Understanding Pedestrians' Perception of Safety and Safe Mobility Practices

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ABSTRACT

Walking is one of the greenest and most common travel modes. However, evidence shows a trend of decreased walking, and safety is a key barrier preventing many people from walking. Additionally, there is a limited understanding of pedestrians' safe mobility practices and safety perception. Drawing on 449 survey responses from a representative sample in the United Kingdom, our work highlights how identities and walking situations intersect with individuals' safety perceptions and diverse practices of pedestrians' safe mobility. The role of technology used for negotiating safety and current challenges in both safe route planning and walking are also highlighted. Our work extends existing insights into pedestrians' perception of safety and practices by adding empirical evidence and more nuanced contexts. This paper proposes two implications for design in response to design opportunities that surfaced from our mixed-method data analysis. Both the contributions and limitations of our work are also discussed.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI); Empirical studies in HCI**;

KEYWORDS

Pedestrian safety, safe mobility, perceived safety, safety, safe walk, personal safety, safe route navigation

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1 INTRODUCTION

Mobility is an essential part of human life. The diversity of mobility options includes walking, cycling, vehicular driving, public transport, etc. Walking is the most common mode of travel because it is inexpensive and accessible to most people. Walking has lots of benefits for physical health [40, 40], mental health [51], the environment [76], and communities [110]. For example, medical research has confirmed the effectiveness of physical activities in preventing several chronic diseases (e.g., diabetes, cancer, obesity, hypertension, and depression) and premature death [102]. However, the National Travel Survey has found that walking trips in England decreased in 2020 [23], and over a fifth (22%) of the UK (United Kingdom) population never walk for leisure or exercise [59]. Many factors that affect people's walking decision-making have been identified in the literature, with safety being one of the most important factors [45, 48] that prevent pedestrians from walking and lead people to switch to alternative travel modes [48]. In the most recent Living Street survey [59], people report not feeling safe walking alone, which is the second most-mentioned barrier to walking. Another UK-nationwide Opinions and Lifestyle Survey [97] asked about feelings of personal safety when walking alone in different public settings. Based on a sample of 16,112 adults, it is found that people feel less safe walking alone after dark and women are more likely to feel unsafe than men.

HCI scholars also highlighted that safety concerns could influence people's use of space [83]. In the street harassment survey conducted in 42 cities around the world [21], it was found that 85% of women chose a different route home or a destination, 67% changed the time of travel to avoid street harassment or assault, and 68% would avoid the specific areas of a town or city. However, prior work on safety in HCI has mainly focused on the personal safety of people from vulnerable groups, such as women [2, 44, 54, 109], school children [98], LGBTs [84], and transgender people [84, 93], and communities from the global south [1, 2, 12, 108]. A critique of current HCI work on safe mobility is that HCI researchers put more focus on mobile technology, rather than mobility [103]. Indeed, there is limited empirical work that explores safe mobility practices [43, 104] of people with diverse identities and how they use existing technology to mitigate their safety concerns. Our research aims to fill this gap in HCI research. Specifically, we investigate the following two research questions:

RQ1*: What are people's perceptions of safety during walking?*

RQ2*: What are the current practices of people managing their safety when planning and taking walks?*

We examined these research questions through an online survey with both open-ended and close-ended questions. Based on 449 responses from a representative sample of UK residents, this paper reports on the current practices of pedestrians when managing their safety during planning and walking. The findings highlight how intersections of identity and walking situations affect pedestrians' safety concerns and strategies for managing safety during planning and walking, and the role of technology in safe walking and its challenges are also emphasized. In this paper, we consider the term '*safety*' as the state of absence of harm and loss caused by arbitrary or intentional human and technical failure [52]. Hence,

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we refer to '*safety concern*' as the feeling of worry about potential harms such as perceived traffic hazards and perceived risks of being a victim of crime. We adopted the definition of perceived personal safety from Chandok [19], "*a person's immediate sense of security and an absence of anxiety of becoming victimized when traveling through a particular environment at any given location*." Our work extends the literature on pedestrian safety perception and practices by providing empirically grounded evidence of how different identities and more nuanced situations interact with pedestrian safety perception and situated practices. This enriches the HCI community's understanding of design considerations for safe route planning and navigation technology.

