPS) and a connection to the internet or other databases through mobile networks or Wi-Fi connections. Secondly, it examines the potential for new research through technology, specifically the use of machine learning and artificial intelligence (technology as a research device).

Behavioural models have been extensively used to understand active travel mobility. The theory of planned behaviour has been particularly influential, which is likely due to its use in understanding and predicting a wide range of behaviours (Ajzen, 2011), as well as in the development of interventions for behaviour change (C.-F. Chen & Chao, 2011; Jing et al., 2019). These studies employ structural equation modelling to examine the connections among pertinent variables relating to technological adoption or behaviours (Paige Willis et al., 2013; Singleton, 2020; Sun, 2017). Despite behavioural theories forming the foundation for understanding mobility decisions and technological relationships (C. Chen, Ma, et al., 2016), they face several challenges. The abundance of theories makes it difficult to select the most appropriate, with many considered either too simple or complex (Chng, 2021). They often overlook how mobility is intertwined with social practices, physical environments, and broader political contexts (Barr & Prillwitz, 2014), and instead suggest that mobility decisions are based on subjective norms, desirability, and an individual's readiness for change. Because of this, contextual inquiry is often lacking, with little emphasis on lived experiences and the importance of materiality (Hampton, 2018). Thus, there is a requirement for a more extensive, inclusive line of inquiry that integrates an understanding of experiential influences, historical views of location and existing safety practices, such as is not currently available through social psychological approaches.

Instead, I turn to social practice theory (SPT), an approach that views practices as a fundamental component of the social world (Shove et al., 2012). This framework addresses the limitations of socio-psychological approaches by considering societal norms, material settings, and cultural contexts (Meier et al., 2018; Mercuur et al., 2020), and is thereby able to provide insight into changes with respect to the individual, home, community, and societal scales (Breadsell et al., 2019). SPT offers a conceptual alternative and, importantly, has precedent in exploring the role of the non-humans (material things) and its consumption in social practices (Shove & Pantzar, 2005), mobility (Heisserer & Rau, 2017), and the dynamics of social change (Spaargaren et al., 2016). I believe that SPT offers a valuable and fresh perspective, emphasising the importance of material elements, competences, and meanings in shaping practices (Risner et al., 2022).

In applying SPT as a framework, it is believed that the relationship between humans and technology, inclusive of any shortcomings, can be found and evaluated by separating the components of practice into materials, competences, and meanings (Shove et al., 2012). In establishing the integrated nature of material and practice and the social ontologies that situate it, Schatzki (2010) believes that it is possible to focus any investigation, such as my own, and to suggest connections in among empirical findings.

1.2 Research Questions and Objectives

Women's safety persists as a pressing issue in modern society. One area in which safety is important to women is in their active travel behaviour, leading to the additional cost of 'safety work' (Vera-Gray & Kelly, 2020). This inequality is recognised by the United Nations as a globally neglected issue where Goal 11.2 of the United Nations Sustainable Development Plan, explicitly acknowledges that reducing inequality in transportation for individuals in 'vulnerable situations, women, children, individuals with disabilities, and older individuals', is imperative (UN Women, 2024).

Recent research highlights the potential for technology to address women's safety concerns during active travel. Mobile applications and intelligent systems can provide real-time safety features, including location sharing, route prediction, and evidence recording (Gupta et al., 2022). However, these technologies may also inadvertently reinforce victimisation, restrict women's movement further by prescribing 'safe' routes (Das, 2021), make them more vulnerable by increasing their perception of safety (Lindberg & Lyytinen, 2013; Line et al., 2011; Nasar et al., 2007), or impact their psychological health (Carleton et al., 2019).

In the wake of Sarah Everard's murder these devices were offered up by the government as a possible 'solution' to women's safety. Although this was met from fierce opposition from women's groups citing the potential risks (Topping, 2022). In the absence of significant experiential research into how technology may influence women's safety inclusive of technological devices targeted towards women to keep them safer whilst active travelling, the overarching research question explored throughout this thesis is:

RQ0. How can technology be deployed to improve women's perception of safety of active travel?

It is formulated using the phrase perception of safety. It is not presumed that this thesis will be able to conclude that technology can empirically prove that technology can reduce actual risk to harm, instead influence perception of safety.

This question led to three specific research sub-questions (see below) formulated to generate insights that would support an argument in response to this question. These sub-questions are explored in depth in the main body of this thesis. The first looks to using technology as a source of information. Specifically, it targets the data collection afforded by technology to address the issues surrounding the lack of reporting, knowledge, and understanding of women's active travel safety. Here, analysis of social media data is conducted to answer RQ1.

RQ1. How can technology enable a greater understanding women's perception of safety whilst active travelling?

RQ2 addresses the influence and needs of women as associated with existing practice.

RQ2. How does technology contribute to, or influence, a women's perception of safety whilst taking part in active travel?

The last question (RQ3) looks ahead to future technologies, highlighting the challenges that face the introduction of technology in this domain.

RQ3. What are the current challenges and limitations of technology designed to support women's perception of safety when they use active travel modes?

This research sets out to assess the role of technology in supporting women's safety through the activities and social practices that women engage in whilst active travelling, using a practice perspective and shifting the focus away from the individual. It looks at two distinct areas of 'practice' where technology is used. The first is the 'doing' of active travel (women's technology-related practice) and the second, reporting and campaigning undertaken online and how this information might be harnessed (technology as a research device).

As such, the research aims to address a lack of understanding of the relationship between technology use, women's safety, and active travel. It does so to contribute to a more equitable transport landscape through the development of appropriate and sustainable technological solutions that consider the lived experience of women.

The following are the primary goals of this research.

- Using applied research, investigate how technology can be used as a tool of research by exploring new methods for data acquisition and analysis.
- Gain qualitative insights into the current use of technology by women, accessing the feasibility and sustainability of the technological features on offer.

1.3 Contribution

This thesis contributes to ongoing research on women's safety and technology in three distinct ways. Firstly, to demonstrate the knowledge gathering capabilities of technology I use an applied methodology to investigate alternative methods for data collection. Secondly, it examines the technology-related practices that women employ in active travel. Finally, this study reveals how current and emerging technologies could be used to enhance women's safety whilst active travelling, and the implications of doing so.

1.4 Thesis Structure

A literature review is presented in Chapter 2, which outlines the significance of gender in the context of safety and active travel.

Chapter 3 details the selection and justification of a theoretical framework that has been chosen to guide this thesis.

Chapter 4 details the overall methodological approach and research design of two identified research streams; technology as a research device, and women's technology-related practices.

The results, discussion, and conclusion of the (technology as a research device) study are included in Chapter 5.

To identify the distinct characteristics of digital technologies utilised for safety purposes, the focus groups necessitated an assessment of various current and pre-existing digital technologies. The findings of this review are detailed in Chapter 6.

Chapter 7 contains the findings and discussion from the focus group study. It outlines the dominant themes found within the qualitative data taken from the focus groups, where I use social practice theory as a framework to gain further insights. The chapter is split into three sections, which follow the guiding architecture of social practice theory; practices as entities, practices as performances, and a summary of the three elements of practice (meaning, competence, and material) (Shove et al., 2012).

Chapter 8 details further insights surrounding the wider social implications of adopting technology for the personal safety. Whilst this also resulted from the focus group data, it warranted a separate chapter outside the practice lens that guided the primary focus group discussion.

Finally, conclusions from both research streams are combined in Chapter 9, which is inclusive of proposals for future research.

Chapter 2

Literature Review

Chapter 1 introduced the problem of gendered journeys how safety impacts the active travel behaviours of women, and the concept of using technology to remedy the safety fears of women in the form of personal safety devices. It outlined the key questions and goals for this research, namely, whether technology can support women's active travel safety and in turn improve their experience of active travel, or whether their introduction necessitates further inquiry.

This chapter serves to establish a research and theoretical basis regarding the topic of technology for personal safety during active travelling, through a review of existing literature and identifying the gaps in existing knowledge in this area. Research at the intersection of technology, safety, and active travel is considered, and grounded in the historical problem of women's safety. It introduces ideas around the influence of technology on mobility and, in turn, the concepts, and approaches of sociotechnical evaluation.

This chapter begins by situating the development of technology through the lens of gender and mobility. It then explores the evaluation and development of technologies inclusive of the key perspectives used in their design, and finally, existing literature on personal safety devices and the methods and approaches to their evaluation, use, and the perceptions of users are considered.

2.1 Literature Search Strategy

Existing literature was primarily located via Google Scholar and Web of Science using a keyword search that demonstrated the field. In the initial searches terms related to gender (women, woman, female), technology (artificial intelligence, information, and communication technology [ICT], computer, software), mobility (active travel, walking, cycling) and safety (violence, harassment). The references cited in pertinent papers have also illuminated

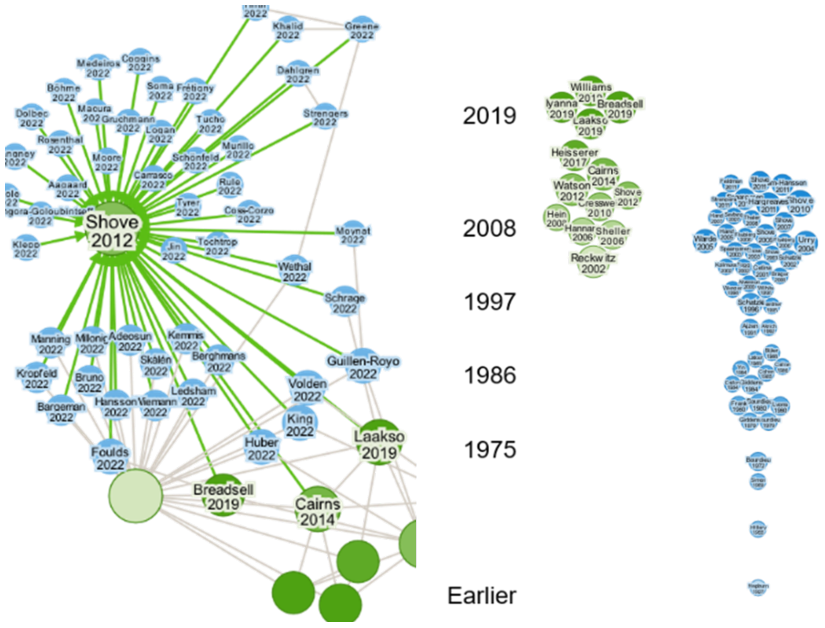

FIGURE 2.1: Network diagrams (left) Chronological (right) showing a visual representation of connected research in Research Rabbit.

supplementary literature for further examination. No exclusion criteria were set on the published dates of articles, but papers were limited to those written in English. In addition to this traditional literature search strategy, I also used several innovative research tools that were available to me. Namely, Research Rabbit (ResearchRabbit, n.d.) and Elicit (Elicit.org, n.d.). These tools were used to find related articles through natural language programming and network connectivity diagrams. Figure 2.1 shows how searches on Research Rabbit can identify similar or related works using network diagrams.

2.2 Technology

While definitions differ, technology is generally understood to exist at the intersection of people, machines, and organised knowledge, serving to accomplish practical goals inclusive of tools and methods (Fox, 2019). Whilst technology is considered to be a physical artifact, to examine all its facets, consideration must be given to its use and perceptions (Verbeek, 2005). McOmber (1999) identifies technology as an instrument, a tool of industrialisation, and an innovation, all of which focus on technology as purely functional. Yet, technology functions in many ways and can mediate tasks, as highlighted by Fox (2019) through two components. A two-component definition comprises functional and knowledge elements, previously proposed by Benson and Magee (2015), has been adopted for this research. They consider this as facilitating objective analysis of technological domains. The definition of technology varies across sources, but these common themes emerge.

There are several definitions of technology that are essential for comprehending this research study and its implications. The following definitions cover some fundamental terms used throughout, to avoid ambiguity and facilitate a more in-depth understanding of the arguments and findings presented. This thesis considers a 'newer' swathe of small portable electronic technological devices that use tools such as global positioning systems (GPS), and connection to the internet or other databases through mobile networks or Wi-Fi connections. Digital technologies, therefore, are tools that employ various systems and methods to undertake tasks and solve problems.

2.2.1 Technological Devices

A technological device is an object used to aid in the execution of a given procedure or process. I specifically detail it as electronic, something that requires power and electricity to work, is made up of electronic components, and is plugged in to charge or battery powered. The term could include a toaster or a large desktop computer; however, in the context of this thesis' research (women's technology-related practice) and personal safety focus, I consider items such as panic buttons, drones, cameras, activity trackers, smartwatches, and mobile phones and their associated applications. It might indeed be possible that a toaster is considered more useful than these tools, albeit a little impractical to (active) travel with. In the cases above, the tools use software to operate, and I would like to further specify that they are digital, in that they use binary code to represent and process information and are usually connected to the internet or some other kind of database or network. Technology may therefore be regarded as one or a combination of the following elements: a physical device that the user interacts with, software that enables the device to operate as intended, third-party software such as mobile applications that are downloaded onto devices, and tools such as video and audio recording. Whilst other studies in this domain have included technology such as closed-circuit television (CCTV), I have chosen not to due to the lack of individual interaction, and it being considered a passive technology. Instead, I will focus on tools and devices with which the individual has personal interaction with.

2.2.2 Automatic Systems

Automatic systems are technologies that will operate or perform a task with minimal input from users. For example, tracking software (once instigated by the user) can work in the background without user input. This term is not specifically used to define artificial intelligence (AI), yet artificial intelligence forms a considerable component of some automatic systems.

2.2.2.1 Artificial Intelligence

As the name suggests, artificial intelligence is intelligence that is artificial, rather than naturally created (human intelligence) where machines are programmed to behave and reason like humans. To achieve this, algorithms and models that can mimic human intelligence, through learning from data, making decisions, and performing tasks autonomously, are designed and curated (Tecuci, 2012). The goal of using artificial intelligence is to assign hard and time-consuming tasks to machines to increase productivity, reduce human error, and solve complex problems. There are varying levels of AI which are placed in categories dependent on the degree to which they can represent human cognition and its real-world application, and, in the case of strong AI, its theory of mind prerequisites (Morandín-Ahuerma, 2022). Artificial intelligence has been used for decision-making activities in a wide array of domains, such as healthcare, autonomous vehicles, chatbots, recommender systems, robotics, computer vision, and analytical tasks. All these implementations are considered to be weak AI.

Weak AI, or narrow AI, is used for a specific or narrow task, hence the name. It is unable to learn from evolving data and is usually programmed based on data to be able to perform a specific task, and is thereby unable to expand its capabilities based on evolving datasets unless reprogrammed. Examples of weak AI that are integrated into existing tasks are things like the use of natural language programming in virtual assistants (chatbots and Siri) and junk email filtering. The key takeaway is that there is no 'real' intelligence, in that whilst there is increased complexity it is derived from programming alone, and it is unable to learn.

All implementable AI that is used for personal safety is weak AI. These systems rely on programmable inputs to achieve the goals of designers. Examples include route recommender systems designed to take information about street-level layouts and form a route based on rules like the quickest trip duration. In this case, AI is used to help make decisions, but it relies on human input.

A subset of weak AI is machine learning. Machine learning is a way of progressing the use of artificial intelligence whilst remaining within our current reality. Enabling the learning coveted by strong AI, machine learning is the application of artificial intelligence to learning from data without additional human involvement. One of the main AI technologies used in existing personal safety devices is machine learning technologies like Natural Language Programming (NLP). NLP is a broad term used for a branch of computer science that is concerned with the process available to computers to enable the human-like understanding of text or the spoken word. For example, recognising words that act as a trigger for a panic button that causes a loud noise to sound or calls emergency services. Therefore, this technology offers computers the ability to understand human language. The definitions summarised in this section provide a clear framework for the concepts and terms that are integral to the study.

To clarify the concept of technology in the primary research question RQ O., this section outlines the definition of technology and highlights additional terms frequently mentioned in scholarly articles and the media, enabling the reader to grasp the discussions presented in the remainder of this thesis.

2.3 Situating Mobility, Gender, and Safety

Active travel modes are particularly susceptible to experiential variation due to the dynamic changes associated with time and space (C. Chen, Chorus, et al., 2016). Studies show that individuals who active travel enjoy improved mood when in green spaces (Glasgow et al., 2019), are heavily influenced by weather (Zhao et al., 2019) and intentionally extend leisure trips, especially when sightseeing is included (H. T. K. Le et al., 2020). These findings highlight the complex relationships between travel modes, built and natural environments, and individual experiences, as well as the importance of considering both short-term and long-term dynamics in active travel research and planning.

Whilst environmental considerations, such as infrastructure, weather, and time of day are easier to perceive, active travel modes also have additional layers of social complexity (Aldred, 2013; Aldred & Jungnickel, 2014; Daley & Rissel, 2011; Félix et al., 2019; Steinbach et al., 2011; Yeboah & Alvanides, 2013) that impact active travel experience and, in turn, its uptake.Jones and Spencer (2024, p. 38) uses Jensen's (2013) staging mobilities model to describe how active travel is 'staged from above' through the use of infrastructure, but also choreographed 'from below' through social and cultural conditions. These cultural, identity, and gender-related factors (Aldred & Dales, 2017; Brainard et al., 2019; Sivasubramaniyam et al., 2020) play a significant role in the lived experience of practitioners (H. T. K. Le et al., 2020). Practitioners of active travel can be influenced by interactions with others they encounter in shared spaces (both good and bad) and communities they foster through events centred around specific activities.

This very different experience of space was recognised with the emergence of feminist geography in the late 20th century. Feminist geography aimed to critique the existing status quo of spatial science (Calkin & Freeman, 2020). It considers the intersectional representation (race, class, ability, and sexuality) of both researcher and research subjects, as well as the approaches used in research (Cockayne & Richardson, 2020). It was here where the division between the terms space and place emerged, where space is measurable and can be occupied (Goodchild, 2015; Krishan & Singh, 2019), and place is founded in perception (Tuan, 1975). Before this, there was a lack of consideration of the social elements involved in how space and place were experienced.

Feminist geography examines how gender is implicated in the social construction of space and place. Key themes relating to these two aspects include the representation of women in maps

and the environment (Z. Gardner et al., 2020), sense of place (Price & Shildrick, 1999, p. 362), how power is assigned and reduced by space (S. Hanson, 2010), and how gender shapes lived experiences of different geographical locations (Beebeejaun, 2017). Myrdahl (2019) highlights how these themes have implications with respect to everyday experiences, mobility, sense of identity, practices, and perceptions. Massey's work, as reviewed by Skogheim (1995), emphasises the connection between space, place, and gender, asserting that particular ways of thinking about space and place are tied to specific social constructions of gender relations. These perspectives collectively demonstrate the significant role of spatial dimensions in shaping and reproducing gender structures.

Gender is also evident in travel behaviour patterns and the lived experience of space generated through social processes (Martens et al., 2019). According to Peake (2009) these processes include diverse modes of mobility and ways of moving around, the labour market, gender-based violence, care giving responsibilities, and utilisation of spare time. By way of illustration, with respect to mobility, women's irregular travel patterns result in 'trip chaining', which refers to a series of interconnected trips starting from an origin, passing through multiple stops, and ending at a destination (C. Chen & Susilo, 2021) and is identified by McGuckin and Murakami (1999, p. 49) as predominantly sited in the 'domain of women'. Trip chaining aims to satisfy requirements for both work and caring duties (Acker & Ng, 2018; Criado-Perez, 2019) by linking tasks together, and does not align with traditional journey modes, such as travelling from home to the office (Z. Li et al., 2013). In addition, economically, women tend to have lower incomes, which limits modal choice given that higher living expenses are of often associated with well-connected and accessible locations (Lecompte & Juan Pablo, 2017; Root et al., 2000). Traditional models of transport prediction often overlook these gendered aspects of mobility, failing to account for the unique experiences and constraints faced by women and other gendered groups in their daily activities. Highlighting correlations between gender and space has uncovered inequalities and redirected the focus of research so that policy and practice can be adapted to help shape more equitable environments.

Gendered patterns of mobility are seen in active travel modes and have been well documented (Miralles-Guasch et al., 2016; Shaw et al., 2020). Active travel is considered a flexible transport mode, especially for shorter journeys, and is considered more suited to complex travel patterns, like trip chaining (Venter et al., 2007). Studies indicate that women on average tend to walk and cycle more than men in urban areas, and these modes are more often used by women both as means of transport for errands (Pollard & Wagnild, 2017; Tran & Schlyter, 2010), rather than purely for leisure (Heesch et al., 2011; Mahadevia & Advani, 2016). These patterns are indicative of key considerations of women when taking active travel and reflect the environmental and social contexts they navigate daily.

A determining factor for women's active travel behaviour is their perception of safety (Basu et al., 2021; Ravensbergen et al., 2020). These safety concerns primarily relate to gender-based violence (Kaladelfos & Featherstone, 2014), although also factors such as

infrastructure and environmental responses (Markvica et al., 2019; Pelclová et al., 2014), social-spatial environment (Johansson & Haandrikman, 2023; Scarponi et al., 2023; Yates & Ceccato, 2020), activity-based fears (Ravensbergen et al., 2020; Rišová & Sládeková Madajová, 2020), and dominant power structures (Cresswell & Uteng, 2016). Despite it being more common for men to be victims of crime in public spaces (Fisher & Sloan III, 2003), women are more fearful than men (Beebeejaun, 2017), and especially more fearful of sexual violence. This fear is not wholly misplaced, as women are more likely to experience harassment or suffer assault (Aldred, 2015; Evans et al., 2018; Gekoski et al., 2017). Women's perception of safety is a complex problem that is underpinned by both contextual and social problems.

Safety Considerations affect route selection and frequency, where women will search out safer routes even if it means travelling greater distances (Aldred et al., 2017; Loukaitou-Sideris, 2014). More recently, research by Scarponi et al. (2023) demonstrated that perception of safety is also contingent on 'place', such as designated havens and no-go areas, as well as spatial features and usage. This spatial assessment associated with fear is complicated further, where the comparison of two users' perceptions of safety in the same environment will likely depend on their previous experiences and evaluation of it (von Stülpnagel & Lucas, 2020). Examples of approaches that women employ to reduce the effect of safety concerns on mobility have been grouped into three categories by García-Carpintero et al. (2022), as avoidance, confronting risks, and empowerment. Avoidance strategies include not walking alone, not walking in the dark, and not wearing revealing clothing (Tandogan & Ilhan, 2016). Confronting risks is identified as using tools such as panic buttons and mobile phones to mediate fears. Empowerment indicates efforts to travel in spite of any fears, although it is often more likely that if a journey is considered unfeasible due to concerns surrounding safety, women feel 'captive' by their travel options (J. Stark & Meschik, 2018, p. 319). These examples are just some behaviour modifications in the arsenal of women's strategies that Vera-Gray and Kelly (2020) termed 'safety work'. The desire for safety is therefore a crucial factor in the feasibility and sustainability of women's mobility, highlighting a significant barrier to the adoption of active travel modes among women.

By incorporating feminist perspectives, where emphasis is placed on the need for gender-sensitive approaches to instil women's safety concerns into transportation planning and policymaking, it becomes possible to address the specific mobility needs and challenges faced by women in accessing transportation options and navigating public spaces (Joelsson & Scholten, 2019). Acknowledging and understanding the different perspectives towards space and place is imperative to answering RQ0. with the task of assessing technological intervention and its potential to improves women's experiences of active travel.

2.3.1 Technological Interventions

Technology has played a pivotal role in the way we interact with the world around us (Campbell et al., 2023). You only need to look at applications like Google Maps, social media, or Facebook like buttons to see evidence of this (Eranti & Lonkila, 2015; Wagner et al., 2020). Their pervasive use is only set to grow given the recent statistics on mobile downloads, with 2023 seeing an increase of 80% on downloads made in 2016 (Statista, 2024). Evidence of this includes work; work-life balance, employee voice, and surveillance (Holland & Bardoel, 2016); education; altered teaching and learning procedures, rendering them more enjoyable and effective; (Raja & Nagasubramani, 2018) and health; the adoption of information management systems increases the quality and efficiency of healthcare provision (Chaudhry et al., 2006). This vast technological shift has reshaped our expectations and our dependence on digital solutions in our daily practices(De Kare-Silver, 2011).

Technology has progressively evolved into a pervasive element in mobility, allowing people to perform increasingly complex tasks with greater efficiency and is as true of the development of the bicycle, as it is the modern smartphone (Ling, 2004). Sheller and Urry (2006) highlighted the integrated-ness and sociality of transport and travel in the new mobilities paradigm. They identified that everyday activities that move us from one place to another involve places and timescales where social interactions or 'entanglements of movement, representation, and practice' (Cresswell, 2010, p. 17) happen. The paradigm emphasised that mobility now encompasses media, transport, and technology, enabling additional forms of movement, and ultimately called for more in-depth evaluation and lines of enquiry into these enhancements and how they influence mobility activities. In response to this call, albeit 18 years later, this section examines how technology is integrated into mobility, influencing user behaviour, and introduces the concept of technological interventions for personal safety. It also looks at research that has sought to determine the breadth of safety features that are in circulation

The increasing reliance on technology for everyday mobility tasks is evident across various contexts. Arguably, the most prevalent use of technology in mobility focuses on improving efficiency and accessibility across transportation modes using routing algorithms. One example, Google Maps offers various features to help users navigate and explore the world (Laoudias et al., 2018), has a 70% share of the global market, and is used by more than one billion people worldwide (The Economic Review, 2019). As a web-based geographical information service, it provides users with access to satellite imagery, street views, traffic conditions and route planning with options to alter modal preferences. These routing algorithms are primarily concerned with economising time, although algorithms that provide a more tailored approach to active travel modes do exist (Barth et al., 2018; Shah et al., 2020); however, these are often optimised by physical parameters such as separated cycle paths or route gradients with emphasis on the risk of physical injury due to infrastructure or other road users. Other, more subjective, assessments have also been made and used as the

basis for routing mechanisms. Projects such as Happy Maps (Quercia et al., 2014) evidence the potential for incorporating human response to spatial elements to improve transport experience, in both infrastructure design and route planning. In the context of Mobility as a Service (MaaS), AI-based frameworks can integrate preferences, needs, context, and environment to assist them with offering a personalised experience and service to provide customised transportation recommendations (Raja & Nagasubramani, 2018). These systems utilise data from smartphones to learn individual preferences and create personalised transportation options, potentially revolutionising the mobility ecosystem (Gruel & Piller, 2016).

Technology can also indirectly affect mobility behaviour. For instance, Line et al. (2011) documents how users adopt technology as part of their everyday mobilities to determine if and when they should be mobile. Targeting students who were technically literate, interviews are conducted to understand their mobility behaviours associated with technology. Technology was found to accommodate uncertainties, such as adjusting schedules based on new knowledge such as public transport delays or changes to work calendars. Interestingly, the study highlights what are considered detrimental social outcomes of technology, where meeting friends or shopping in person has been replaced with telephone text and video communication and shopping online. With respect to safety, the study documented behaviours associated with safety where users phoned others whilst walking (on the advice of police) to look less vulnerable (Line et al., 2011).

Modal options have increased due to technology's integration into mobility practices, with ride-sharing, bike, and scooter schemes have become more prevalent due to mobile phones. Smartphone ownership has also increased the likelihood of using flexible multi-modal travel (two or more modes of transport in a single trip) (Astroza et al., 2017) where choices can change at a moment's notice (Matowicki et al., 2022). Technology has been used to encourage desired active travel behaviours. Satellite navigation and route recommenders are examples of this, but, more recently, mobile applications have included what is described as targeted design intent (Line et al., 2011).

Built into mobile applications, targeted design can take the form of two available design strategies, digital nudging and persuasive design. Both strategies have been used to successfully influence active travel behaviours through incentivising users to undertake sustainable and healthy practices, but they differ in approach. Digital nudging involves guiding individuals towards making better choices without restricting their options (Jesse & Jannach, 2021), often through user feedback. In contrast, persuasive technologies are firmer in their attempt to change attitudes through the introduction of incentives, rewards, or punishments (Anagnostopoulou et al., 2019). Gamification is a specific form of persuasive technology that supports behaviour change through material rewards (Andersson et al., 2018; Di Dio et al., 2018) and competition (Pajarito Grajales et al., 2020; Yen et al., 2019). The prevalence of mobile applications and growing access to smartphone devices opens technological behaviour

change, how technology can influence and shape human behaviour, to a much wider audience (Y. Rogers, 2012, p. 9).

As well as direct solutions, to be used in emergencies, access to new information and alternative modes of transport is seen to support safety. The widespread adoption of ride-sharing mobile applications has transformed transportation options for many women, offering alternatives to traditional modes of travel. Ride-sharing is not seen as involving the safety concerns associated with public transit (Mohamed et al., 2020) or walking alone at night (Fileborn et al., 2022).

The adoption of technology as a solution to safety with respect to mobility has gained considerable attention. The view that technology is a possible remedy to safety issues associated with active travel is upheld, unsurprisingly, by the media and its developers (Cardoso et al., 2019), but also by women (Nasar et al., 2007; Tozzo et al., 2021). Both Cumiskey and Brewster (2012) and J. Stark and Meschik (2018) found that individuals considered mobile phones to be weapons of defence and ways of arming themselves. Conversely Nasar et al. (2007) also found that individuals were more likely to walk in unfamiliar areas with a mobile phone and that their situational awareness was reduced. Carleton et al. (2019) highlight that constant access to safety cues, and the reassurance-seeking behaviours enabled by these technologies, has the potential to reduce individuals' ability to tolerate uncertainty in everyday life.

M. Zhang and Bandara (2024) used a mixed-methods, survey-led approach to how place and space impact users perception of safety, and existing safety practices associated with technology. For example, the identification of social media to plan walks by consulting reviews from Facebook and Tripadvisor, and taking two mobile phones when out walking due to the risk of technology failure. The findings uncovered distinct identities and practices identifying how technology is used by individuals to navigate their perception of safety.

Several content analyses have been made of mobile applications designated as personal safety devices(Bivens & Hasinoff, 2017; Chanmanwar & Nirkhi, 2022; Eisenhut et al., 2020; Ford et al., 2022; Maxwell et al., 2020; Moret et al., 2022; Sumra et al., 2023). These are formed primarily of quantitative evaluations and have focused on detailing the typologies of available mobile applications and their availability by country. Eisenhut et al. (2020) found that 46.78% of all 171 applications accessed as part of the study were designed to offer immediate help in 'emergency situations' emphasising the lack of use in prevention and a lack of proper evaluation through empirical testing. These emergency applications constitute the largest proportion of mobile applications globally and are described by the author as skewed towards one-time solutions rather than having long-term sustainable goals. These typologies are revealing, and the findings are emulated by Bivens and Hasinoff (2017) and Sumra et al. (2023) where there is seen to be an emphasis on the development of emergency interventions, over others, to address safety.

Content analysis of safety technology has also been extended to technologies other than mobile applications. Cardoso et al. (2019, p. 2) searched online sources (websites, videos, podcasts etc.), using search terms including types of technology, type of violence and what the authors call 'action of interest'. Action of interest denotes whether the technology is reported as being used to protect an individual or perpetrate a crime against an individual. 46.5% of the sources referred to how technology could be used to protect women, 34.7% highlighted how it could be used to perpetrate crime, and the remaining mentioned both. The study highlighted the varied nature of devices available for safety, but also revealed the lack of technological development that could help with crime prevention, with only 5.9% designed in such a way as to improve policy that can address wider societal issues that contribute to women's safety.

There is limited research scrutinising the use of technology within the context of application. A recent study by Kaur et al. (2022) sought to fill this gap by conducting research that requests experiential information around the context of use of existing technologies, building on existing HCI-based studies. The yearlong qualitative study of women's perceptions of technology used for safety in India reveals concerns for data privacy when downloading personal safety mobile applications and extends the possibility of using chatbots for supporting women in long-term support and healing. In addition, both Kumar and Aggarwal (2019) and Karusala and Kumar (2017) have made use of qualitative data to assess perceptions of personal safety devices in India. Karusala and Kumar (2017) look at panic buttons specifically, due to an India-wide mandate for all phones to have panic buttons after the Delhi gang rape (BBC News, 2016).

In addition to placing women's safety in the context of mobility, this section analyses how prior studies have tackled research on technological tools designed for personal safety, to identify the extent, diversity, and categories of research that have been undertaken previously. This review of existing personal safety device studies show demonstrate that much of the research to date has been focused on IPV, and sexual violence conducted against women Doria et al., 2021. Existing content analysis research fails to fully account for the lived experiences and ingrained safety practices of women, and thereby fails to centre product development in the context of use and the lived experiences of women (Kaur et al., 2022). Where assessments have been made on non-specific features, occurring primarily in surveying methods, where participants are asked about their potential to use such a feature without context there is a risk that further questioning would be required.

In comparison to other methods such as surveying and content analysis, qualitative assessment, either through interviews or open survey questions, demonstrate that firstly that existing safety practices undertaken by women with technology exist. These studies were able to gauge the varied requirements of women as they navigate mobility and safety in public space, enabling a dialogue for further questioning to examine the effectiveness of technology in situations that women find themselves in daily. There are few studies that look at technology use in the context of active travel specifically and this is limited in its contextual

enquiry, with qualitative studies looking at how they are used in everyday practice and are only just emerging (Kaur et al., 2022; M. Zhang & Bandara, 2024). These are tools designed for safety, as opposed to existing technologies that have been adopted.

These findings suggest the need for further qualitative enquiry in order to answer RQ0. re-emphasising the need to recognise both existing behaviours and future requirements to avoid techno-determinist leanings. It raises questions surrounding what kind of technology needs assessment and how best to achieve it.

2.4 Social Media Analysis

Doria et al. (2021) synthesised qualitative information on the perceptions of users by conducting a systematic literature review of twelve existing qualitative analyses of personal safety applications used to combat sexual violence. The review found three key themes, security, accessibility, and knowledge across existing studies. The overarching theme of security was used to refer to privacy of data and stigma avoidance. The fear of being judged, which prevents reporting violence, was a component of stigma avoidance, where individuals found it simpler to engage with technology than with a healthcare provider or their social network. The cause of underreporting harassment, for example, is twofold, first, there are limited channels of reporting available (UN Women, 2024) and second, women do not believe that some events warrant reporting (Fitzgerald et al., 1995; Reich et al., 2021). While the focus of the review was mainly on technology used in cases of IPV and dating violence (eight out of twelve studies), this discovery suggests the potential uptake of technology for documenting safety incidents that might otherwise go unreported. This underreporting of personal safety incidents, for example, can reduce the possibility of change in education, policy implementation or urban design framework (Witten et al., 2022). If more information is made available, it may in turn facilitate more equitable active travel.

As well as the practice of doing mobility itself, technology can offer researchers the opportunity to analyse mobility behaviours. Existing research has demonstrated the use of Global Positioning Systems (GPS) data from mobile devices, Bluetooth, and activity trackers as commonly used examples (Molloy et al., 2023). This information, used with existing Geographic Information System (GIS) data, crowdsourcing and traditional survey-based methods, can provide a rich dataset that enables a more in-depth understanding of users' motivations, experiences, and needs (Schoenau & Müller, 2017). These studies demonstrate that there are novel ways to analyse mobility behaviours in various contexts.

Another use of technology is the dissemination of information, where individuals can evaluate other's data and entrust others with their own simultaneously. The ability to do this expanded with what is collectively known as Web 2.0. Web 2.0 represents the second phase of the evolution of the World Wide Web, which emphasises interactive and collaborative user

engagement (Murugesan, 2007). It is characterised by social networks, bidirectional communication, and diverse content types (Cormode & Krishnamurthy, 2008). Web 2.0 technologies, primarily social media, have been shown to increase access and engagement with information, allowing users to evaluate its credibility and relevance (Metzger et al., 2010).

Web 2.0 technologies offer promising opportunities for innovative data analysis, which has been demonstrated primarily within discourse analysis.

Discourse analysis of social media data has been accomplished in many areas. It has been shown to offer extensive insights into public opinion and is frequently utilised in projecting political polling, gauging an understanding of support for particular political policies (Sarddar et al., 2020), by private firms looking for feedback on products and services (Berezina et al., 2016; Guo et al., 2017), in disaster management (Karami et al., 2019; Keim & Noji, 2011), in health (Bosley et al., 2013), and more recently during the COVID-19 pandemic (Boon-itt & Skunkan, 2020; Garcia & Berton, 2021; Lyu et al., 2021). Within the mobility domain, SMA is principally concerned with behaviour (Habib & Anik, 2021) and sentiment (Aldisa et al., 2021; Chaturvedi et al., 2019; Savita et al., 2021), with the goal of identifying user needs and opinions (Gal-Tzur et al., 2014). Although the assessment of public transportation service provision (Politis et al., 2021; Purnomo et al., 2021) and network congestion (Almohammad & Georgakis, 2020) have more recently been completed, analysis of SMA specific to active travel research has yet to be explored in earnest. Alattar et al. (2021) emphasised this gap highlighting the potential for using alternative data sources, such as social fitness networks, in-house (developed) mobile applications, participatory mapping, imagery, bike sharing systems and social media to increase understanding of user behaviour, to inform policy and incentivise active travel uptake. Existing literature that is pertinent to this study falls into three main categories: general discourse and sentiment analysis, transport mode analysis, and harassment analysis, inclusive of feminist discourse analysis.

Social media has been utilised to gain a more in-depth understanding of safety perceptions, especially in situations where opportunities to report and voice safety concerns are limited. According to Hokkanen (2016), public safety organisations and users can interact with these technologies, thereby promoting shared awareness and involvement in initiatives. This engagement has been demonstrated by active travel practitioners where experiences considered less significant, such as near misses and harassment, fall outside the remit of existing reporting channels such as to insurers, local councils, or the police. This informal reporting behaviour has been demonstrated where cycling near-miss experiences have higher levels of recording on modal-specific applications such as BikeMaps(BikeMaps, n.d.) and are recorded in far greater detail (Branion-Calles et al., 2017; Fischer et al., 2022; Vanlaar et al., 2020).

Like modal-specific applications, social media platforms such as X (formerly known as Twitter) allow users to further outlets for reporting. X is a microblogging and social networking service

where registered users can post and interact with others. Posts (formerly known as Tweets) provide users with an outlet to discuss and share information when reporting through official channels is limited (UN Women, 2024). Incidents like near-misses (Gorrini et al., 2021; Poulos et al., 2019) and harassment (Kumar & Aggarwal, 2019) are commonly reported, with posts often accompanied by images and video footage. Reviews of locations or requests for information relating to safety have been documented and shown to have significance for individuals planning routes in unfamiliar places (M. Zhang & Bandara, 2024). In addition, posts are not subject to the limitations that traditional survey methods, such as questionnaires (Maghrebi et al., 2015). These studies highlight the potential for technological interventions in improving safety reporting and perceptions across different active travel environments.

X has been, and continues to be, used for social discourse, and more recently as a feminist resource, with hashtags, #yesallwomen (Barker-Plummer & Barker-Plummer, 2017) and #metoo (Andersson et al., 2018; Bogen et al., 2021; Manikonda et al., 2018; Modrek & Chakalov, 2019; Nutbeam & Mereish, 2021; Xiong et al., 2019) being extensively analysed by researchers. Research indicates that social media platforms, particularly X, are increasingly used by women to discuss safety concerns and share experiences related to their safety, such as domestic violence and medical errors. The #WhyIStayed hashtag provided a space for women to anonymously share their stories of abuse and reasons for staying in abusive relationships (Weathers et al., 2016). It has also been used to challenge victim-blaming narratives through hashtags like #safetytipsforladies (Rentschler, 2015). These studies highlight X's role as a connective mechanism for women to share experiences, access support, and contribute to discussions on safety-related issues.