2 RELATED WORK

To answer our research questions, we consider safe mobility to include both walk planning and safe walking during the journey. Therefore, we review the related work in three areas: 1) pedestrian road choice and safety concerns, 2) Safe route planning (before the journey), and 3) Technology-mediated personal safety (support during the journey).

2.1 Pedestrian Route Choice & Safety

Pedestrians make many decisions before and during walking [6], and one of the tactical decisions made for walking is pedestrian route choice [49], which is a complex process. According to Tong & Bode [99], pedestrians subjectively perceive, integrate, and respond to the limited available information, and make their trade-off choice of route and this decision-making process varies with the context. A recent systematic review [6] has revealed a total of 105 factors associated with pedestrian route choice which were divided into three categories: socio-demographic factors, built environment factors, and trip characteristics (e.g., familiarity). Pedestrian demographics (e.g., gender, age, disability) have been widely explored in deciding route choices. Because mobility-impaired pedestrians may consider road accessibility instead of the distance of the route, and people with visual impairment may prefer to take a safer route even if it takes longer [99]. Much attention has been given to studying built environment factors (see [4, 7, 94] for review) and it is demonstrated that pedestrian's perceived safety is a function of a wide range of built environmental factors [29, 48]. Martin [66] has reviewed the built environmental factors influencing pedestrian perceived traffic safety by analyzing factors in the causation of historical pedestrian collisions, such as pedestrian crossings and type of road [60]. It has been demonstrated that some built environment characteristics play key roles in encouraging or deterring crime in urban areas [61]. Certain places may encourage criminal activities, thus easily evoking fears. For instance, abandoned buildings, bars, bus/train stations, and adult bookstores are considered to attract crime; while other places featuring '*defensive space*' may mitigate crime [72], e.g., good lighting and visibility, the Neighborhood Watch sign. Other reviews have suggested that perceived safety [4] is one of the most crucial factors influencing pedestrians' route choice [27].

Pedestrian safety has been explored from two aspects in prior work: traffic safety and crime safety. While some researchers have differentiated '*safety*' from '*security*' based on intentionality [6, 52]: safety is mainly related to harm caused by non-intentional events such as road/traffic safety, while security is related to deliberate acts of people such as criminal activities, most of the research uses the terms '*safety*' and '*security*' interchangeably. Safety concerns have frequently emerged from the literature as barriers to walking [15, 30]. The perceived safety [45, 48], such as fear of crime [27], prevents pedestrians from walking and leads people to switch to alternative travel modes [48]. Foster et al. [29] found that the gendered concern about personal safety constrains women's route choices [20, 74, 85]. For example, women may have a fear of crime when they are alone [62] and are less likely to walk alone or at night. Fear of crime [30] is an individual's anxious emotional state [90] due to the perceived likelihood of being victimized [73]. Gates and Rohe's model [39] categorized three types of reactions to fear of crime: avoidance, collective, and protective behavior. For example, the elderly [13] or lone females [26, 63] are more likely to take avoidant or preventive actions [24, 47]. The uncertainty in unfamiliar contexts (e.g., strangers, places) may increase anxiety [70] and be perceived as unsafe [64, 75]. An increased fear level may lead pedestrians to take detours to avoid certain places or critical times of the day [77] or even avoid or minimize walking [48].

2.2 ICT for Safe Route Planning

The last few decades have seen growing research interest in human-centered pedestrian route planning and navigation [37]. Safety is increasingly considered a key factor given that active travel (walking, wheeling, cycling) [50] has been promoted by many governments. Previous research in safe pedestrian route planning could be categorized into two groups: *accident-free* and *crime-free* [92].

The accident-free route planning systems mainly consider historical accidents [41] and built environment factors, such as landmarks [5, 33], route accessibility (e.g., slope, steepness, curb ramps) [3, 35], and lightning and width of routes [5]. Some systems were developed to reduce physical safety risks, especially for specific population groups. For example, *AccessMap* [3] was proposed to recommend accessible routes to users with limited mobility. Most existing crime-related safe route planning systems recommend a safe route based on crime probability models [34] and provide a hot spot crime map visualizing and representing risks geographically. Historical crime data [34, 69, 87, 88] and social media data [32, 55] are the main resources considered; some systems also adopt crowdsourced data such as user-reported crime [58] or user ratings of safety perception [41]. For example, the *TREADS* safe route recommendation system [32] used location-based Twitter data and Yelp reviews to improve the travel experience in an unfamiliar city; *SafeRoute* [58] used recent crowdsourced crime data (shooting, assault, and robbery) from *SpotCrime*[1] to provide safe routes from street harassment for non-vehicular users. Some mobile technologies go further by combining accident data and crime data [41, 81], as well as post-crime support during the journey. For example, Sandeep et al. [38] combined accident data and crime data from the *New York City Open Data* to come up with a risk score [81]. Goel et al. [41] have proposed a proof-of-concept system, which combined static data (historical accident and crime data, route qualities from government databases) with dynamic data (online news and crowdsourced user feedback of the journey).

[1]https://spotcrime.com/

However, it is worth noting that current safe route planning technologies are very data-dependent, and lack of relevant data is the typical culprit of the limited applicability of these systems [68]. Most of the previous research was conducted by researchers in public health, sociology, urban planning, and policing; some work focused on specific users or sophisticated methods. As a result, many safe route planning systems are implemented as proof-of-concept and lack applicability evaluation by users in the real world.

2.3 Technology-mediated Personal Safety

HCI researchers have examined personal safety from a variety of perspectives across a range of platforms for a few decades, especially focusing on the personal safety of individuals from vulnerable groups, such as women [2, 44, 54, 109], school children [98], LGBT [84], and transgender individuals [84, 93]. For example, Blom et al. [12] identified the need to alleviate the fear of women living in an urban context. Starks et al. [93] interviewed 9 transgender and non-binary individuals to understand how participants use existing technology to navigate safely in the physical world, and they found that participants managed safety by using text messaging, social media, and phone calls to inform friends of their location.

There are many personal safety mobile apps on the market (see [28, 67] for personal safety app reviews). The technologies designed for increasing personal safety mainly target enabling social interactions digitally: 1) connecting with other people physically or virtually on the route, 2) allowing pedestrians to report suspicious activities or unsafe places, and 3) post-crime support such as emergency calls or forensic evidence capture. For example, Bhowmick et al. [10, 11] have proposed the walking buddy scheme based on the assumption that the presence of other people in proximity could reduce the likelihood of victimization [10]; *Safe Mathare* [44] helped women in Kenya commute safely during dusk and dawn hours. *ComfortZones* [12] was designed to mitigate fear at night in the urban context by allowing people to share safety concerns and seek social support and interactions. The wearable technology U-Signal [93] facilitates users in sending out an SOS emergency message and location to their pre-designated emergency contacts. Some applications provide real-time warnings and incident details such as disturbances, disasters, and threats (e.g., the *WalkSafe* app [101] detects vehicles to aid in walking and talking). Users can report information about areas where a suspicious activity or crime is taking place, other users can then avoid serious crime areas by geofencing to choose a safe route [12, 53, 88]. Similarly, *Safe Street Rangers* [96] allows users to monitor and report road safety concerns such as lighting and road conditions.

However, understanding pedestrians' perceptions of safety and the use of personal safety technology is still limited. One preliminary qualitative study conducted by Williams et al. [104] indicated that different social identities (e.g., age, gender, race) interact with each other to shape people's experience of safety and navigation strategies. They also highlighted the largely overlooked intersections of identities (especially race) in pedestrian navigation technologies. However, this work is only based on interviews with 12 US-based participants. Our work is built on this theme of empirical understanding of pedestrian safe perception and safe walking practices, and we extend it further by adding broader geographical responses and more nuanced walking contexts, we use mixed methods of data analysis to enhance the validity of our findings. Our work also sheds light on identity-situated pedestrians' safety perceptions, behavioral strategies, the role of technology, and current challenges and barriers to negotiating their safety during pre-walk planning and walking.

3 METHODOLOGY

An online survey was conducted via the online survey platform *Qualtrics*[2]. Participants were a representative sample of adults living in the UK recruited via the *Prolific*[3] platform. The study was approved by our Institutional Review Board under standard practice. Participants were given the option to withdraw their participation at any time. The average time participants took to complete the survey was about 30 minutes, each participant who completed the survey was rewarded with £5 via *Prolific*. Descriptive and inferential statistics were used for analyzing the close-ended questions via *IBM SPSS 28*. The thematic analysis [14] was used for analyzing responses to open-ended questions by using *NVivo 12*, with all authors working on coding and discussing the themes that emerged from the data.