The topical reporting of harassment during active travel journeys through a gendered lens has been covered in less detail. Vasquez-Henriquez et al. (2020) and Luo and He (2021) both use a three-step approach to analyse the perceptions of users in a public transport context using data scraped from social media. The methodology consists of the following: user profiling used to infer gender, inference of transportation topics in the discussion, and measurement of gender differences. Gender inference by Vasquez-Henriquez et al. (2020) is achieved using machine learning whilst Luo and He (2021) accessed metadata indicating user gender, available directly through the platform itself. Clear themes were uncovered regarding the travel modes investigated. Interestingly, safety, which is part of this research's focus, was one of the main topics mentioned by bloggers who were women, which is consistent with findings showing women are more concerned with safety than men. Through these examples, SMA has been proven ripe for analysis regarding informing travel policy, infrastructure design, and personal safety.

Although social media data analysis is important due to its large size and qualitative richness, it must be approached cautiously to fully grasp its insights and produce high-quality results (Tinati et al., 2014). One obvious limitation is that X is only representative of a small part of a population, and researchers should be weary of extrapolating to a wider group (Al Baghal

et al., 2020; Jiang et al., 2019). For instance, X users in the UK tend to be younger, male, and more liberal in their political leanings (Mellon & Prosser, 2017). Other challenges, identified by Stieglitz et al. (2018) as the four V's (volume, velocity, variety, and veracity). Whilst developments in computing power enable researchers to tackle volume and velocity, the variety and veracity of data are more complex issues.

Overall, while social media offers innovative means for safety communication, challenges remain in establishing best practice and evaluating its impact across domains. Questions are also raised as to what the best method is for analysing data, the validity of that data and what its future uses might be. I now look to existing SMA to explore the processes previously undertaken to tackle this data analysis.

Most SMA is concerned with either sentiment or topic analysis. Sentiment analysis determines the feelings a user has towards a particular product or service (Medhat et al., 2014). Topic analysis, or modelling in its most basic form, involves the manual coding of documents and collecting them into semantically similar groupings (Meddeb & Romdhane, 2022). These activities are time intensive and subject to certain biases of the coders performing this task, and in the case of large datasets, such as social media data, the approach is considered unworkable for most researchers. In these cases, machine learning can be employed to perform topic modelling. The class of NLP machine learning algorithms is an unsupervised modelling method that categorises texts without the need to train a model first, by grouping words found in short texts into topics. The use of machine learning for SMA demonstrates the possibility of conducting a more detailed analysis of social media content by incorporating different aspects of analysis which can be performed on large datasets.

Historically, Latent Dirichlet Allocation (LDA) is the most extensively used topic modelling technique. LDA is a probabilistic topic model that determines the likelihood of a document being about a particular topic or topics (Jelodar et al., 2019). LDA relies on keyword extraction to gather topic information, as is the case for most NLP activities. Here, a bag-of-words (BoW) model is used to extract features from text for use in modelling. A BoW involves a document containing known words and a quantitative measure of the presence of known words within it (Shakambhari et al., 2022). The model is only concerned with whether known words occur, and not where they appear, in the document. Table 2.1 documents the approaches that studies have used as part of their SMA. Whilst this is only a snapshot of research conducted using these methods, there is a common approach between the studies. Namely, data is often collected using keyword searches for the purposes of sentiment analysis or topic analysis, and where topic analysis is performed LDA is the predominant approach used.

Table 2.1: Summary of SMA analysis reviewed

Author	Domain	Themes	Analysis	Platform	Data Collection	Processing/Analysis
(Aldisa et al., 2021)	Transport	Public Transport	Sentiment	Twitter	Web scraping script	Naïve Bayes Classifier
(Ayo et al., 2020)	Computer	Hate speech	Topic	Twitter	Web scraping script	Hybrid embeddings
(Boon-itt & Skunkan, 2020)	Health	COVID-19	Topic and sentiment	Twitter	Keyword Search via API	LDA
(Bosley et al., 2013)	Health	Cardiac Arrest	Topic	Twitter	Keyword Hashtag search	Manual Assessment
(Eason et al., 2019)	Disaster Management	Decision- Making	Sentiment	Twitter	Keyword Search	LDA
(Guo et al., 2017)	Travel	Consumer Reviews	Topic	Tripadvisor	Web scraping script	LDA
(C. L. Hanson et al., 2013)	Health	Drug Use	Topic	Twitter	Keyword Search via API	Manual Assessment
(Hidayatullah et al., 2018)	Sport	Football	Topic	Sport News	Targeted Twitter accounts	LDA
(Karami et al., 2019)	Disaster Management	Opinion	Topic and Sentiment	Twitter	Keyword Search	Lexicon-based classifier
(Luo and He 2021)	Transport	Service feedback Gender	Topic	Weibo	Keyword Search	LDA
(Lyu et al., 2021)	Health	COVID-19	Topic and sentiment	Twitter	Keyword Search	LDA
(Pasta et al., 2021)	Health	COVID-19 Anti-semitism	Topic	Twitter	Keyword Search	Manual Assessment
(Sarddar et al., 2020)	Politics	Policies	Sentiment	Twitter	Keyword Search	LDA
(Y. Zhang et al., 2023)	Logistics	Employee satisfaction	Sentiment	Mobile Application	Text mining	LDA

2.4.1 Approaches to Twitter Clarification

As Table 2.1 shows, LDA has routinely been used as part of the analysis pipeline in SMA. However, there are concerns that when dealing with short text documents, such as Twitter data, LDA is less useful (Osorio-Arjona et al., 2021). LDA focuses on documents consisting of multiple topics. With Twitter, it is usual that a single document (Tweet) is limited to 280 characters and is more likely to only consist of a single topic. A comprehensive evaluation of short text topic modelling was undertaken by Albalawi et al. (2020), highlighting the struggles with analysing unstructured short text data that are only a few sentences long and contain a lot of noise, such as links, usernames, abbreviations, and spelling mistakes. LDA requires the implementation of significant text pre-processing, which can lead to context removal with the potential for over- or under-fitting. LDA also requires that the user specify how many topics there are at the beginning of the analysis, and if the defined number of topics is too high there will be significant overlap between the defined documents (Liang et al., 2021). Finally, a level of aggregation of short messages is necessary to circumvent data sparsity (Albalawi et al., 2020). Alternative methods for analysis have therefore been mooted.

X data collection is often achieved by requesting data via the API, or, in the case of older studies, through third-party providers. In doing so, searches are limited to the inclusion or exclusion of certain metadata indicators as well as keywords. The collection of data via keyword searches is difficult due to the irregularity and diversity of language used (X. Chen et al., 2014; Zhou et al., 2017). Despite this, the phrase 'keywords related to [enter subject here]' is often included in the data collection methodology of Twitter-based research, as there is no alternative. In these cases, search terms are determined by author consensus, which can inadvertently introduce a level of bias in the study by restricting data collection. Studies completed by Bosley et al. (2013) and A. E. Kim et al. (2013) discovered that only a small percentage of Tweets found by their search terms were relevant or, conversely, that omitting particular words meant that large portions of relevant Posts would have been missed. Data collection using an API is often the easiest way of collecting social media data, but it restricts the collection to instances including keywords, which can limit the inclusion of relevant data.

The limitations of solely using a keyword search are often cited, but alternative approaches are limited. Joseph et al. (2014) addressed the difficulties with finding relevant Tweets and developed a method for ranking keywords from a sample dataset that was statistically most likely to collect those that were relevant. Manual iterative inspection of search term outputs is an alternative methodology, as proposed by A. E. Kim et al. (2013), to tackle keyword bias, but for large datasets this iterative process may be considered unfeasible. In 2022, Twitter's API v2 introduced context annotations. This is where searches are no longer limited to searching for keywords or terms. Over 50 context annotations were available and were inferred by Twitter from the Tweet text and classified internally. These were rather general context areas and therefore unavailable to be used for focused research topics, reliant on the researcher's trust or outsourcing the Twitter topic classification (shown in Table B.1). Where

analysis is focused on a particular hashtag, as with previous feminist discourse studies, or company, the data selection can be considered more straightforward than when trying to understand larger topics.

One way of potentially maximising the available dataset and removing an element of keyword bias is to leverage sentence encoding. Word, sentence, and complete document encoding is a way of assigning a numerical value to the word or words contained within the dataset in vector space. Sentence encoding, such as Bidirectional Encoder Representations from Transformers (BERT), assists in addressing challenges with Twitter content classification, such as language limitations (Ruiz Soler, 2017). These transformer-based models are relatively new with respect to their use in topic analysis in comparison with LDA. BERT is a type of language model that has been trained in both directions (left to right and right to left), and has an improved understanding of context compared to single-direction language models (Devlin et al., 2019). There are several BERT models available, and whilst the number of models has expanded since their inception, BERT (Devlin et al., 2019), RoBERTA (Liu et al., 2019) and ALBERT (Lan et al., 2020) were the original benchmark. A general BERT model can then be used for several NLP tasks, including semantic similarity or classification, chatbots, and question and answer. Recently, BERT has been used for topic modelling (Rini Anggrainingsih et al., 2021; Roitero et al., 2020; Valdes et al., 2021) and sentiment analysis on Twitter datasets (Naseem et al., 2020; Osorio-Arjona et al., 2021; Xie et al., 2021) with A. Rogers et al. (2020) labelling BERT as a ubiquitous baseline in NLP experiments. BERT has shown promise in reducing the need for manual keyword selection in various natural language processing tasks. It outperforms traditional keyword extraction methods by leveraging contextual word embeddings to capture semantic relationships (M. Q. Khan et al., 2022). The KeyBERT model, which utilises BERT's contextual embeddings, achieved 51% similarity with author-assigned keywords, surpassing conventional approaches (M. Q. Khan et al., 2022).

This section demonstrates opportunities for using technology to gain insight into active travel safety from through the thoughts and perspectives of individuals who post on social media, with a view to informing change. This presents an alternative use of technology to gather information on the topics of safety whilst active travelling. I consider that this exploration is able to aid in the answering RQ0 methodologically, using technology to gather information rather than just seeing it as a technological intervention in the practice of active travel. It was written from the hypothesis that collecting data relating to the experience and views on active safety may be completed using social media data, where reporting is completed as part of the social systems and processes enacted on these platforms. Reporting on feminist discourse and active travel safety has previously been documented and shown to exceed those through traditional means (Deal et al., 2020; Sanghani, 2014). Therefore, safety themes such as harassment or gendered violence may be more prevalent on social media platforms. The literature has demonstrated limitations in its ability to be representative of populations outside of those using these platforms, yet given the size of the potential dataset it could be

used to find topics that inform more traditional research avenues and provide input regarding further lines of enquiry such as events and reports that can feed into other areas of the study.

The focus of this literature review now turns back to the use of technology in the 'doing' of practices (women's technology-related practices) such as active travel, with a focus on the development of relevant tools.

2.5 Balancing Innovation with Responsible Design

A focus on technical problem-solving leans towards a problem-solution (constructivist) epistemology (Clemmensen et al., 2016). Given the social implications of technology use for mobility, such as its behavioural influence detailed in section 2.3.1, technology for mobility and safety is a sociotechnical problem, requiring social and technical elements to be co-designed with equal emphasis. This section considers the basis for technological design, the social values that technology should embody, factors associated with its adoption, and the potential outcomes of that adoption. Firstly, I introduce human-computer interaction as a field of research and as a foundation for the concepts of ethics, trust, embodiment, affordances, and empowerment in technology development.

2.5.1 Human Computer Interaction

Human-computer interaction (HCI) is a field of research and development concerned with advancing computer technology in the implementation of interactive computer systems that focus on the interaction between human users and computers. HCI addresses the co-evolution of the activities humans engage in and experience and the artefacts that mediate those activities (Carroll, 2003). Therefore, this thesis falls squarely in the HCI research domain, with active travel acting as the activity and technology as the mediating artifact. HCI serves as a foundational framework tying the concepts of values, ethics, trust, embodiment, affordances, and empowerment in technology to humans.

HCI as a specific research field came into being due to the increase in personal computers, which moved from offices into the home. More recently, mobile phones and ubiquitous computing (Internet of Things), and the integration of computing into everyday objects and environments, provided another expansion, where HCI is no longer considered a speciality of computer science (Carroll, 2003). Instead, it is multidisciplinary and is made up of computer science, human factors, and cognitive sciences among others (Grudin, n.d.). In technical terms, HCI considers and prioritises usability. Although, given the entanglement of computers and social life, usability means far more than just functional requirements, encompassing greater user needs and expectations. These include a will to further human experience, and looking to future technological needs and wants to prioritise values (Tollon, 2022), but also

reveals the embodiment of technology and its limitations. The discipline has therefore extended its reach into a vast array of fields of research, of which technology is now part.

The discipline is often characterised as split in two, namely research, and design. The research side seeks to understand the nature of lived experience, the relationship between people and technology, and technology's impact on society, taking cues from psychology, physiology, and social interaction theories. Conversely, applied design focuses on understanding user experience (UX) and interaction, to inform future design. Whilst there is a separation of the two, there is a cycle between research and understanding and its implementation, which is called the task artefact cycle, where the artefact (inclusive of object and environment) influences practice, and an understanding of the practice influences the design of the artefact. I highlight this divide as there is a distinct difference in HCI literature on personal safety technology, where much of the literature comes from a design perspective. This is often referred to by authors of a social scientist persuasion as an HCI paper. In reality, HCI is a broad field of study, such that a more accurate description should be design-focused, where emphasis is placed on the development of a product or service. This is the term I will use henceforth.

Within the HCI domain, affordance encompasses the capabilities and constraints of a technology, influencing how it is utilised and the behaviours it enables. Coined by Gibson (2014, p. 118), the term 'affordance' describes the possible uses or actions that the environment could afford an animal that was situated within it. Later, the concept of affordance was introduced to the field of HCI by Norman (1988) to understand how humans engage with digital tools and platforms (McGrenere & Ho, n.d.). Affordance is seen to play a critical role in shaping how individuals interact with technology, and is considered by many as fundamental in the field of HCI, for determining whether a tool is supportive or not (Kaptelinin & Nardi, 2012).

The use of technology and its associated affordance has been used to determine social change has been postulated by Hutchby (2001) among others (Hutchby, 2003; Majchrzak et al., 2016). They showed that the limitations of the broader uses of technology align with their affordance, and can therefore be used as a theoretical mechanism to determine their constraints and limitations within a given context of use. For example, affordance has been introduced into existing sociological theories such as structuration theory (Giddens, 1986) to account for material artefacts and objects where originally there were none. Affordances have been used to design social media interventions, helping researchers select appropriate platforms through their affordances and potential for action (Moreno & D'Angelo, 2019). Despite this, the concept of affordance has also been criticised for its ambiguity and limited relevance to individual interactions with specific artefacts (Oliver, 2005).

Understanding affordance is not limited to technology as an artefact (object or thing) in isolation. It is recognised that it is also subject to how it is situated, inclusive of user competence and the subjective assumptions made about its affordances, such as values

(de Boer, 2023). Within the context of this thesis, understanding technological affordance is considered essential to recognising how technology can be harnessed to support women. Affordances may be seen to reinforce power dynamics (Salamoun et al., 2022) or afford actions and behaviours (Lindberg & Lyytinen, 2013), placing affordance within the social-technical context whereby it can directly influence social practices. For instance, mobile applications or wearable devices that enhance women's safety by providing real-time location tracking or emergency assistance can be considered to be leveraging the technological affordance of GPS to address gender-based violence. By examining how technologies afford certain actions or behaviours, researchers can better understand the dynamics of human-technology interaction and its implications for social practices (Molina & Sundar, 2020). Conversely, by examining the practices adopted by women, it is possible to reverse engineer user needs from studying practice, avoiding techno-deterministic approaches.

Researchers examined the perceptions of personal safety applications (Cumiskey & Brewster, 2012; McCarthy et al., 2016b; Nasar et al., 2007; Potter et al., 2020; Tozzo et al., 2021; M. Zhang & Bandara, 2024).McCarthy et al. (2016b) focused on privacy, safety, and purchase preferences with respect to these devices. Tracking is isolated as a feature in some instances, but there is no indication of what it affords the user and how it does it. This is true of all studies conducted in the early development of the smartphone, where mobile applications of this nature were less established. The lack of clarity on functionality and the situations in which it could be used mean these results have less meaning to future studies. Although it is widely recognised that affordances can be both intended and unintended, and that their existence does not mean they will be utilised, if they are inconsistent with user goals or needs (Mesgari & Faraj, 2012). By accessing the features or affordances of the technology, it is possible to evaluate the fundamental attributes that technology does or does not provide to its users.

Focusing on women who drink alcohol, Blayney et al. (2018) reviewed the use and perceptions of a specific safety application (Circle of Six) on college campuses to assess the acceptability of the mobile application to college women. Using a similar mixed-method surveying approach to that of Demissie et al. (2021), initial focus groups were conducted to establish a baseline (existing technology use), and then the women were introduced to the mobile application and provided with guidance on its use. Features under review included text communication for different types of safety contexts and access to educational resources and links to safety groups. Following two months of use, the participants were then interviewed and completed a questionnaire. The findings showed that connectivity with friends was the most liked aspect of the mobile application, with the ease of connecting with multiple people discreetly, with location-based services coming in second. Whilst there were positive responses, participants stated that existing messaging services could perform similar affordances, and group messaging made some of them uncomfortable. The study also identified that whilst women are more likely to be vulnerable whilst drinking alcohol, the

mobile application was used less when participants drank more. Therefore, in the context of drinking, the integration of technology was less useful.

There is an ongoing discussion that questions whether affordance avoids technological deterministic approaches (Michaels, 2003) by understanding from the 'investigation of the nature of ordinary actions in the context of such material enablements and constraints' (Hutchby, 2003, p. 583). Bloomfield et al. (2010, p. 415) argue that affordance is not determined by an artifact in situ, but instead 'shaped by historically situated modes of engagement and ways of life'. The task artifact cycle, as described above, relies on this fact, and is instead situated somewhere in the middle (Graves, 2007). The ongoing discussion highlights the complexity of understanding technology's role in society and the need for nuanced approaches that consider both material properties and social contexts (Bloomfield et al., 2010). In the context of this thesis and RQ0. the use of affordance provides an opportunity to understand what technology can offer to women in their efforts to remain safe, and in turn, what is lacking. In early surveying research, a lack of detail about how prospective tools' functionality limited the extent to which these could be useful in future technological development. Overall, the affordance perspective has been shown to provide a valuable approach to analyse how technology enables and constrains social practices across diverse domains.

2.5.2 Technology Adoption and Trust

Several theories have been curated to understand technological adoption since the widespread adoption of computers into workplaces in the 1980s. The technology acceptance model (TAM) aims to predict and explain user behaviour towards technology adoption through user motivation, where motivation is influenced by attitude, perceived ease of use, and perceived usefulness (see Figure 2.2). It suggests that if a technology is perceived as useful and easy to use, users are more likely to form a positive attitude towards it, leading to a higher intention to use it and, ultimately, actual usage (Chuttur, 2009). Social influence was later added to the original model (extended technology acceptance model) in the form of subjective norms, voluntariness, and image. TAM has been utilised to study technology adoption across various research domains such as healthcare, education, business, and transportation. TAM has also been successfully used to look at the different priorities depending on gender with respect to on technology acceptance, (Venkatesh et al., 2000). Mogaji et al. (2024) cite TAM's inability to capture 'contextual factors' as one of its limitations, and question whether TAM remains relevant for younger generations and technologies that incorporate artificial intelligence and social media.

The Theory of Planned Behaviour (TPB) (Ajzen, 1991, 2011) explains that in most people, planned behaviour is not determined by general attitudes, but is 'a process of self-regulation', where individuals process available information before then acting out a particular behaviour. These factors (see Figure 2.3) are defined as motivation or intention, which is the measure of

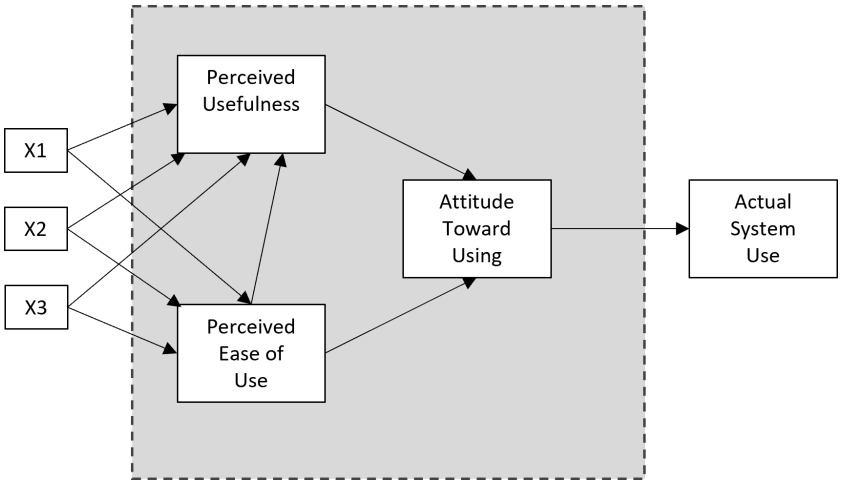

FIGURE 2.2: Diagram showing the interdependency of factors associated with technology acceptance in TAM. (Davis & Davis, 1989)

how hard someone is willing to try to complete a particular behaviour, and perceived behavioural control (PBC), the perceived ease or difficulty of performing the behaviour considering potential obstacles. Intention is not only influenced by the PBC but also by two other factors, attitude (towards the behaviour), and subjective norms (socially accepted standards of conduct). Past behaviour and habits are also mentioned as part of the theory, although it has been demonstrated that the contribution of habit to PBC and attitude is not isolated, as forming an action that becomes a habit is, at the beginning, predetermined. It is therefore challenging to isolate the role of habit from the other variables.

Like TAM, TPB has been used to explore gendered differences in technology adoption and sustained use (Venkatesh et al., 2000), where both identified that women's adoption of technology is more heavily influenced by subjective norms and perceived behavioural control (Venkatesh & Morris, 2000). Where uncertainty is greatest, such as in public transit, the role of PBC has more significance in predicting behaviour (Donald et al., 2014; Neto et al., 2020). Given the uncertainty associated with active travel, this suggests that focusing on PBC and how this is formulated in terms of infrastructural elements or technology could improve active travel network design for women.

Technology acceptance models have been created in response to large-scale adoptions of technology. One critique of their use in understanding technology adoption in other domains is that they are context-specific, having primarily been developed for use in workplace environments. The Unified Theory of Acceptance and Use of Technology (UTAUT) to address this issue through the integration of eight existing innovation acceptance models, inclusive of TAM and TPB. It was developed to mitigate the need for domain-specific theories and to enhance the capabilities of existing technology acceptance models (Venkatesh et al., 2003). Two of the models used to develop the UTAUT are Innovation Diffusion Theory and Social Cognitive Theory. The UTAUT was updated in 2012 (UTAT2) (Venkatesh et al., 2003) and again in 2021 (Blut et al., 2021) to add further factors to an already complex model, thereby

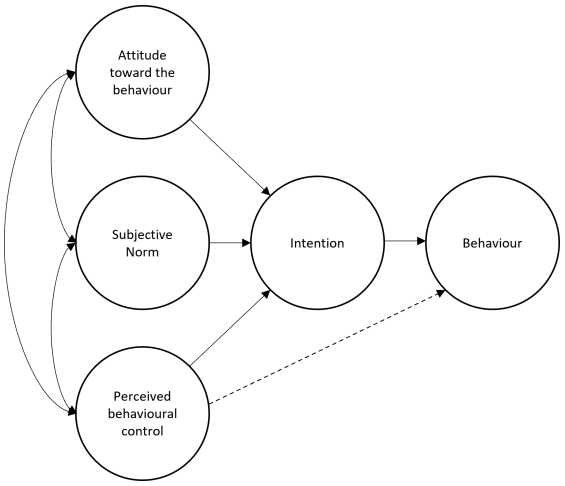

FIGURE 2.3: Diagram showing the interdependency of factors associated with planned behaviour in the Theory of Planned Behaviour. (Ajzen, 1991)

increasing its relevance outside of organisation acceptance to the consumer market. These theories have moderators that consider the potential outcomes, including personal outcomes, of adoption and may therefore be more applicable in understanding the relationship between personal risk and uptake of technology.

Two limitations identified with the domain-specific theories are that they overlook complex technologies (Venkatesh et al., 2003) and they focus on individual experiences, purchase decisions and use cases (Brown et al., 2015). The context of use and goal orientation of adoption models, which is often workplace environments, are also wildly inappropriate to describing the use of technology for personal safety devices.

(Demissie et al., 2021) uses the UTAUT with the integration of the Web Trust Model (WTM) to investigate the determinants of user acceptance of the mobile application Peace of Mind (POM). The WTM is integrated with the acknowledgment that adoption of technology is influenced by trust. Although, I must highlight here that, like other adoption theories, the WTM was developed to understand trust in e-commerce practice and may not align with trust in safety technology. Demissie et al. (2021) found that the factors of performance expectancy, trusting belief, facilitating conditions, and social influence had a direct impact on individuals' adoption of mobile safety devices. In general, the findings imply that personal safety devices are beneficial, based on the uptake and continued use of the product, with Demissie et al. (2021, p. 51) claiming they have 'tremendous promise'.

Several questions remain, around whether adoption-based assessment is viable for personal safety devices. Firstly, whether the assessment of a single product or service can extend to others due to the varied features and affordances of personal safety devices. Secondly, without an understanding of the ways in which they are being used, it is difficult to ascertain whether adoption is linked to improved safety or just users' perception of safety. For example, UTAUT is also derived from the social psychological perspective and therefore lacks context-specific information that can alter acceptance criteria. Thirdly, whether adoption

theories are applicable to modern technology use. For example, Chuah et al. (2016) developed their own theoretical framework to understand the proponents of Smartwatch because they found that existing theories of adoption are not appropriate when views of technology are considered not just as functional items but as fashion items. And finally, a willingness to adopt and download does not demonstrate a sustainable use case if 'use' means more risk to the user (Line et al., 2011; Nasar et al., 2007).

Trust is considered an abstract topic (Gebru et al., 2022) with varying definitions across different domains, and is therefore difficult to definitively pin down. In medicine and health, trust has been described as a 'justified expectation regarding the trustworthiness of the trustee under conditions of uncertainty and risk' (Wrigley & Wolfensberger, 2019, p. 71) or the intention or willingness to be vulnerable based upon positive expectations of the intentions or behaviour of another (Thielmann & Hilbig, 2015, p. 251). However, some researchers argue that trust is not a calculated probability or a willingness to be vulnerable, but rather a choice to place confidence in others (F. Li & Betts, 2003). Trust in technology is closely related to trust in service providers, particularly in healthcare, where patients' perceptions of the utilisation of technology have a significant impact on their trust in both the technology and the healthcare provider (Montague & Asan, 2012). Previous accounts of trust in technology have centred on security and encryption (Dizon, 2023), however with the increased ubiquity of computing, trust has been explored in other areas, taking into account the social implications and human interaction, described by Saputra (2020) as a truster's confidence in a trustee's ability to provide expected results in an interaction or similarly by Golbeck (2006) in social networks where technology is considered a facilitator connecting humans. Mcknight et al. (2011) consider functionality, helpfulness, and the reliability of technology as a framework for defining trust in a technological artefact. This structure moves away from a humanistic description that focuses solely upon benevolence and integrity (Lankton et al., 2015). Understanding these trust dynamics is essential for improving user experiences and technology adoption across various domains.

Practices of use associated with technology are seen to vary with states of distrust (Chib & Ang, 2023). Due to its embedded social nature, this means that distrust and trust also directly influence social cohesion. Chib and Ang (2023) demonstrated this variation using four states of vulnerability and uncertainty (four-box model) of refugees as they recount mobile phone usage during their migration and settlement in a new region. Transitions between high and low states of vulnerability and uncertainty are shown to elicit different levels of trust in mobile practices, shifting between independent and community-driven methods. Here, trust is used as a conceptual lens to determine the reasons behind mobile use strategies. These consider personality traits and existing user experience and acceptance. The linkage between trust and risk provides opportunities for developers but also identifies the constraints and limitations of technologies with respect to certain solutions. Trust in technology is therefore also dependent on social situations, and fluctuates as needs change.

Research suggests that gender influences trust in technology and eventual adoption patterns. Men tend to be more influenced by their attitudes towards new technology, while women are more affected by social norms and perceived behavioural control (Venkatesh & Morris, 2000). Gender differences also impact online shopping behaviour and website design preferences (Shaouf, 2018). Trust in technology is associated with different mental models for men and women, with men focusing on the functional aspects and women on perceptual features (Sims et al., 2004). The perceived age and gender of anthropomorphic technology can interact with users' own demographics to affect trust, highlighting the importance of considering stereotypes in interface design (Pak et al., 2012). The successful implementation of AI has been observed in the fields of health and education. Other uses for AI, such as requests for application personalisation and integration with mHealth, suggest potential user acceptance for AI within personal safety technology. In these areas, among others, its adoption has been welcomed, offering both increased productivity and improved decision-making. Yet, this view is conditional on many factors and is not true of all AI, due to the distinct and varied implementations available (see section 2.2.2.1) and variation in what those who interact with the AI are willing to accept. A review conducted by Bach et al. (2022) found that user characteristics were the dominating theme influencing trust in AI, where women have a higher level of trust (Morana et al., 2020). However, further research is required to determine whether the use of AI, and which variants would be considered supportive by women with respect to their personal safety.

Technology adoption is a complex social process involving cognitive, emotional, and contextual aspects, with individuals forming unique perceptions of technology that shape their adoption decisions (Straub, 2009).Overcoming implementation limitations and adoption barriers is essential for enhancing the widespread use of safety-focused technologies (Gruel & Piller, 2016). With respect to RQ0. To evaluate the potential of technology to support women's safety, I must therefore consider women's requirements for its adoption in the first place. Existing adoption models discussed have been shown to be inappropriate for this purpose. Instead, I look to trust as a critical component in technological adoption (Bahmanziari et al., 2003). Moving forward I will consider the component of trust consider this as a line of enquiry and I adopt Saputra's (2020) definition of trust, as a choice to place confidence in someone or something to provide the expected results with consideration for the social implications and human interaction of technology.

2.5.3 Embodiment and Empowerment

The embodiment of technology explores how individuals integrate technology into their everyday lives, shaping their experiences and interactions with the world around them. Ultimately, this is completed after initial adoption and trust is present. This ubiquitous integration and embodiment renders technology invisible (Ingraham & Grandinetti, 2023). The embodiment of technology is demonstrated in various ways in human-technology

interactions. Embodiment, as described by Nelson et al. (2019, p. 1) is 'to experience external objects in such a way that they are perceived as an integral part of one's own body'. The concept of embodiment extends to social information processing, where bodily states and simulations of experience in the brain's modality-specific systems influence attitudes, social perception, and emotion (Niedenthal et al., 2005). In tourism experiences, wearable augmented reality technology exemplifies embodiment through dimensions of ownership, location, and agency, enhancing enjoyment and experience (Tussyadiah & Miller, 2020).

Embodiment as a tool for personal safety is taken from existing 'safety work' practices facilitated through connectivity (Nasar et al., 2007), although J. Stark and Meschik (2018) illustrate the embodiment of a mobile phone as a weapon too, where participants describe how its use and proximity while walking constitute arming themselves. This relationship between the mobile phone and weaponisation can be seen more literally in the research completed by Cumiskey and Brewster (2012), where the line of questioning of two groups amounted to whether they would prefer a mobile phone or pepper spray when out walking to protect themselves. In doing so the study directly compared the feelings associated with carrying these two items when walking. The impact of holding a mobile phone was described as significant and had comparable, if not stronger, associations with safety than pepper spray. Just having a phone on their person without additional third-party applications evoked feelings of safety for people. These feelings are likely to be explained through the social cohesion afforded by a mobile device which is sustained through mutual belonging to a social world with shared meanings and experiences (Chib & Ang, 2023). These studies demonstrate how technology has become viscerally integrated into human actions and experiences, and demonstrates the perception of safety that is felt by users through having that connectivity.

The embodiment of technology serves as a powerful catalyst for empowerment through the integration of technology into many facets of human life, such as communication, education, and healthcare, people are able to access possibilities and resources that were previously unattainable. Therefore, technology's embodiment changes not just how we engage with the outside world, but also how we relate to our own empowerment. Empowerment has many definitions, although a succinct and to-the-point description is presented by Perkins and Zimmerman (1995, p. 570): 'simply a process by which people gain control over their lives, democratic principles in the life of their community'. Therefore, I consider technological empowerment to refer to how technology can facilitate agency, autonomy, and self-determination, particularly for marginalised groups such as women (Ibrahim & Alkire, 2007).

One area of research that has conducted extensive research into the relationship between technology and empowerment is in mobile health. Mobile health (mHealth) is where technological devices, such as smartphones and wearable devices, are used to improve the health outcomes of patients (Kreitmair, 2024), where, 'effectiveness, cost efficiency and empowerment' are promised (Al Dahdah, 2017, p. 137). As with the perceived role of personal safety devices in empowering women, there is a concern that mHealth is unable to

satisfy the prerequisites for empowerment, leading only to the feeling of being in control and unintentionally burdening individuals (Kreitmair, 2024).

Gender inequalities in access to mobile technologies in developing countries further complicate the empowerment narrative (Al Dahdah, 2017). Empowerment is defined byAl Dahdah (2017) as knowledge and education that lead to 'healthy behaviours', where lack of knowledge limits the opportunities to make good decisions, 'dispelling local myths'. However, the study indicated that knowledge provision was not always guaranteed by technology, given that participants often decided not to follow the advice delivered by the mobile service. They instead deferred to their own advice or that of other 'trusted' individuals. Here, trust was applicable to the information and the delivery method, where messages without a human face became less trustworthy. This suggests that despite having access to new information, delivery via a mobile phone does not provide enough gravitas for it to be enacted. Despite these challenges, it is possible that more human-like technologies, such as large language models, can provide greater opportunities for implementing trust (Pak et al., 2012). This example reinforces the idea of a slow integration of technology into existing practices and beliefs, rather than a rapid U-turn with respect to what users 'know' to be true.

Despite many examples of the empowerment that technology can provide (Niroo & Crompton, 2022), there persists an ongoing divide between those who have access to it and those who do not (Borah & Kalita, 2019). The availability of technology and mobile devices in high-income countries is widespread and ubiquitous, with no gender gap in technology access and adoption. However, this is not the case globally, and even when infrastructure is available access is limited in communities with strong patriarchal structures maintaining them (Chib & Ang, 2023). In low- to middle-income countries (LMIC) the gender divide in mobile phone ownership is high (Jeffrie, 2023), where men are the controllers of the household mobile phone (Kibria & Nayeem, 2023). In these areas, women are less likely to have access to smartphones, and, in turn, are less likely to have access to mobile applications that solely operate on those platforms, reducing their opportunities for empowerment. Technology is rendered redundant when access is reduced, limited or non-existent. Therefore, empowerment through technology must also be considered within the context of use.

Within feminist geography, technological empowerment is a central goal, advocating for the development and deployment of technologies that enhance women's access to resources, information, and opportunities. The varied nature of technology requires research to be specific as to what it is that influences user behaviour. By leveraging technological affordances and understanding the embodiment of technology, innovative solutions can be developed to promote women's empowerment and safety in both public and private spheres. This relationship between empowerment and agency in embodiment links the concepts of trust, adoption, embodiment, and empowerment.

The feminist theory of technology sheds light on how technological advancements intersect with gender dynamics. Women's empowerment through technology is a central theme within

this framework. It emphasises the importance of considering how technology is designed, implemented, and used within social contexts, highlighting that it can both reinforce and challenge existing gender inequalities (Ceia et al., 2021). Understanding the embodiment of technology is also crucial for recognising how women's experiences and empowerment are mediated through technological tools and platforms.

The empowerment of users through technology is often cited in the literature (Niroo & Crompton, 2022), yet it often fails to isolate the various factors, inclusive of platform affordances and constraints, responsible for this empowerment. For example, Mackey and Petrucka (2021) found that existing research on empowerment through technology identified interventions in both a broad and a narrow sense. The lack of clarity meant that often the specific cause of empowerment was not discovered. For example, citing 'the internet' vs specific web pages or email, which both need the internet to access but provide different affordances. Here I associate empowerment in active travel as a positive and supporting measure that technology can provide. Therefore, in order to answer RQ0. it is necessary to understand if personal safety technologies empower, and if so what features contribute to this empowerment in the domain of personal safety. One way of approaching this is through the idea of technological affordance (see section 2.5.1).

TABLE 2.2: Summary existing PSD research in date order. Design-focused studies have not been included

Author	Target	Type	Technology	Method Category	Aim	Key Findings
(Nasar et al., 2007)	College Students	Campus Safety	Mobile phones	Survey-based	To access how the perception of safety of mobile phone users changed with respect to having one	Behaviour changes due to reduction of fear with a mobile phone
(Cumiskey & Brewster, 2012)	College students (women)	Safety	Mobile phones	Survey-based	To determine if women believe that mobile phones are weapons of self-defence	Women believe that mobile phones are more effective than a weapon
(Simpson, 2014)	Children	Safety	GPS tracking (Life360 and Eyewatch mobile applications)	Content Analysis (Discourse)	To find the implications of using GPS tracking for safety. Review of existing mobile applications	Concern that mobile applications influence autonomy
(Glass et al., 2015)	College students (women)	Dating Violence and IPV	web-based and mobile application	Survey-based	To understand women's decisional conflict and safety behaviour use when making difficult safety decisions	Shown to aid in decision-making activities
(McCarthy et al., 2016b)	Transport Users	Public Transport Safety	Personal safety application (looks at tracking and police monitoring)	Survey-based	To determine perception of individuals towards personal safety device	Respondents would consider downloading a personal safety application although Women are less likely to download and men were less favourable of tracking
(Henry & Powell, 2018)	Adults	Sexual Violence	Digital devices that use the internet	Review	To assess the risk of technology in facilitating harm	Technology facilitated sexual violence is prevalent
(Bivens & Hasinoff, 2017)	No target user	Rape	Mobile applications	Content Analysis	To investigate the relationship between technical design and social norms	PSD generally reinforces and reflects pervasive rape myths, targeting potential victims and reinforcing stranger-danger

TABLE 2.2: Summary existing PSD research in date order. Design-focused studies have not been included

Author	Target	Type	Technology	Method Category	Aim	Key Findings
(Hasinoff, 2017)	Family	Safety	Life360 (mobile application)	Content Analysis (Discourse	To evaluate Life 360 through the features and marketing provided by the company	PSD reinforce 'Silicon Valley's' prevalent ideas about safety, technology, and information
(Karusala & Kumar, 2017)	Women (Public Locations)	Safety	Panic Buttons	Interview	To examine the efficacy of panic buttons	The environment, technology and other people influence the effectiveness of panic buttons
(Cardoso et al., 2019)	Women	VAW	Search was not limited in its scope and defined 16 technologies including (mobile devices and applications, websites, social media etc.)	Content Analysis	To find out how new technologies can support women and be used against them	New technologies are also used to perpetrate cyber- and in-person stalking. Common misbeliefs about gender-based violence and victim-blame tropes are embedded in the marketing of protective technology
(Potter et al., 2020)	Colleg Students (USA)	Sexual Assault	uSafeUS (mobile application)	Survey-based	To determine if mobile applications are a way of making college students aware of sexual violence resources	Reasons for downloading the application although did not explain if it was useful
(Maxwell et al., 2020)0	No target use (Public locations)	Public stranger violence	Personal alarms, crowd-sourced hot spot data, and geofencing (Mobile applications)	Content Analysis	To ddress lack of evaluation	Many of the reviewed applications did not work, which suggests that they reduce fear of crime but are limited in reducing risk to harm
(Eisenhut et al., 2020)	Women	VAW	Mobile Applications	Content Analysis	To conduct an analysis and functional categorisation of applications addressing violence against women	The majority of mobile applications for safety are for emergency situations

Table 2.2: Summary existing PSD research in date order. Design-focused studies have not been included

Author	Target	Type	Technology	Method Category	Aim	Key Findings
(Tozzo et al., 2021)	College Students (University) (Italy)	VAW	Mobile applications	Survey-based	To investigate the knowledge and propensity to download PSD (mobile application)	Mobile applications would be less useful than other interventions (education and policy). Calling for help would be the most useful feature. Less inclined to use the application if it was integrated with social media
(Doria et al., 2021)	Women	VAW	Mobile applications	Review	To review the scope of the literature on women's experiences of safety apps to ascertain the potential of using smartphones of improving women's safety. What is the scope of the literature on women's experiences of safety apps in relation to sexualized violence?	Only 12 studies were found based on the requirements of the search (8 IPV), three themes were found (security, accessibility, and knowledge)
(Demissie et al., 2021)	College Students (USA)	Safety	Peace of Mind (mobile application)	Adoption Theory	To investigate the determinates of user acceptance and adoption of Peace of Mind (POM)	Performance expectancy, trusting belief, facilitating conditions, and social influence had direct effects on the students' behavioural intention to use the mobile application
(Philbrick et al., 2022)	Women and children in low- and middle-income countries	Sexual and Gender-based Violence (IPV)	ICTs (mobile phones, tablets, and web-based applications using laptop computers)	Review	To establish a baseline for the state of the evidence connected with the use of ICT against women and children in LMIC.	The baseline for using ICT to prevent and/or respond to VAW and children in LMIC is nascent.

Table 2.2: Summary existing PSD research in date order. Design-focused studies have not been included

Author	Target	Type	Technology	Method Category	Aim	Key Findings
(Moret et al., 2022)	No target user	IPV and Sexual Violence	Mobile applications	Content Analysis	This study aims to evaluate the prevalence and quality of freely available mobile phone applications targeting intimate partner violence (IPV) and sexual violence (SV) prevention and response	Safety applications were found to have low-to-moderate quality, with the overall subjective quality mean for the reviewed applications being 2.65 (95% CI 2.58-2.72)
(Kaur et al., 2022)	Women (India)	Sexual Violence	Not specific but primarily mobile applications	Interview	To find existing technology use existed for safety	Participants wanted technology to help them escape by providing information on nearby places they perceived to be safe
(Ford et al., 2022)	No target user (UK)	IPV	Mobile applications	Content Analysis	To find evidence on the availability and user experience of smartphone applications aimed to prevent violence	Over half (52%) of applications were targeted towards the general population, with 16% targeting women and 13% targeting families
(Gupta et al., 2022)	Women	Mobility Safety	Safetipin (mobile application)	Interview	Identify criticisms of the mobile application so they can be used for evaluation	Found four themes criticising applications(1) they project the fear of assault onto the urban environment (2) they put the responsibility of being safe on women (3) they enable surveillance and control (4) they disregard intersectionality
(Wood et al., 2022)	No target user	Prevention of crime, violence, and abuse	Mobile applications	Content Analysis	(1) to establish the extent, range, and nature of research into smartphone applications with a primary crime prevention function (2) to locate gaps in the PSD literature (3) to develop a typology of primary crime prevention apps.	Mobile applications for safety lack evaluation, and are not evidence-based

Table 2.2: Summary existing PSD research in date order. Design-focused studies have not been included

Author	Target	Type	Technology	Method Category	Aim	Key Findings
(Sumra et al., 2023)	No target user	Domestic Violence	Mobile applications	Content Analysis	To improve the awareness of domestic violence and its prevention.	not reviewed in a context based, unclear who and how the apps were reviewed.
(Sengupta et al., 2023)	No target user (Public locations)	Safety	Crowdsourcing from Mobile Applications	Review	To measure potential algorithmic bias in the context of crowdsourced safety ratings using real-world data	Found a significant gender differences in safety perceptions and associated vocabularies
(Paiva et al., 2023)	No target user	Sexual Violence	Wearable Devices	Review	The review is mainly of design-focused studies that generally have a positivist stance of using technology for safety	Identified the main attributes of wearable devices used for women's safety
(M. Zhang & Bandara, 2024)	Pedestrians	Safety	Technology used in safety practice whilst walking (safe routing and planning)	Survey-based (Qualitative)	To understand the perception of safety of pedestrians and the safe mobility practices	Discovered that how people identify themselves and their surroundings affects how safe they feel and how they practice safe walking

2.5.4 Ethics and Value Sensitive Design

The majority of literature on personal safety devices is design-focused. Tayal et al. (2021) propose a women's safety device that uses GPS and GSM modules to track a woman's location and send emergency messages to contacts and the police in case of danger. Kabir et al. (2020) and Yadav et al. (2021) have focused on the creation of an Android-based safety applications for women who travel long distances, utilising GPS and algorithms to provide efficient safety measures, with Aggarwal et al. (2022) reviewing various applications and devices designed for women's safety, including those utilising GPS and SOS buttons before suggesting their own. This presents a small selection of the literature written from a design perspective.

Design-focused studies are predisposed to encouraging the potential of technology in enhancing women's safety whilst active travelling. Arumugam (n.d., p. 410) claim that 'an android phone can be used to protect the women in risky situations', and Aggarwal et al. (2022, p. 1) argue that 'technology is offering the solution to almost all the problems existing[sic]'. This literature is not explicitly activity led, although walking and public transit are often mentioned. Instead, they focus on functionality, such as battery life, hardware integration, and compatibility with other Internet of Things (IoT) devices and tends to serve as design documentation for the development of safety devices (Agarkhed et al., 2020; Chanmanwar & Nirkhi, 2022; Kabir et al., 2020). There is often no evidence of user research, and the link between the problem and the design space remains unclear. Whilst it provides insight into their development, it illustrates a narrow consideration for the contextual and social implications of use and to the reader is evidence of techno-solutionism or techno-optimism - the belief that technology can solve every problem known to humans.

Despite this, some design-focused research engages in a more thorough investigation into the needs of users before providing solutions. The diary studies and semi-structured interviews completed by X. Y. Huang et al. (2023) were conducted to understand the environmental factors and lived experiences of women that influenced their perception of safety in public spaces. In doing so, the study picked up on issues that were unidentified in other design-focused literature, such as the role of others in women's safety work. This included the influence of family and friends, the role of sharing and being part of a community, and how technology has been able to facilitate these existing practices. In response to these findings the proposed technological solution included more refined services, such as using crowdsourcing data to report on the public transit schedules so that individuals would be aware of delays to services and acknowledging issues surrounding digital literacy and accessibility.

All but one of the design-focused papers reviewed a personal safety device that required active participation. That is, the user was required to activate the device through an additional physical action, such as pushing a button or shaking a mobile phone. However, an alternative method using machine learning has been suggested by Rodríguez-Rodríguez et al.

(2020). Used with biosensor data, the device aims to work autonomously, avoiding the preplanning and manual activation of a panic alarm, as proposed by others. The device is reliant on continuous monitoring of bio sensed data, which is then analysed using artificial intelligence and infers whether an abnormal situation is occurring. Existing literature regularly alludes to artificial intelligence and how it can further support safety and be a significant addition to existing personal safety devices (Gupta et al., 2022; Sumra et al., 2023). Whilst it is assumed that it is being referred to as utilised by Rodríguez-Rodríguez et al. (2020), it is a broad term used for many facets of technology. It is therefore not clear as to what the authors mean when using this term. AI appears to be being used as an additional buzz word used for these devices' promotion.

Four themes from existing literature are resolved by Gupta et al. (2022), representing how technology fails to support women in their safety efforts. The four themes are the projection of fear into the environment, placing the responsibility on women, enabling surveillance and control, and lack of intersectionality. These themes were then used as a framework for interview questioning to investigate and resolve these failings.

Both Simpson (2014) and Hasinoff (2017) conducted in-depth analyses of just one mobile application (Live 360). This popular application enables family members to view each other's locations along with safety data, such as crime hotspots. The findings concluded that these applications paint a picture of development that is self-serving, where ideas about safety technology and data, such as a positivist approach to data-driven solutions, are reproduced (Doroudi, 2024). Hasinoff (2017) focuses on the features and marketing of the application, whereas Simpson (2014) explores GPS and the implications of being tracked. Ultimately, they both find there are big biases in the data and what is deemed to be safe by these applications.

In addition to the categorisation and typologies of technology performed at functional and feature levels, additional content analysis has been conducted in order to establish efficacy. Maxwell et al. (2020) 'tests' the functionality of mobile applications for their use in public stranger violence. The major findings of the review highlighted that found that 9% of the mobile phone applications tested in their study did not work, mentioning the potential dangers associated with poor functionality, but also the ongoing support and maintenance of digital tools. Ford et al. (2022) takes this further by analysing the online reviews of these applications to gauge their effectiveness. Achieved through sentiment and thematic analysis, the derived themes indicate that whilst over 50% of the reviews were positive, nearly 40% were negative. Positive reviews were associated primarily with a feeling of safety and 'peace of mind' afforded by communication, and negative themes identified functional problems, similar to Maxwell et al. (2020), and ethical issues regarding data privacy. Moret et al. (2022) also aimed to establish the quality of personal safety mobile applications using the Mobile Application Rating Scale (MARS) (Stoyanov et al., 2015). Using this scale, derived from 372 explicit criteria, the majority (95%) were of 'low to moderate quality' (Moret et al., 2022, p. 1). Wood et al. (2022, p. 1093) looked at mobile applications that were designated primary care prevention applications developed 'to prevent crime, violence, and abuse', and included

'self-surveillance apps, decision aid apps, child-tracking apps, educational apps, crime-mapping/alert apps, and crime reporting apps'. Similarly to other content analysis with the aim of identifying the typologies of these applications, Wood et al. (2022) also aimed to examine where authors had sought to establish the efficacy of the application in question, and the means through which they did this. The results are damning, with the findings showing significant gaps in evidence for mobile applications' effectiveness at supporting safety and prevention of crime, and showing that the 'recent enthusiasm over these forms of victim-facing app-based crime prevention interventions is not supported by adequate research or evaluation evidence' (Wood et al., 2022, p. 1093).

None of the applications evaluated by Maxwell et al. (2020) or material evaluated by Cardoso et al. (2019) targeted men only. This finding is significant considering the statistics on genders most likely to be subject to criminal behaviour, and is problematic in two ways. Firstly, this potentially reinforces gender stereotypes of the weak woman who needs to be protected, and must not walk alone (Cardoso et al., 2019; Sauerborn et al., 2022), and secondly, whilst many applications are 'free' it engenders an additional cost to women's safety, where profit is made from the long-standing issue of violence against women (Cardoso et al., 2019). This cost is not only financial, but also may restrict the right to privacy (where personal data is sold for profit) and time, through additional 'safety work' practice. Sauerborn et al. (2022) call for the further evaluation of personal safety technology through the lens of structural justice, inclusive of epistemic injustice.

Bivens and Hasinoff (2017) examined the features of applications along with their intended user (victim, bystander, or perpetrator) for each user and the social implications of these features (mapping, GPS, audio, etc.), asking 'What ideas about the nature, cause, and prevention of this social problem do those features reflect?' (Bivens & Hasinoff, 2017, p. 1051). At this feature level, the author is able to investigate the relationship between technical design and societal norms, such as the likelihood of these technologies perpetuating and reinforcing victim blaming and the stranger danger myth. Within just a few papers, the literature shows again, the variety of technology that is available for personal safety, but that it has repercussions in terms of reinforcing social norms.

It has been shown that where there is high uncertainty and high vulnerability individuals may use technology without considering the potential risks (Chib & Ang, 2023). In the case of COVID-19 mobile applications, there was limited to no public consultation about what risks the public was willing to take on to benefit from them (Michael et al., 2020). This imposition, whilst under different pressures, is also true for personal safety applications, where promises of effectiveness coupled with growing fear and uncertainty imply the need to use such tools. Therefore, it is equally, if not more, important to ask when it is 'appropriate' to develop technologies as solutions. Yes, technology has demonstrated success in many areas of society, yet are we too quick to adopt these solutions as quick fixes to long-standing issues such as violence against women?

Numerous authors have identified ethical concerns pertaining to personal safety devices. These are the undesirable consequences of their development. Operationally, they promise risk reduction, but they do so without empirical proof (Cardoso et al., 2019) using untested platforms (Simpson, 2014) that are unreliable Maxwell et al. (2020) and with a lack of appreciation as to how affordance can change with context of use (Cumiskey & Brewster, 2012). The findings of this section demonstrate several ethical considerations associated with personal safety devices. Whilst the solutions evaluated here indicate that sociological and ethical enquiry is not happening, as is the case with the findings of Hasinoff (2017) and Simpson (2014), Bivens and Hasinoff (2017) found that the development timelines and requirements set by funding bodies can impede a solution that considers all ethical requirements.

Baumer and Silberman (2011) highlight the rarity of documenting failure cases or inappropriate usage of technologies, and believe that doing so will increase the consideration of technology as a potential failure rather than the technical optimistic techno-solutionism that is generally presented by many communities. The following questions are suggested by them as a framework for establishing technology as appropriate in different situations. Are there low-technology solutions already available? Does deployment result in more harm than good? And does it solve a computationally tractable problem? (Baumer & Silberman, 2011). Whilst the case study used to exemplify these issues is not bound to wider institutional problems, such as with violence against women and what that means for the perception of safety in public spaces, these questions can still serve to pursue technological development from a broader and more inclusive point of view. Whilst this study aims to evaluate and not design. RQ3 is written to look at the potential of technology. This section serves to highlight the ethical challenges of personal safety devices, such as undesirable affordances and biases. The reflexivity identified by Baumer and Silberman (2011) and the awareness of must be part of my research and should be addressed in my evaluation and answering of RQ0.

2.6 Chapter Summary

Technology enables greater flexibility and multitasking, fundamentally changing mobility patterns in terms of time and space (Cohen-Blankshtain & Rotem-Mindali, 2016). Turning to it in times of need of decision-making and aid. Yet, despite their pervasive use, Martínez-Díaz et al. (2018) warns us that technological implementation should be critically evaluated due to the risk of them becoming 'consumer fantasies' that fail to address any social requirements that will improve personal mobility (Martínez-Díaz et al., 2018, p. 2). As evidence of this, technology has also been shown to facilitate bad actors (individuals that wish to do harm) and influence behaviours, increasing risk exposure (Carleton et al., 2019; Line et al., 2011; Nasar et al., 2007).

All authors call for consideration of the unintended consequences of using technology with work by Sauerborn et al. (2022) stressing the importance of looking at the ethical implications of using mobile applications as intervention strategies. Given the lack of evidence for efficacy, adoption can currently only imply a sense of safety rather than actual increased safety from harm or injury (Maxwell et al., 2020; Wood et al., 2022).

A summary of the reviewed research on personal safety devices is shown in Table 2.2.

These perspectives collectively highlight the ongoing challenge of balancing objectivity with value considerations in social research. Whilst not a systematic assessment, there appears to be a trend towards greater scepticism with respect to these tools and their use in this domain, with views on privacy, heightened awareness of bad actors, and the detrimental effects of social media suggest changing views on techno-determinism.

This chapter summarised the literature, as divided into three sections, representing the three different fields of research that underpin the development of this study moving forward.

Section 2.3 re-emphasised the impact of fear-based concerns and how women's perception of safety impacts their mobility choices. Technology and mobility are now synonymous, and there is a risk that this adoption has encouraged the use of technology for women's safety in active travel prematurely. Despite emerging literature on technology use to address safety concerns, there are significant gaps in our understanding of how individuals use these devices. For example, where maps that use safety data (Live 360), what are women's expectations of that information and the undesirable or unintended consequences of that integration. Technology was introduced as a source of information to tackle underreporting of safety issues within the sphere of mobility. This is an area that I wish to explore further following the reporting undertaken on social networks from both feminist and mobility perspective.

Section 2.4 looks at how technology can be used to gain more information around women's safety in public spaces. Specifically using social media data.

Section 2.5 looked at the approaches in HCI research to consider the development, interactions, and desired outcomes of technological interventions using applicable research from the mobility and women's safety domain. This covered the affordance of technology and how this varies with embodiment and adoption, and the associated influences of trust and risk. By leveraging technological affordances and understanding the embodiment of technology, innovative solutions can be developed to promote women's empowerment and safety in both public and private spheres. This relationship between empowerment and agency links with the concepts of trust, adoption and embodiment. Whilst empowerment is readily promoted through technological innovation, empowerment is not guaranteed and cannot be assured. Considering the stages of development through affordance of features and the resulting implications for trust, adoption, embodiment, and eventual empowerment

is more likely to lead to success. Existing empowerment literature identifies that integration into existing practice and cultures needs to be gained to achieve this.

Information gathered from prior studies indicates various levels of detail regarding technology use and integration. Mobile phones (Cumiskey & Brewster, 2012; Nasar et al., 2007), then generic mobile application (McCarthy et al., 2016b) specific tools (Demissie et al., 2021; Glass et al., 2015) or features (Ford et al., 2022). It prompts me to consider at what level I must investigate this connection to address my research queries. It is likely that future technologies will integrate many of the features, as they have done previously, using a kind of 'pick and mix' of available options, therefore identifying these individual features and their resultant affordances provides an opportunity for the results to be relevant to future research and development.

The common thread in this literature review is the lack of contextual and social enquiry into the lived experiences of women. Given that active travel, technology use, and safety work are performed practices — something that is usually or regularly done, often as a habit, tradition, or custom, I propose that a better way of understanding the relationship between them is to move from the individual to the practice lens. The subsequent chapter aims to establish a method of focusing on practice by using a suitable theoretical framework.

Chapter 3

Theoretical Framework

A theory is a statement of relations among concepts within a set of boundary assumptions and constraints (Bacharach, 1989). Its purpose is 'to organize or simplify a complex world, and then explain that world to others in a way they can apply the theory in other situations' (Schneberger et al., 2009, p. 53). Theories can therefore provide researchers with different perspectives from which to examine problems, directing focus towards different elements and offering a structured approach for analysis (Reeves et al., 2008).

Having argued in the previous chapter that existing research on technology's relationship to safety whilst active travelling is relatively scant and often technologically deterministic, I now direct my attention to practices that are currently in place and the affordances of technology. The practice focus leads me to social practice theory (SPT) as a suitable framework to guide my exploration of the topic, due to its ability to 'open up a way of seeing and analysing social phenomena' (Reckwitz, 2002, p. 257). In this chapter, I will present and discuss the key components of SPT and further detail why it is an appropriate lens through which to view my study.

I will begin by providing an overview of SPT and its evolution. I then argue for its suitability in relation to my main research question by examining how this theory has been used in previous research with respect to the key components of my study, those of mobility, materiality and the practice of 'safety work (Vera-Gray & Kelly, 2020). This chapter then summarises the literature review and three further sub-research questions that have been formulated to answer my main research question.

3.1 Background

SPT is situated within the broader theoretical framework of practice theory, or as one of the 'theories of practice'. Two of the most notable contributors to the theory are Giddens (1986)

and Bourdieu (1977). Both use a theoretical framework that posits that structures and agency are not separate entities but instead influence each other, and are cyclical and dynamic. According to structuration theory, structures are preserved and altered through agency, much as a person's autonomy is impacted by their environment (Giddens, 1986). Both Giddens's and Bourdieu's views were a departure from existing practice theory, where practice was considered a product of an individual's autonomy, as influenced by the surrounding environment.

Whilst social-psychological theories consider the social dimension, guided by shared norms, values, and understandings, they do so at an individual level, convinced that society is made up of individuals defined through their pursuits (Thompson & Fine, 1999). In challenging actor-centric approaches, two limitations are conceived by Heisserer and Rau (2017). Firstly, that there is a lack of focus on contextual factors (something that is important to technological affordance as detailed in section 2.5.1), and secondly that they consider behaviour to be the result of conscious choice.

Expanding on these limitations with three further points in the context of mobility, the authors first consider that modes of transport carry meaning, such as safety, status, flexibility, and independence. This resonates with the topic of this thesis, where women rank safety as highly significant and having variable meanings. Secondly, the requirement and dependence on others in mobility cannot be based on individual requirement. As often, primary caregivers with responsibility for others with various transport needs and requirements are not consistent (influenced by external factors outside their control). And finally, they highlight the limitations of actor-centric transport models in allocating '(infra)structural aspects', such as policy, infrastructure, laws, and regulations (Heisserer & Rau, 2017, p. 582). In summary, they believe that social-psychological theories restrict the explanatory power of actor-centric approaches as centred on the individual.

To address these limitations, SPT skips ahead (deliberately) 'diverting attention away from the individual and moments of decision-making to the doing of various social practices' (Beatson et al., 2020, p. 198). Practice is now the core unit of discussion. This emphasises the importance of understanding the interconnected-ness of individual action, social structure, and cultural norms rather than the cognitive process of decision-making. SPT recognises that we are all these things at once, and we cannot understand behaviour without considering all these parts (Reckwitz, 2002).

To achieve completeness, practice theorists required an additional concept to be introduced beyond the rule-based individual. This means that as well as considering homo economicus, whose actions are a direct result of pursuing the highest level of well-being for themselves, and homo sociologicus, whose primary objective is to fulfil their role in society, as influenced by the social context in which they find themselves (Reckwitz, 2002), practice theory also considers homo habitus, who operates below the level of consciousness. Bourdieu introduced the concept of 'habitus' in part to account for actions that did not align with reason. Habitus

describes practice that can be implicitly learnt and which 'goes without saying because it comes without saying' (Bourdieu, 1977, p. 167). However, the reconciliation of rule-based actions, unconscious action and motivation was one of the early critiques of Bourdieu and Giddens's practice theory (Galvin & Sunikka-Blank, 2016). The unconscious action dilemma was later remedied by Schatzki, by reframing the habitus with a form of embedded understanding that came from doing them with repeated rational rule thinking intent (Schatzki, 2010).

Schatzki (1996, p. 89) describes practice as a 'temporally and spatially dispersed nexus of doings and sayings'. Along with the reframing of habitus, he introduced the idea that motivation was also not related to rule-following, but instead to feelings, such as 'goals, belief and expectations', labelling this as 'teleoaffectivity', from the Greek 'telos' meaning end or goal and the Latin 'affectus' which means affection or mood (Schatzki, 1997, p. 303). These two modifications were subsequently incorporated into Schatzki's practice definition as something that is a 'temporally evolving, open-ended set of doings and sayings linked by practical understandings, rules, teleoaffective structure, and general understanding', where routinised practices dictate not only how the world functions through activity and actions but also how it is understood through observation of them, facilitating the exchange of knowledge (Schatzki, 2001, p. 87). Schatzki also makes a clear distinction between the individual element 'entity' of practice, the understandings, rules and teleoaffective structure and the collective unit of the 'performance'. The elements of practice you cannot see and the ones you can (see Figure 3.1). To use the performance of showering, you require the feeling and meaning behind what it means to be 'clean', the skill required to shower, and the material entities (shower and soap) to be able to 'perform' the act of showering.

Reckwitz (2002) places SPT in the shadow of other cultural theories such as cultural mentalism (the mind, feelings), textualism (meaning symbols and signs) and intersubjectivism (language and the transfer of knowledge) with commonalities such as mental structure and activity. Practice is therefore summarized by Reckwitz (2002, p. 249), as something more specific than that of Shatzki's practice, consisting of 'forms of bodily activities, forms of mental activities, "things" and their use, background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge'. This provided yet another evolutionary transition, since Schatzki did not place material elements at the fore until much later, when they were recognised as having significance to social thought and being part of the fabric of society (Schatzki, 2010). Reckwitz's elements are characteristic of 'current' practice theory, emphasizing the focus of SPT on the 'everyday' and 'lifeworld'. They offer something which more closely resembles the widely adopted Schatzki approach and are a precursor to the streamlined and easily applied elements of Shove et al. (2012).

Shove et al. (2012) considers practice to be made up of the following elements, materials, competencies, and meanings. Materials are things that are integral to performing a practice. For example, in the context of this study, technology, other people, and surrounding infrastructure constitute all constitute material elements. Competencies are the skills and

knowledge of those taking part in the activity, the ability to use and understand the technology, and also the skill with which to be able to actively travel. Meanings can include ideas and aspirations, indicating that practices hold significance and are symbolic within a community or society. For practices to exist, all three of these components must be present and connected (Shove et al., 2012). An illustrative representation of practice as active, not yet active (proto-practice), and broken (previously connected) is shown in Figure 3.2.

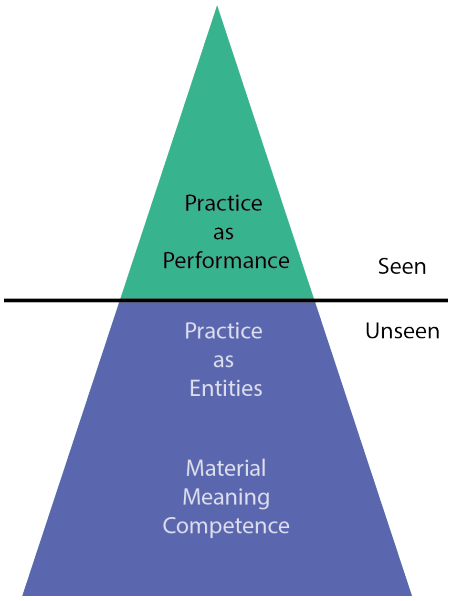

FIGURE 3.1: Diagram visualising the difference between Schatzki's 'Practice as a Performance' and 'Practice as Entity' (adapted from Flores et al., 2015).

The three-element model has garnered praise for its efficacy in examining all aspects of practice. This is inclusive of non-human and material components, diverse forms of intellectual and embodied knowledge, and cultural disparities, putting the spotlight on elements with distinct ontological attributes and fruitful analytical assistance (Hampton, 2018). The structure is simple and can be applied in different ways to focus a study, in order to curate a holistic understanding of practice both as a performance and as an entity. Figure 3.1 shows the difference between the unseen entities and seen performances using the elements proposed by Shove et al. (2012).

SPT has been used successfully to gain insights into social phenomena. These include, organisational studies, anthropology, sustainability and green consumption (Breadsell et al., 2019), mobility (Heisserer & Rau, 2017; Kent & Dowling, 2013), marketing (Beatson et al., 2020), and health research (Frost et al., 2020). As well as large-scale assessments, practice theories have also been found to be relevant for the study of small social phenomena, such as daily routinised activities such as showering and washing, and dispersed practices such as walking (Harries & Rettie, 2016). Furthermore, and pertinent to this study, it has also been used to explore the role of the non-human and its consumption in social practices (Shove & Pantzar, 2005), mobility (Heisserer & Rau, 2017), and the dynamics of social change (Spaargaren et al., 2016).

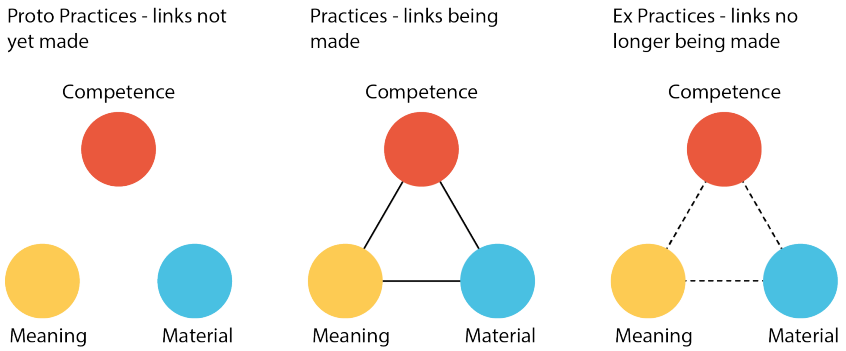

FIGURE 3.2: The makeup of a practice shown as a combination of material, competence and meanings, where practices are connected and proto-practices are not connected. (Shove et al., 2012).

Modifications of Shove et al.'s (2012) simplified structure demonstrate the theory's accessibility and flexibility in wide-ranging fields of research. These modifications include networks of shared elements (Higginson et al., 2015), micro-macro level practices (Hampton, 2018) and qualitative representation in empirical studies (Heisserer & Rau, 2017; Higginson et al., 2015). The bubble model of Kuijer (2014) differentiates between the performances and elements within practices, choosing to illustrate them with a representative scale to signify their importance. The introduction of a quantitative value means that SPT can further lend itself to fields of study where numerical representation and analysis are important (Higginson et al., 2015).

SPT is considered an alternative approach to promoting behaviour change. Using sustainable consumption as a test case, Breadsell et al. (2019) evaluated and compared social psychological and social practice theories. They posited that while these methods work well together, SPT excelled in comprehending lived experiences and tackling consumption factors from the bottom up. It is these valuable characteristics that make it favourable for enacting changes in ingrained habitual practices that might be difficult to alter.

Sustainable consumption is where the lens of SPT has been applied most readily and successfully. Shove and Warde (2002) believe consumption to be a result of practices, and that it should therefore be focused on in this way. They emphasise the importance of meshing material and social contexts in considering people's 'everyday consumption of distance', where mobility is 'negotiated' within social constructs rather than as an individual choice, as it is with Theory of Human Motivation (Stern et al., 1999) and Theory of Planned Behaviour (Ajzen, 1991). Importantly, and as is the case with my study, they situate material elements as consumptive parts of the practice that explain changes in practice over time.

SPT's clear and flexible structure means that it can be accommodated within wide-ranging fields of research. Its extensive use not only demonstrates its popularity, but also the ease with which it can garner insights and opportunities for policy impact and influence.

3.2 Suitability

The following section assesses how well SPT aligns with integrating technology into active travel practices and safety measures, and how easily it can be implemented in my research.

3.2.1 Safety Work

I established in Chapter 2 that a large part of what it means to be a woman, and to actively travel, involves conforming to a set of social rules or practices to keep oneself safe (Kelly, 2012). This 'safety work' is implicit knowledge that is learnt and practised (Vera-Gray & Kelly, 2020). Safety work is a collection of practices used by women to reduce the risk of harm (Vera-Gray & Kelly, 2020). This is done in many facets of life, but particularly when individuals are active travelling in what are deemed risky situations. Likened to the deeply ingrained unsustainable practices detailed by Breadsell et al. (2019), women's safety practices are also deeply ingrained. Fear and avoidance of risk are not likely to change due to someone saying, 'come out, it's safe to walk alone now, statistically it is unlikely you will be attacked'. Or, as Shove et al. (2012) put it, 'if communities of practice are born of the experience of doing, they cannot be willed into existence or designed from afar'. Existing habits must be considered when attempting to change or alter practice. By isolating elements, it is feasible to identify any deficiencies or potential modifications, thereby facilitating the possibility of modifying practice. It may also be the case that 'Safety work' is so deeply ingrained and unchangeable, that technology may only be able to support it rather than eradicate it via emergency interventions.

3.2.2 Materiality

Materiality is central to this study, given that I am concerned with the technology that women use as part of their active travel practices. Schatzki (2010) stipulates that materiality is inherent to social phenomena, not just interwoven, but an additional dimension. The technologies outlined in section 2.2.1 have become ubiquitous in travel practices and are currently being developed and promoted for the purpose of personal safety. In establishing the integrated nature of material and practice and the social ontologies that situate it Schatzki (2010) believed that it was possible to focus any investigation, such as my own, by suggesting connections in empirical findings.

Schatzki (2010) also considers that the environment and material artefacts should be differentiated as two separate entities. This provokes some questions regarding the designation of technology in practice, as it can be argued that it is both environment and material. For instance, third-party applications on a mobile phone, social media and the 'metaverse' create pseudo environments that can be perceived as an object accessed by

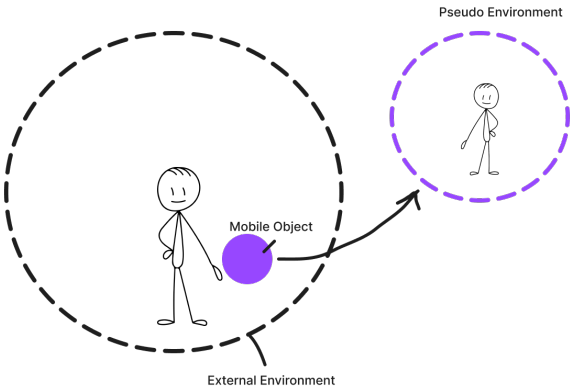

FIGURE 3.3: Technology enables the creation of pseudo environments through social media

another object (see Figure 3.3), wearable IoT technology that uses the affordance of another object (mobile phone and GPS) can create complex arrangements of material things. Furthermore, it is possible that a tool like a route recommender that avoids unsafe spaces can be considered in the same light as a map. However, it is more than just a passive element, instead it is feeding back information that can alter travel behaviour. At what point then do they defer from material and instead become meaningful elements, like a sister providing advice, taking on new meanings grounded in their data? At what point does it have more significance as the initiator of a social phenomenon (Heisserer & Rau, 2017)? In essence, it becomes a hybrid entity (de Souza e Silva, 2006) and prompts discussion on how best to categorise a technological tool for assessment within the context of SPT and how it shapes knowledge dissemination and communication. It is therefore necessary not only to determine the material arrangements, differentiating between the elements under scrutiny, but to recognise their role in practice (Schatzki, 2010, p. 129).

SPT has been used successfully to explain the implications of material integration into existing practice. Using the practice of Nordic walking, Shove and Pantzar (2005) articulate how the practice of walking can be reimagined with the integration of a stick. It is possible to draw some, if tenuous, parallels between walking with sticks and walking with phones. They are seen to increase security, with links to modernity and newness, and give rise to positive feelings (Cumiskey & Brewster, 2012). The findings also mirrored the concerns of technology use in the sphere of safety found by Sauerborn et al. (2022), emphasising the importance of equipment and market expansion, which places pressures on developers and consumers by political powers and mainstream media. These previous explorations of material in practice using SPT evidences its use and alludes to the kinds of outcomes that this lens could deliver.

The literature review looked at technology that was considered a personal safety device. The variety of technologies available and their quick advancement means assessing them is difficult. Taking the literature reviewed in section 2.5 as examples there is a progression in the complexity of technology, its research, and subsequent findings. From mobile phones (Cumiskey & Brewster, 2012; Nasar et al., 2007), to personal safety devices with loosely defined features (McCarthy et al., 2016b), specific mobile applications (Glass et al., 2015; Simpson, 2014) and more recently integration into the lived experience with features (Kaur et al., 2022; M. Zhang & Bandara, 2024). This progression supports using affordance theory in conjunction with SPT to gain further insight as to how the specific features of personal safety devices are used.

3.2.3 Practicality

It is important to highlight that this study has been approached from a feminist standpoint, by which I mean that I intend to investigate this subject to raise awareness and contribute to the equality and equity of a future society. Therefore, as well as a theoretical framework that enables me to describe behaviour, I also want to use a theory that can action problem-solving and be applied practically. Not only do I feel that SPT aligns with my epistemological values and broadens my approach to and understanding of the study, but also has the potential to address inequality through use of the outputs to inform policy and change.

Hampton (2018) demonstrates the effectiveness of SPT in the context of policy implementation as a practice. The work builds on the introduction of social practice theory as an analytical lens used to understand sustainability and energy practices and to direct top-level policy guidance. Combining the existing Multi-Level Governance and three-element model, Hampton (2018) was able to analyse interview data. Despite challenges of implementation for large-scale projects that consist of complex bundles of practice and performance chains, they were successfully combined effectively. The framework therefore facilitated engagement with policy practitioners and demonstrated the viability of using SPT to influence policy in the real world.

The concepts within SPT are clear and consistently defined. It is well known as a solution-driven approach, providing a solid, descriptive blueprint for understanding the complexities of human behaviour and social life (Blue et al., 2016). The study is goal-oriented, in that it is hoped that the results will enable further understanding of active travel, and the safety practice behaviours of women to encourage technology development in the areas that will best support women. Active travel, being the collective practice, should therefore be kept at the forefront of the research so that it is possible to find out what elements enable this. Through an examination of the successful and unsuccessful mechanisms by which technology is employed, it will also be possible to determine whether there is potential for continued longevity. As someone new to the field of social science, it makes sense to apply a framework

with the flexibility to accommodate the elements of technology, infrastructure, and active travel.

3.3 Summary and Research Questions

Situated at the intersection of three domains, the main research question considers: people (women), technology, and mobility. This somewhat broad categorisation permits the use of several theories that could support the research moving forward. These include behavioural theories and their modifications that have been used to describe transportation and mobility behaviour (the theory of planned behaviour), technology adoption (United Theory of Acceptance and Use of Technology), or theories that have been used to understand the interactions between humans and technology (Activity Theory). These theories are all positioned within a social psychological standpoint, with the view that, given certain information, behaviour will result as a process of an individuals' 'conscious' decisions.

Existing literature tends to adopt a narrow approach to the practice of active travel and technology adoption. They often use structural equation modelling to analyse the relationships between relevant factors (Paige Willis et al., 2013; Singleton, 2020; Sun, 2017) of adoption. Most importantly, the lived experience and the contribution of non-human elements are not considered (Hampton, 2018). Therefore, there is a need for a broader, more inclusive contextual line of enquiry that combines an understanding of existing practice, experiential factors, and historical perceptions of place.

I argue that by conceptualising active travelling with technology for safety as a technological practice, it becomes feasible to highlight the material, meanings, and competencies that are required to perform it. Consequently, the obstacles and deficiencies hindering this practice will emerge, revealing whether it qualifies as a fully developed practice or remains in a proto-practice stage — lacking cohesive linkages between material resources, meanings, and competencies. If it falls short of being a complete practice, the enquiry can turn to what modifications can be made to these elements to facilitate its evolution into a practice that women can adopt, endorse, and sustain.

The overarching research question explored throughout this thesis is:

RQ0. How can technology be deployed to improve women's perception of safety of active travel?

This question and the findings from the literature review led to three specific research sub-questions.

When contemplating personal safety technology for use in active travel, the initial focus often centres on the objects and physical tools employed to enhance the 'doing'. However, social media, as highlighted in section 2.4, has been able to reveal valuable perspectives and

viewpoints not uncovered through traditional methods of enquiry in several fields of research. Social media data presents an opportunity to collect insights into the concerns, anxieties, and requirements of women. This non-invasive approach offers a pathway for gathering information that could inform subsequent investigations. This kind of analysis has been conducted for public transit modes but has not been achieved for active travel. Using BERT, as outlined in section 2.4, has been identified as an opportunity to conduct research to answer RQ1.