3.1 Materials

The questionnaire was structured into three parts with 41 study questions and 4 attention check questions. The questions are designed based on the literature review and tested subsequently. The first part asks participants to reflect on their experience and describe their practices of managing their safety when planning and going on walks in the past, together with safety concerns and barriers associated with these activities. Because we wanted to explore pedestrians' perception of walking-related safety, we did not give explicit definitions of '*safety*' and '*safety concern*', instead encouraging participants to freely disclose their views. Examples included "*How do you currently manage your safety when planning pedestrian journeys?*" "*What are the barriers and concerns associated with safety during your walk and planning routes for a walk?*" (For the full questionnaire, see supplementary material). Participants were also prompted to describe their experience of planning and walking in an unfamiliar area because perceptions of being unsafe in this context were reported in the literature [64, 75], together with the need to perform spatial tasks such as navigation [70]. The second part measured participants' safety concerns in different contexts using the 32-item scale (*Cronbach's* $\alpha = 0.922$), considering factors such as familiarity with the route, accessibility of pathway, crime, presence of other people, and travel time. All items were measured on 5-point Likert-type scales ("*strongly disagree*" to "*strongly agree*"). Participant demographics, the frequency and purpose of walking, and the use of existing technology for safe walking were also collected. For this paper, we mainly focused on the responses to the first and second parts of the questionnaire, which are purely based on participants' self-reflection on safe mobility practices.

[2]https://www.qualtrics.com/
[3]https://www.prolific.co/

Table 1: Dependent variables, examples of questions, reliability, and score range.

Dependent variables (Safety concern score related to)	Number of items	Example statement: *I am concerned about my safety when: - (1 = strongly disagree, 5 = strongly agree)*	Cronbach's α	Score Range
Daytime walk	6	*I am walking alone during the daytime*	0.839	6-30
Nighttime walk	6	*I am walking alone during the nighttime*	0.812	6-30
Facility	6	*My route is poorly lit after dark*	0.706	6-30
Crime	6	*My route has crime/incidents that happened recently*	0.779	6-30
Familiarity of route	7	*My journey takes a route that is familiar to me*	0.775	7-35
Presence of others	9	*My journey after dark is through areas with lots of other people in cars*	0.841	9-45
Walk with friends	2	*I am walking with a group of friends/families during the daytime*	0.735	2-10
Walk with strangers	2	*I am walking with other people who I don't know during the daytime*	0.739	2-10
Presence of strangers in the daytime	4	*My journey during the daytime is through areas with lots of other people on foot*	0.804	4-20
Presence of strangers at night	4	*My journey after dark is through areas with lots of other people on foot*	0.760	4-20
Walk with a few strangers	2	*I am walking with a few other people who I don't know during the daytime*	0.739	2-10
Walk with many strangers	2	*I am walking with many other people who I don't know during the daytime*	0.785	2-10
Total safety concern	32	*The sum of all 32 items including the above examples*	0.922	32-160

3.2 Measures

For inferential statistical analysis, dependent variables were measured by adding the 5-point Likert responses of relevant items (Table 1), and this method was guided by [9]. For example, the safety concern score of walking with a few strangers was a sum of responses of two items (statements) about safety concerns on walking with a few strangers during the day and nighttime (See supplementary material for more details).

3.3 Participants

665 participants responded to the survey, and after removing incomplete and failed-attention-check responses, a total of 449 responses were used for data analysis (222 identified as female, 224 male, 3 non-binary; age range 18-84, median 40, see Figure 1 for the distribution of age group, and people aged over 60 is identified as the older people [107]), and the valid return rate was 69.1%. Participants were predominantly White/Caucasian (73.1%), followed by Asian (8.7%), Others/Unknown (6.7%), Black/African American (5.3%), and mixed ethnicity (4%), and 2.2% of participants chose not to disclose their ethnicity information. Most participants had a university education and above (60.1%), followed by secondary education (33%) and others (4%). 47.4% of participants reported living in a semi-urban area, followed by 35.6% from an urban area and 16.9% from a rural area. The majority (92.4%) reported having no long-term mobility issues, and 2.2% of participants needed a walker aid or wheelchair; 2.2% were pushchair users. Most participants walk at least once a day (66.6%), followed by 26.3% of participants walking 2-3 times a week and 6.5% walking once a week or less. Walking for exercise was the most frequently mentioned purpose of walking (72.4%), followed by shopping (55.9%) and day out (37.6%) (see Figure 2).