RQ1. How can technology enable a greater understanding women's perception of safety whilst active travelling?

Questions two and three address the 'doing' of active travel and in both cases the contextual enquiry into the existing and potential practices of women with respect to their active travelling safety. RQ2 has been formulated in direct response to the fear that women have when undertaking active travel and the 'safety work' that is undertaken to mitigate against those fears, while RQ3 looks to the development of future technologies in this domain.

RQ2. How does technology contribute to, or influence, a women's perception of safety whilst taking part in active travel?

RQ3. What are the current challenges and limitations of technology designed to support women's perception of safety when they use active travel modes?

In the following chapter, I will discuss the methodological approaches chosen to answer these research questions, inclusive of the rationale for their selection.

Chapter 4

Methodology

This research sets out to assess the role of technology in supporting the uptake of active travel among women and to answer the broader research question: RQ0. How can technology be deployed to improve women's perception of safety of active travel?. This chapter outlines my methodological approach inclusive of research design, data collection, and analytical techniques employed to enable the examination of this question and other inquiry questions detailed in section 3.3.

The main research question can be spilt into two distinct problems. The first considers technology as a research device (see section 4.1), enabling the collection of data through new technological methods. The second, women's technology-related practices (see section 4.2 focuses on understanding how technology is used whilst 'doing' active travel. There was a clear differentiation between the types of data, such that two distinct methodologies were required.

The first lent itself to a quantitative approach, using algorithms to collect data and transform this data into numbers. For the second, a qualitative approach has been chosen to create descriptions of how participants engage with technology. Qualitative research methods can offer a more in-depth understanding of users' experiences and perceptions. Therefore, understanding the intricate relationship between technological advancements and societal wellbeing is achievable. This enables better policymaking, the establishment of ethical standards, and the innovation of technologies that benefit people and society.

The remainder of this chapter is therefore guided by this structure. It details the selected strategies and reasons for using these two different methods, demonstrating their compatibility with the study's objectives. The research design, data collection, analytical techniques, ethical concerns, limitations, and challenges are detailed for each approach. Figure 4.1 illustrates how all components come together in the research process.

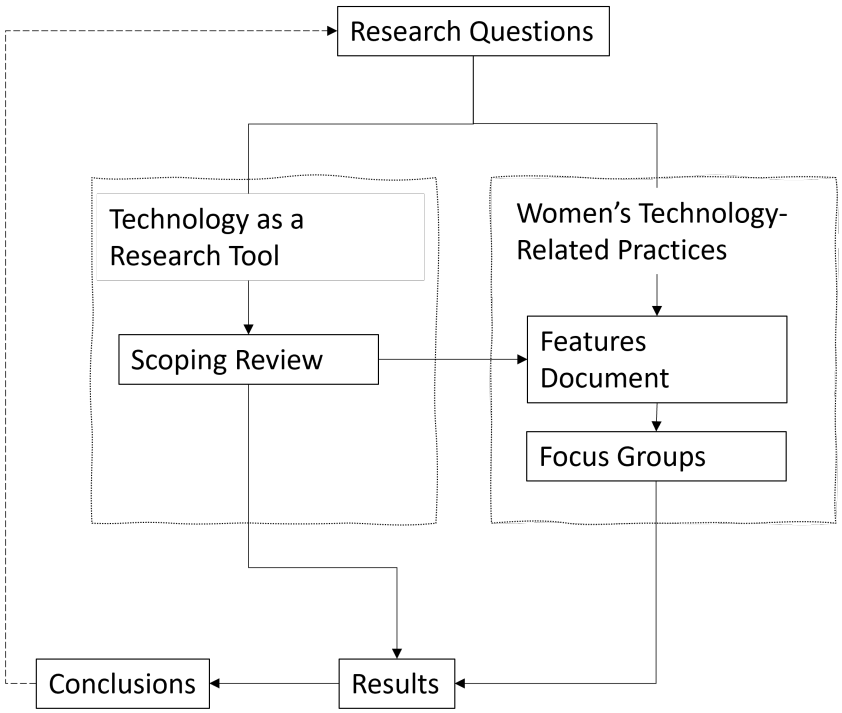

FIGURE 4.1: Overall research process diagram showing the two research streams.

4.1 Technology as a Research Device

The purpose of this research study is to examine the ways in which technology can be harnessed to understand safety in the context of active travel. Given social media's role as a reporting and campaigning platform, it looks to social media data as an alternative source of information. The study aimed to discover, using an applied methodology, if this information can be collected and made sense of. This work builds on existing studies completed on online data sets as detailed in section 2.4.

This research stream has two objectives: first, to investigate content on social media regarding the topic of harassment in public places (whilst active travelling), and second, to test a methodological approach for acquiring data on the subject. The following questions have been defined as part of the research design, which follows existing SMA identified in Chapter 2. Questions RQ1a-RQ1c aim to evaluate social media, in terms of the data it elicits and the methodology used for its collection.

- RQ1a. How are experiences and views of harassment concerning active travel recorded by users on social media?
- RQ1b: How many incidents/comments associated with harassment are recorded by the platform users, and do they fall into recurring and distinct typologies?
- RQ1c: Is there a gender differential with respect to the different typologies?

X (formerly known as Twitter) is a microblogging and social networking service where registered users can share and interact with other posts (formerly known as Tweets). In this space, users can post with very few limitations apart from the 280-word limit and the platform content rules. It is a platform where women are known to engage in digital activism, frequently challenging the status quo through campaigning and reporting (Morgan, 2021). Whilst analysis of social media data shows significance as a dataset that is both large and qualitatively rich, not subject to the limitations of traditional survey methods such as questionnaires (Maghrebi et al., 2015), it needs to be tackled carefully to maximise understanding and provide better quality outputs (Tinati et al., 2014). In the case of active travel, X's data has been shown to provide additional behavioural insight into active travel users, with significance for social science researchers, policymakers, urban planners, and transport companies (Alattar et al., 2021; Gal-Tzur et al., 2014). Given this history X's data was chosen to be used as the data source for this study. This section and the results chapter (Chapter 5 will now refer to X Posts as Tweets and X as Twitter, as this was their designation during the analysis period.

The literature review demonstrated that the use of Bidirectional Encoder Representations from Transformers (BERT) was a way to classify Tweets from a larger repository where likely keywords are not included. For example, the context of harassment may not always be contextualised in terms of specific words, yet the researcher may be able to determine this, as is the case with the Tweet 'What I would give to be that saddle and have you riding me baby'. Here the Tweet implies the catcalling of the Tweeter whilst they were riding a bicycle. It would be unlikely that this Tweet would be included in a search for catcalling whilst active travelling as it fails to include any indication through common search words such as cycle, harassment, or catcall, etc. Whilst there is existing research in the domain of harassment and sexual violence, it is common for researchers to use popular hashtags or specific keywords to target data for analysis. Whilst the same is partially true of this study, the aim was to use minimal keywords to collect a large dataset and then use BERT sentence encoding to filter the data using unsupervised and supervised methods to create a focused selection for analysis.

Applying a gendered perspective to reveal the ways in which gender affects various aspects of lived experience is something that other social media analysis has achieved. This has been completed on a small scale, through direct connection with users, using existing social media user information (collected through available datasets where user gender is declared) and by employing machine learning. A gendered lens encourages a critical examination of societal norms and practices, with a view to fostering a more equitable and just society for all genders. Within this study, machine learning offers a gendered lens through which to study how gender influences active travel experience. It is hoped that by adding this additional layer a more comprehensive understanding of any social phenomena will be possible. The application of a gendered lens is achieved by using a pre-existing machine learning tool that can identify user gender. This addition allows for a limited level of intersectionality to be investigated within the discourse.

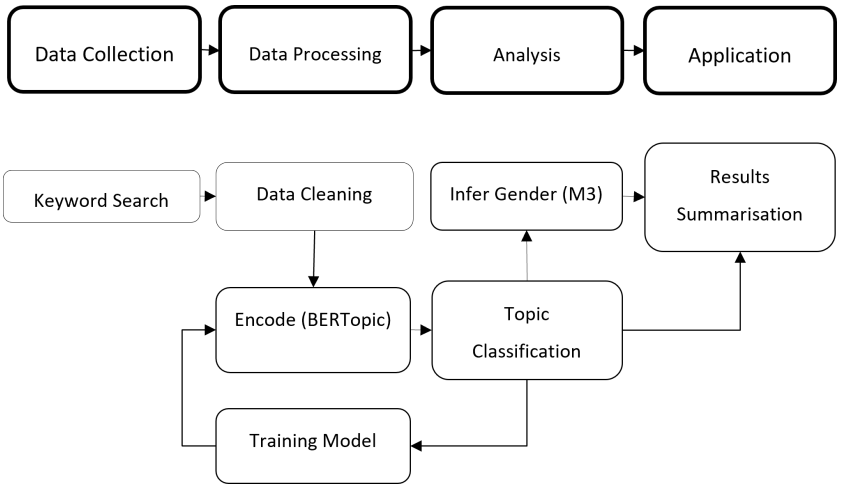

FIGURE 4.2: Flow diagram representing the workflow elements contained within the technology as a research device methodology.

In summary, suggested approach to classifying semantically similar Tweets uses BERT sentence transformers using BERTopic (Grootendorst, 2020) and a separate machine learning library (M3 Inference) to infer user gender (Wang et al., 2019). The diagram in Figure 4.2 represents the methodological workflow of the 'technology as a research device' study, the following sections detail each stage in greater detail.

4.1.1 Data Collection and Processing

The initial objective of this study was to gather and analyse data that utilised keywords to identify Tweets pertaining to public space and active travel. Despite the drawbacks of keyword selection, as set out in section 2.4, the initial data collection through the Twitter API required the utilisation of keywords. To minimise bias, it was hoped that by using a broad keyword selection that all tweets indicating use of public space and/or active travelling may be collected. The words selected to use in a query would either indicate location or active travel mode. Location words selected included (pavement, road, path, pathway, subway, trail, track, street, way, alley) and activity (bike biking, cycle, cycling, ride, riding, run, running, walk, walking). The following query was used.

twarc2 search (pavement OR road OR path OR pathway OR subway OR trail OR track OR street OR way OR alley OR bike OR biking OR cycle OR cycling OR ride OR riding OR run OR running OR walk OR walking) -is:nullcast -is:retweet place_country:GB lang:en –start_time=2018-12-01 00:00:00.00Z –end_time=2021-01-01 00:00:00.00Z > results.json

This query resulted in the collection of over 1 million tweets. The computational processing available was not enough to be able to classify this collection of tweets. Therefore, the scope of the study was altered to focus on harassment only, which ultimately reduced the number of tweets to a computable level, but also limited the scope of the study.

Fear of harassment was identified within the literature review as having significant impact on women's perception of safety in public space and to test whether but that will be able to differentiate between treats that were relative to harassment in public space this also meant that more emphasis is placed on the researcher to decide whether the tweets were placed in public space or not.

In total, the study collected 13124 Tweets that were posted between December 2018 and December 2021 and that included at least one of the words 'harassment', 'harassed', and 'harass'. The timescale was selected to account for the shifting travel behaviours before and during the COVID-19 pandemic (Dingil & Esztergár-Kiss, 2021). Twitter posts were limited to those written in English and originating from UK-registered accounts and content which is 'open' (not blocked and restricted to followers only). The search query did not include promoted tweets or ads (see in the query as -is:nullcast) and retweets (see in the query as -is:retweet).

Data was collected using Twarc (Summers et al., 2022), a command line tool, and Python library for collecting and archiving Twitter JSON data via the Twitter Application Processing Interface (API). It had separate commands (Twarc and Twarc2) for working with the older v1.1 API and the newer v2 API which included academic research access. The following query was used.

twarc2 search (harass OR harassment OR harassed) -is:nullcast -is:retweet place_country:GB lang:en –start_time=2018-12-01 00:00:00.00Z – end_time=2021-01-01 00:00:00.00Z > results.json

The 'academic product track' allowed access to 10 million historical Tweets per month to university affiliated researchers (this option is no longer available to X developers). Twarc could output .csv format with a column selection feature to reduce the output file size, and this functionality was implemented after the initial data collection using the command line. The 'Tweet object' has a long list of fields available to request through the Twitter API. For

this analysis only the following fields were required.

- Tweet ID – The unique identifier of the Twitter post
- Tweet Text – The textual content of the Twitter post
- Author ID – The unique identifier of the author
- Author Username – The authors unique username (@...)
- Author Name – Given name of the author
- Author Profile Image – Used by M3 Inference
- Author Description - Used by M3 Inference
- Created At – The timestamp of the Twitter post. Used for temporal analysis of data.

All data processing and analysis was run in Visual Studio Code with a virtual environment running on a GPU with CUDA 11. The complete list of Python libraries used for the analysis is shown in Table B.2 in Appendix B.

4.1.1.1 Data Cleaning

Twitter data is inherent with 'noise' and for topic modelling methods such as LDA text cleaning such as stop-word removal and lemmatization, is important (Fani et al., 2018). The necessity for stop-word removal for BERT is less well established. BERT relies on word placement within a sentence, so removing stop-words may 'confuse' the model. Since there are currently no Twitter, harassment, or active travel BERT models available, it was important to make an assessment of the importance of cleaning data for use with BERT. An initial analysis was completed to establish the influence of these variables on how the general BERT model classifies individual Tweets. The variables that were considered are abbreviations, usernames, and links. It is common practice for users to use abbreviations to maximise the available Tweetable space. Sometimes, usernames are included, and their inclusion can improve topic clustering due to the referencing of the same username, although they are unlikely to be part of the BERT model used for sentence encoding. Users may also incorporate links, typically to provide additional context to a Tweet.

The BERTopic (inclusive of UMAP and HDBScan see section 4.1.2.1) settings were kept at the default values for each analysis. The random seed value was set at 42. Hashtags and emojis were reserved for later analysis. Removal of some HTML artefacts such as newline characters (\n), ampersands (&amp, &and) and greater and less than signs (&gt and &lt) were also replaced.

TABLE 4.1: Comparison of outputs with different cleaning methods

	Topics	Topic	Count	Name
No change	199	-1	5932	Harassment, sexual, sexual harassment, people
		0	476	reported targeted, reported, targeted harassment, targeted
		1	289	twitter, tweet, tweets, twittersupport
		2	265	sexual harassment, sexual, accused, guy
		3	261	Gay, rights, community, ppl
		4	158	harassment https, https, like harassment, getting
		5	156	Racist, black, racism, white
Abbreviation Expansion	200	-1	5922	Harassment, sexual, sexual harassment, just
		0	327	Twitter, tweet, tweets, twittersupport
		1	312	Culture, staff, bullying, bullying harassment
		2	255	Gay, rights, community, ppl
		3	208	sexual harassment, sexual, harassment case, harassment
		4	203	like harassment, sorry, targeted harassment, just harassment
		5	185	Committee, Scotland, handling, harassment complaints
Link Removal	165	-1	5924	Harassment, sexual, sexual harassment, just
		0	346	Twitter, tweet, tweets, twittersupport
		1	334	Students, school, schools, university
		2	318	culture, staff, bullying, bullying harassment
		3	312	sexual harassment, sexual, guy, alleged
		4	258	gay, rights, people, community
		5	237	sorry, just harassment, like harassment, harassment
Username Removal	204	-1	5475	harassment, sexual, sexual harassment, https
		0	425	targeted harassment, targeted, woman, reported
		1	352	twitter, tweet, tweets, targeted harassment
		2	284	family, report, rules, child
		3	271	trans, gay, rights, gender
		4	172	workplace, employers, sexual harassment, sexual
		5	132	black, racist, racism, white
All cleaning methods	179	-1	5091	sexual, sexual harassment, harassment, women
		0	430	targeted, targeted harassment, twitter, woman
		1	367	twitter, tweet, tweets, targeted harassment
		2	312	culture, staff, bullying, bullying harassment
		3	295	men, women, woman, assault
		4	279	trans, gay, rights, people
		5	241	police, police harassment, harassment police, arrested

The results shown in Table 4.1 suggest that the different 'cleaning' processes have an impact on topic classification. Although the significance of each is subjective. There are clear similarities between the topics created. Topics have shifted in their ranking position, but none

are lost entirely. There are less unassigned topics (Topic -1) when all cleaning processes are implemented. The total number of topics and topic sizes do not vary greatly. However, topic description is easier to understand when cleaning has been performed.

Given the results, I decided to implement the strategy, using regular expressions, of removing links and audio/video tags, expanding abbreviations to normalise text between users, and eliminating HTML text such as newline characters. Usernames were preserved as they serve as a link between Tweets.

Correction of spelling errors was considered early in the development of the process. However, there was an inherent possibility that the miss-spelt word could be changed to something that the user did not intend, only further skewing the meaning of the Tweet, and therefore no spelling corrections were made.

4.1.2 Analysis

4.1.2.1 BERTopic

Described in section 2.4, BERT is a way of conducting NLP on textual data. It uses transformers, a way of numerically describing how the words are connected in a sentence to determine likely words in a sentence and, in turn, understand its context. This study used a pre-existing Python library called BERTopic on the collected dataset. Working with BERT over other techniques to identify topic clusters allows the collection of semantically similar sentences that do not contain the same words. For example, the Tweet ‘Constant harassment when out walking!’ will be clustered with ‘Being harassed on the street is not cool…’ despite different words being present within the text. BERTopic uses a technique that leverages BERT sentence transformers to classify textual data using a pretrained transformer model. Like LDA analysis (see section 2.4) it can create easily interpretable topics where the final topic representations taken from the clusters using TF-IDF, assigning the most representative words of each cluster (Grootendorst, 2020).

BERTopic allows the use of any sentence transformer model. However, in the absence of a pre-trained Twitter model, a baseline English sentence transformer model was selected for the purpose of topic modelling. Given an input text, it outputs a vector which captures the document’s semantic information, and can be used for tasks like information retrieval, clustering, or sentence similarity tasks (Henderson et al., 2019). They are intended to be used as a sentence and short paragraph encoder (input text longer than 384-word pieces is automatically truncated using these models) which is well suited to the length of a Twitter post (a Tweet can contain up to 280 characters or Unicode glyphs, although some glyphs count as more than one character). BERTopic is also able to support semi-supervised topic modelling, where clustered data can be trained to look for keywords identified by the user

and has several visualisation features that reduce data processing time and can be useful for discourse analysis of short texts.

4.1.2.2 Coding

BERTopic was first run unsupervised. This is where extracted data is clustered into groups of semantically similar Tweets using a general BERT language model (all-MiniLM-L6-V2). The second iteration of classification was a semi-supervised method utilising tagged data from the initial unsupervised output. This part of the methodology required that I perform an inductive content analysis on the initial unsupervised output.

Whilst the coding of topics is not related to a moral or sentiment assessment, variation between people and cultures will impact upon how the Tweet is interpreted. It is therefore important to consider why some topic groupings generated by BERTopic have been removed. Table 4.2 details the reasoning behind removing these Tweets from the dataset, with examples. Table 4.3 details the tagging convention that was created after the first inductive coding. The tag is made in the following format: Subject.Location.Type.Mode.Other. For example, Misc.Public_Space.Sexual_Harassment.Public_Transport.Reporting would indicate a Tweet that comments on reporting sexual harassment in a public space and on public transport. Misc is used when location was implied (running) rather than explicitly mentioned.

Table 4.2: Codebook for Tweet inclusion or exclusion

Topic	Description	Example quote
Harassment at work	Comments relate to harassment in the workplace	1 in 2 women has been sexually harassed at work. Sexual harassment thrives in workplace cultures where behaviour violating the dignity of women is treated as acceptable banter. @fawcettsociety have released 5 steps employers must take to prevent.
Related to a Political Party	Comments relate to harassment that is related to political parties	In rare good news from @UKLabour, @JennieGenSec has just emailed members about new sexual harassment procedure within the party. Still wish it was fully independent but well done to all the sisters, especially @LabourWomensNet, @LabourToo and @bexbailey who helped make it happen.
Online Harassment	Comments that mention being harassed in a digital space.	you do think to yourself no wonder many adults and children commit suicide through depression and through online harassment and bullying intimidation
Targeted Harassment	Comments that mention targeted harassment (often relating to online harassment) or has no contextual information.	Reported as targeted harassment @TwitterSupport
Location	Twitter posts referencing locations outside of the UK	We're proudly supporting the launch of the public awareness campaign #elsekkaaman. Together with our client Egypt National Rail, National Council for Women and Ministry of Transport, @EBRD is helping reduce #GBV and harassment on public transport and promote mobility for all in #Egypt @Jodie33392934 @geowilinger @trustednerd @Ilovecanada13 It seems like the @LangleyRCMP and @VancouverPD dont find sexual harassment of teenage girls a crime?
No context	A Tweet that has no context	See I have evidence of systemic harassment

TABLE 4.3: Target name assigned manually using the following tags.

Subject	Location	Type	Mode	Other
Men	Misc	Harassment	Cycling	Campaign
A(M/F)AB	Public_Space	Gendered	Public Transport	Behaviour Modification
Misc		Sexual	Walking	Catcall
Women		Violence		Clothing
				Definition
				Event
				General
				Mens_Responsibility
				Night
				NotallMen
				Policy
				Reporting
				Running
				Sarah
				Stalking
				Statistics
				Street Lighting
				Upskirting

4.1.2.3 M3 Inference

Social science research often uses information about participants' demographic attributes to characterise groups and find patterns. Twitter does not request that users specify gender or age when creating an account, and therefore this information cannot be requested via the Twitter API. In order to determine if there is a gendered aspect to the conversation about harassment on Twitter, it is crucial to identify the gender of users using a different method. The machine learning gender inference tool is utilised in this study.

M3 Inference (Wang et al., 2019) is a deep learning system that infers demographic attributes directly from social media profiles. It is an open-source machine learning Python library that can infer user gender. The library outputs the probability that a user is a woman, man, or organisation. In some instances, probabilities can be high for both a gender and an organisation. On inspection of the data, this correlates with self-employed business owners with a single user controlling the account.

To classify these user demographics, a simple Python code has been developed to place users into bins based on the M3 probability outputs. The high confidence value for gender is set to 0.7. If the resultant probability is high in more than one category, then the user will remain uncategorised. Table 4.4 defines the final categories using the M3 Inference output.

TABLE 4.4: Categories defined using a predictive value greater than 0.7.

Female	Female user not representing an organisation or company
Male	Male user not representing an organisation or company
Org -Female	Female user representing an organisation or company
Org – Male	Male user representing an organisation or company
Uncategorized	Organisation with no clear gender determined

4.1.3 Limitations and Challenges

Stieglitz et al. (2018) have labelled the challenges associated with social media analysis are the four V's: volume, velocity, variety, and veracity. With advances in computing power, researchers can tackle volume and velocity, but the variety and veracity of data pose a greater challenge. BERT has been successful in its ability to classify large datasets that consider the contextual factors of a Tweet; however, it is unable to mitigate against some fundamental issues associated with social media analysis.

One obvious limitation is that Twitter data is only representative of a small part of a population, and researchers should be wary of extrapolating to a wider group (Al Baghal et al., 2020; Jiang et al., 2019). For example, X users in the UK tend to be younger, male, and more liberal in their political leanings (Mellon & Prosser, 2017). This limitation is well known, and therefore the study's aim at the outset was to find new insights into individual experiences which could then lead to more focused studies or questioning.

Geographical location data can be extracted via the Twitter API, and it was anticipated that this data could be used as part of the analysis process to identify the locations of events, providing an additional layer of knowledge. However, only a small percentage of Tweets contained this information (which can be selectively turned on and off by users). This reflects levels in other domains, such as 2% in the case of crisis-related domains (Burton et al., 2012), showing there is some limitation to using the geospatial components of the data.

The Twitter API limits access to the deeply nested replies to Tweets where some relevant comments may be found. This is a limitation of the API, and a different data collection method would have to be found to expand the data collection to include nested replies.

Twitter data is also fluid, in that users have the right to delete Tweets. Tweet selection for the study was completed in January 2022, and if it was conducted again in the same way in 2024 it is likely the results would not be the same.

This approach involved gathering data from the API using Python libraries that already exist. Python libraries are interdependent, and therefore their version and installation order required some consideration and control to work as expected. There were some nuances and technical challenges in maintaining stability among the required libraries.

4.1.3.1 Gender Inference

M3 Inference has a stated accuracy of over 90% for gender inference and 80% for organisation, the analysis output is therefore subject to the same levels of accuracy. Currently, it can only infer binary gender identities and was an acknowledged limitation of using this method.

> 'While our training data uses self-declared binary gender identities, the M3 model reports gender identity as a continuum using prediction probability along a graded scale. We recognize that the current approach does not yet support non-binary gender identities, which we view as an important future task for full representation' (Wang et al., 2019).

4.1.4 Ethics

The research received the University of Southampton's ethics committee's approval, granted under ERGO application 66448 on the 13/09/2021. As well as the guidance provided through the ethics process, additional guidance was taken into account to make sure that this research is in line with up-to-date practices of handling social media data (AoIR, 2019).

Whilst data from X is publicly available, it can easily be misconstrued as data that has no protection. One of the reasons for this is that it resides in a virtual 'no man's land', as both primary data and secondary data. Primary data, due to having been provided directly from an individual, similar to interview data, and secondary data as Twitter is the intermediary holder of that data. Gold (2020, p. 5) suggests that when considering the ethical use of social media data, it should be more correctly described as 'private data on public display' to avoid confusion. Social media data is still regulated under the General Data Protection Regulation (GDPR), and data protection had to be considered. In line with this, provision was made to pseudonymise data by deleting usernames and handles (personal data).

Special category data that may pertain to the impact of religious or cultural aspects may be used in the research, and raw Tweets cannot be published in line with GDPR and ethics guidance. It was always the intention to aggregate data (via topic clustering), thus reducing any re-identification risk (i.e., I will not quote directly in any publication which would lead to simple searches). At the time of conducting the data collection, Twitter could provide access to up to 10 million Tweets per month (including historical Tweets) to an academic research account holder. To access this information via the Twitter API it was necessary to sign up to a developer account and Twitter's terms and conditions. In doing so, you are bound by a legal contract with them and must abide by the contract agreement.

The following section details the methodological approach to the qualitative analysis of women's technology-related practices.

4.2 Women's Technology-Related Practices

Chapter 2 identified the absence of a qualitative assessment of the integration of technology into women's active travel practice, particularly in relation to personal safety. In order to understand user experiences and perspectives on personal safety technologies, I decided to use focus groups as a primary data collection method. The subsequent sections outline the rationale behind various methods employed for data collection and analysis, encompassing their limitations, challenges, and ethical considerations.

The focus groups aimed to develop a more in-depth understanding of the topics discovered in Chapter 2 and to gain insight into the existing and potential role of technology in supporting women's experiences of active travel modes. Ultimately, it aims to explain the practices or phenomena that link technology to active travel. It was hoped that this would lead to further insight into future strategies for technological development and integration. The following research questions were defined for the second iteration of this study.

RQ2. How does technology contribute to, or influence, an individual's perception of safety whilst taking part in active travel?

RQ3. What are the current challenges and limitations of technology designed to support women's perception of safety when they use active travel modes?

4.2.1 Rationale

The rationale for conducting focus groups as part of this study was centred around the need to explore thoughts, feelings, and beliefs about how technology is able or unable to support women's safety. Focus groups are useful to this study as they are considered more inclusive and can encourage participation with the view to obtaining multiple perspectives on a single topic (Kitzinger, 1995). Focus groups furthermore enable participants to question one another and to consider the possibility of re-evaluation of personal understandings and experiences (Kitzinger, 1994), leading to more themes per participant (Guest et al., 2017). Importantly, they can detail both the complexities of social phenomena, such as social practices, and demonstrate how they are embedded in social life (Cyr, 2019) and are useful to investigate topics where there is community debate or social normative influences (Cleary et al., 2014).

As well as capturing the nuances of lived experience, focus groups were also a practical solution, in that they enabled the collection of quality information in a short timeframe, and generated more themes per participant than interviews would have (Guest et al., 2017). Although reducing project timescales was not a significant concern, I was cognisant that a PhD has a limited time frame within which it can be accomplished, and this approach provided a welcome advantage.

4.2.2 Target Group

The target group for this focus group research study comprises individuals who are women (including self-identification) and over the age of 18. As well as a basic acceptance of technology, its use in the 'practice' of active travel was required. However, due to the diverse and varied nature of available technologies, there was no requirement to have used a personal safety device previously. It was anticipated that many women would not have been exposed to targeted personal safety technologies, and therefore activity trackers, mapping tools and similar technologies satisfied this requirement.

4.2.3 Recruitment and Preparation

Participants were recruited using convenience sampling (Etikan, 2016), and this was completed using a call for participants via Twitter on an internal university system. The sign-up process was completed using a Qualtrics online survey (Qualtrics, 2022), which enabled the secure collection of personal data and was aligned with existing university policy around preferred providers.

Initially, the study aimed to recruit six to ten participants to take part in two focus groups (12–20 participants in total). Research on focus group sample sizes suggests that data saturation can often be achieved with relatively few groups. Carlsen and Glenton (2011) observed a wide variation in focus group numbers (ranging from one to 96) and poor reporting of sample size justification in published studies. Hennink et al. (2019) reported that four groups were sufficient for code saturation, though more were necessary for meaning saturation. Similarly, Guest et al. (2006) found that the recommended number of focus groups ranged from two to 40 to achieve saturation, although 80% of themes could be found within two to three focus groups (Guest et al., 2017). The authors acknowledged that this was dependent on factors such as study purpose and group stratification. With a lack of clear guidance or justification with respect to sample size, many practitioners rely on rules of thumb (Dworkin, 2012), while others aim to maximise the sample size within the project's available time and budget.

Striving for thematic saturation is not necessarily required to generate reliable and valid findings (Boddy, 2016). Instead, Gandy (2024) has suggested that the relative importance of achieving thematic saturation from qualitative data collection depends on the sampling goal. I concluded that a minimum of two focus groups should be conducted, in line with work by Guest et al. (2017), for two reasons. The study does not aim to be representative of the population, but instead comprehend the connections between technology, safety, and active travel, and due to the sampling method, the target group is expected to be homogenous in nature, such that fewer groups will be required to meet saturation (Hennink & Kaiser, 2022; Hennink et al., 2019).

After the first pilot group (see section 4.2.5.1) participant recruitment was decreased to only six participants per group because of the tendency for individuals to talk over each other due to the limitation of physical cues in body language. I felt that this provided a balance between having a range of individuals (age and viewpoint) and allowing everyone to contribute within the allotted time. Due to the number of applicants, the number of groups was extended to four, with attendance varying according to availability.

The initial demographic inquiry and questions pertaining to existing technology use and views on safety were completed via Qualtrics at sign up. A short survey inquired as to the extent of the individual's concern for their safety when active travelling, the amount of time they spent active travelling and what technological devices they employed with respect to active travel. Groups were formed to include individuals of different ages, to encourage the discussion of different perspectives where age may influence technology uptake (S. Hanson, 2010) and how thoughts or opinions are formed (Medeiros et al., 2008). For example, users of activity trackers such as Strava (Strava, 2024) are commonly identified as being more confident cyclists and runners, (Sun, 2017), such that their perception of safety may differ from the 'average' person.

Unfortunately, scheduling issues dictated that many of those who initially signed up were unable to take part in the final focus groups. In total, 16 individuals were interviewed in groups ranging from two to five people. A summary of the participant demographics and initial survey questions is shown in Table 4.5.

TABLE 4.5: Summary table of interview participants (Names have been anonymized)

People	Age	How much does safety and concern for your wellbeing contribute to your decision to take an active travel mode?	How much time do you spend active travelling per week on average?	Which activity tracker applications or travel planning applications do you currently use?
Rosa	40-49	A moderate amount	1 - 2 hours	Google Maps, Samsung Health
Ayesha	30-39	A lot	>2 hours	Google Maps
Isabelle	30-39	A moderate amount	>2 hours	Garmin Connect, Strava
Beatrice	18-29	A lot	>2 hours	Google Maps
Clare	50-59	A lot	30 - 1 hour	Google Maps
Mariam	40-49	A moderate amount	30 - 1 hour	Apple Watch
Caroline	40-49	A lot	1 - 2 hours	Garmin Connect, Google Maps, Weather apps, i.e. sunset sunrise times. Prefer daylight travel if on foot. And for some biking areas too.
Jemima	18-29	A great deal	30 - 1 hour	Google Maps, Public Transit planning application (Unlink app), Sending my live location via WhatsApp etc
Ana	40-49	A moderate amount	1 - 2 hours	Google Maps
Ellie	30-39	A great deal	>2 hours	Google Maps
Sam	50-59	A lot	30 - 1 hour	Fitbit
Caitlyn	18-29	A moderate amount	>2 hours	Google Maps, Public Transit planning application (CityMapper), Health (Apple Built in App)
Ffion	40-49	A little	1 - 2 hours	Google Maps
Sana	40-49	A lot	15 - 30 minutes	Google Maps
Laura	30-39	A lot	1 - 2 hours	Google Maps
Lisa	30-39	A lot	>2 hours	Google Maps

4.2.4 Features Document

The guidance questions aimed to prompt participants to consider their use of technology during their active travel experiences. They also required them to consider how they might use technologies that are unfamiliar to them, or still in the conceptual stage. To elicit this experiential discussion, an additional resource, the features document, was created and supplied to the participants in advance of the focus group. This document aided in the participants' comprehension of technological features during the focus group discussion by providing clarity on their use. The creation of the document drew from existing HCI research such as the use of scenarios and speculative design, storyboarding and low-fidelity prototyping, which collectively consider the potential influence of technology on society and human experiences (Zhu et al., 2024).

Storyboarding, originally used in filmmaking (Atasoy & Martens, 2011), has emerged as a valuable tool in research and design. It serves as a creative space for narrative analysis and allows researchers to work with complex lived experiences (Naicker et al., 2020). This creative approach has been widely adopted to increase engagement in focus groups and participatory research (Cross & Warwick-Booth, 2016) enabling the collection of richer data sets and the development of narratives around the lived experience. It has also demonstrated its application in reflexivity in research design rather than in just 'outward-facing' practices of data collection and communication (Ayrton, 2020, p. 1235). Storyboarding proves to be an effective method for engaging participants and generating insights across various research and design contexts, and importantly within their lived experiences.

Given that storyboards have been used to elicit ideas and user experiences, they have been used as an intrinsic part of the design process in technological development. A storyboard is a linear sequence describing a sequence of events, and because it is linear, it allows users to position themselves more easily as a technology user (K. Li et al., 2016). In a design setting, storyboards can be used for product creation to investigate the best way humans and computers can interact with each other (Lupton & Leahy, 2019) but also be used to commute conceptual ideas and receive feedback. As a user-centred design approach, storyboarding helps capture functionality requirements, align project perspectives, and identify knowledge gaps in software development (Doyle et al., 2013). The approach of supplying storyboards as low-fidelity prototypes for usability testing has been widely used in HCI research. In these cases, importance is placed on designing technology that optimises and enhances the user experience (Rudd et al., 1996). This aim herein is not solely to understand 'button pushing' but also seeks to recognise how individuals interact with technology in the wider context. I used a storyboard as a low-fidelity prototype to convey an idea to the participants and to elicit a response or evaluation. To think about how their storyboard, their lived experience, might differ from the one presented.

The concept of using storyboards to convey the functioning of features was also derived from post-phenomenological research. Post-phenomenological research methodologies extend the

insights of phenomenology to understand how technologies mediate and shape human experiences (Ritter, 2021). They explore the complex interplay between humans and technology, emphasising the importance of acknowledging the impact of technology on our perception of and engagement with the world, relying on actual user experiences. Emphasis is placed on commentary that describes the experiential relationship between humans and technology, thereby enabling participants to 'position themselves with respect to that technology' (Rosenberger et al., 2015, p. 9). A similar method was used by Kaur et al. (2022) who presented scenarios to the participants to gauge a comparative assessment of different types of situations where they may be inclined to use personal safety devices. In the context of this study, the features document serves as an intermediary tool assisting participants to imagine how they may behave and respond where previous experiences do not exist.

In the features document, the prototypes exist as screenshots of existing mobile applications, diagrams, and text showing how a feature is intended to be used. This document can be found in Appendix A. In the case of technology designed for emergency situations like drones and panic alarms, the technology is illustrated in a linear sequence. In placing these technologies within the context of real-world use, such as having participants incorporate them into their current active travel routines, participants are able to make an assessment on whether it would work for their active travel practices. I was then able to assess the technology using social practice theory. Through this lens, it was possible to highlight the material, meanings, and competencies that are required to 'perform' it. By comprehending the elements of practice and viewing practices as performances, we can establish achievable goals for upcoming research or development (Shove et al., 2012). Figure 4.3 shows the methodological process for the women's technology-related practice research stream.

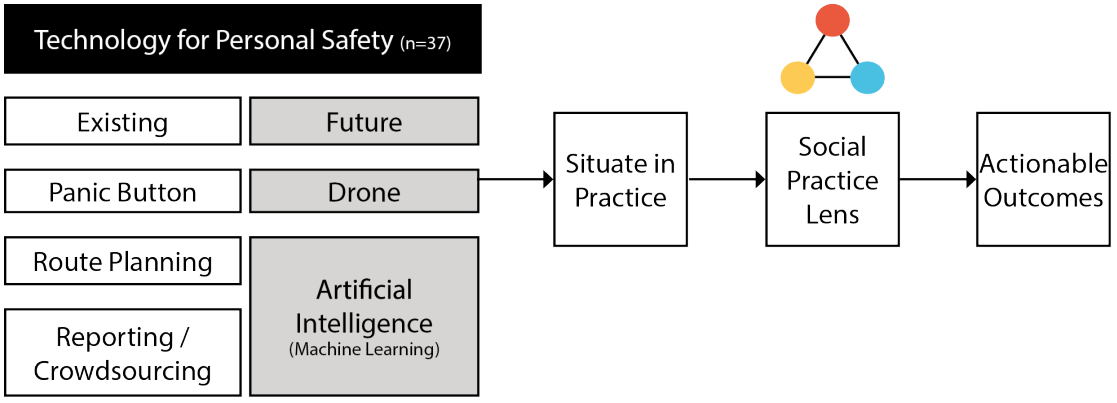

FIGURE 4.3: Process diagram showing the successive phases of the focus group methodology and analysis.

4.2.5 Data Collection

During the COVID-19 pandemic, research online became a necessity, making it far more commonplace (Menary et al., 2021). As a newcomer to research, the evaluation of whether it

was better to conduct research online or offline was an important choice to be made at the outset. Without previous experience of either, the following benefits and pitfalls of offline and online groups were collected from colleagues and existing literature.

Face-to-face focus groups benefit from the observation of individuals in person, capturing more than just verbal input, which leads to a deeper comprehension of the topics being addressed, where gestures and non-verbal cues are recognised to have a crucial impact on interpreting responses (Denham & Onwuegbuzie, 2013). From a process perspective, conducting focus groups in person also ensures fewer distractions, allowing for a more focused and effective discussion (Deakin & Wakefield, 2014). Despite this, offline discussions can also present challenges, particularly in terms of recruitment. These sessions are often more costly, both for the study and for participants, due to the time and travel required (Namey et al., 2020). In turn, they can be more difficult to coordinate, with the unintentional consequence of restricting participant uptake, especially for individuals with caring responsibilities.

Online focus group discussions offer several advantages over offline sessions. Recording and transcribing are easily completed as these features are now integrated into the software designed and used for online meetings. The emotional distance provided by online platforms means confident personalities are less likely to dominate the conversation (Lijadi & van Schalkwyk, 2015). A level of anonymity can also be maintained, as participants can turn off their cameras and change their display names (though this feature varies by platform, with Zoom offering more anonymity than MS Teams, which reveals email addresses) (Flayelle et al., 2022; Lathen & Laestadius, 2021; Stewart & Shamdasani, 2017). Additionally, the familiar and comfortable environment of participating from home can encourage people to speak more freely and openly (Woodyatt et al., 2016). Recruitment is often easier in online discussions, as the virtual environment eliminates the need for travel, allowing for more flexible meeting times and potentially increasing participation (Namey et al., 2020; Poliandri et al., 2023; Santhosh et al., n.d.).

Despite these benefits, online discussions also face challenges. The anonymity afforded by online platforms can be abused, with participants potentially joining studies they do not qualify for, especially if there is remuneration involved (Andrew et al., 2024). Technical difficulties such as network and connectivity problems can disrupt the session. This technical concern also extends to ensuring all participants are capable of using the required software and having a backup plan in case of technology failures, to avoid excluding communities less able to participate (Namey et al., 2020). Furthermore, the relative ease of participating online can result in a higher likelihood of last-minute dropouts, as participants may feel less committed (Daniels et al., 2019).

Given the above, it was decided that the focus groups would be conducted online to increase participation. The discussion was recorded using the hosting platform Zoom, transcribed using the integrated software, and then manually checked for errors. To preserve the

participants' ways of speaking and delivering information, it was left in its raw state, grammatically 'imperfect'.

4.2.5.1 Pilot Study

A pilot study was conducted ahead of the first focus group to test whether the method and analysis were suitable for answering the research questions and refining the procedures. For instance, to make sure that any questioning guidelines could generate datasets and to develop the required practical skills. The pilot study also gave some indication of the timings and number of participants that should be included in an online focus group for it to run smoothly, and led to changes to the presentation of the features document. Chiefly this was concerned with the clarity and presentation in an online format. The format was changed from a document that was intended to be read 'offline' before the focus group, to a PowerPoint presentation that could be viewed in an online meeting room and navigated with greater ease.

4.2.5.2 Focus Group Protocol and Interview Questions

To ensure a productive and respectful environment, a focus group protocol was established. Initial group introductions were followed by declarations that the session would be recorded to capture the discussion accurately. Participants were then reminded that if they felt uncomfortable and wished to leave at any point, they were free to do so. I also stated that, due to the limitations on anonymity, there was a requirement to respect the privacy of fellow participants by not repeating what was said in the focus group to others. At the same point, the participants were reminded of the definitions of active travel, safety (perceived and actual), and technology.

The creation of effective interview questions is an essential step in the focus group research process. These inquiries are intended to facilitate discussion, prompt comprehensive responses, and provide valuable insights into the participants' experiences, perceptions, and expectations regarding personal safety technologies.

The line of enquiry for each focus group was constructed with three goals in mind. First, to establish the existing perceptions of safety in public spaces whilst active travelling. Second, to evaluate any existing features of technology used by the participants that may improve or diminish apprehension surrounding personal safety. And finally, to investigate whether there is scope for additional technological features or tools that could aid in improving the safety of women whilst active travelling.

The protocol and interview questions were considered moderately fluid. Additional enquiries based on previous participant responses were used to see if there were recurring themes

across the focus groups. In some cases, there was no accordance in the views and opinions held by others, although, in some, the probing did elaborate or expand on points that perhaps would have been overlooked if the previous session had not discussed it. This transpired through the course of conducting the analysis and was an intuitive response to digesting previously acquired data.

The focus group guidance questions consisted of opinion questions to elicit participants' attitudes to available digital technologies. Clarifying questions were used to understand prior responses. For example, when discussing the topic of safety, participants were asked to clarify whether they were talking about perceived safety (how they felt) or actual safety (the level of risk for harm). Probe questions encouraged participants to expand on their responses. A request for follow-up discussions (if needed for clarification) with participants was made at the outset of each focus group. These follow-up discussions were completed with two participants to clarify their comments during the focus group. Focus groups lasted between two and three hours, which was not intentional, but occurred due to the willingness of participants to continue talking about the topic.

4.2.6 Analysis

The analysis process began with the transcription of the recordings. The first pass of the transcription was made using NLP, followed by a manual check that made sure that the transcriptions were faithful to the recordings, adjusting where necessary. Whilst this stage is part of the data collection process, it also allowed me to familiarise myself with the data, making observations ahead of the coding stage.

Once the transcriptions were available, coding could take place. This was initially conducted line by line, with no codes being pre-established from the literature or elsewhere prior to starting the coding exercise. This inductive approach avoids rigid practices where codes and categories are forced (Braun & Clarke, 2022).

The approach to data analysis was to first code the data taken from the focus groups using reflexive thematic analysis, a variant that emphasises the role of the researcher's positionality (see section 4.3) in the process of coding and theme generation (Braun & Clarke, 2022). Thematic analysis is a tool that qualitative researchers employ to process data, and is considered an accessible and flexible approach that can successfully generate new insights from data without losing information or meaning (Braun & Clarke, 2022).

Despite the modest size of the dataset, numerous codes were nonetheless generated at the outset. These were consolidated into similar groups after the initial coding. After trying to do this manually, I ultimately chose to use NVivo for the task, primarily for the ability to copy and manipulate the original codes without destroying those initially generated. Through thorough and systematic data exploration, I was able to gain a deeper understanding of the data. The

emergence of themes and patterns resulted in a significant reduction of data, thereby making it more manageable.

The term 'code saturation', or 'thematic saturation', refers to a stage in the data analysis process where codes or themes start to repeat and no novel information or connections between them are emerging (Naeem et al., 2024). According to Hennink et al. (2017), saturation serves as an indicator of an effective sample size in qualitative research. Yet, it is up to the researcher to decide whether it has been achieved, where the conditions for saturation must be self-set, but also justified (O'Reilly & Parker, 2013). I believe code saturation started to emerge after two focus groups, with future code assignments feeding into pre-existing ones. These codes went through successive iterative stages that involved renaming, reassigning, merging, and splitting.

Main themes were identified using both NVivo and an affinity diagram, which is typically used in HCI user research to discover connections between the discovered themes (Sharp et al., 2019). The affinity diagram process involved placing codes and key texts into Mural (https://mural.co/) and grouping codes until key themes and patterns emerged. This process is most closely related to the process of axial coding associated with grounded theory, although it has been seen to produce different results (Aung et al., 2016).

The study was informed by social practice theory, and thus it was necessary to examine the themes identified in the analysis using this perspective. To accomplish this, each theme identified in the thematic coding was evaluated relative to elements of practice, those of meaning, materials, and competencies (Shove et al., 2012). The definition of 'technology' as material was expanded to 'technology as human activities' and 'technology as knowledge', to account for the different ways in which technology is used by participants, as is the case with the practice of planning routes, which links with the practice of walking (Matthewman, 2011).

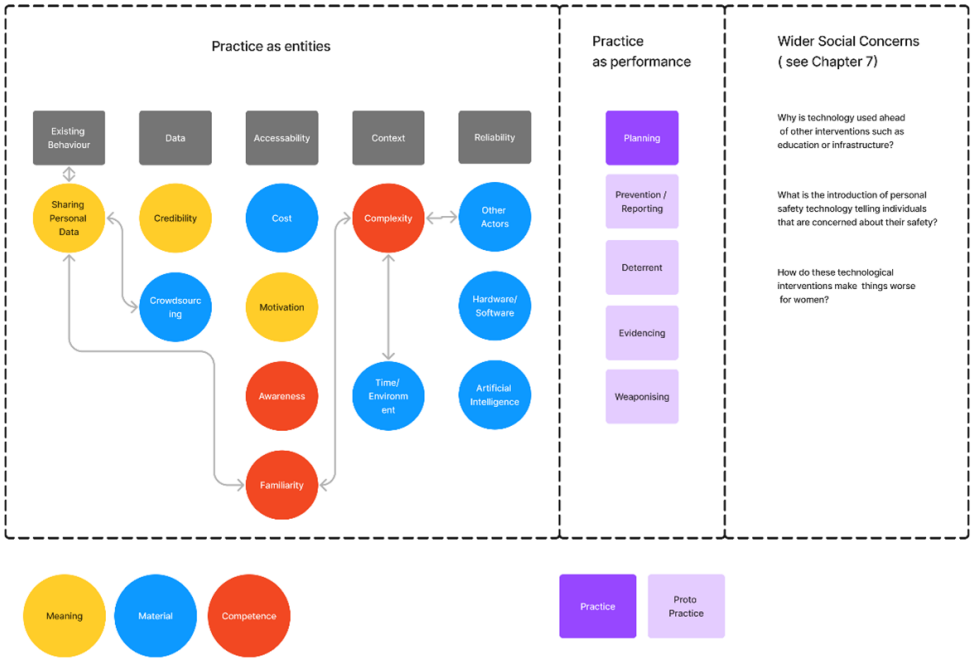

FIGURE 4.4: Affinity Diagram showing the main themes taken from the qualitative analysis. The primary element colour consistent with Shove et al. (2012) is used, although the majority of themes identified in 'practice as entities' fit more than one.

TABLE 4.6: Summary of emergent themes and their descriptive categories

	Themes	Element	Element Components
Existing Behaviour			
Sharing personal data	Privacy	Meaning	Risk
Reliability			
	Whether a service is available	Material	Technology
	(Battery/network and service failures)	Meaning	Risk
	Is it subject to attack or being destroyed	Material	Technology (Human Activities)
		Meaning	Risk
	Repeatability (Artificial Intelligence)	Material	Technology (Human Activities)
		Meaning	Risk
	Good Actors (People as part of the service)	Material	Other Actors
		Meaning	Risk
	Bad Actors	Material	Other Actors
		Meaning	Risk
Data			
	The type of data and how it is visualised	Material	Technology (Knowledge)
Crowdsourcing / Reporting	The source of the data	Meaning	Trust
	The act of data Interpretation	Competence	Knowledge

Table 4.6: Summary of emergent themes and their descriptive categories

	Themes	Element	Element Components
Context			
Time	The time you have available to use technology	Material	
Environment / Infrastructure	This can include both natural and man- made infrastructure.	Material	Infrastructure
Complexity		Competence	Process
Accessibility			
Familiarity	The familiarity of technology and whether an individual has used it before	Competence	Process
		Meaning	Being open to new opportunities for use
Awareness of Available Technologies	Being informed of new technology available for personal safety	Competence	Knowledge
	There are countless technologies,which one should I use, how to decide	Meaning	Choice
Willingness to use technology	How willing practitioners are to use technology	Meaning	Motivation
		Meaning	Trust
Cost	The cost of technological interventions	Material	Money
		Meaning	Accessibility

Three thematic groups were identified from the focus group data: practice as entities (elements), practice as performances, and wider social issues. These groups and their related themes and connections are shown diagrammatically in the affinity diagram (see Figure 4.4). Explaining how each theme relates to the practice of active travel through the concepts of elements, practices, and bundles/networks presents an opportunity for a comprehensive picture of practice and its accompanying elements to be formed. The key themes identified in Figure 4.4 are restructured using social practice theory in Table 4.6 and form the basis and structure of the discussion and findings of the study, which can be found in Chapter 7. Five major themes are existing behaviour, reliability, data, context, and accessibility, and there are eight sub-themes, namely privacy, crowdsourcing, time, environment, complexity, accessibility, familiarity, informed-ness, and willingness, where each is associated with the element typologies in line with Shove et al.'s (2012) elements of practice (meaning, competence, and material), and are coloured in accordance with this convention. These have been selected due to their simplicity and their existing usage in the mobility (Sunio et al., 2023) and sustainability research domains (Beatson et al., 2020).The first two thematic groups, practice as entity and practice as performance, form the foundation of the discussion in Chapters 7 and 8.

Shove et al. (2012) emphasise the flexibility of social practice theory in its application. Therefore, it took time to evaluate the themes presented within this chapter as they relate to and recirculate around each other. There were no predetermined guidelines regarding the classification of each theme's elements, for example, 'data' was particularly challenging to classify as it can be deemed to be material (as information), meaning (subjective interpretation by different uses), and competence (the skill required to interpret the data).

4.2.7 Challenges and Limitations

Whilst preparation is key to making sure focus groups are productive, 'unexpected setbacks will occur' (Cyr, 2019, p. 40). The subsequent operational challenges and limitations of focus groups are now considered.

Often, inter-participant dialogue and engagement appeared to be restricted. Depending on the group, the characteristics of the discussion sat somewhere between focus groups and group interviews, with certain groups requiring more structure and direct questioning to obtain information.

Whilst the features document was provided to participants ahead of the focus group, in some cases participants had not reviewed the document beforehand, such that additional explanation was required during the group itself. This stalled progress on occasion, although questions were anticipated, and it was important for the concepts of features to be fully grasped by the participants.

The focus groups use a statistically small sample size population, whereby the opinions expressed cannot be extended to a wider population. Focus group results can only be indicative of the sample selected, and further research is needed to expand understanding beyond the demographics of the participants within the focus groups.

Inter-coder reliability checks were not performed on the focus group data due to the nature of a PhD project carried out by a sole researcher, although the need for a formal inter-coder reliability check has been shown previously to provide no additional benefit (Cheung & Tai, 2023).

4.2.8 Ethics

The research received the University of Southampton's ethics committee's approval. Ethics approval was granted under ERGO application 73011 on 11/11/2022.

When conducting focus groups, it is important to consider consent, confidentiality, anonymity, and risk of harm. In accordance with the ethics application requirements, guidance on the content (line of questioning) and participants' rights, including the ability to withdraw from the research at any time, were provided well in advance of the groups themselves. Guarantees of confidentiality and anonymity in focus groups cannot be made due to the need for attendees to 'meet' each other. However, an online platform such as Zoom makes this more possible and, as mentioned previously, is one of the reasons for using this method. Despite this, it was made clear that the discussion would be anonymised in any research output, and it was requested that attendees not disclose any of the content or discuss the names of attendees outside the focus group itself. Due to the content of the focus group (women's safety), consideration for the mental health and well-being of the participants needed to be prioritised. Despite the absence of guidance questions requiring participants to share distressing experiences directly, there existed a potential for participants to share distressing or traumatic experiences with the wider group during the discussion. It was therefore made clear at the outset that participants would have to make their own risk assessment before consenting to taking part. This was a necessary measure to prioritise the well-being of the group. However, I was aware of the possibility of this requirement reducing the recruitment of participants with relevant and specific experiences that could contribute to the study.

4.3 Study Rationale and Positionality in Research

It has been established that the position of the researcher is central to how studies are thought of, conceptualised, and analysed (Savin-Baden & Major, 2023). Therefore, to produce a 'trustworthy and honest account' (Wilson et al., 2022, p. 44), it was necessary to consider

my own thoughts and beliefs by evaluating my experiences within this domain and the implications for the research design.

I chose to investigate this topic due to several factors. My experience within the landscape architecture industry demonstrated the scope for technology to build new ways of thinking through the exploration of data in urban planning and equitable design. The idea of urban informatics and data-driven problem-solving is not new, but the scope for data acquisition on a large scale made me consider the different ways in which technology in its broadest sense could be used (Batty, 2021; Foth et al., 2011; Kontokosta, 2021).

Ultimately, it was my own experiences of safety coupled with the high-profile cases of women in 2021 and 2022 (see Chapter 1) that really solidified my need to act on the topic. I approached the study from a feminist standpoint, by which I mean that I intended to investigate this subject for the purpose of raising awareness and contributing to the equality and equity of a future society (Leavy & Harris, 2019, p. 32). As well as methods and frameworks enabling me to describe behaviour, I was eager to discover information that could action problem-solving through exploratory qualitative research with the potential to be applied practically at the development or policy level.

In terms of social positionality, as a woman, I consider myself to be an insider to this topic. I have my own understanding of safety and what that means in terms of mitigating the feelings associated with safety whilst planning or undertaking active travel. Although I am aware that being a woman, especially a privileged, educated, gender-conforming, white woman, does not qualify me as being party to every woman's lived experience or beliefs on the topic. Therefore, I continued to be mindful throughout the data gathering and analysis phases of potential bias. This was especially true in the collection of focus group data, where bias can be introduced in data collection and analysis. Whilst bias is not considered detrimental to analysis (Braun & Clarke, 2022), data was not collected in response to a specific hypothesis and was therefore not limited or inhibited by the drive to collect specific data. Instead, data was collected more generally to allow me to develop understanding from the bottom up. For example, I was mindful to ask general questions before specifying further during the focus groups.

4.4 Summary

Taking the form of two research streams, this chapter outlined the two methodological approaches (technology as a research device, and women's technology-related practices) taken to answer my research questions. It described the rationale and steps that were used in the design, implementation, and analysis of both the social media and focus group data to ensure robust and insightful findings. The following chapter will detail the findings of the social media analysis (technology as a research device), with a view to answering RQ1. The

subsequent chapters, 6,7 and 8, contain the findings of the focus group interviews (women's technology-related practice).

Chapter 5

Findings: Technology as a Research Device

Social media platforms such as Twitter, Facebook, and Instagram have revolutionised how information is shared and consumed (Kapoor et al., 2018), often reflecting and shaping public opinion, behaviours, and societal trends (Liao, 2023). Section 2.4, illustrates how researchers have previously analysed this data to gain greater comprehension of diverse phenomena.

In the last chapter, I set out the methodological approach of conducting a study to answer RQ1; How can technology enable a greater understanding women's perception of safety whilst active travelling? The objective of this study was twofold. Firstly, to investigate the discourse on Twitter surrounding the subject of harassment in public spaces, taking advantage of the data's immediate accessibility, depth, and variety of viewpoints. Secondly, to evaluate the methodology detailed in section 4.2, of utilising BERT and M3 Inference for clustering semantically similar Tweets and studying these through a gendered lens.

This chapter presents the findings of the study. These findings are organized around the formulated research design questions (see section 4.1) which are explored and supported by quantitative data and qualitative insights extracted from the user Tweets.

5.1 Findings

5.1.1 RQ1a. How many incidents/comments associated with harassment are recorded by the platform users, and do they fall into recurring and distinct typologies?

Within the specified data collection window, 1015 Tweets were relevant to the study. These Tweets fell into recurring themes, with the most significant shown in Figure 5.1.

Nearly 14.7% of the Tweets were shared for the purpose of campaigning. This included event promotion, raising awareness of harassment, and making calls for policy change challenging the status quo. Tweets about campaigning tended to be posted multiple times by the same user, unlike other Tweets identifying events or experiences. Specific harassment events, such as catcalling, were predominantly contributed by women. The predominant events recorded were those of having often been catcalled whilst running. Tweets expressing frustration with the need to modify behaviour, such as travel behaviour or clothing choice, to mitigate against harassment were also prevalent. 14% of Tweets questioned what the definition of harassment was. This examination of what is, and what is not, sexual harassment is contested depending on individual user experiences. For example, some users identifying themselves as women and of an older generation (self-described) commented positively on catcalling, suggesting it should be taken as a compliment, and labelled the younger generation as overly sensitive. Tweets focused on solutions to the problem of harassment considered the role of men in changing their behaviour through education, along with policy implementation and campaigning, as stated previously. Many Tweets included reference to the case of Sarah Everard, which was highly publicised in the UK, with the frequency of Tweets about harassment peaking as a direct response to this. Tweets including a reference to harassment statistics were often accompanied by other key themes. The statistics served as reinforcement for the need for change, highlighting the lack of awareness of harassment in society.

TABLE 5.1: List of hashtags used within the dataset by frequency of use.

Hashtag	Count
#SarahEverard	27
#MeToo	10
#ReclaimTheStreets	8
#ISayItsNotOK	6
#ReclaimTheseStreets	6
#CrimeNotCompliment	5
#harassment	5
#Sexism	5
#NotAllMen	4
#EnoughIsEnough	4
#stalking	4
#shewaswalkinghome	4
#crimenotcompliment	3
#TooManyWomen	3
#16Days	3
#AllWomen	3
#HeForShe	3
#Harassment	3
#OpCerium	3
#sexualharassment	3

Only 400 Tweets used hashtags out of a total dataset of 1015 (see Table 5.1). This indicates that keyword searches to collect data using hashtags are not necessarily representative of the

discourse surrounding the subject of public harassment. In total, 257 different hashtags were used within the dataset, with the top 20 shown in Table 5.1.

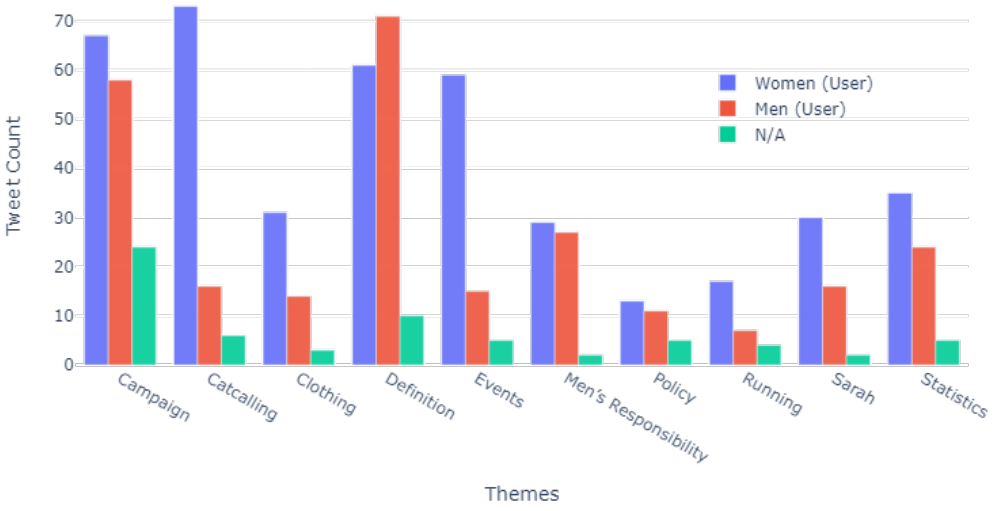

FIGURE 5.1: Main themes found within the collected dataset (M3 Inference user classification for Women and women-org and for men and men-org have been combined).

5.1.2 RQ1b. Is there a gender differential with respect to the different typologies?

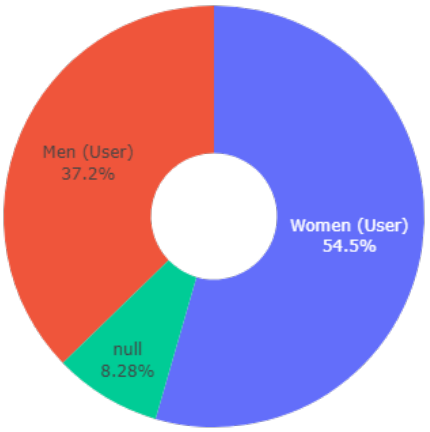

FIGURE 5.2: User gender as inferred by M3 Inference (M3 Inference user classification for women and women-org and for men and men-org have been combined).

The data shows a gender divide with respect to the themes of the Tweet and the gender of the user that Tweeting about those themes. Namely, women Tweet more about harassment

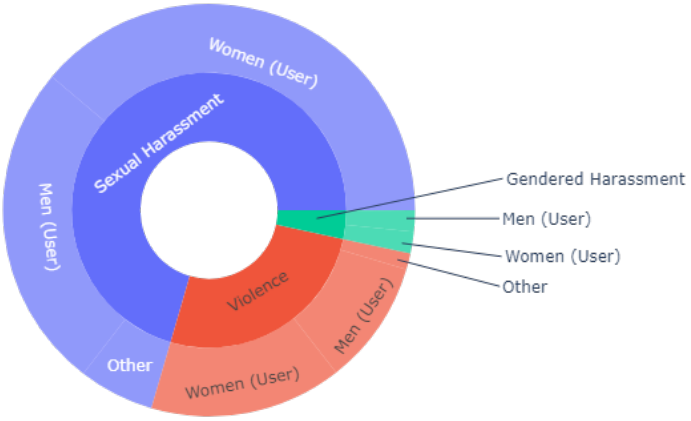

FIGURE 5.3: Harassment type

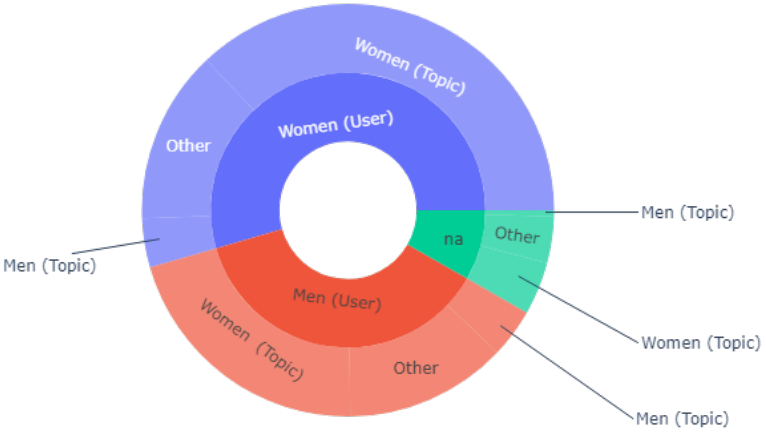

FIGURE 5.4: Tweets that indicate gender as a subject of a tweet (M3 Inference user classification for Women and Women-Org and for Men and Men-Org have been combined)

overall and about harassment in public spaces. 55% of users tweeting about harassment on the platform were women, with 62% of Tweets explicitly referencing women as the target gender (gender as a topic of the Tweet) (see Figure 5.4). This is consistent with studies showing that women feel more at risk of experiencing harassment overall and in public spaces (European Social Survey, 2018; UN Women, 2024).

Mobility behaviour is different for different gender groups, and that behaviour is directly related to an individual's perception and subjective view. These views and perceptions are formed from both personal experience and external data sources, and experience is shaped

by social demographics, cultural background, and gender. Given the nature of the data, the importance of intersectionality cannot be fully considered here and is therefore a significant, but known, limitation of the study. Due to the nature of the data, the study is unable to fully address the importance of intersectionality.

5.1.3 RQ1c. Can BERT be leveraged to reduce the impact of keyword selection bias in Twitter data collection?

BERT encoding has been successfully leveraged to perform topic analysis on Tweets. Whilst the data set is relatively small, it demonstrates that the collection and subsequent reduction of data using BERT is possible and can reduce the workload of social media researchers. Using 'harassment' as a catch-all search term enabled the collection of a range of Tweets that were significant to active travel modes. If a more focused keyword selection was made with more specific terms, then this volume of Tweets may not have been recovered.

5.2 Summary

This study was devised to answer RQ0 to look at technology not only as a tool in the doing of active travel, through the development of emergency personal safety devices aimed to address women's safety directly, but also indirectly through the gathering of data that is not available due to the evidenced lack of reporting (UN Women, 2024). The literature review showed that Twitter data had previously demonstrated success in discovering feminist and safety discourse, therefore these results contribute to answering RQ1 How can technology enable a greater understanding women's perception of safety whilst active travelling?

The original research design aimed to collect data through generalised active travel keywords, and that this would collect a dataset that would collect Tweets that could be missed by using safety keywords. It was hoped that this in turn would be able to reveal safety experiences and concerns, such as events, that are considered as widely unreported by women (UN Women, 2024). An initial test of this methodology rendered far more data than was computable by the proposed method. Therefore, a decision to reduce the amount of data was made. The study then focused on the discourse of harassment in public spaces on the social media platform Twitter using a gendered lens with the aid of machine learning.

Women have been found to be the primary targets of harassment in public spaces (Aldred, 2015; Evans et al., 2018; Gekoski et al., 2017) they therefore have a keen interest in being involved in discourse surrounding this subject, this is reflected in the collected data with the women accounting for near all descriptions of harassment events occurring whilst active travelling. One of the most interesting findings is that a large proportion of Tweets, from men,

was surrounding the definition of harassment. Here, the majority of Tweets expressed confusion as to what was considered harassment.

Twitter has previously been used to analyse specific hashtags surrounding harassment, this study has made a broader assessment using a generalised keyword search. It also contributes to the discourse about harassment in public spaces using data from social media. This also serves as a review of the toolset and methodology available for Twitter analysis, and makes the following research contributions. BERT IS used to mitigate against the irregularity and diversity of language and to enable the filtering of a large data set to include only Tweets of significance. Methodologically, BERT sentence encoders have not been used in this way. Whilst this method of filtering a large dataset without constraining the number of topics at the outset is not a solution to keyword selection bias, the topic model created by BERT could go on to be used on even larger datasets.

Whilst BERT was shown to render good classification of data, contextual enquiry was lacking, both in terms of the reporting from lack of data, such a location information, and was unable to speak to the true meaning and experiences behind reporting and it did not lead to any new lines of enquiry that could feed into the focus group study.

5.2.1 Future Work

The original scope of the study looked to analyse Tweets that indicated 'active travel' commentary. For instance, keywords such as pavement, road, cycling, run, etc., with a view to removing more subjective indicators as to what safety is. Due to time and computational constraints, I had to reduce this scope, and concentrated on harassment to determine if the methodology was valid. As stated previously, the perception of safety is a wide and diverse topic, including concerns surrounding close passing, pollution, and on-street parking (these are all events that are reported via Twitter). Future work may therefore be extended to consider the original conception.

Methodological updates could include the use of other tools integrated within the BERTopic library, such as guided topic modelling and topic merging, to make the fine-tuning of data more seamless and manageable on a larger scale. Further tests need to be completed regarding UMAP (McInnes et al., 2020) and HDBScan (McInnes et al., 2017) settings.

The results have not been normalised to show individual users. For instance, several Twitter posts centred on campaigns were tweeted by the same account and their frequency was greater. Normalisation of the results would show the distribution of unique user contributions.

The subject of topic model evaluation is yet to be resolved. As is the case with existing methods of topic classification and modelling approaches, numerical evaluation in terms of recall, precision, F-score, and topic coherence should be a consideration moving forward.

Emojis, imagery, and videos play a significant role in shaping the context of Twitter posts. This is also true of a long thread (multiple Tweets joined together). An investigation as to whether it is possible to extract and combine these elements may elicit further insight. This will enable the inclusion of Tweets, such as images or videos, that are removed due to lack of context within the textual data alone. Whilst spatial analysis has not been completed within the study, it is possible to retrieve geolocation metadata from Tweet objects. Luo and He (2021), Maghrebi et al. (2015), and Osorio-Arjona et al. (2021) have successfully performed spatial analysis using Tweets, and this could be further explored and may be significant for event reporting.

Looking further afield than Twitter the methodology could be applied to other datasets. Discourse analyses of how the media reports on sexual harassment have been conducted previously (Leifermann, 2018; McDonald & Charlesworth, 2013; Saguy, 2002). These studies found that the media did not report harassment as an issue of gender inequality or a wider social problem, but rather as a matter of individual responsibility. Since the UK murders of Sarah Everard and Sabina Nessa in 2021 and Ashling Murphy and Zara Aleena in 2022, reports of harassment of women whilst walking (Guill, 2017) and cycling (BBC News, 2021) have been increasingly discussed in the media. Given this level of reporting, it may be interesting to apply this methodology to media reports rather than social media.

This chapter presents the findings from the SMA (technology as a research device) research stream, which aimed to identify patterns in social media data recording harassment in public spaces. It tests the methodology of using machine learning tools to consider the data through a gendered lens. The following chapter (Chapter 6) contains the findings of a review of the features of personal safety devices that were evaluated prior to conducting the focus groups.

Chapter 6

Findings: Features

The landscape of personal safety has undergone significant transformation recently, driven by advancements in technology and an increasing awareness of the need for effective safety measures.

This chapter presents the findings from a review of available technologies designed to enhance personal safety for use whilst active travelling. The purpose of this review was to identify the distinctive features of these technologies so they could be presented as part of the focus group discussion (see section 4.2.4), rather than assessing the usability of a specific piece of software (Nielsen, 1994). Features infer affordance, which is used by HCI researchers to gauge usability (Y. S. Kim, 2015).

Despite features being an indication of affordance and usability, the majority of personal safety device analysis is not categorised by feature (Eisenhut et al., 2020; Maxwell et al., 2020; Sumra et al., 2023). For instance, a category, such as an 'emergency application', identified by Eisenhut et al. (2020), may include a multitude of technological features, including, but not limited to, panic alarms (with or without loud noises), video recording, and location tracking. Instead of using these criteria, I have foregrounded their distinct features to prompt discussion.

This chapter details the data collection method, identifies common trends in the typology of safety devices and their features, and finally the origin (location) of their development. The chapter outlines the features utilised in personal safety technologies, identifying common trends in terms of target users and developers, and is structured according to these trends.

6.1 Data Collection

A list of available personal safety technologies was curated from web-based searches. This included using web search engines and the Google Play Store using the search terms 'safety'

and ‘technology’. There were only two exclusion criteria for the search. The first was that the technology had to be useable whilst an individual was active travelling and secondly, it should not be specific to a particular form of violence such as IPV.

The primary focus of the task was to identify distinct available features, so these could be used as a prompt for discussion in the focus groups. Whilst I believe that saturation was achieved (referring to the point at which no new themes, categories, or insights are emerging from the data being analysed) it is worth noting that as an Android user based in the UK, mobile applications were limited to those available in the UK, on Google Play, free, and provided in English.

In total, 42 digital technologies were assessed with respect to their features and integrations. Not all technologies targeted women as potential users, as this was not a specific exclusion used for the search. The features identified by this analysis were being proposed or were on the market in September 2022. Where crowdsourcing information from the user was a feature, the type of information that could be reported was also collected.

- 37 mobile applications were assessed for common safety features (36 were available on Google Play and ‘existed’ as functional applications that could be used at the time of the search)
- 2 technologies considered conceptual technologies in the personal safety domain, such as drones and a mobile application and wearable device that use machine learning to detect when an individual needed help.
- 2 web-based reporting platforms
- 1 co-design platform

The identified technologies were first coded by category (activity tracker, social Network, mapping…), following which the developer’s location, tag line, target user, and their available features were found. All 42 technologies used more than one distinct feature.

The main features of each technology were evaluated using content analysis. For mobile applications, this was achieved by downloading, navigating, and using the available features of each product. This assessment was extended to searches via the internet (such as through the developer websites) to determine or clarify the intended operation, function, and developer location. I largely abstained from conducting tests, as in I did not make reports or connect with individuals on social networks to make this assessment, as I would rather not alter the function of these applications through my own intervention. In one case, however, I wanted to clarify whether a safety routing feature, that takes reporting into account when offering route suggestions, lets individuals know of the report when re-routing. It did not, and instead, it was routed without any apparent justification.

6.2 Findings

Regions used in the following results are those designated by the World Bank (The World Bank, n.d.).

6.2.1 Developer Location

The identified technologies comprised 95% mobile applications, which were downloaded from a UK-registered device via the Google Play Store. Figure 6.1 shows the distribution of the developer locations both by region and by country. The distribution by region was shown to be 38.1% (16) North American origin, 28.6% (12) European, and 23.8% (10) South Asian. The distribution of technologies via regions is not unexpected. They all originate from countries with historically active digital platform development and use the English language (UK availability).

The three remaining technologies were developed through collaboration between two geographical areas: Norway/United States, India/United States, and India/Sweden. South Africa contributed a single mobile application. Despite being available in the UK, the application required setting user location, and it appeared to only function if the user was based in South Africa. It is understood that this distribution is not representative of the technologies and tools available globally due to the limitations of the data collection method.

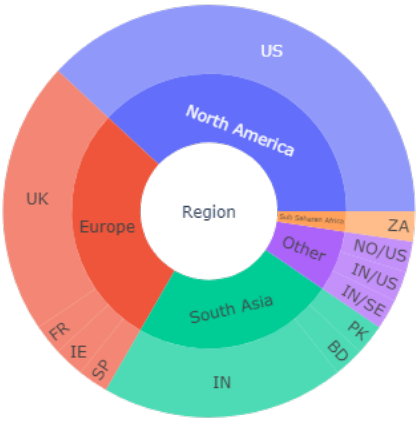

FIGURE 6.1: Distribution of developer location using regions designated by the World Bank

6.2.2 Target Group

Cardoso et al. (2019) and Maxwell et al. (2020) found that personal safety technology is largely targeted towards women. In my assessment, the target group was identified based on the language used for marketing the product or service — 'Walk with women anywhere, everywhere', 'Sister', 'Sorority'. Although a significant proportion of the technologies were directed towards women, or women and marginalised groups (31%), the majority did not specify an intended audience (69%) (see Figure 6.2). This is perhaps surprising, given that it has been determined that women are more concerned about their safety, despite being less likely to be subject to harm (Fisher & Sloan III, 2003). Two likely explanations for this distribution can be speculated upon. Firstly, this review is limited to one geographical region, with the majority of technologies being mobile applications downloaded in the UK. Therefore, the technology is likely to be representative of the social and cultural norms of this geographical region. This is evidenced when developer locations are considered (see Figure 6.3), where the majority of technologies targeting women (62%) were developed in South Asia. Secondly, existing studies assessing mobile applications have included women in their search criteria (Eisenhut et al., 2020) and are therefore more likely to find technologies that are targeted at women. Despite this, like Cardoso et al. (2019) and Maxwell et al. (2020) I found that none of the mobile applications included in this review targeted men.

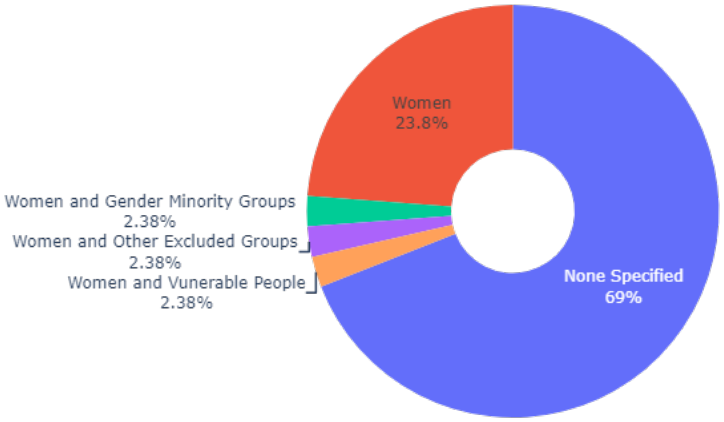

FIGURE 6.2: Distribution of target groups identified by the technologies reviewed

The Women, Peace, and Security Index is intended to rank countries based on the status of women in terms of security, inclusion, and justice. It may therefore be possible to draw some parallels between differences in legal provision regarding sexual violence in these countries and the target users of these applications, with countries situated within the South Asia region scoring lower than those in North America and European Regions (Georgetown Institute for Women, Peace and Security and Peace Research Institute, 2023, p. 3). Further

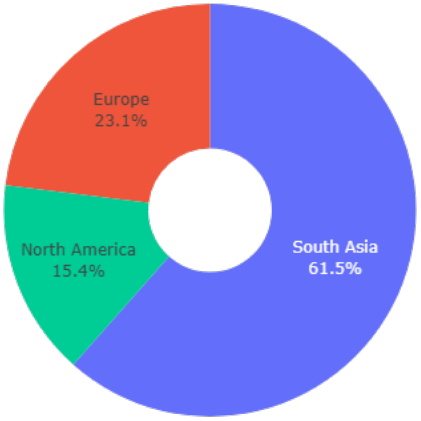

FIGURE 6.3: Location of developers associated with technologies that targeted women

work would be required to establish this link, and this should also consider the gender divide in mobile ownership, which is more notable in low to middle income countries. In South Asia, women are 41% less likely to own a mobile phone than men, in comparison to 4% in Europe (Jeffrie, 2023).