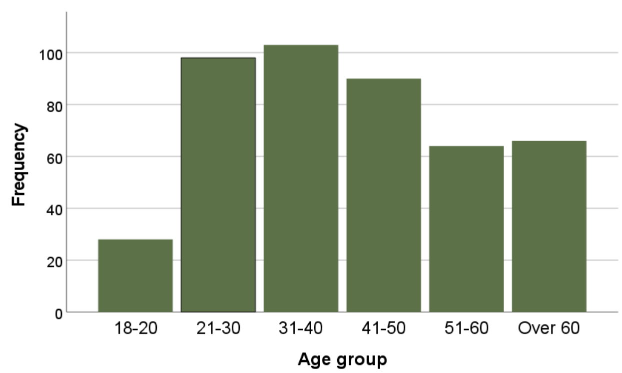

Figure 1: The age group distribution

4 FINDINGS

In organizing the findings, we first present the participants' perception of safety and safety concerns, followed by the participants' current practices in managing their safety before and during their walks, including considering various route choice factors, hybrid ways of getting information, multiple behavioral strategies, and the role of technology played in the safe mobility practices. We then highlight current challenges and barriers in pedestrian route planning and walking.

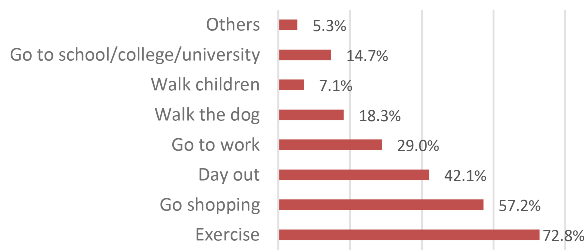

Figure 2: The walking purpose of participants

4.1 Safety Perception and Safety Concerns

Findings show that participants' perceptions of safety include both road safety and crime-related safety before and during walking. We found that safety concerns are shaped by intersections of pedestrians' identities and situations, which we call *identity-situated safety concerns*. Compared with walk planning (10.7%) and arrival at the destination (3.9%) phases, participants were concerned more about their safety during walking (82.3%). We first elaborate on general road safety concerns and crime safety concerns and then introduce the identity-situated safety concerns.

4.1.1 Road Safety Concerns. The risk of injury is the main road safety concern expressed by participants, which might be caused by poorly designed or maintained road facilities and infrastructure, unexpected road work, other road users (e.g., fast cyclists, scooters, motorized vehicles), animals (e.g., vicious dogs not being on a lead), and severe weather (e.g., *heavy rain, flooding, high wind*).

Participants highlighted hazards and risks due to bad pathway conditions, including lack of streetlights, insufficient crossings, poor signage, no pathway along a busy road, faulty traffic lights, rubbish, difficult terrains (e.g., uneven, wet, muddy), road works, and obstructions of pathways (e.g., parked cars on the pavement, overgrown hedges). Participants were concerned about careless drivers and/or cyclists who moved too close to pedestrians and/or too fast without signaling, and some even disobeyed the traffic rules. For example, participants reported: "*Some drivers go through traffic lights when they are changing*" and *"Some cyclists go through a red light around pedestrian crossing*". Therefore, many participants preferred pedestrian-only pathways without sharing with travelers of other modes (e.g., cyclists, and e-scooters). Some participants were worried about the safety of children, as one participant highlighted: "*I am concerned when I see cyclists moving at speed along walkways as I often walk with a young child, and I have to be mindful of them."*

4.1.2 Crime Safety Concerns. Being victimized and fear of crime were reported by most participants as main crime safety concerns. As one participant pointed out: "*When I think of safety, I think of the danger posed by other people, rather than road safety.*" Participants were concerned about being robbed/mugged, attacked, and/or sexually harassed (especially women). For example, one participant suggested, "*more careful using phones when in an area where thieves on two wheels might have opportunities.*" The group of young people hanging around concerned some participants, who thought the youth "*may be a little reckless and less responsible*". Fear of crime was found among some participants. As one participant said: "*fear caused by news, lack of lighting and lack of community policing."* And the fear caused the unpleasant walk: *"We even have to consider safety when out and about walking and can't just enjoy being out and about without fear."*

Moreover, some participants suggested that safety cannot be planned and even out of control during the journey. As one participant said: "*I feel the barriers with safety during a planned walk is that regardless of what area you are in there can always be unexpected dangers that I would not have been able to prepare for such as being attacked or if there are new damages to the path that could cause injuries.*" As one participant stated, "*You just have to assume that everyone could cause harm.*"

4.1.3 Identity-situated Safety Concerns. Our findings highlight the identity-situated safety concerns. We examine the difference in safety concerns among different identity factors (gender, age, ethnicity, living environment), and various situational factors (daylight, presence of strangers or acquaintances, familiarity with the route, crime, infrastructure).