6.2.3 Features

Personal safety technologies are devices and applications that are designed to safeguard people in various situations. Their perceived effectiveness and appeal are largely influenced by the innovative features they incorporate (Ford et al., 2022). These features are seen to not only enhance functionality, but also to have a significant impact on user experience, accessibility, and overall trust in the technology. A list of technological features found through the review is shown in Table 6.1.

Figure 6.4 depicts the total distribution of features found, with Figure 6.5 detailing this distribution across the three regions of North America, Europe, and South Asia.

Recording incident data (pictures and sounds), tracking using GPS, and informal panic buttons, that send alerts to designated individuals using mobile phone technology, are the most common features. Social networking was not found in any of the applications developed in the global south. However, existing literature has found that there is limited preference for technology uptake if social networks are used (McCarthy et al., 2016a; Tozzo et al., 2021).

Providing education (primarily self-defence information) and ‘safe place’ locations on a map are safety features that is only found within South Asian products. These findings on safe spaces aligns with those of Kaur et al. (2022), where users highlighted that the ‘safe space’

TABLE 6.1: The description of distinct features available of the applications. All the mobile applications combine at least one of these features.

	Description
Panic Button (Informal/friends)	Panic Button and alerted nominated friends and family to the user's location. Instigated by button pressing or sound.
Panic Button (Authorities)	A panic button that alerted/connected with the local emergency service
Route Planning taking safety into account	Route planning that takes user reports or official crime reports into account
Route Planning	Route planning that does not take safety reporting (any type) into account
Reports (Informal) / Crowdsourcing	Data collection reporting safety concerns. Accomplished informally through the mobile application and does not file a formal report to a government authority or official body.
Reporting (Formal)	Ability to report directly to an official body.
Tracking/Location sharing	Live tracking (Location data available to nominated trusted persons)
Social Networking connection to people in vicinity	Ability to connect to other users in your vicinity to provide help or support in an emergency
Automatic Alerting (Movement)	Automatic alerting based in changes in movement. Inclusive of crash detection (rapid deceleration).
Automatic Alerting (Timeout periods)	Automatic alerting (location data sent to trusted person/persons) if no activity in specified timeout period
Safe Places	Locations of safe places positioned on a mapping interface
Fake Call	Incoming call to pretend you are on the phone to someone
Real-time alerts of incident/ recording data	Evidencing through collection of video and sound data recording (usually at the instigation of alert such as a panic alarm by the user)
Education	Provision of knowledge through a mobile device
Preventative	Co-design tools aims to collect community requirements to make spaces safer for users.

feature was one of their most used. Confronting an attacker was less favourable than ignoring and escaping the situation. This feature may be less preferred in other countries and cultures, which emphasises the importance of personalisation.

6.2.4 Crowdsourcing

Crowdsourcing is an online model for problem-solving and task completion that requires input from a vast number of individuals. Brabham (2008) described this as work outsourced by organisations, but it can also be used to describe a kind of collective intelligence, where the diverse skills of many participants are used to solve problems, generate ideas, or, in the case of personal safety, gather information (Wood et al., 2022).

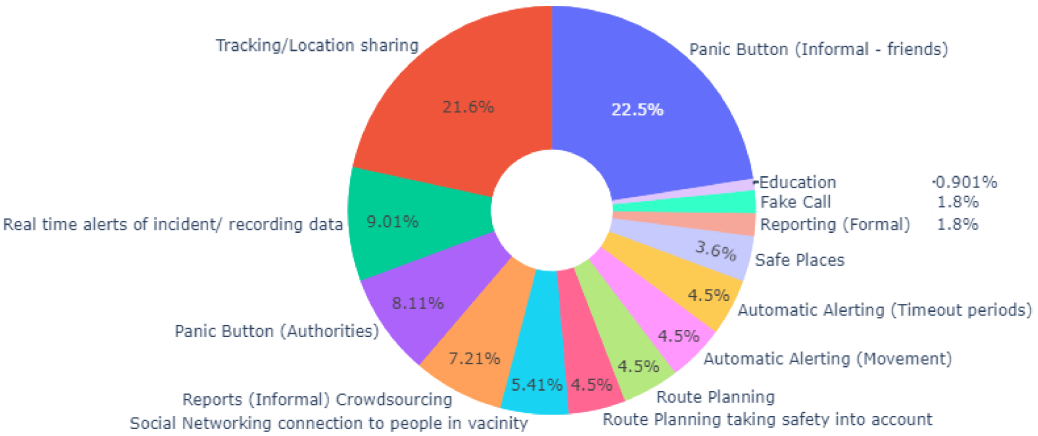

FIGURE 6.4: Total distribution of all features identified in the review. Total > 42 due to individual 'technology' being comprised of multiple features

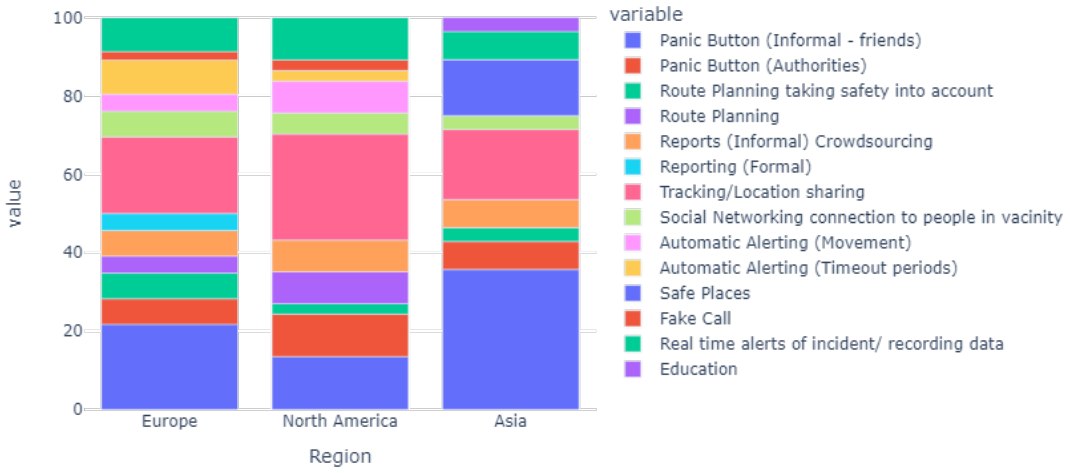

FIGURE 6.5: Distribution of features by region.

Seven mobile applications collected crowdsourced data to be used as part of routing software (mapping). Safetipin was the only mobile application requesting crowdsourced information from users to influence policy and policing in areas which are considered by users to have safety issues. The crowdsourcing data collection can be classified into reporting events, causal factors, infrastructure, and miscellaneous items. Tables 6.2 through 6.5 show the type of data that can be gathered, and often examined, through mobile applications, with Table 6.2 showing the variety of events that can be recorded by these applications. There is a large variance in the topics that can be reported. Some focus on specific types of sexual violence, whilst others only require users to report as either 'safe' or 'unsafe'. Table 6.3 shows that Safe

TABLE 6.2: Crowdsourced event or report types

	Walksafe (UK)	Safe in the City (UK)	Safe City (IN/US)	Safetipin (IN)	Path Community Safety (UK)	Safe Community (ZA)	Wander safe (US)
Catcalling/Commenting		x	x				
Chain Snatching/Robbery			x				
Crime						x	
Domestic Violence			x				
Hate Crime							
Human Trafficking			x				
Indecent Exposure/Masturbation		x	x				
Ogling/Facial Expressions/Staring			x				
Online Harassment			x				
Physical Assault			x				
Rape			x				
Safe							x
Sexual Assault		x	x		x		
Sexual Gestures		x					
Showing Pornography without Consent			x				
Spiking		x					
Stalking		x	x				
Suspicious						x	
Taking Photos — unwanted photos		x	x				
Threat of Violence					x		
Touching/Groping		x	x		x		
Unsafe							x

City is the only mobile application to identify the causal factor associated with a safety event. Table 6.4 shows infrastructural and environmental related safety concerns, of which Safetipin is the most comprehensive. Table 6.5 shows miscellaneous items that are specific to the country of development or do not fit into the other categorised themes. All mobile applications provide an option for the user to report 'other', so are not limited to the categories identified.

The sample size is too small to identify any trends in terms of crowdsourcing, although it is possible to see the focus of the application through the data they are trying to collect. At times, they are very specific in the nature of their reporting. Reporting a snake was an option

TABLE 6.3: Crowdsourced causal factors relating to an event

	Walksafe (UK)	Safe in the City (UK)	Safe City (IN/US)	Safetipin (IN)	Path Community Safety (UK)	Safe Community (ZA)	Wander safe (US)
Disability			x				
Ethnicity			x				
Gender			x				
Intimidation			x				
Other			x				
Sexual			x				
Sexuality/Perceived Sexuality			x				

available in the mobile application made in sub-Saharan Africa, an unlikely requirement for the UK.

6.2.5 Marketing

As expected, the reviewed technologies claim to enhance user security. Although, as Eisenhut et al. (2020) and Sauerborn et al. (2022) highlight, definitive empirical proof is lacking. Yet, the marketing associated with these technologies makes promises of increased safety with tag lines such as 'protecting the world', 'Feel protected 24/7' and 'We exist to make your world a safer place' suggesting that they have some kind of superhero-esque abilities. These imply, intentionally or otherwise, that users are victims needing to be rescued. In some cases, the language also downplays user intelligence 'Be safe, be smart' and suggests a lack of user confidence 'Feel safe. Be confident'. When women constitute the primary audience, both these statements reinforce gender-normative constructs (Fileborn, 2016), emulating existing research that identified that mobile phones were actively promoted to women as necessary because women needed protecting (Cumiskey & Brewster, 2012).

Another theme identified in the review of marketing terminology is that of connection and community, with phrases like 'Alone Together' and 'Never walk alone'. This theme relates to existing literature where participants feel safe with a phone because of its ability to connect with others or the idea of safety in numbers. More promises of safety are relayed for mobility purposes. 'Safety on the Move', 'Keep safe on the go' and 'Stay active. Stay safe.'.

TABLE 6.4: Crowdsourced infrastructure and environmental factors

	Walksafe (UK)	Safe in the City (UK)	Safe City (IN/US)	Safetipin (IN)	Path Community Safety (UK)	Safe Community (ZA)	Wander safe (US)
Feeling – How safe do you feel				x			
Gender Usage – Presence of women and children near you				x			
Lighting – Availability of enough light to see all around you				x			
Openness – Ability to see and move in all directions				x			
Other	x	x	x				
People – Number of people around you				x			
Public Transport – Availability of public transport like metro, buses, autos, rickshaws				x			
Restricted Access	x		x				
Rowdy Groups		x			x		
Security – Presence of police or security guards				x			
Street lights/Poor Lighting	x	x		x	x		
Taking Photos				x			
Uneven terrain					x		
Visibility – Vendors, shops, building entrances, windows and balconies from where you can be seen				x			
Walk Path – Either a pavement or road with space to walk				x			

TABLE 6.5: Crowdsourced miscellaneous factors

	Walksafe (UK)	Safe in the City (UK)	Safe City (IN/US)	Safetipin (IN)	Path Community Safety (UK)	Safe Community (ZA)	Wander safe (US)
Miscellaneous							
Fire						x	
Medical						x	
Municipal (Services)						x	
Other	x	x	x		x	x	
Snake						x	
Tip							x
Traffic						x	

6.3 Summary

This chapter has consolidated the review of existing technological interventions developed to provide personal safety whilst active travelling. The features were not gathered through a systematic review, and thus it is deemed limited in its scope with respect to describing broader global trends. Nevertheless, it demonstrates a variability in feature development across global regions and raises questions about the efficacy of these applications and the suitability of their marketing and cultural variation.

The review has also highlighted avenues for future research and development. Namely, the expansion of this evaluation to a systematic review that considers technologies available in different geographic regions and in other languages, to explore features and their cultural and social differences. An evaluation of costs associated with these technologies was not completed, however many charge for their services. In one case, users are requested to pick a subscription service based on how many events they anticipate they need to protect themselves against per month, with higher costs associated with services that have no data limits. Therefore, further work on the impact of corporate interests and capitalism on technology in this domain would be beneficial.

The examination of a diverse range of technological advancements and AI-driven solutions contributes to the answering of RQ2 and RQ3 in two ways. These findings lay the foundation for the focus group line of enquiry and discussion by thematically describing current technological features available. In doing so, the line of enquiry is at feature level, rather than

assessing a product or service 2.5.1. This feature level enquiry is therefore more able to pick apart the affordances they provide and contribute to future technologies that may include one or a combination of these features.

Unexpectedly, it has also given rise to the understanding of cultural differences in these products and highlighted targeted marketing can also be seen to try to contribute and influence an individual's perception of safety. By suggesting women are already unsafe by not using the service on offer.

The following chapter details the findings of the focus group study where the identified features are presented and assessed.

Chapter 7

Findings: Practices

In the last chapter, I reviewed the existing technologies that were used to prompt the focus group discussions. The review divided 42 technologies inclusive of mobile applications, wearable devices and IoT technologies, into features, so that a broad examination of personal safety technology could be undertaken and presented to the participants. As such, identifying these features was the first step in preparing for the focus group study.

This chapter presents and summarises the findings of the focus group study aimed at exploring the perceptions, experiences, and expectations of women regarding personal safety technologies used whilst active travelling. The primary goal of this focus group study was to understand the real-world applications and perceived effectiveness of various personal safety technologies using their common features as a prompt for discussion, enabling them to be positioned with respect to the practice of active travel.

This chapter details the subsequent findings of the focus groups. It is structured around the framework of social practice theory, beginning with the key themes situated within 'practices as entities' and 'practice as performances' (see Chapter 3). This enables identification of the elements of practice that are necessary for women to perform the practice of active travel. The section 'Practice as performance' details what practices are already undertaken or considered to be potential practices by participants.

7.1 Findings and Discussion

The following definitions align with existing social practice theory (SPT) literature described in Chapter 3 and will be used in this chapter to describe the elements that make up social practices (meaning, competence, materials) and those who undertake them (practitioners) (Shove et al., 2012). A carrier of practice is not only an agent that carries out 'routinized, oversubjective complexes of bodily movements, of forms of interpreting, knowing how and

wanting and of the usage of things' (Reckwitz, 2002), but someone who also influences and recruits others to the practice (Shove et al., 2012).

7.1.1 Existing Behaviour

Although existing behaviour was not the direct focus of the study, it was important to understand the participants' existing behaviours to contextualise their responses and 'to develop a provisional account of the elements or ingredients of which practices are made' (Shove et al., 2012). As such, the groups were asked about their current methods of active travel, their safety worries, and the strategies they employed, whether technological or not, to address them.

It quickly became apparent that the participants' primary responses centred on protecting themselves from perceived risk by not entering dangerous situations. This often meant not taking part in active travel if the risk was considered to be too high. Risk was associated with factors such as the dark (both time of day and poorly lit locations), quiet routes (those without vehicular or pedestrian traffic), or areas being unfamiliar to them. Participants said that they avoided poorly lit areas or quiet areas by sticking to main routes when walking, where in some cases, this meant switching modal preference (despite active travel being feasible in terms of distance and ability), travelling further, or even opting not to travel at all.

> 'I suppose, coming back from the station, you know, if it's late at night, I probably wouldn't take the footpath I'd stick to going down the main road, for example, it's a longer route, but it's lit the whole way.' (Rosa)

These behaviours were consistent with research showing that women are guided by their perception of safety (Basu et al., 2021; Pelclová et al., 2014; Ravensbergen et al., 2020; Scarponi et al., 2023), often making behaviour modifications to search out safer routes even if this means travelling further (Aldred et al., 2017; Loukaitou-Sideris, 2014). Spatio-temporal considerations, such as a low level of lighting (Markvica et al., 2019), or a lack of activity or people in areas such as parks and alleyways, spaces near pubs and bars, or in the presence of drinking are also related to a higher level of fear in women (Rišová & Sládeková Madajová, 2020; Yates & Ceccato, 2020). More recently, research by Scarponi et al. (2023) demonstrated that perception of safety is contingent on hotspots as well as spatial features and usage.

This precautionary behaviour would particularly impact physical activity during the darker months. In some cases, walking in the dark was completely avoided, even if roads and pathways were well-lit artificially. This was true even if the area was known to them. An increased feeling of vulnerability in the darker months was consistently mentioned.

These behaviours were about minimising risk, and reducing potential exposure to harm. The notion that technology would change any existing risk avoidance behaviours was readily

dismissed by most of the participants. Clare emphasised that technology was not a weapon, highlighting what she perceived as its limited capabilities in emergencies.

> 'It doesn't change what someone could do there and then. Technology […] it's not a sword. Which is probably what you do need.' (Clare)

Despite this view, participants were unanimous in their opinion that they felt safer with a mobile phone on their person. According to Beatrice, this was not due to its ability to be used as a deterrent, but because if an incident should happen, she would be able to contact the authorities or friends and family to come to her aid. The technological affordance of communication provided reassurance, rather than any assurances around thwarting a would-be attacker. However, some participants noted that their circumstances, such as being foreign or unfamiliar with the area, meant they were unable to employ conventional safety strategies, such as texting or calling a partner as mentioned by other participants, and that their options were somewhat constrained by their circumstances.

> 'I do feel safer with a phone. Like I feel I don't leave the house when it's dark without a phone. Because just having it in my pocket and holding it makes me feel safer. Because I know if something happened, I could just call the police or something like that or whatever.' (Beatrice)

Similar findings were also reported by Chib and Ang (2023), who discovered that technology usage can strengthen and reaffirm social connections, highlighting how mobile devices afford connectivity and support social relationships. The feelings of safety expressed by participants contrast with those associated with other technological devices such as the introduction of CCTV, where feelings of safety are unchanged and limited (Zurawski, 2010).

It has been observed that when a journey is deemed unfeasible due to safety concerns, women experience a sense of being held captive by their travel options (J. Stark & Meschik, 2018). This finding was upheld by Caroline's description of using technology when it was dark. She demonstrated that a kind of permission was sought for entering into risky situations, which in some cases could be afforded by the presence of technology. For example, in the case of a panic button feature, Caroline indicated that she might be more inclined to go for more walks with this available.

> 'Having that sense of safety would probably allow me to get out more. I think. I'd probably be more inclined to go for little walks in the evening and stuff. If I felt like I had something like that.' (Caroline)

The feelings of safety expressed by participants due to the presence of a mobile phone suggest its ability to provide reassurance when active travelling. These results build on

existing post-phenomenological research by Hardley et al. (2021) which has shown that mobile phones can mitigate against fears and anxieties with respect to darkness, not only through the affordance of communication but by giving users the ability to appear preoccupied, thus preventing engagement with other people or decreasing the likelihood of appearing intimidating.

Nonetheless, in certain circumstances, technology was also deemed detrimental to safety by participants, and its utilisation was actively avoided to maintain focus on their immediate surroundings. Echoing the 'unrealistic' rhetoric following the airing of the Samsung advertisement in 2022 (Kelsey, 2022) Caitlyn stated,

> 'I think if it is dark, like I avoid listening to music, I just want to like and if it is a quiet area, or something like that. I[…] even though I have my headphones, I just don't listen to music, and I just try to be aware of my surroundings.' (Caitlyn)

The findings indicated that while technology can enhance feelings of safety among participants, it does not significantly decrease actual risk of harm. In only one case, Caroline's, did a participant suggest that technology might make them go out more. Participants noted that technological tools and features provide a sense of reassurance and could play an important role in post-event scenarios, but their capacity to prevent or mitigate safety risks in real-time is limited in their current form.

7.1.1.1 Sharing Personal Data

Personal information such as age, email address, and location data is frequently gathered for user authentication or operational needs when using digital technologies. This information gathering is anticipated to increase proportionally to the development of more sophisticated solutions (Hustinx, 2024), such as those identified in Chapter 6.

Some participants were resigned to the fact that sharing personal data was a necessary part of technology use, inclusive of that used for active travelling. Choosing to use it ultimately resulted in a digital footprint that they did not want but had no means of avoiding.

> 'I don't really want to be sharing this information. But actually, you […] everyone these days, as soon as you touch your mobile phone, you have such a massive digital footprint anyway, that it's probably not that big a deal.' (Isabelle)

These perspectives were also observed with respect to the use of Google Maps and the practice of planning, which are detailed further in section 7.1.6.1. Participants perceived it as a double-edged sword, but ultimately for practices where they considered it necessary they would opt to use technology, such that the requirement to share data did not necessarily

hinder uptake. Caroline illustrated this through discussing her activity watch, which conflicts with her beliefs regarding the desire to avoid being observed.

> 'Because actually, I say that I don't want to be watched. But I'm wearing a Garmin watch. And it's tracking everything about me. So it's almost subtly coming into my life in a way that I'm becoming dependent on it. So I feel like I can't do my exercise without my Garmin watch.' (Caroline)

When participants did share information, they were clear that control over who had that information was important.

> 'I want to be able to be very specific about who I was sharing my information with.' (Lisa)

The participants' views on privacy are consistent with existing studies on technology adoption, whereby concerns for privacy are considered an inhibitor to technology uptake (Doria et al., 2021), which is also true beyond the realm of personal safety technologies (Naiseh et al., 2024). However, reconciliation due to its necessity of use sets a dangerous precedent for technology reliance, and with respect to 'payment' through the sharing of user data (Bamberger et al., 2020; Chib & Ang, 2023), especially if that product's primary use is protection. Whilst privacy was considered a concern, there was no agreement among the participants as to what degree of data collection (what is collected or how it is used) would be acceptable. In the UK there are some protections, however, globally there have been numerous cases where companies have used data illegally (Marinos, 2020, 2021).

7.1.1.2 Familiarity

As well as using more 'traditional' modes of 'safety work' (Kelly, 2012), like using a mobile phone to call friends and family when arriving at an intended destination, the location-sharing features of WhatsApp and Find My Phone, along with route planning using Google Maps/Street View, were recognised as technologies currently being utilised by the participants.

The participants were unaware of the products and features shown to them in the features document and were surprised by the variety available. Whilst the range meant that the choice was expansive, it was an issue of trust. Participants raised questions such as how they would know which one to use. How would they know who else was using it? Was the dataset large enough to be valid? Participants suggested that they were more inclined to adopt software that was familiar and used frequently, with searching out new types of devices not being a priority if they could use technology that they already knew and were comfortable

with. WhatsApp and Google Maps were preferred due to the information they provided, their widespread usage, and their familiar interface.

> 'I do like the WhatsApp one, seems really useful, because we all use WhatsApp all the time, or most people do.' (Sam)

> 'So I probably wouldn't necessarily go to something that I didn't know. And I would be more likely to use something that's already embedded in a phone, like Find My Friends.' (Isabelle)

A saturated mobile application market means that individuals have a myriad of choices available to them to aid their safety (Statista, 2024). However, none of the participants used any of the applications identified through the review of features. This is partly due to the fact they did not know they existed, but they were also not motivated to look for them as their needs were adequately supported by existing applications. At the outset, the participants were surprised by the sheer quantity of applications available. During the conversation, they made occasional mentions of how they would choose one from the numerous options available and what criteria they would use to make their decision. Both Kaur et al. (2022) and Doria et al. (2021) found that individuals reverted to familiar technologies that already satisfied their safety requirements after downloading specific mobile applications for safety. The theory of affordance stipulates that users will generate their own affordances dependent on their situation. Participants have developed their own 'safety work' practices from existing familiar technologies which have a broader application and can be used for multiple tasks.

7.1.2 Reliability and Affordance

The theme of reliability persisted in the discussion on usability. Reliability can be characterized as the possibility that a system or service will be able to repeatably fulfil its promise or perform well under specific circumstances. Affordance is dependent on the reliability of the device but also its supporting infrastructure. As an example, the features examined in the focus groups (see Table 6.1) were mainly centred around mobile devices and their applications. For an application to be reliable and to facilitate its promise of communication, there must be available battery and network coverage. Participants like Sana felt more vulnerable when this availability was reduced. This vulnerability to technology has been demonstrated in existing research, where participants catered for reliability concerns by engineering redundancy into their practice of walking by taking two phones (M. Zhang & Bandara, 2024).

> 'Sometimes the internet connection is not [available], and the coverage is sometimes not that good. It makes me feel a little bit vulnerable and unsafe when I'm out if it's not there.'(Sana)

Participants were very aware that battery life was often compromised when using location-tracking features. This knowledge meant an assessment had to be made as to whether using it was more beneficial than the risk of not having battery when you needed it. As a keen cyclist, Isabelle indicated that the safety feature offered by Strava would be useful if it were not for its increased battery usage.

> 'But if you're doing something a bit more unusual, like running or cycling or something, like Strava Beacon or things like that [would be good], but then the only caveat to all of these is they absolutely rinse your phone battery.' (Isabelle)

Alongside reliability, the participants briefly discussed the vulnerability of technological systems and services to physical external attacks or alterations. This durability concern was raised by Clare regarding drone technology.

> 'If you had a personal drone with you at all times filming and these were like a known thing, you know, obviously somebody who could obviously shoot at it and just, you know, obviously there are ways of disabling drones. And but, you know, they're fairly flimsy items, I have to say even military ones.' (Clare)

These concerns influenced the basic level of trust that is required by users to use technology, which was an issue especially when considering emergency situations. It increased their perception of the risk associated with using technology where an emergency response was required. These results demonstrate that trust is fundamental for technology uptake at a very basic level (hardware), where the perceived risk directly influences their affordance.

According to current activity tracker research, users exhibit a decreased level of motivation to utilise technology when battery life is deemed problematic, with participation declining in accordance with the level of trust in performance (Maher et al., 2017). Fitness technology research has previously focused on how battery is presented as part of the user interface and is associated with competence in understanding the user interface, rather than what it means in terms of the consequences of running out of battery (Rupp et al., 2018). In both of these cases, there is a significant disparity between the implications of running out of battery with a fitness tracker, and its use as a personal safety device to help mitigate or reduce personal harm. Assessing risk to personal safety is one of the ways in which women navigate active travel, inclusive of technology. They use risk as a controlling factor as to what they can and cannot do, and make constant assessments both before and during active travel to reduce their exposure to harm. The implications of this suggest more research is required into how levels of risk coupled with reliability influence technology uptake.

Previously, adoption models have served to explain the factors involved in technology acceptance. However, perceived risk, reliability, and trust are not distinct factors in

established technology acceptance models such as the Technology Acceptance Model (TAM) and its extended versions (Davis & Davis, 1989; Ghazizadeh et al., 2012; Venkatesh & Davis, 2000). In the larger complex model of UTAUT (Venkatesh et al., 2012), risk, reliability, and trust form part of a moderator entitled Performance Expectancy (PE). 'PE is the degree to which an individual believes that using the system will help him or her to attain gains in job performance' (Venkatesh et al., 2003, p. 448). Within the moderator of performance expectancy, extant literature considers financial risk (Obaid & الدماغ, 2021), privacy, and performance risk, but less consideration is given to personal safety and the risk of harm. Literature relating to trust in the automation of electric cars (Farzin et al., 2023; Naiseh et al., 2024) or technology used as personal protection equipment may therefore be more applicable. That said, even in these domains, research evidencing links between perceived risk, trust, and adoption rates is scant. Hence, it is feasible to investigate how the modification of trust in technology based on the potential risk could be advantageous in situations where risk to personal safety is substantial, which may have implications for other fields of research as well.

Stuck and Walker (2019) assessed 23 common technologies and their perceived risk, where five types of risk were identified (financial, performance, physical, psychological, and social). The motivation to define specific typologies rather than overall risk was considered important, as 'mitigating general perceived risk to increase technology adoption is difficult without considering specific risk types' (Stuck & Walker, 2019, p. 1316). A smartphone was included as one of the common types of technology. A smartphone can present different types of risk dependent on how it is being used (affordance). Therefore, the risk to a user varies depending on the affordance being provided, such as mental health or privacy, rather than the technology in isolation.

Heidenstrøm (2022) examines the use of social practice theory in risk research and considers the benefit of approaching risk research from the practice theory perspective. Whilst this was not the intention of the study, risk was identified as a significant theme. It revealed a layer of risk associated with using technology for the practice of active travel, which would benefit from further investigation.

7.1.2.1 Good and Bad Actors

It is expected that the technology itself will work with a certain degree of repeatability, operating within a set of parameters. Yet, many of the features discussed in the focus groups require that other humans become part of the service and therefore the repeatability that would be expected from a solely technical solution could not be guaranteed.

Human-technology co-agency acknowledges the collaborative nature of human and technological interaction, emphasising that technology acts as a tool or enabler, and human involvement is crucial for certain aspects of the service. This idea foregrounds the strengths

of both humans and technology in enhancing the overall effectiveness and quality of the service being provided. In 'human-assisted' or 'human-augmented' services, technology plays a role in initiating or facilitating a service, but human intervention is also integrated into the process to provide additional support, expertise, or decision-making. Features that use social networks, location trackers, and alerting systems require that other individuals are connected, attentive, and act in the manner you would expect. Consequently, participants' concerns were not solely directed towards the technological component of the service but also the human aspect. Interestingly, these concerns were present for both 'chosen' individuals who were known to and selected by the user and strangers on a social networks. Sam highlighted that good intentions do not necessarily equate to usefulness.

> 'Just because you want to help doesn't necessarily mean you're going to be the most helpful person.' (Sam)

As well as good actors technology also facilitates the potential for bad ones. Bad Actors are individuals or organisations with malicious intentions, acting in a way that is harmful, illegal, or morally wrong. Whilst the influence of bad actors on data quality was considered problematic for crowdsourcing by participants (see section 7.1.5), their primary concern was the presence of bad actors in social networks due to the high risk associated with letting unknown individuals know you are vulnerable. The use of social networks to aid personal safety immediately raised a few eyebrows, with it being cited as 'random' and 'weird'. Vetting was at the top of the list of concerns, citing the potential for fake profiles and misuse. The participants were cognisant of the technology's capability to provide anonymity to individuals, and lacked confidence in the robustness of a vetting process to disqualify them. When services incorporated unfamiliar but local users into their services (social networks), participants inquired about their ability to discern whether they were trustworthy actors and whether they were of any use.

> 'The very cynical part of me would wonder who else is accessed it. Things like that. Yeah, it's so easy to fake profiles and things like that, that actually, you could get anyone really who's targeting women.' (Isabelle)

It is worth noting here that social networks used in personal safety devices have been repeatedly discounted by participants in previous research (Henry & Powell, 2018; Tozzo et al., 2021), although it was not explicitly stated in these previous studies why this was the case. Here, the reason is the trust, or lack thereof, that users have in the provider to adequately vet individuals, opting instead to phone a known individual who was trusted, even if they were further away.

Chib and Ang (2023) found that trust and safety are placed in social networks made of friends and acquaintances, where the affordance of social cohesion and connectedness generated

feelings of safety. Therefore, it is important to differentiate between social networks, social media, and other social activities carried out on mobile devices. There is a clear distinction between the curated affordance of safety derived from known associates, and the random collection of individuals on a social network, even if they are shown to have common goals or traits, such as being a woman, as is the case with some social network oriented third-party mobile applications under review. Social networks, if not connected to friends and family, are no substitute for what is considered the 'first wave' of mobile telephony integration (Chib & Ang, 2023, p. 779).

Technology is regarded as a facilitator of nefarious acts, through provision of anonymity, global reach, automation, and encryption. There are numerous instances of identity theft, which include catfishing, online scams, fake news, data breeches, and trolling. While efforts are being made to eliminate the risk posed by bad actors, participants indicated that these individuals are a strong inhibitor to uptake.

One high-profile case demonstrating the potential impact of bad actors and unintended affordance of technology is the Apple AirTag. The AirTag was designed to help people locate their personal belongings, not to track people or another person's property, but it has been misused for such a purpose. Whilst a solution to the problem was developed for Apple users, it took six months for one to surface for Android users (Heinrich et al., 2022), and it has since been shown that the solution can be easily circumvented by cloning the device (Shafqat et al., 2023). This issue exposes potential problems with ongoing support and compatibility with respect to technology (Baumer & Silberman, 2011), illustrative of the ongoing challenges for responsible technological design and innovation.

This phenomenon of unintended consequences can be explained as a pacing issue where technology undergoes rapid changes, whereas change to social, economic, and legal systems is more incremental. This phenomenon leads also to the Collingridge dilemma (Genus & Stirling, 2018), which describes how inadequate information is available to anticipate potential technological consequences, and how, once it is made available, its integration into society can often prove too challenging or costly (Kudina & Verbeek, 2019).

The findings indicate that there remains a significant degree of apprehension towards technology based on current comprehension of its misuse, which hinders its adoption. The risk associated with bad actors in social networks was of particular concern and would stop participants from contemplating using these networks for personal safety. The participants did not suggest ways in which this could be improved or what level of vetting would be required for them to trust in the service more.

7.1.3 The Situatedness of Affordance

Context is described as relating to the circumstances that form the setting for an event. The impact of the surrounding conditions, inclusive of infrastructure and time, on the type of

technology that could help address safety issues was examined as part of the focus group discussion. Participants described context in terms of their physical surroundings, the type of activity that was being undertaken, and the perceived level of risk. For example, when discussing a drone support system, several participants raised concerns about the physical environment and how tree cover might limit its effectiveness as a deterrent or evidencing tool.

> 'What if you're running in the park, but there's like a lot of tree cover or something. So you just have a drone randomly flying around in the midst of you having like this thing going on. But it can't really capture much on the video. And the attacker is just like, well, this isn't going to stop me, you know what I mean? So, I feel like it's only useful, like, in very specific situations.' (Lisa)

Ana highlighted that a panic alarm's (both old and newer digital versions) effectiveness is somewhat dependent on someone being in the vicinity.

> 'I think the thing that occurred to me was as well, depends on where you are. So if I was walking where there was nobody else around at all, I would feel like that alarm would be less effective. Yes. Maybe even always would scare them off. But if they know, nobody's gonna hear it anyway, it might not actually be very effective. So something that alerts somebody [sending an SMS or similar] might be obviously better.' (Ana)

Time was considered to be the main inhibitor with respect to technology's effectiveness in emergency situations. This was attributed to the insufficient time available in high-stress situations that necessitate prompt thinking to act and operate technology.

> 'If somebody comes up behind you or whatever to attack you, you're not going to be rummaging through your phone looking for the app that calls the drone. You're going to be in the moment just trying to get yourself safe.' (Rosa)

How long the solution takes to have a positive influence, such as connecting with a local person (social network) or calling drone support, coupled with the complexity of operating the technology in a high-stress situation, were also considerations for users. Where functionality is overly complex this becomes a deterrent to use.

> 'Actually, if you have to go into a situation where you might want to, to go for a panic button, you have to remember that you've got one, you know, and that's, that's not so easy. In that kind of stressful situation to remember your options then mentally go through your options. It's not as easy as it sounds.' (Sam)

One of the ways to remedy this was to pre-plan its use.

> 'I've walked home from the station at night, and I've made certain that my phones in your hand you know, should something occur? so I'm not rooting around for my phone.' (Rosa)

Whilst many device developers had thought about accessibility and creating easy activation methods, many features were still considered moderately impractical. Pre-planning was a remedy to this problem, although in most emergencies this was not considered to be realistic by the participants.

> 'It depends on the context, obviously. Because I was thinking that like, I don't always necessarily have my phone easily accessible during a commute and things. But then again, if I was walking home from a club at night, like, yeah, so I think it depends on context. A lot of the travel that I have, I don't think it would be really useful.' (Lisa)

Participants perceived that the affordance of technology can drastically change when considering contextual factors in their use for active travel. These results build on existing evidence, presented in Chapter 2, as to how the perceived affordances of technology alter with the context of use (Hutchby, 2001). The complex interplay between technology, users, and context emphasises that the effectiveness of personal safety technologies is not fixed but dependent on various factors within their usage environment. This complexity cannot be accounted for by a personal safety device, even if it has multiple features. Research by Sumra et al. (2023), amongst others, has suggested that one solution to this complexity is the incorporation of AI.

7.1.4 Artificial Intelligence

Artificial intelligence provides an opportunity to resolve some contextual limitations identified by participants in section 7.1.2 with respect to facing emergency situations. Through the use of machine learning models, technology, in theory, could distinguish between an individual's 'I am not in danger' and 'I am in danger' status (Rodríguez-Rodríguez et al., 2020). To a certain extent, this kind of prediction is not too far removed from travel demand forecasting, where the prediction of modal choice and route choice is made. Forecasting in this context is primarily based on data gathered from individual smartphones, including GPS data such as speed, heading and location (Zhou et al., 2017).

Given the relative availability of tools that can access biometric data (S. Khan et al., 2020), it is feasible to develop a method that can identify when an emergency is occurring, with no, or

minimal, input from the user. The tools that are currently integrated within existing fitness tracker units are already capable of accomplishing this task, such as Garmin Incident Detection, which leverages changes in acceleration as a trigger, but it is not difficult to locate accounts of inaccurate detection on the internet. Wild geese stopping you in your tracks and the act of slowing down too rapidly after a sprint finish have also caused detection of an emergency occurrence, sending alerts to designated individuals (Garmin, 2024a). I have a watch that proudly tells me that I have walked up ten flights of stairs, when in reality I have only been digging at the allotment for an hour.

Therefore, it was not surprising to find that focus group participants were concerned about the use of this kind of technology for personal safety. Lisa and Isabelle both brought up the issue of complexity, asking how a system would be able to understand 'the complexity of me'. Especially if that complexity included contextual factors like riding up a hill, crossing the road in a rush to get out of the way of a car, dancing at a party, or wild geese (Garmin, 2024b). Although only a small proportion of products suggested the use of biometric data, caution was extended with respect to voice-activated alerting systems using natural language processing too.

> 'There is a lot of ways it could be misunderstood. You know, like, again, what if you go to a party, and you know, your heart rate, or you get surprised, and your heart rate goes up? And I just, I just don't have enough faith in AI to be able to sort of like, interpret the complexity of me.' (Lisa)

> 'I just think things like heart rate and stuff like that, would you have to map out your route, so it knows where there's a massive hill that you're going up, so your heart rate is going to go up anyway?' (Isabelle)

Participants were sceptical about the use of AI in this domain, in part due to its emergent nature. Although participant comments indicated that in time it may have a level of reliability that they would trust.

> 'But if these things are still in early stages, they're probably not polished.' (Isabelle)

Sam highlighted that if the risk was extraordinary, and the cost/benefit tipped in the balance of the latter, then it was probably worth using or investing in. There was also an acknowledgement that after further development and wider societal acceptance AI may be useful.

> '…it's not 100% guaranteed that it won't be you. And whether you think that remote possibility is enough for you to trust the AI. And, and I think it is, I think

> nobody wants to, obviously doesn't want to be that one person, but nobody wants to be close to related to that one person either. And from that point of view, I think it's worth it.' (Sam)

Where devices had the potential to be activated accidentally, participants had the additional concern of alerting and panicking someone unnecessarily (mainly close friends or relatives). It is possible for unintentional activation to arise not only from a misinterpretation of the AI criteria, but also from a more fundamental requirement for adaptability in less sophisticated solutions. For instance, in addition to the contextual considerations highlighted previously, participants raised the possibility of deviating from a pre-determined route due to innocuous factors such as road congestion or inadequate lighting. This would also be considered problematic.

Participants could see scope for the use of more complex AI in this domain in the future. They could see how it would improve safety and remove some contextual related problems. At this time, they were unable to trust that it would perform well in complex situations. Trust in AI's ability to detect emergency events was low, and this, coupled with the risk of unnecessarily alerting friends and family, meant that participants were not inclined to use this type of technology without further testing and development. They would only be inclined to its use where risk was extraordinarily high, and for most individuals taking part this was not the case. Whilst this is an individual opinion, it was interesting to find that participants were perhaps more concerned about worrying others unnecessarily, thereby highlighting the role and inclusion of others in personal safety.

7.1.5 Crowdsourcing as a Technological Affordance

It has been suggested that the under-reporting of safety events such as harassment or sexual violence may partly be attributed to the limited reporting channels available (UN Women, 2024). It is considered that under-reporting reduces the likelihood of change with respect to education, policy implementation, or improving urban design frameworks (Witten et al., 2022) which has the potential to facilitate more equitable active travel. Consequently, crowdsourcing provides an opportunity through technology to address the shortcomings of traditional reporting methods, such as the lack of action, judgement, and lack of reporting channels (Franklin & Pender, 2020). A domain-specific example of this is provided by Doria et al. (2021) who found a common theme of participants' preferences was the opportunity to interact with an application rather than having to discuss safety events with others in person. In section 2.4, I speculated that by collecting information and data surrounding women's safety from social media, where 'reporting' is completed as part of the social systems and processes enacted on these platforms, this lack of reporting can be somewhat remedied.

Crowdsourcing is a targeted activity which involves obtaining information from a large group of people. This information is often collected in the form of opinions or reports submitted via

the internet, social media, or smartphone applications. The crowdsourcing features discussed as part of the focus group collect reports and opinions from users with the intention of improving personal safety. Information is usually contained within the application itself and returned to the user in the form of safety maps and safe routing features, although in some cases, information was shared to non-application-users (Safe City—at a cost) or to local government and police forces (Saftipin). Information was presented to users in three ways: as raw data, as a curated 'safety map', and, finally, as route planners where hotspots (for crime) were avoided.

In general, the participants agreed that having additional information to aid in decision-making was a good thing, however, excessive information could also prove overwhelming, potentially resulting in escalating anxiety and limiting movement. Primarily this was due to the number of reports, but also the level of detail presented. Whilst not setting out to review specific user interfaces, this serves as a reminder of how technology as a method of data delivery can influence meaning and competence (Carleton et al., 2019).

> 'I wouldn't feel safe, I think, I mean, I live in London, and there's lots of things happening here all the time. And knowing all of that information would make me probably not go out.' (Caitlyn)

Participants also contemplated the possibility of presenting this data with a supplementary layer that transforms reports into a banded colour scheme, rather than divulging individual experiences or pinpointing exact locations.

> 'I'm not interested in kind of individual experiences being shared.' (Sana)

Overall, whilst some presentation and design aspects were considered inappropriate, participants welcomed having access to information that informed decision-making. Maps were favoured over route planning tools that took safety reports into account but did not show them as part of the map.

> 'But I'm more for things that have helped me to make a decision, rather than tell me what to do.' (Ffion)

These views were shared independently of further discussion on how the source of the information affected its credibility. The technology assessed as part of the features document either used police data (official reports of assaults and knife crime), or crowdsourced data (reports from individuals contributing information directly using the application). At first glance, crowdsourcing can be seen as moving away from the top-down decision-making that has previously been prescribed by developers (Hasinoff, 2017; Simpson, 2014). However,

participants discussed, at length, the 'problem with giving opinions'. The participants were very aware of how their own subjective opinion may not apply to others and were much keener on the idea of judging 'things' (infrastructure and the environment) than feelings. In doing so, they felt more secure in making an unbiased and 'useful' contribution.

> 'So the trouble with the crowdsourcing thing is what you're, you are asking people to judge other people's behaviour. And I think that's the problem. Whereas with the ones where you're reporting, that this is an area that feels a bit dangerous, you're reporting on the area, as opposed to the behaviour of the people that you're seeing in that area.' (Sam)

This idea is reinforced by the participants' responses as they question their own value, in both their ability to assess and judge the situation, and if that information would be useful to others. Mariam would only use a safe route planning feature in an unknown area if she had tested it in a known area first to see if the advice or information presented reflected her own opinions, in effect gauging the collective opinion against her own.

> 'Or may possibly use it, then I'd use it in a situation where I would probably test it. But I don't think I would naturally go to it. It would be something I'd probably want to check myself in advance to see whether or not it would be useful.' (Mariam)

Credibility concerns have been shown to result from trusting the crowd (crowd as source), but also trusting one's own abilities to be considered an expert (self as source) (X. Y. Huang et al., 2023; Sundar & Nass, 2001). This view is evidenced here by the participants' tendency to question whether their subjective assessments bestow an accurate spatial assessment of the safety. Ellie highlighted that context also plays a role in individuals' perception of a location, and that other aspects must be considered, such as time of day and the presence of people contributing to the feelings of safety.

> 'If it was the case of everyone was reporting when they didn't feel safe? Because [it] also depends on how light and how dark it is, and what time of day it was. So there are so many different variables, that would alter people's perception.' (Ellie)

Participants also raised concerns about the statistical significance of the data based on the number of users.

> 'So it's getting the message out there so enough people are using it so that it's accurate.' (Ellie)

Like the participants, existing literature argues both for and against objective opinions of locations. T. Le (2022, p. 51) argues that the removal of feelings in the mechanism of spatial assessment promotes a 'way of seeing space and social phenomena that is profoundly disembodying', such that it is unable to adequately convey the lived experiences of women (T. Le, 2022). Conversely, Sengupta et al. (2023) suggest that crowdsourcing's value is undermined by subjective experience, and in terms of the tools that use that data, such as curated safety maps, may put individuals at risk. Gupta et al. (2022) also acknowledge the potential for bias, but highlight developers' attempts to rectify unjust assumptions about neighbourhoods through helping individuals without access to mobile phones to contribute to the dataset. For example, Safetipin actively removes individuals' data from their posts in an active measure to record all contributions as equal. Sengupta et al. (2023) attempted to empirically measure potential algorithmic bias in the context of crowdsourced safety ratings using real-world data. They found that gender significantly influences assessment of space, and in turn the importance of intersectionality, in the credibility of crowdsourced data. Without identifying patterns within data, there is a real concern that any true understanding may be lost in terms of the intersectional nature of reporting variance. Dewey (2021) raises the importance of intersectionality in crowdsourced data and the potential for it to create bias against certain members of society. This, coupled with an awareness of bad actors and their potential to influence personal safety maps for fun or nefarious means, adds to the level of distrust in the validity of crowdsourced data.

Extending the reach past crowdsourced data to police data, participants had opposing opinions about what kind of data they would consider more credible, with each group taking a very different stance. Those with a preference for police data, like Ellie, considered it more trustworthy and made frequent reference to the effect of user perception on the quality of crowdsourced data.

> 'I suppose so I think it's probably because it's not down to user perception. If there's a lot, if there's been a high number of police incidences is more in one particular area, then I'm going to assume that there's probably a lot of other data as well. Or if you were to say interview everyone who lived in the area, you might say that it was an unsafe area as well. So I would more likely to divert my route away from an area that had a high number of police incidences.' (Ellie)

Whilst acknowledging that individuals may not report incidents to the police, Ana would still prefer something 'official'. Rosa considered that an endorsed application or one created by the police would also be more favourable:

> 'I don't know, maybe I'm cynical, but I'm not always convinced that everybody, everything gets reported or logged in a way. But hey, I guess it's better than nothing. It's more official than lots of people's opinions.' (Ana)

> 'I'd probably use it even more if it was an official kind of police app.' (Rosa)

Participants who favoured police data also had some doubts about its validity and applicability. Rosa, whilst previously thinking she would trust police data over crowdsourced data because it was not based on user perception, then proceeded to question the authenticity of the data presented through a mobile application, suggesting that the information's delivery method (mobile application) made the data less credible.

> 'You know, if it was real because then I don't know, there's something still at the back of my mind that actually is that police data?' (Rosa)

Mariam, who also implied that she would be more likely to trust police data then questioned the data's significance if it was historical:

> 'Because if it's incidences in a place that about a year ago, and a lot has changed in the year, that will be very different. So, it just, it just depends how the data has come through on that. But I would say on the face of it, the police data would be the one I'd prefer to go on, go for.' (Mariam)

Participants who considered police data unreliable questioned the validity of the dates and locations, and debated whether these reports were relevant for the safety of women.

> 'The trouble with police data is it's notoriously unreliable in because it relates to where the crime was reported, which isn't necessarily where it happened.' (Sam)

Within the focus group there was a clear division as to whether the police could be considered trustworthy, this has also been seen in studies by Karusala and Kumar (2017) and McCarthy et al. (2016b), conducted in India and Ireland respectively and therefore this problem transcends geographical and cultural boundaries.

All participants worried about user perception in crowdsourced data, citing the fact that one user's view might not be the same as another. This was considered a double-edged sword, with potential for both over- and under-reporting of events. Although in comparison with police data Sam argued that crowdsourced data might be more representative of actual events.

> 'But I think the thing about the crowdsource thing above the police collected data for me would be that there might be a small incident that most people probably would think, right, I'm not going to report that to the police. But you might be inclined to put it on to that kind of an app or crowdsourcing app' (Sam)

The divisiveness of crowdsourcing data and its credibility is well documented (Y. Huang & Sundar, 2022). In the health domain, the credibility of crowdsourcing is linked to lack of traditional authorship and the anonymity of authors (Metzger et al., 2010), which explains to some extent the views favouring police data over that of crowdsourced reporting. Despite participants agreeing that information that helps inform decisions would be welcome, it was apparent that it needed to be the right kind of data and delivered in a specific way to inform active travel practice. For instance, the information must be presented so as not to overwhelm users, to increase credibility, and so that users are willing to collaborate in creating this information in the first place. Greater transparency with respect to the origin of data and where and how the information is used (for example in routing algorithms that take safety into account) can ensure that trust, transparency, and control are preserved. This aspect of design really highlights an opportunity for personalisation within the design space, accounting for individuals' differing perspectives of what safety means for them. These findings highlight the need for greater understanding of how users perceive crowdsourced data for personal safety in terms of its use in providing safety information and the influence of data bias.

7.1.6 Practice as Performance

A 'practice as a performance' refers to the idea that practices, which are routine actions or behaviours, can be viewed by others as performances in a social context (Shove et al., 2012). Knowing safe routes, having keys in your hand, and calling someone to let them know you are at your destination are just some examples of practices that women have undertaken to ensure their personal safety whilst active travelling (Orr et al., 2023). These practices are fully centred around the task of risk management with respect to personal safety (Bates, 2023; Orr et al., 2023) and collectively make up the larger performance of 'safety work' (Vera-Gray & Kelly, 2020).

Participants identified how active travel and the consideration of safety changed depending on the type of travel they were doing. For instance, there was a difference between commuting home from work in the dark and walking home from a club, because of the items you might have available to you, the route you might take, and the people you might encounter. Previously adopted technological devices may be seen as more acceptable due to their flexibility and ability to become easily routinised, having already been integrated into other existing practices, as opposed to new safety-specific devices.

This section explains in greater detail how identified practices have remained the same, evolved with the introduction of a technological device, or have the potential to become established using the elements of SPT (material, competence, and meaning) (Shove et al., 2012). I look at practices that are created by the features of personal safety devices and discussed by participants. These include planning, prevention, deterrence, evidencing, and weaponisation.

7.1.6.1 Planning

Planning a route was a common practice undertaken by the participants. This involves a stage of data gathering followed by an assessment of available options against a set of user-set criteria (cheapest, carbon-neutral, scenic, etc.). This second stage is achieved through the utilisation of algorithms and data found in technological tools such as Google Maps.

The practice of planning for personal safety was undertaken by all the participants. Google Maps and Google Images were applications that were repeatedly mentioned in discussions about planning and evaluating routes. Planning addressed safety concerns by enabling users to look less out-of-place and, in turn, less vulnerable, and to minimise their exposure to risky situations.

> 'So I like to know where I'm going and not look, you know, not be obvious about not knowing where I'm going.' (Jemima)

This position of anonymity involved creating a sense of familiarity with the route undertaken before or during a journey. Finding practical information enabled them to estimate journey duration so that they would not have to wait for public transport connections for long (less exposure to risky situations), they would be able to advise on their anticipated time of arrival, and finally, it was used to make assessments of how safe an area looked.

> 'I tend to go on Google Maps and see what route we are taking, so it's familiar to me when I'm in that place.' (Ellie)

> 'I look at Google Maps and street view when trying to figure out what looks you know what's in the area. If I'm completely unfamiliar with something, obviously, it's not going to tell you the difference between a sort of well-lit at night or not. Because it's always daytime photos. But yeah, I might check out the route and see what that looks like there's stuff around, or well—how dingy everything looks.' (Ana)

The practice of planning was considered necessary and whilst participants understood that this would leave a digital footprint, the risk of doing so was outweighed by the benefits of planning. Lisa explained how she felt bound by this choice.

> 'I feel like it's a bit of [...] an almost necessary evil at this point. Because you kind of have to, but like, I hate when Gmail sends me a message, and it's like, oh, here's an overview of how you use Google Maps this year, it freaks me out to see how much data they have. But I kind of feel like there's no better option. Because

> like, you do need some way to like, think about and plan the route. And in the world we live in right now, that's the best way to do that. So you kind of feel a bit of a bind.' (Lisa)

Participants Jemima and Ana described the influence of technology when walking in new locations. Both highlighted the benefits of being able to remain incognito whilst travelling unknown routes. They felt that they appeared less out of place, which in turn made them less vulnerable.

> 'And something that actually does make me feel a lot less safe. And it's only partly to do with being a woman, and partly to do with being seen as, like, a tourist is always having my phone out to check the route where I'm going. Because I feel like, you know, if you're, if you're disoriented, and you've got your phone out, that can kind of make you an easier target. Or at least that's what I was […] I learned, I was taught.' (Jemima)

Jemima felt that although technology assisted her in being able to navigate unknown areas, she minimised her time spent interacting with it, guided by the rule that she should not let others know she was vulnerable. In this sense her mobile phone was also putting her at risk. By simply adding a set of headphones, Ana explained that she enjoyed having access to information without the same risk that Jemima identified.

> 'In terms of safety, I much appreciate being able to walk in a city or an area that I don't know, with my earphones on, and listening to my instructions of where to walk so I don't look like a complete newbie standing by the side of the road, trying to get where I am going, which is obviously something that makes you look more vulnerable.' (Ana)

The practice of planning has altered with the introduction of technology, and planning routes is now synonymous with using technology. This reliance highlights how technology 'changes – often in very subtle ways – [the things] people can do and how they can do them' (Sætra, 2023, p. 12).

Again, as raised in the discussion in section 7.1.5, individuals would rather not be told what to do, especially by data that they consider to be questionable, as they are often sceptical of the information and guidance provided in the form of routing software for safety. Participants felt more accepting of raw, less processed data, like images from Google Street View, which they could use to come to a decision themselves.

7.1.6.2 Prevention and Reporting (Proto-practice)

Technology enables the large-scale collection of data, but large-scale adoption hasnt yet occurred. Whilst there is low risk in reporting, participants questioned the value of their own opinions, the problem of bad actors skewing datasets, and bias that could be introduced as a result. The meaning, thoughts and feelings, behind reporting is the inhibitor to this practice.

7.1.6.3 Deterrence, Evidencing and Weaponisation (Proto-Practice)

An initial question asking the participants if digital technologies might influence existing active travel behaviours prompted further discussion on arming themselves. Whilst this was clearly meant in jest, in a conversation between Beatrice and Clare, Clare said that the only technology that would help change her existing behaviour would be a robot dog with a gun. She indicated that technology devised for safety may have been created by a male-dominated industry to solve a problem, perhaps with little understanding of the safety concerns of other genders, while what she really wanted or needed was a weapon.

> '... so I need one of those Boston Dynamics dogs as a security guard. So then you're talking about robotic security guards like I need my Boston Dynamics dog with me at all times. Who is armed.' (Clare)
>
> 'Yeah, that would be good. I would like that. Yeah.' (Beatrice) 'That would fulfil the tech bro fantasy and also would serve my safety.' (Clare)

As well as robot dogs with guns, each group candidly discussed arming themselves in different ways, either due to their own previous experience or those of others in terms of what they might hope for in the future, spray canisters (body spray), dogs, drones, personal bodyguards and guns.

A global study into mobile application designed to address VAW by Eisenhut et al. (2020) found that 46.78% of 171 applications assessed as part of the study were designed to offer 'immediate help in emergency situations'. These emergency applications therefore constitute the largest proportion of personal safety mobile applications globally. Whilst deterrence, evidencing and weaponising technologies have different goals, they all need to be used in emergency situations and are therefore grouped together here.

In all three practices, participants needed to trust that the device would work as intended and that it would be effective. The limitations and added complexity exposed in section 7.1.2 meant that elements of material and meaning, in terms of feelings (risk and trust), cannot be linked together with competence and remain a proto practice.

7.1.6.4 Summary

The adoption of technology as part of safety-related practices is conducive to the low vulnerability and uncertainty states of users (Chib & Ang, 2023). Adoption is considered more favourable when there is less risk associated with the task. In the case of planning, technological tools are widely accepted and relied upon by the participants as they are considered to have low vulnerability and low uncertainty. None of the participants considered technology as a weapon, and all practices associated with emergency situations were unlikely to be adopted, due to the high risk involved.

Shove et al. (2012) have argued that practices extend beyond their performance, owing to their integration with social life, wherein they are characterised by 'shared states of emotions, understandings, and a network of things, norms, and embodied know-how'. This is evident in the practice of planning, where looking less 'like a newbie' was a motivator for using technology. Planning is the only practice that is 'complete' in terms of materials, competence, and meaning. Table 7.1 summarises the elements with respect to the practices identified in the focus groups, detailing their current 'status quo' and what could, or needs to, change for them to become fully formed practices rather than proto-practices.

TABLE 7.1: Practice summary, identifying elements that are inhibitors to fully formed practices (Weaponisation is not included.)

Practice	Material	Competences	Meaning	Status Quo	Possible shift
Planning					
	Mapping and route planning application, street view visualisation (Google Maps and Google Street View)	Image interpretation	To not look out of place, minimise exposure to risk	An active practice where technology is a significant aid to feeling less vulnerable	Integration of crowdsourcing data to increase knowledge and allow informed decision- making
Prevention and Reporting					
	Application that facilitates Crowdsourcing (Safetipin)	The competence to assess infrastructure, feelings and or reporting events	Distrust in data (for example too many platforms and what this means for the data it is trying to represent)	Crowdsourcing widely incorporated to existing safety mobile applications	Move to make reporting more mainstream needs to address meaning and competency problems
		The ability to report 'useful' information	What constitutes 'useful' information		
Deterrence					
	Panic Alarm application	Complicated to use and activate in emergency 'high stress' situations	Lacking trust in reliability	Panic Alarms widely incorporated in existing safety mobile applications	Using AI to increase ease of use in emergency situations, mitigating contextual factors
Evidence					
	Video Recording	Complicated to use and activate in emergency 'high stress' situations	Lacking trust in reliability	Video and Audio recording widely incorporated in existing safety mobile applications. Proposed in other technology such as drones.	Using AI to increase ease of use in emergency situations, mitigating contextual factors

7.1.7 Overview of Practice as Entities

It has been shown that practices require a combination of materials, competences and meaning, to exist (Blue et al., 2016). This summary examines the evolving landscape of technology use for safety in active travel through these three elements, both in its present and potential forms.

Shove et al. (2012) describe the evolution of practices as slices of the three elements. Over time, the elements grow and change in significance as society and technologies develop and change. Figure 7.1 shows a simple representation of how these elements may alter in significance over time. As a simple illustration, the introduction of the Apple iPhone in 2007 may have shifted the practice of mobile phone use with the new affordances it provided. Not only was greater competence required to use these additional affordances, but the 'meanings' associated with these affordances have also changed. Taking the case of social media, meaning takes on a larger part in this practice. Whilst not all social media meanings are considered negative, I use some examples presented by Amedie (2015) to make my case, such as increased mental health problems, users finding it addictive and time-consuming, reduction in interpersonal skills, and the facilitation of criminal activity.

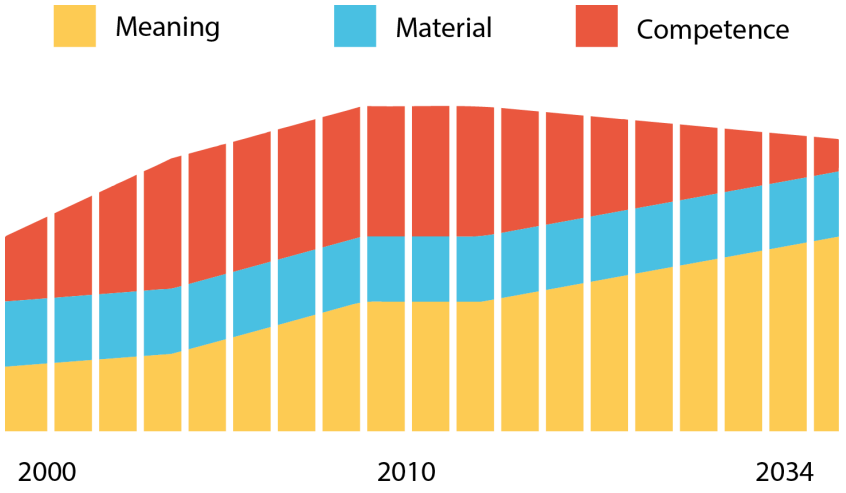

FIGURE 7.1: The evolution of technology-related practice split into the entities of meaning, materials and competence where future developments having meaning as the dominant reason for an unconnected proto practice

7.1.7.1 Competence

Competency was conspicuous in its absence within the focus group discussions. Participants were required to have some previous experience of using technology for travel, so this absence was not entirely unexpected, nevertheless it was surprising that participants did not mention it with respect to other individuals they knew.

When examining research that evaluates the requirements of users to utilize mobile technology, it is evident that a flurry of research was conducted during periods of mobile development, such as its early introduction circa the mid to late nighties and then again in the mid- to late-noughties. Since then, mobile technologies have become an integral part of daily life (Ling, 2004), with 93% of the adult population now owning a mobile phone (ONS, 2022). This transition in competence has shifted with both increasing complexity and integration into daily activities such as banking and health.

Looking forward to the potential of AI (more advanced weak AI or general AI) in automating tasks (Rodríguez-Rodríguez et al., 2020), the competences required for personal safety devices could see a significant decrease.

7.1.7.2 Meaning

Increased complexity has not brought with it competency issues, but has instead given rise to meanings in the form of trust. Lack of trust is an inhibitor to using technology in the practice of active travelling.

Given the nature of active travel, where context changes both in respect to mode, surrounding infrastructure, and risk of multiple types of events, the complexity of the situations leaves individuals to make a complicated evaluation of risk. The level of trust required to adopt and use technology within the practice of safety is connected to the risk associated with the activity itself and weighing up the benefits. Trust needs to be placed in the data to inform decision-making, and in individuals who are part of the process.

Planning is an example where the trust/risk balance has tipped in favour of using technology. Whilst the participants had all used technology within the mobility domain as a prerequisite to the study, several individuals did admit to being ‘technophobic’, and there was resignation among the groups about technology use, specifically with respect to sharing their location. It was recognised as a double-edged sword, but as worth engaging with when performing trusted practices like planning.

The results demonstrate that technology is able to take on many forms. This moves away from the traditional categorisation of technology as just a functional tool. As technology integrates more AI and becomes more ‘human-like’ the consideration for technology as a meaningful element will become more prevalent. The feelings, thoughts, and ideas associated with technology will become the decisive element in this practice.

7.1.7.3 Materials

The following limitations were discussed regarding how materials influence the practice of using technology for safety. In line with understandings across other social practice, materials

encompass physical or tangible elements such as technological objects and tools, other individuals, surrounding infrastructure including natural elements (Shove et al., 2012).

It is a surprise to me that this section is the smallest of all the components. The main material elements relating to the practice of active travel are people and the surrounding environment. This is often an unknown and continually changing element outside the control of the user. Technology is considered to be unable to adapt to these changing conditions. Participants perceived this poor ability to adapt as decreasing their levels of trust, and this is especially prevalent in high-risk environments.

The successful and prevalent use of technology for planning showed that individuals wanted to have information that helped them make decisions. However, there was a disconnect among the participants to what data would be useful and trustworthy and how it should be presented.

7.2 Chapter Summary

The focus group study asked participants about their about their previous safety practices and use of technology whilst active travel. It then asked them how the features identified in Chapter 6 would fit or modify existing active travel practices. Participants were able to describe how they currently used technology to increase their perception of safety and also how they might be used and the challenges and limitations associated with them. The assessment has therefore enabled the answering of RQ2 and RQ3 by analysing the discussion on their existing use of technology whilst active travelling. It is acknowledged that some findings are based on hypothetical situations, and could be considered unsubstantiated. Nonetheless, I contend that the participants possess a good understanding and experience of the features, so as to make an accurate assessment of how they would be used as part of their active travel.

The study employed social practice theory as its theoretical framework, providing a structured lens through which to analyse the relationship between technology, behaviours, and social contexts. Using this theory, the study examined how personal safety technologies are integrated into daily routines, the meanings attributed to these technologies by users, and the competencies required for their effective use. Therefore, the insights gathered from this study offer a novel understanding of how these technologies are perceived and used within everyday practice.

In line with existing literature, technology, in particular the connectivity of a mobile phone increased the perception of safety of participants. The findings show that access to data through technology, especially mapping services such as route planning, were described as necessary and widely used by participants. They believed that in familiarisation to a location made them look less out of place and in turn less vulnerable – in effect their perception of

safety was increased. However, technology was also able to increase vulnerability if not used discreetly. Whilst it increased their perception of safety, it was not recognised as a solution to decrease actual risk to harm. Aside from the practicalities of using technology in an emergency, trust was key limitation of its uptake. Views on privacy and the potential for bad actors demonstrated an acute awareness of the detrimental effects of social networks and connectivity, suggesting changing views on techno-deterministic solutions for personal safety which is counter to existing literature on personal safety devices.

The focus groups highlighted that for women the practice of active travelling also meant adopting other types of practice, namely, the practice of risk management and technology-related 'safety work' (Kelly, 2012). Vera-Gray and Kelly (2020) use this term in the context of women's fear and women's freedom in public, and it relates to routine strategies that women employ to feel safe. The focus groups highlighted that technology-related 'safety work' practices were made up of several more specific practices (planning, prevention, deterrence, evidencing, and weaponisation). In presenting new and existing technologically-based features, participants were able to discuss proto-practices (practices that did not currently exist) as well as those that were well established, such as planning.

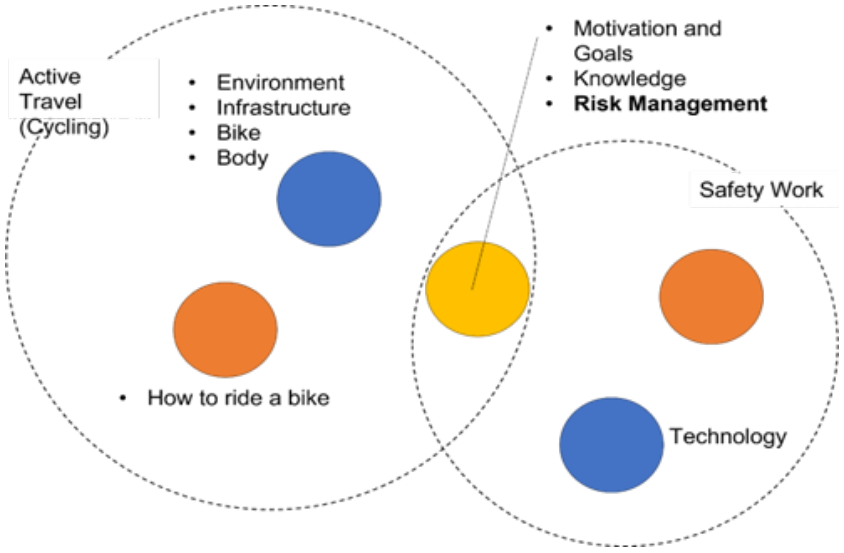

FIGURE 7.2: Shared element diagram showing the sub practice of risk management.

Adapting the shared element diagram (Shove et al., 2012), Figure 7.2 depicts technology not as part of the practice of cycling, but instead as part of the meaning element of the practice of 'safety work' as risk management. This shared element provides a link between technology (forming part of the material element) in the practice of 'safety work' and the practice of active travelling. The findings demonstrate that this was more representative than describing technology as a material element used directly in the practice of active travel.

For example, cycling is a competitive exercise for many, where users will record data to compete not only with themselves, but also with other individuals via an online platform. With respect to this practice, technology has become an intrinsic material component of

exercise, for example an individual wanting to record their ride using Strava. Here, technology is a significant material component of what it means to cycle for them. For the participants within the study group this was not the case, with technology instead constituting part of the material element in a separate practice, the practice of 'safety work'.

Participants views on trust tended to support a shift in technology use that supports or improves existing practices rather than creating new ones. The provision of new information and data into the practice of planning would be the most promising implementation of technology in the near term, so that individuals can make informed decisions rather than implementing concepts that are too far removed from existing safety work practices. This would enhance tools and practices that they were already comfortable using. There were optimistic musings from participants that in time, and after significant testing, they would be more open to adoption of AI and machine learning technology into their existing practices in this domain and could foresee much wider adoption.

The focus groups discussion also raised 'meanings' that, I felt, did not fit within this chapter, such as those around wider social concerns surrounding technology implementation for the safety of women. These were questions surrounding why the technology is needed in the first place, what its development is telling the individuals it is designed for, and the prospect of them making active travel more unsafe. These are addressed in the following chapter.

Chapter 8

Techno-optimism, Techno-solutionism and Techno-feminism

> ”Give a small boy a hammer, and he will find that everything he encounters needs pounding.” (Kaplan, 1964, p. 28)

Kaplan’s ‘Law of the Instrument’ alludes to the fact that it is in the nature of the scientist to try to use the tool you know the best to solve the problem. In an age of rapid technological advancement, it is no surprise then that technology in the context of contemporary society is a hammer that has both the ability to hit the nail on the head and to create a massive hole in the wall.

Techno-solutionism is the conviction that digital technologies and data-driven solutions are instruments that can solve complex societal problems quickly and effectively. Critically, due to its innate optimism, it has the potential to overlook the broader social, ethical, and political contexts that can ultimately lead to undesirable outputs (J. Gardner & Warren, 2019) with the prospect of fuelling inequality (Milan, 2020).

Both the extant literature and participants (described in Chapter 2 and Chapter 7 respectively), exhibited optimism about future technical solutions within the domain of personal safety, but also voiced concern at their development. This chapter addresses three ‘hole in the wall’ scenarios identified by the participants, adding to the discussion on whether technological interventions are acting in the interests of women and serving their needs on all fronts (Eisenhut et al., 2020; Sauerborn et al., 2022). Firstly, why is it that technology is used ahead of other interventions such as education or infrastructure changes? Secondly, what is the introduction of personal safety technology telling individuals who are concerned about their safety? And, finally, how might technological interventions make things worse?

8.1 Findings

8.1.1 Why is technology used ahead of other interventions such as education or infrastructure changes?

> 'Of course, what none of this technology does is improve the behaviour of men. So none of this addresses the underlying social condition of why is it that women feel unsafe on the street? So there's a there's a way in which it becomes a bit like techno-solutionism, like we can solve a massive social problem with a flippin' app.' (Clare)

The reason for Clare's scepticism not only relates to the aspirational quick fix but is also embedded in the belief that techno-solutionism comes from a male-dominated stance. Historically, at least in Western society, there is a significant correlation between masculinity and 'technical prowess and power' (Wajcman, 2001), and there continues to be a gender imbalance in technical roles, with only 26% of data and AI positions in the workforce being held by women (World Economic Forum, 2021). One of the participants was quick to point out the role of the 'tech bro' in technology development. To revisit the quote from Clare:

> 'That would fulfil the tech bro fantasy and also would serve my — serve my safety.' (Clare)

In a follow-up interview, I asked Clare to elaborate on what she meant by her 'tech bro' fantasy comment.

> 'I mean, tech bros is a sort of term for like Silicon Valley. Which, which is very male-dominated. ' (Clare)

She believed that tech bro and Silicon Valley were synonymous. I then asked if she thought that technology was masculine.

> 'No, I wouldn't say I wouldn't say technology is inherently masculine, but people who get to build make and fund technology are masculine. And obviously, you know, as we know, technology, the way that technology gets built, is infused with the values and beliefs of those who make the technology. Obviously, technology is not it's not agnostic, what ends up being built, the design choices, the initial use case, the design choices, the implementation. If that's all done by tech bros, you're going to end up with something that serves their values, interests, and needs. Obviously, if you had a piece of technology designed by a team of women, it may look different. '(Clare)

What is interesting about Clare's commentary is that it evidences a continuing belief that technology is created by men, with the gender divide in technology development substantiating that belief. This gender division is not only seen in the technological industry, but also in education (Master et al., 2023), research (Hearn & Husu, 2011), and accessibility (Jeffrie, 2023).

It was recognised by feminist scholars that for women to fit in within the technological sphere meant being less feminine and more compliant with the existing status quo. Drydakis et al. (2017) found that women who exhibited 'masculine traits' benefited from increased occupation exposure because feminine traits were seen to reap fewer market rewards. Given that the personal safety industry is set to be worth over 7 billion dollars in 2030 (Zion Market, 2023) is it possible that women who are making personal safety technology are conforming to this environment and adopting development strategies that align with the masculine default? Whilst this is outside the scope of this thesis, one of the technologies assessed in Chapter 6, which had been developed solely by women (Sorority, a social network safety mobile application) was discounted by the participants in the study. The feature of a social network in general was not favoured as a form of personal safety device. The women-only platform was intended to form social bonds through gender identification, although for the participants they were strangers regardless of gender. With this in mind, do we know what technology or personal safety technology built by women would look like? Would it be different and better for women? In the case of Sorority no, it wouldn't.

Clare was one of the participants who was more resistant to the technology discussed in the focus groups. I asked her in the follow-up discussion if this was just because she thought that they would be ineffective. It transpired that the primary reason for her choosing not to use technology for anything besides the 'bare minimum' is that she was worried about how the data collected would be used. She highlighted that it 'only takes a change in law', citing the overturning of the Roe vs Wade ruling on abortion in the United States in 2022 (Glenza & Noor, 2024), for benefits to disappear. At the time, there was a call for women to stop using period-tracking mobile applications due to fear of the data being used against them (Daly & Gebhart, 2022). Organisations such as the Electronic Frontier Foundation, an international digital rights group, highlighted how digital technology could be 'weaponised' against consumers without increased protective legislation about data use. It was a poignant moment for techno-feminists, where the hope for liberation through technoscience was extremely fragile and at risk of becoming a false summit (Wajcman, 2007), where empowerment can shift depending on who is controlling the data. This risk is in addition to those immediate — 'in the moment' risk assessments that are made in emergency situations or planned for as part of existing women's safety work.

Further research is required to understand if there is a gendered division in the development of these solutions and to determine if the metaphorical hammer is the same but wielded by a girl rather than a boy. Values based on technological artefacts are also seen in feminist

technological debates, where there is inconsistency between what constitutes a man's or a woman's value. How can we determine a woman's values and processes, and what are they?

8.1.2 What is the introduction of personal safety technology telling individuals who are concerned about their safety?

> 'There's also that thing of, you know, you obviously want to protect yourself as much as possible, but at the same time, it's not fair to put the weight of this onus on the people who are the victims of the, you know, these attacks and feeling unsafe.' (Jemima)

Whilst each group was optimistic about the integration of technology in this domain, they also voiced concern (like Jemima above). Clare felt that the development of technological solutions overshadowed the need to address the wider issue of why women feel unsafe whilst active travelling. Whilst technology can support active travel practice, as evidenced in Chapter 7, it is also seen as setting a precedent for using technology instead of introducing wider societal interventions and strategies to combat the fear and vulnerability felt by women.

Chapter 6 highlighted that the marketing of personal safety solutions was targeted primarily towards either everyone or women, but never men in isolation. Both Eisenhut et al. (2020) and Maxwell et al. (2020) found the same with their larger systematic reviews of mobile applications. This view is also consistent in the media, with reporting around technological interventions reinforcing the idea that they are something women need and should have (Cardoso et al., 2019) to remain safe. This rhetoric plays on the fears that women have regarding their personal safety.

> 'You know, all of these things are lovely, but they kind of, they hand the problem to the people, they hand the problem back to the people that are having these issues in the first place.' (Sam)

> 'Obviously, I want to take all the actions I can to be as safe as I can and protect myself as much as I can, but then going out and telling everyone else, oh, this is what you need to do in order to not, you know, to be spared this horrible experience feels a bit iffy, you know what I mean?' (Jemima)

Jemima highlighted that the presence of these technologies reinforced the idea that safety is the responsibility of the individual, and that this does not aid efforts to address the reasons for women feeling unsafe in the first place, thus unintentionally reinforcing the 'victim-blaming' perspective (Cardoso et al., 2019). Both Sam and Jemima highlighted how all it does is 'hand back' the problem to the victim, so in effect, they are not solutions at all. They have just created yet another layer of 'safety work' for the individual to engage in.

It is not clear from the review of these devices how any collected data would feed back into a wider strategy to both understand and create solutions to the problems faced by women. Crowdsourcing data is considered a potential strategy to remedy this (Gupta et al., 2022), although from the limited information available it appears that with the majority of products the data is only used for its own purposes. There is also scope for further research regarding the implementation of data collected via these technologies, such as how it might inform policies.

8.1.3 How do these technological interventions make things more unsafe for women?

There is an argument that women are still not 'well served' by technology. In the case of personal safety technologies, it may be 'more disruptive or harmful than the circumstances they are meant to improve' (Baumer & Silberman, 2011, p. 2272). The participants suggested that this kind of technology could enable a sense of safety where there is likely not to be any, thereby offering a false sense of security and making matters worse. Ana's commentary relates to the 'doing' part of active travel, but participants also highlighted their concerns about bad actors (see section 7.1.2.1). These concerns ranged from bad actors infiltrating social networks targeting users, and changing crowdsourced data for 'fun'.

> 'it makes you feel safer, that means maybe you put yourself in, you've exposed yourself to more risk because you felt like you had this sort of mitigation strategy' (Ana)

As well as bad actors, attention must be drawn to technological dependence, where users become deskilled in their assessment of risk and vulnerability to bad actors and the external environment, the potential for misinterpretation of data (T. Le, 2022), making decisions with data that is not credible (Wood et al., 2022) and suffer increased anxiety. These are all unintended consequences that can make things more unsafe for women (Carleton et al., 2019).