Gender was highlighted as an important safety factor. The independent samples t-tests were performed to explore whether there was a difference in safety concerns between women and men. The results indicated that women had significantly greater safety concerns than men in many situations (see Table 2). For example, women were concerned significantly more about crime-related safety than men, $t(444) = -3.389$, $p<.001$. The effect size, as measured by Cohen's $d = -0.52$, indicates a medium effect. Being a woman makes participants feel vulnerable. Female participants reported restricted walking areas or the time to walk alone, and extra preparation was needed for lone women. Typical examples are: *"Safety is important during walks due to being female and the risks and barriers that I am faced with - not being able to walk at night in certain areas, ensuring my location is trackable, ensuring I pack personal safety equipment for specific walks, etc."; "As a lone woman I avoid areas that I know will have groups of people, particularly, for example, I wouldn't walk close to a pub or club at night"; "The time of day is a huge barrier as I feel like I can only access certain places in the daytime and try not to stay out too late so that I do not have to walk alone at night."* Women walking alone were concerned about being targeted by perpetrators, mostly men. For example, one participant was very conscious of the presence of men: "*Men will always make me cautious, and women will always make me feel safer.*" On the other hand, some male participants reported fewer safety concerns. For example, young males who reported themselves as tall and "*athletically built*" believed that they were "*not a likely target.*" However, the gender difference in safety concerns was not significant among older people (> 60 years old) in many aspects (see Table 3).

The older people were concerned significantly less about familiarity with the place ($t(447) = -2.896$, $p=.004$, with a medium effect size Cohen's $d = -0.39$), but their safety concerns were significantly higher about the crime than other age group ($t(447) = 2.35$, $p=.019$, with small effect size Cohen's $d = 0.31$). As one participant stated: "*Gangs of youths hanging around on street corners. Being older I feel very vulnerable. Where I live the houses have been made into HMOs*

Table 2: Summary of independent t-tests comparing safety concerns between females and males (N=449)

Safety concern score	Female		Male		Independent t-test		
	Mean	SD	Mean	SD	*t*	*p-value*	*Cohen's d*
Daytime walk	16.13	5.27	14.00	5.34	-4.232*	<.001	-0.40
Nighttime walk	21.26	4.24	18.12	5.45	-6.790*	<.001	-0.64
Facility	20.24	3.80	17.45	4.68	-6.916*	<.001	-0.72
Crime	21.26	4.28	18.81	5.13	-5.482*	<.001	-0.52
Familiarity of route	24.59	5.00	21.26	5.95	-6.011*	<.001	-0.57
Presence of others	29.73	6.45	25.50	7.48	-6.386*	<.001	-0.61
Walk with friends	4.46	2.00	4.23	1.95	-1.241	0.108	-0.12
Walk with strangers	6.83	1.93	5.61	2.07	-6.447*	<.001	-0.61
Total safety concerns	107.73	17.46	93.42	21.48	-7.722*	<.001	-0.73

**Significant for* 95% confidence, SD = Standard Deviation.

Table 3: Summary of independent t-tests comparing safety concerns between females and males aged over 60 (N=66)

Safety concern score	Female		Male		Independent t-test		
	Mean	SD	Mean	SD	*t*	*p-value*	*Cohen's d*
Daytime walk	13.14	4.90	14.95	4.79	1.506	0.137	0.37
Nighttime walk	20.59	5.23	19.46	4.67	-0.923	0.36	-0.23
Facility	20.52	4.21	19.05	4.14	-1.413	0.162	0.14
Crime	22.00	4.89	20.81	4.93	-0.979	0.331	0.25
Familiarity of route	21.52	4.84	20.89	6.45	-0.45	0.654	0.38
Presence of others	27.00	6.67	27.54	6.37	0.335	0.739	0.57
Walk with friends	3.72	2.00	4.24	1.91	1.075	0.286	0.75
Walk with strangers	5.90	1.92	6.19	1.82	0.633	0.264	0.64
Total safety concern	101.59	20.27	98.86	19.01	-0.561	0.577	-0.14

SD = Standard Deviation.