Technology's relationship to power is also identified by Wajcman (2010) as an issue, although with the percentage of technology platforms being made and developed by women is increasing, would it be possible to argue that the development of technology by these women is also giving them power? Although it must also be noted that power is wielded by those organisations that dominate with the products and services considered by users as necessary. This has not been touched upon in this thesis apart from in the case of planning where participants felt the use of Google Maps was 'necessary' and the only way to do this was by using Google Maps, so participants were bound by that dilemma.

8.2 Summary

This section contemplates participant views that are found within the features and tools discussed in chapter x and support the answering of both RQ 2 and RQ 3. The findings suggest that the development of personal safety devises alone continues to reinforce the notion of women 'as inevitable victims' (Kelly, 1999, p. 120), that they are still considered to be masculine tools created by 'tech bro's', and are liable to put women more at risk. Participants emphasised an uneasiness and frustration with what the development of these tools to be used in emergency situations, rather than being used to address underlying social conditions that cause women to feel unsafe.

This calls for a greater understanding of the 'processes and practices of technological innovation', and their influence in constraining or accommodating existing social behaviours, stressing the importance of collaboration and a more thorough assessment of them and their empowerment potential. 'We cannot simply focus on the allure of technology; we must work to make the most of its potential, developing the adequate context for its proper usage.' (Martínez-Díaz et al., 2018, p. 2) asking not only questions of materiality but also sociality, spatiality, exclusion and other implications (Campbell et al., 2023). Questions therefore need to be asked about whether technological interventions are acting in the interests of women and serving their needs on all fronts (Eisenhut et al., 2020). This means evaluating the 'need' for such solutions, asking developers questions about the assumptions made in their design, and evaluating technology's potential to both oppress and liberate.

Chapter 9

Conclusion

This thesis is dedicated to those women who were murdered in the UK during 2021 and 2022 whilst they were out walking and running. These high-profile cases and the public's response to them both inspired and encouraged me in the undertaking of this study. These events demonstrated that despite advances in technology such as personal safety devices, the issue of women's safety persists in modern society. With the systematic adoption of 'safety work' practices undertaken alongside those of active travel, women endeavour to maintain their safety. Adoption of technology-related practices is just one of these practices.

Existing research has established that there are both good and bad outcomes of technology use in the domain, and it can be argued that even the good (an increased perception or feeling of safety) may cause problems in giving rise to risk-taking behaviour (Nasar et al., 2007). The lack of information as to the lived experiences of women only gives more credibility to the assumptive promise of technology in this domain (Cardoso et al., 2019). This thesis aimed to find out how best these tools can support women's safety, whilst protecting their values and complimenting existing practices, so that any solutions can be sustainable. These findings are valuable for women, developers, regulators, policymakers, and those who must understand the implications of over reliance on technology, and other potential detrimental effects.

The research took the form of two research streams. The first used an applied methodology to find new information on harassment in public spaces using social media data, and the second conducted a qualitative study using focus groups with social practice theory as its lens. Through combining these two research streams (technology as a research device and women's technology-related practice) considered the contribution of technology as both a tool of research and a material object actively used in the 'doing' of active travelling. The study contributes both methodologically through providing additional behavioural insight into active travel users. Whilst there are two research streams, attention is focused primarily on the use of technology in the 'doing' of active travel, where the risk of injury and reinforcing

gender power relationships is seen to be the greatest concern of implementing these tools (Bivens & Hasinoff, 2017; Cardoso et al., 2019; Sauerborn et al., 2022).

This chapter summarises the work undertaken and its key findings, the contribution and potential implications of the research, and, finally, suggests possible future research paths.

9.1 Discussion

The overarching research question explored throughout this thesis is: RQ0. How can technology be deployed to improve women's perception of safety of active travel? It is supported by three further sub-questions that aim to evaluate the current and future potential for technology use to aid women's experience of active travel. This discussion section expands on the conclusions derived from the results of these three research questions.

The first, RQ1. How can technology enable a greater understanding women's perception of safety whilst active travelling? was examined through the collection and analysis of social media data, as detailed in Section 4.1 and Chapter 5. It used an applied methodology to 'test' whether greater insights into the active travel experiences of women can be uncovered through examining social media data. Although social media analysis has been used in previous research on feminist topics and in transport, it has not been completed for women's safety whilst active travelling. It was carried out with the goal of exploring alternative sources of information to discover more about women's experiences of active travel. The methodology used BERT to assess harassment reports and opinions submitted to X (formerly known as Twitter), before completing the content and gender inference analysis.

Although women are more likely to be subject to harassment in public spaces, the findings showed that both genders engaged in discourse on the online platform. Women used the platform to post about experiences of harassment whilst active travelling, whereas comments surrounding the definition of harassment were contributed by men. The results also showed that only some collected Tweets included hashtags, suggesting that research relying on hashtags for data collection might restrict the data set obtained.

The scope of the study was reduced from using contextual keywords to collect data on active travel, regardless of whether it was related to safety, due to computational limitations, and therefore, remains unresolved. That being said, it was able to classify semantically similar text without specifying keywords and therefore does demonstrate the opportunity for future enquiry at a larger scale as per its original inception. It has therefore furthered the discussion on women's safety in public spaces, and added a layer of intersectionality provided by gender inference machine learning. This information is useful for ongoing social media studies and the ongoing lines of social science research into harassment.

RQ2. How does technology contribute to, or influence, an individual's perception of safety whilst taking part in active travel? and RQ3. What are the current challenges and limitations of technology designed to support women's perception of safety when they use active travel modes? were formulated to investigate the role of technology in the practice of 'doing' active travel. This was explored through focus groups with 16 women, the results of which are examined in Chapters 7 and 8. The line of enquiry looked first at their existing experiences of using technology for active travel and personal safety and then evaluated unfamiliar features of technology identified in Chapter 6 against existing practices.

Using thematic analysis and the lens of social practice theory, I was able to highlight the thoughts and feelings surrounding technology use for safety that extends past what is already adopted and used, such as a communicational aid, revealing the achievements and deficiencies of technology (personal safety devices) used to support women in this activity. The focus group findings were able to detail the material, meanings, and competencies that are required by women to 'perform' active travel.

In response to RQ2, the results confirm current understanding that technology can create a sense of safety by offering communication and connectivity. It further establishes that the capacity to meticulously plan routes in advance also contributes by making women appear less 'out of place' which they believe reduces their vulnerability. These practices were identified as safety-related 'performances' where technology use had already been established and where meaning, competence and material, the requirements for a fully formed practice, were connected and present.

These findings lead on to RQ3 What are the current challenges and limitations of technology designed to support women's perception of safety when they use active travel modes?

The limitations of features assessed in Chapter 6, that ultimately, technology is unable to protect against actual risk of harm. This finding is consistent with other researchers' assessment of personal safety devices where their efficacy cannot be proven (Sauerborn et al., 2022). Participants stated the only technology that they considered diminishing risk to harm was a weapon, specifically 'robot dogs with guns'. The findings from the focus group study found that personal safety technologies are not considered weapons of defence as previously found by Cumiskey and Brewster (2012) and this knowledge severely limits the potential of technology in this domain. For example, social networks are instead believed to pose a new risk through the introduction of bad actors and are therefore unlikely to lead to an increased perception of safety and changes in behaviour such as uptake of active travel modes.

Other findings showed how some features (identified in Chapter 6) were currently limited in their ability to contribute to an individuals' perception of safety also. For example, features designed for emergency situations would not alter women's existing safety and risk avoidance strategies, because only removing oneself from risky situations or carrying a weapon could

account for all possibilities. Weapons aside, there was a certainty placed in removing oneself from what was deemed a risky situation that could not be afforded by technology.

Whilst developers may have good intentions, participants were disconcerted that their creation meant that responsibility was placed on the victim. Participants stated that this re-emphasised the maxim that the responsibility is with them and reinforced gender-normative assumptions surrounding 'personal' safety practice, such as dressing a certain way and restricting movement. Limitations are also found in the lack of technology to support the improvement of societal understanding and change with respect to women's safety.

The challenges to overcome for technology is to increase trust in these technologies. Not only in terms of hardware such as battery life or the use of AI, but also with respect to privacy concerns and validation of other users and data that is shared. Taking crowdsourcing as an example, how can the validation of other users and the data they post be validated as trustworthy? And then how can this data be made applicable to other users, accounting for local knowledge and understanding of place?

There are limited bodies of work that look at how technology is used in practice, with post phenomenological work by Hardley and Richardson (2019) and active travel assessment by M. Zhang and Bandara (2024) being the most recent. As well as building on this knowledge, this work also contributes methodologically in its use of Social Practice Theory to analyse the results. In RQ3 the use of SPT gave an unexpected, but welcome, result in its ability to isolate trust as a key factor in the lack of uptake in technology. More specifically, the meanings associated with technology and the coupling between trust and risk. It prompted further need for enquiry into features used as prompts for questioning and reveals, and underlaying requirement for trust in technology if the risk is considered high. Establishing how trust and risk are related in technological adoption has not clearly been established.

I have shown that technology can contribute to women's perception of safety in everyday active travel practice. As well as a communication tool, Women use technology to make better-informed decisions as extensions of their existing safety practices. Artificial intelligence was emphasised for its potential to overcome the contextual limitations of using technology in emergencies, though concerns were raised regarding its current ability to understand the complexities of human understanding. The greatest potential for new (not extensions of existing) practice in the future is the act of crowdsourcing, yet participants were divided over which information could be used to best effect, and how.

9.2 Contribution

Whilst the themes of women's safety and equitable transport have been documented in previous research, the contribution of technology within the domain of personal safety has

been less comprehensively covered. This thesis contributes to the body of work on women's safety, active travel, and technology use. More specifically, it contributes to the understanding of how technology integrates in to the existing lived experiences of women.

Methodologically, it has contributed to three main areas:analysis of social media data, methodological approaches in HCI and social science research, and the use of social practice theory to research technology in practice. Contributions to knowledge through user insight also have significance with respect to human-computer interaction and social science research.

Maching learning (BERT and M3 Inference), was adopted to collect and interrogate social media data. Whilst BERT has been performed previously on Twitter data, I contend that there exists a certain novelty in the fact that it has not previously been used for acts of harassment in public spaces, or using the idea of mitigation against keyword biasing. BERT was able to effectively group Tweets based on their context, as inferred from the sentence encoding, and demonstrates that data collection through keyword selection can be minimised. The process integrated a gender inference machine learning model, which enabled a degree of intersectionality in active travel experience to be investigated through this data. As well as the methodological component, the study was able to provide further insights into the experiences and views of users. Harassment events, that were unlikely to have been reported to authorities, were readily recorded and views were revealed at both a macro (male users who were unsure of what harassment was) and micro level (individual users). Whilst there were technical challenges associated with dealing with large quantities of data, the work demonstrated the ability of technology to discover trends in harassment opinions and reports through the classification of data.

The approaches used in the focus groups, such as storyboarding, also extend previous HCI and social science research, both in the understanding of how technology is used by women in their practices of active travel and methodologically in the use of HCI storyboards to enable the incorporation of prospective technologies into existing practice.

Social practice theory offered an organised perspective to investigate how technology, behaviours, and social environments are interconnected. This theory was used to investigate how personal safety technologies are incorporated into everyday routines, the interpretations given to these technologies by users, and the skills needed for their successful implementation. Having not been used previously with respect to the application of digital technology to the active travel domain, to my knowledge, the findings obtained from this research provide a novel perspective on how users perceive and make use of these technologies in their daily routines. The work contributes methodologically through the use of social practice theory as a lens to identify the materials, competencies, and meaning required to undertake active travel, building on previous work where the materiality of practice was explored. As far as I am aware, this is the first time that the theory has been used to analyse technology for personal safety, and in an active travel context.

9.3 Summary

The thesis challenges rather than discredits the optimistic viewpoint of many authors, asking instead that efforts are focused on supporting the existing safety practices of women and instances where technology has already been successfully adopted, such as, the instinctive behaviours involved in planning routes with information to make assessments thereof. These practices take place to remedy the fear and risk associated with criminal actions. The introduction of technology has already enabled transformation of these ingrained practices, where the affordance of communication and letting people know where you are has changed from a landline phone at your destination, to a text or call from a mobile, to letting friends track you on WhatsApp. These are adaptions to existing behaviours rather than new ones emerging. While tracking is considered an extension of this communicative behaviour, the use of a drone, for example, is perhaps too big a jump from those existing practices.

9.3.1 Limitations and Future Research

While some conclusions can be drawn from the current findings, it is evident that ongoing research is necessary to keep pace with technological development. Several key areas have been identified for future research.

The social media study was not completed as initially designed and is therefore unresolved in some aspects of its initial conception. The intention was to retrieve all data relating to the experience of active travel rather than be specific about a safety. Tweets would be retrieved where experience of public space was identified, with the analysis completed using the process detailed in section 4.2. The work completed to date demonstrates the opportunity for future enquiry at this proposed larger scale. Other extensions include using data sources outside the Twitter dataset, and the inclusion of emojis, imagery, and videos.

Some findings of the focus groups detailed in Chapter 7 are inconsistent with those of (Kaur et al., 2022), emphasising the need for further studies to address cultural differences on preferences with respect to technology-related practice.

The focus groups involved a statistically small sample size, which means the opinions expressed are not representative of a larger population and can only be indicative of the sample selected. Further research is therefore needed to expand understanding beyond the demographics of the participants within these focus groups, and should consider qualitative investigations that focus on the intersectionality identities of users.

Research evidencing links between perceived risk, trust, and technology adoption rates is scant. More research into how the modification of trust in technology varies with potential risk could be advantageous, with implications for other fields of AI research as well as personal safety.

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Appendix A

HCI Storyboards

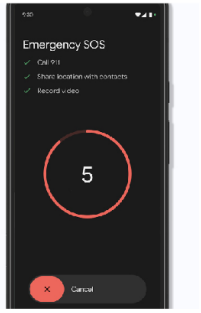
FEATURE A

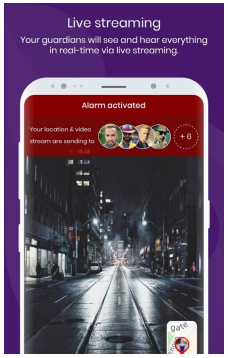
PANIC BUTTON (SOS)

A mobile safety application that provides an instant alert to a monitoring company, the emergency services or friends and family when the user feels they are in danger.

Examples

One Scream - www.noonlight.com
Run Angel -https://runangel.com
bsafe - www.getbsafe.com
SOS Alert - https://play.google.com/store/apps/
Shake2Safety - https://en-gb.facebook.com/Shake2Safety/
Wandersafe - www.wandersafe.com





1. The panic button can be activated by one or more of the following ways:
   i. Voice activation using keywords or scream/sound detection
   ii. Pressing or letting go of a button on the application
   iii. Shaking the mobile device
   iv. Using a separate physical device (like a wrist band) that is connected to the mobile device

2. After activation, the panic button may cause one or more of the following things to happen:
   i. Emit a loud siren
   ii. Communicate with emergency authorities
   iii. Communicate with nominated friends and family
   iv. Communicate with others using the same application in the vicinity
   v. Start to capture audio, video or images from cameras on the device. These are sometimes shared in real time with your nominated 'guardians'.
3. The user's location is shared, and the other users can contact the authorities on their behalf
4. In some cases, recording from the user's device is also shared with authorities and named contacts

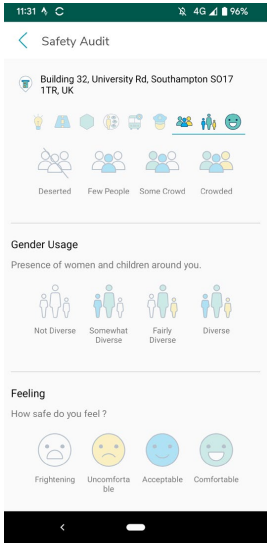
FEATURE B

CROWD SOURCING /REPORTING (INFORMAL)

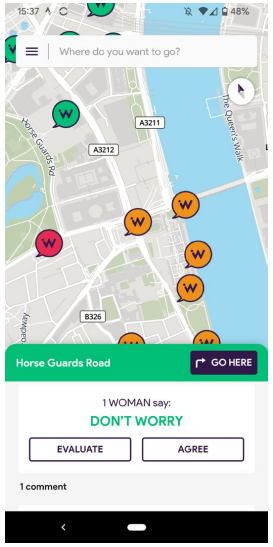
A mobile safety application that has a reporting function that allows users to report information to the platform. These are geo-located in the application and are used to inform safer routing as well feedback information to interested parties.

Examples

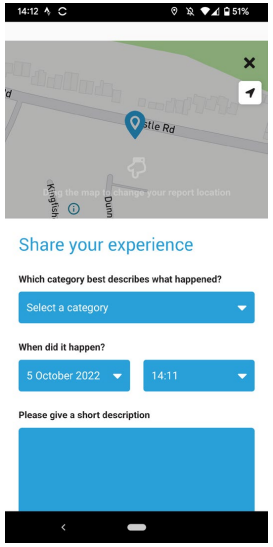
Wandersafe - www.wandersafe.com
Citizen - https://citizen.com/
Walksafe - https://www.walksafe.io/
Safe in the City - https://www.safeandthecity.com/
SafetiPin - https://safetipin.com/
Path (Community Safety) - https://www.pathcommunity.co/
Wher - https://w-her.com/en/



Safetipin User Interface



Wher User Interface



Safe in the City User Interface

1. The user can report safety concerns. Whilst the applications suggests categories, anything can be reported using the 'other' option.

2. Reporting detail and complexity varies between the applications.

3. Reports may or may not be viewed by other users on the application

Please see full list of reportable items in the Crowdsourcing_Feature_B_continued.pdf

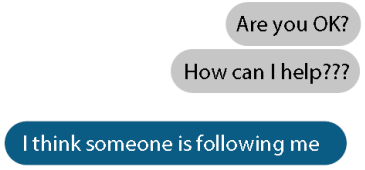
FEATURE C

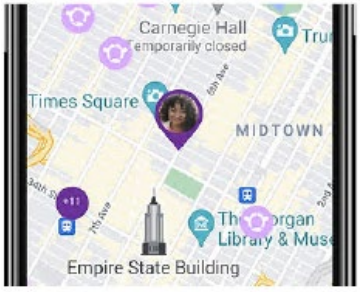
SOCIAL NETWORKS

A mobile safety application that connects women to each other in times of need.

Examples

Sorority - https://en.jointhesorority.com
Safe Up - https://www.safeup.co/
Sister - https://joinsister.com/en/
Wandersafe - www.wandersafe.com





Safe Up User Interface

1. User can report when they consider themselves to be immediate danger
2. Alert sent to other users in the locality
3. Alerted people can contact the person who created the alert. Depending on the application this can be via **text messaging, voice or video calling**.
4. In the case of one application (Safe Up) a training session is provided to users to accept calls for help.
5. The user's location is shared, and the other users can contact the authorities on their behalf

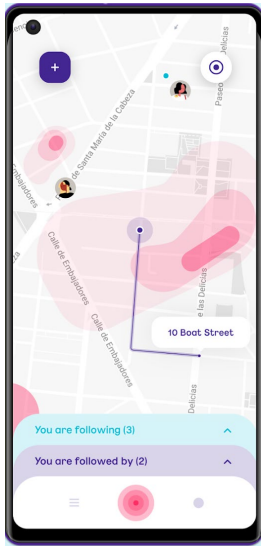
FEATURE D

ROUTE PLANNING (PRIORITISING SAFETY)

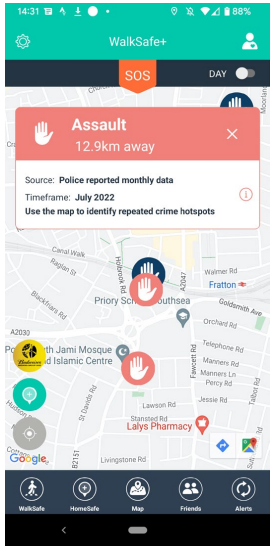
A mobile safety application that plans a route based on either crowd sourced or police data.

Examples

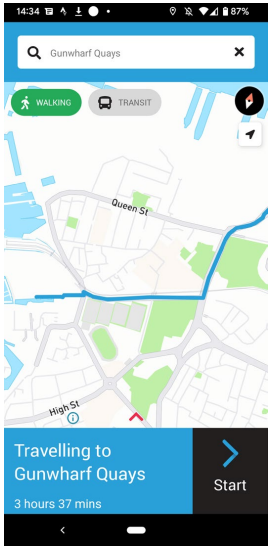
Walksafe - https://www.walksafe.io/
Safe in the City -https://www.safeandthecity.com/
SafetiPin - https://safetipin.com/
Sister - https://joinsister.com/en/
Wher - https://w-her.com/en/



Sister User Interface



Walksafe User Interface



Safe in the City User Interface

1. Safety specific applications use either crowd sourced or police data to suggest safer routes. Some applications will route individuals using main roads. Or individuals may choose their own route by avoiding crime hotspots displayed by the application.

Please see some examples of the applications mapping interfaces to the left.

Sister - risk areas show where other users asked for help

Walksafe - risk points taken from police data of assaults and knife crime and priorities main roads

Safe in the City - No risk areas are shown however crowd sourced reports (through the app) are used for route planning

FEATURE E

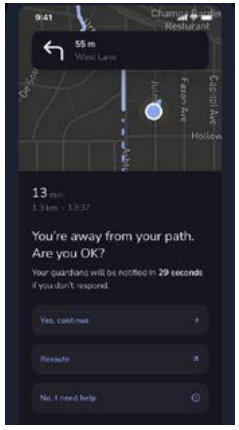
AUTOMATIC ALERTING

A mobile safety application (sometimes connected to an additional personal device such as an activity watch) that can detect irregular behaviour. When detected the application or device can alert nominated individuals to your whereabouts using a mobile phone connection

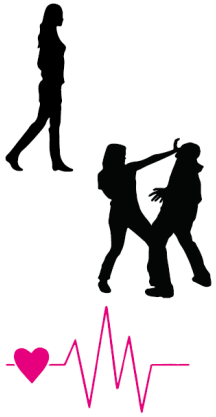
Examples

Garmin Connect - https://connect.garmin.com/
Noonlight - https://www.noonlight.com/
Path Community Safety - https://www.pathcommunity.co/
Hollie Guard - https://hollieguard.com/
Epowar - https://epowar.com/://runangel.com
bsafe - www.getbsafe.com
SOS Alert - https://play.google.com/store/apps/
Shake2Safety - https://en-gb.facebook.com/Shake2Safety/

Wandersafe - www.wandersafe.com



Path Community Safety
User Interface



bsafe User Interface

1. Automate alerting can be activated in the following ways.
   i. Basic Functionality
   ii. Deviation from pre-planned route
   iii. Time-out Periods
   iv. More complex methods using data collection that infers levels of distress
   v. Biometric indicators (e.g. Heart rate)
   vi. Movement detection (e.g. acceleration)

2. **Epowar** uses AI to determine when an individual is in distress using movement and biometric indicators in unison.

3. Like the Panic button the application may do one or more of the following.
   iii. Emit a loud siren
   iv. Communicate with emergency authorities
   v. Communicate with nominated friends and family
   vi. Communicate with others using the same application in the vicinity
   vii. Start to capture audio, video or images from cameras on the device

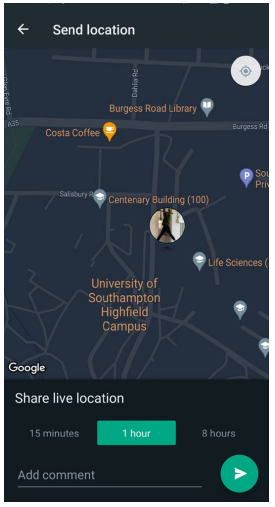
FEATURE F

TRACKING / LOCATION SHARING

A mobile safety application that allows users to share their geographical location with other users in real time.

Examples

Bsafe - https://www.getbsafe.com/
Citizen - https://citizen.com/
Glympse - https://app.glympse.com/
Guardians - https://www.getguardians.com/
Hollieguard - https://hollieguard.com/
Imsafe - www.imsafe.app
She/Safe - https://shesafe.org/
Sister - https://joinsister.com/en/
Wearsafe - https://wearsafe.com/
Whatsapp - https://www.whatsapp.com/



WhatsApp User Interface

Guardians User Interface

bsafe User Interface

1. Share with any of your contacts your live location.
2. A notification is sent to them so they are aware you would like to be followed virtually.
3. Once the user finishes the journey, location sharing can be stopped. **WhatsApp** asks users if they want to share for a set time period.

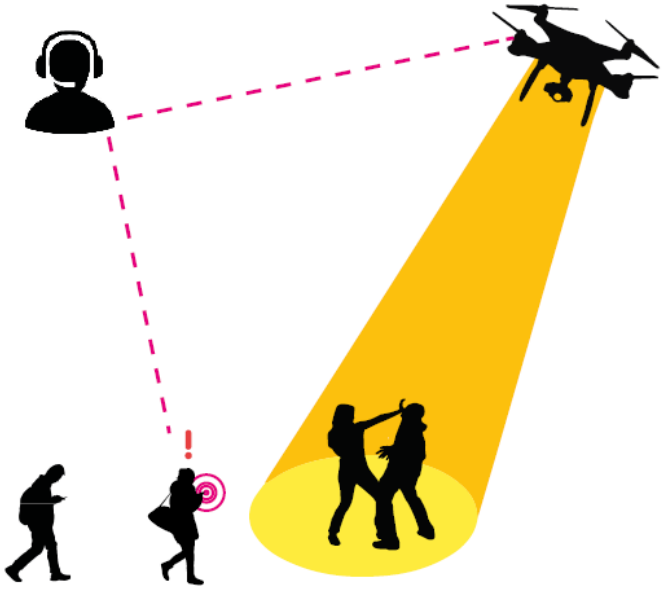
FEATURE G

DRONE ESCORT

A service that allows users to summon a drone to their location using a mobile application.

Examples

Drone Defence - https://www.dronedefence.co.uk/.com



1. A drone would be summoned on a mobile application by an individual who fears a predator is nearby to deter would-be attackers
2. The drone would arrive within 4 minutes
3. Powerful spotlights and thermal cameras to scare off would-be sex attackers and stalkers

Appendix B

Social Media Study Additional Data

Name	Version	Build	Channel
absl-py	0.13.0	pypi_0	pypi
aiohttp	3.7.4.post0	pypi_0	pypi
argon2-cffi	20.1.0	py39h2bbff1b_1	
astunparse	1.6.3	pypi_0	pypi
async-timeout	3.0.1	pypi_0	pypi
async_generator	1.1	pyhd3eb1b0_0	
attrs	21.2.0	pyhd3eb1b0_0	
backcall	0.2.0	pyhd3eb1b0_0	
bertopic	0.9.4	pypi_0	pypi
blas	1	mkl	
bleach	4.1.0	pyhd3eb1b0_0	
bottleneck	1.3.2	py39h7cc1a96_1	
brotlipy	0.7.0	py39h2bbff1b_1003	
ca-certificates	2022.2.1	haa95532_0	
cachetools	4.2.2	pypi_0	pypi
certifi	2021.10.8	py39haa95532_2	
cffi	1.15.0	py39h2bbff1b_0	
chardet	4.0.0	pypi_0	pypi
charset-normalizer	2.0.4	pyhd3eb1b0_0	
clang	5	pypi_0	pypi
click	8.0.3	pypi_0	pypi
colorama	0.4.4	pyhd3eb1b0_0	
conda	4.11.0	py39haa95532_0	

Name	Version	Build	Channel
conda-package-handling	1.7.3	py39h8cc25b3_1	
cryptography	36.0.0	py39h21b164f_0	
cudatoolkit	11.3.1	h59b6b97_2	
cudnn	8.2.1	cuda11.3_0	
cython	0.29.23	pypi_0	pypi
debugpy	1.5.1	py39hd77b12b_0	
decorator	5.1.0	pyhd3eb1b0_0	
defusedxml	0.7.1	pyhd3eb1b0_0	
entrypoints	0.3	py39haa95532_0	
filelock	3.4.2	pypi_0	pypi
flatbuffers	1.12	pypi_0	pypi
freetype	2.10.4	hd328e21_0	anaconda
fsspec	2021.8.1	pypi_0	pypi
future	0.18.2	pypi_0	pypi
gast	0.4.0	pypi_0	pypi
gensim	4.1.0	pypi_0	pypi
git	2.34.1	haa95532_0	
google-auth	1.35.0	pypi_0	pypi
google-auth-oauthlib	0.4.6	pypi_0	pypi
google-pasta	0.2.0	pypi_0	pypi
grpcio	1.40.0	pypi_0	pypi
h5py	3.1.0	pypi_0	pypi
hdbscan	0.8.27	py39h5d4886f_0	conda-forge
huggingface-hub	0.4.0	pypi_0	pypi
icc_rt	2019.0.0	h0cc432a_1	
icu	58.2	ha925a31_3	
idna	3.3	pyhd3eb1b0_0	
importlib-metadata	4.8.2	py39haa95532_0	
importlib_metadata	4.8.2	hd3eb1b0_0	
intel-openmp	2021.4.0	haa95532_3556	
ipykernel	6.4.1	py39haa95532_1	
ipython	7.29.0	py39hd4e2768_0	
ipython_genutils	0.2.0	pyhd3eb1b0_1	
ipywidgets	7.6.5	pyhd3eb1b0_1	

Name	Version	Build	Channel
jedi	0.18.0	py39haa95532_1	
jinja2	3.0.2	pyhd3eb1b0_0	
joblib	1.1.0	pyhd8ed1ab_0	conda-forge
jpeg	9d	h2bbff1b_0	
jsonlines	3.0.0	pypi_0	pypi
jsonschema	3.2.0	pyhd3eb1b0_2	
jupyter	1.0.0	py39haa95532_7	
jupyter_client	7.1.0	pyhd3eb1b0_0	
jupyter_console	6.4.0	pyhd3eb1b0_0	
jupyter_core	4.9.1	py39haa95532_0	
jupyterlab_pygments	0.1.2	py_0	
jupyterlab_widgets	1.0.0	pyhd3eb1b0_1	
keras	2.6.0	pypi_0	pypi
keras-preprocessing	1.1.2	pypi_0	pypi
libpng	1.6.37	h2a8f88b_0	
libtiff	4.1.0	h56a325e_1	anaconda
libuv	1.40.0	he774522_0	
libwebp	1.1.0	he774522_0	anaconda
llvmlite	0.38.0	pypi_0	pypi
lz4-c	1.9.2	hf4a77e7_3	anaconda
m2w64-gcc-libgfortran	5.3.0	6	
m2w64-gcc-libs	5.3.0	7	
m2w64-gcc-libs-core	5.3.0	7	
m2w64-gmp	6.1.0	2	
m2w64-libwinpthread-git	5.0.0.4634.697f757	2	
m3inference	1.1.5	pypi_0	pypi
markdown	3.3.4	pypi_0	pypi
markupsafe	2.0.1	py39h2bbff1b_0	
matplotlib-inline	0.1.2	pyhd3eb1b0_2	
menuinst	1.4.18	py39h59b6b97_0	
mistune	0.8.4	py39h2bbff1b_1000	
mkl	2021.4.0	haa95532_640	

Name	Version	Build	Channel
mkl-service	2.4.0	py39h2bbff1b_0	
mkl_fft	1.3.1	py39h277e83a_0	
mkl_random	1.2.2	py39hf11a4ad_0	
msys2-conda-epoch	20160418	1	
multidict	5.1.0	pypi_0	pypi
nbclient	0.5.3	pyhd3eb1b0_0	
nbconvert	6.1.0	py39haa95532_0	
nbformat	5.1.3	pyhd3eb1b0_0	
nest-asyncio	1.5.1	pyhd3eb1b0_0	
nltk	3.6.7	pypi_0	pypi
notebook	6.4.6	py39haa95532_0	
numba	0.55.0	pypi_0	pypi
numexpr	2.8.1	py39hb80d3ca_0	
numpy	1.19.5	pypi_0	pypi
numpy-base	1.21.2	py39h0829f74_0	
oauthlib	3.1.1	pypi_0	pypi
olefile	0.46	py_0	anaconda
openssl	1.1.1m	h2bbff1b_0	
opt-einsum	3.3.0	pypi_0	pypi
packaging	21.3	pyhd3eb1b0_0	
pandas	1.3.5	py39h6214cd6_0	
pandocfilters	1.4.3	py39haa95532_1	
parso	0.8.3	pyhd3eb1b0_0	
pickleshare	0.7.5	pyhd3eb1b0_1003	
pillow	8.4.0	py39hd45dc43_0	
pip	21.2.4	py39haa95532_0	
plotly	5.5.0	pypi_0	pypi
prometheus_client	0.12.0	pyhd3eb1b0_0	
prompt-toolkit	3.0.20	pyhd3eb1b0_0	
prompt_toolkit	3.0.20	hd3eb1b0_0	
protobuf	3.17.3	pypi_0	pypi
pyasn1	0.4.8	pypi_0	pypi
pyasn1-modules	0.2.8	pypi_0	pypi
pycld2	0.41	pypi_0	pypi
pycosat	0.6.3	py39h2bbff1b_0	
pycparser	2.21	pyhd3eb1b0_0	
pydeprecate	0.3.1	pypi_0	pypi

Name	Version	Build	Channel
pygments	2.10.0	pyhd3eb1b0_0	
pynndescent	0.5.5	pypi_0	pypi
pyopenssl	21.0.0	pyhd3eb1b0_1	
pyparsing	3.0.4	pyhd3eb1b0_0	
pyqt	5.9.2	py39hd77b12b_6	
pyrsistent	0.18.0	py39h196d8e1_0	
pysocks	1.7.1	py39haa95532_0	
python	3.9.7	h6244533_1	
python-dateutil	2.8.2	pyhd3eb1b0_0	
python_abi	3.9	2_cp39	conda-forge
pytorch-lightning	1.4.6	pypi_0	pypi
pytorch-mutex	1	cuda	pytorch
pytz		pyhd3eb1b0_0	
pywin32	302	py39h827c3e9_1	
pywinpty	0.5.7	py39haa95532_0	
pyyaml	5.4.1	pypi_0	pypi
pyzmq	22.3.0	py39hd77b12b_2	
qt	5.9.7	vc14h73c81de_0	
qtconsole	5.1.1	pyhd3eb1b0_0	
qtpy	1.10.0	pyhd3eb1b0_0	
rauth	0.7.3	pypi_0	pypi
regex	2021.11.10	pypi_0	pypi
requests	2.27.1	pyhd3eb1b0_0	
requests-oauthlib	1.3.0	pypi_0	pypi
rsa	4.7.2	pypi_0	pypi
ruamel_yaml	0.15.100	py39h2bbff1b_0	
sacremoses	0.0.47	pypi_0	pypi
scikit-learn	1.0.2	py39hf11a4ad_0	
scipy	1.7.3	py39h0a974cb_0	
send2trash	1.8.0	pyhd3eb1b0_1	
sentence-transformers	2.1.0	pypi_0	pypi
sentencepiece	0.1.96	pypi_0	pypi
setuptools	60.5.0	pypi_0	pypi
sip	4.19.13	py39hd77b12b_0	
six	1.15.0	pypi_0	pypi
smart-open	5.2.1	pypi_0	pypi
sqlite	3.37.0	h2bbff1b_0	

Name	Version	Build	Channel
tenacity	8.0.1	pypi_0	pypi
tensorboard	2.6.0	pypi_0	pypi
tensorboard-data-server	0.6.1	pypi_0	pypi
tensorboard-plugin-wit	1.8.0	pypi_0	pypi
tensorflow	2.6.0	pypi_0	pypi
tensorflow-estimator	2.6.0	pypi_0	pypi
termcolor	1.1.0	pypi_0	pypi
terminado	0.9.4	py39haa95532_0	
testpath	0.5.0	pyhd3eb1b0_0	
threadpoolctl	3.0.0	pyh8a188c0_0	conda-forge
tk	8.6.10	he774522_0	anaconda
tokenizers	0.10.3	pypi_0	pypi
torch	1.11.0	pypi_0	pypi
torchaudio	0.9.0	pypi_0	pypi
torchmetrics	0.5.1	pypi_0	pypi
torchvision	0.10.0+cu111	pypi_0	pypi
tornado	6.1	py39h2bbff1b_0	
tqdm	4.62.3	pyhd3eb1b0_1	
traitlets	5.1.1	pyhd3eb1b0_0	
transformers	4.15.0	pypi_0	pypi
typing-extensions	3.7.4.3	pypi_0	pypi
typing_extensions	3.10.0.2	pyh06a4308_0	
tzdata	2021e	hda174b7_0	
umap-learn	0.5.2	pypi_0	pypi
urllib3	1.26.7	pyhd3eb1b0_0	
vc	14.2	h21ff451_1	
vs2015_runtime	14.27.29016	h5e58377_2	
wcwidth	0.2.5	pyhd3eb1b0_0	
webencodings	0.5.1	py39haa95532_1	
werkzeug	2.0.1	pypi_0	pypi
wheel	0.37.1	pyhd3eb1b0_0	
widgetsnbextension	3.5.1	py39haa95532_0	
win_inet_pton	1.1.0	py39haa95532_0	
wincertstore	0.2	py39haa95532_2	

Name	Version	Build	Channel
winpty	0.4.3	4	
wrapt	1.12.1	pypi_0	pypi
xgboost	1.4.2	pypi_0	pypi
xz	5.2.5	h62dcd97_0	anaconda
yaml	0.2.5	he774522_0	
yarl	1.6.3	pypi_0	pypi
zipp	3.7.0	pyhd3eb1b0_0	
zlib	1.2.11	h8cc25b3_4	
zstd	1.4.4	ha9fde0e_3	anaconda
zlib	1.2.11	h8cc25b3_4	
zstd	1.4.4	ha9fde0e_3	anaconda

TABLE B.2: Python libraries used for scoping study

TV Shows	46 - Brand Category	79 - Video Game Hardware	115 - Video Game Conference
4 - TV Episodes 6 - Sports Events	47 - Brand	84 - Book Music Genre	116 - Video Game Tournament
10 - Person	48 - Product	85 - Book Genre	117 - Movie Festival
11 - Sport	49 - Product Version	86 - Movie	118 - Award Show
12 - Sports Team 26 - Sports League	54 - Musician	87 - Movie Genre	119 - Holiday
27- American Football Game	55 - 56 - Actor	88 - Political Body	120 - Digital Creator
28 - NFL Football Game	58 - Entertainment Personality	89 - Music Album	122 - Fictional Character
35 - Politicians	60 - Athlete	90 - Radio Station	130 - Multimedia Franchise
38 - Political Race	65 - Interests and Hobbies Vertical	91 - Podcast	132 - Song
39 - Basketball Game	66 - Interests and Hobbies Category	92 - Sports Personality	136 - Video Game Personality
40 - Sports Series	67 - Interests and Hobbies	93 - Coach	137 - eSports Team
45 - Brand Vertical	68 - Hockey Game 71 - Video Game	94 - Journalist	138 - eSports Player
	78 - Video Game Publisher	110 - Viral Accounts 114 - Concert	139 - Fan Community

Table B.1: Twitter set context