[Houses in Multiple Occupations] *and there are some very suspicious people.*"

People from minority groups showed identity-related safety perception. For example, one participant reported: "*Being a gay male with anxiety I sometimes feel quite vulnerable walking the streets late at night.*" Participants with mobility difficulty felt that the presence of walking aids made them vulnerable: "*I cannot run away or escape quickly from a difficult situation. I'm also more noticeable and also vulnerable when walking with a stick.*" One Asian female participant was concerned about "*anti-social behaviors targeting East Asian people*". However, ethnicity has no statistically significant effects on participants' safety concerns as determined by one-way ANOVA ($F(4, 434) = 0.338$, p=.852).

Our data shows that walking at night increased safety concerns. A paired-sample t-test was conducted to compare safety concerns during the daytime and the nighttime. It suggests that people had statistically significantly higher safety concerns during the night compared to walking during the daytime $t(448) = -22.331$, p <.001. Similarly, participants had significantly higher safety concerns about the presence of strangers at night than walking with strangers during the day. The **crime** makes participants significantly more concerned about safety compared to the **facilities** of pathways (medium effect size, see Table 4), and walking with **a few strangers** would make people more concerned than walking with **many strangers** (large effect size, see Table 4). A Wilcoxon signed-rank test showed that participants were significantly more concerned about safety when **most of their routes have a high crime rate** compared with only a small part of routes that have a high crime rate ($Z = -5.222$, p <.001). And these situated safety perceptions were also found among older people. There was no statistically significant difference between people who live in **rural, semi-urban,** or **urban** areas in terms of safety concerns related to crime, familiarity, daylight, facility, and the presence of other people.

Familiarity with the place was also reported by participants related to walking safety. Findings indicate that participants felt very anxious about crime-related safety in unfamiliar areas and worried about getting lost. As one participant stated: "*For walking in towns and cities I didn't know I'd be more aware of safety in terms of the threat from people.*" Participants especially were concerned about potential risks caused by other people, for example, one participant reported: "[being] *worried about being attacked by someone.*" There was a statistically significant difference in perceived safety concern depending on how familiar the start place and destination were, $\chi^2(3) = 439.964$, p <.001. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at p <.008. The statistical

Table 4: Summary of paired samples t-tests comparing safety concerns in different situations (N=449)

Safety concern score	Descriptive stats		Paired sample t-test		
	Mean	SD	*t*	*p-value*	*Cohen's d*
Daytime walk vs.	15.08	5.41	-22.331*	<.001	-1.05
Nighttime walk	19.70	5.12			
Facility vs.	18.85	4.48	-6.926*	<.001	-0.33
Crime	20.04	4.87			
Presence of strangers in daytime vs.	10.94	3.97	-10.819*	<.001	-0.51
Presence of strangers at Night	12.79	3.71			
Walk with friends vs.	4.35	1.97	-20.932*	<.001	-0.99
Walk with strangers	6.24	2.09			
Walk with few strangers vs.	10.15	2.73	17.148*	<.001	0.81
Walk with many strangers	8.20	2.86			

**Significant for* 95% confidence, SD = Standard Deviation.

Table 5: Summary of Wilcoxon signed-rank tests comparing safety concerns related to familiarity with the starting place and destination (N=449).

Safety concern score related to familiarity of starting place and destination	Negative ranks		Positive ranks		Wilcoxon signed-rank test		
	n	Mean rank	n	Mean rank	Ties	Z	*p-value*
FamilarStartNotEnd vs. FamilarStart&End	118	154.34	191	155.41	67	-3.701*	<.001
FamilarEndNotStart vs. FamilarStart&End	30	104.13	243	141.06	128	-12.183*	<.001
UnfamilarStart&End vs. FamiliarStart&End	15	139.70	298	157.87	96	-14.173*	<.001
FamilarEndNotStart vs. FamilarStartNotEnd	60	67.80	146	118.17	173	-7.795*	<.001
UnfamilarStart&End vs. FamilarStartNotEnd	12	174.75	268	138.97	108	-13.192*	<.001
UnfamilarStart&End vs. FamilarEndNotStart	11	115.18	210	110.78	204	-12.543*	<.001

**Significant for* 99.2% confidence. FamilarStart&End = Both starting place and destination are familiar; FamiliarStratNotEnd = The starting place is familiar, but the destination is unfamiliar; FamiliarEndNotStart = The starting place is unfamiliar, but the destination is familiar; UnfamiliarStart&End = Both starting place and destination are unfamiliar. The left-side variables are significantly higher than the right-side ones.

test results implied that participants were significantly more concerned when either the starting place or destination the walking route with an unfamiliar start place but familiar destination than the route with a familiar start but unfamiliar destination (see Table 5). For example, participants believed that the local area is safer, as one participant phrased *"Where I walk locally, safety has never been a consideration for me."*

4.2 Diverse Practices in Managing Safety During Planning and Walking

Findings indicate the diverse practices of participants when managing safety during route planning and walking. This includes multiple factors considered by participants, hybrid ways of collecting safety information at the planning stage, and multiple strategies used for keeping safe during walking. The role of technology was also highlighted in supporting planning and navigation.

4.2.1 Multiple Factors Considered for Route Planning. Consistent with safety concerns, many factors have been reported to be considered by participants when planning a walk. These safety-related factors could be grouped into factors for *reducing risks of inj*ury (e.g., weather, pathway facility, infrastructure, accessibility), factors for *minimizing risks of being victimized* (e.g., safety, the time of the day, reviews of the place), and *other contextual factors* (e.g., the length of the journey, type of walk/area, effort, scenery, travel with people with special needs). Some factors are related to both risks of injury and being victimized depending on participants' perceptions (e.g., familiarity with the area, reviews of the place, and traffic density). For example, participants have mixed views on traffic density. Some participants perceived the presence of others as protectors and chose a populated route, as one participant mentioned "*I want to ensure there is enough of the public around in case something was to happen";* while others preferred to avoid areas with fast traffic due to pollution, noise, risk of injury, or catching COVID-19. As one participant suggested: "*Built-up, busy areas pose a significant risk compared to quieter routes. Areas such as town centers and schools, and such, would have more people using the area at the same time.*" Another example is shared by a mum with autistic children: "*I have two young children, one autistic, so local walks have to be planned to avoid peak traffic (too noisy and dangerous) and avoiding busy narrow roads where possible.*"

Participants had inconsistent attitudes towards safety considerations. Some participants gave safety a high priority, while others did not consider safety. Participants who have safety concerns mainly searched for **crime**-related information (e.g., crime rate, crime map, local reputation) and **road** safety information (e.g., "*accident blackspots*", road safety rules). Several reasons for not considering safety during the route planning were also revealed by participants. First, self-efficacy makes people more confident about the journey. Second, participants felt other aspects are more important than safety, e.g., getting lost. Third, participants believed that the walking area is safe (e.g., local area), as one participant phrased: *"Locally I make no plans for my safety as I live in a fairly safe neighborhood."* Lastly, individual experience affects participants' feelings of safety. As one participant reported: "*I don't have any concerns about my safety because I have never had any situation that made me feel alert or concerned about it.*"

It is worth noting that individuals might consider different factors for different walking situations. For example, some participants used their local knowledge to plan a walk in their local areas or did not plan at all, while sufficient planning was frequently mentioned for a holiday walk. As one participant reported: "*If I'm planning a local walk, most areas near me feel safe, but I might avoid areas I don't know if I'm unsure. If I'm walking around at night and I'm not sure of the area, I will stick to well-lit roads, which tend to be the main thoroughfare. On holiday I will research routes online before I go and will look up information about safety in certain areas of the town or city. I might ask questions on a travel forum.*" Participants often considered multiple factors: *"I started by performing a search on traffic congestion in the area, the crime rate, and available police stations so that I don't put myself in any unnecessary danger."*

4.2.2 Hybrid Ways of Getting Safety Information. Participants got information either online and/or offline. Participants reported asking friends and family, or someone local for safety advice, such as the local library, local council, local guides, or just watching TV news. Participants reported using different technologies for planning a walking route for different purposes. For example, some participants used walking apps such as *Komoot* when planning a hike in the countryside. Participants normally consulted safety information via social media platforms (e.g., *Facebook*) and travel websites (e.g., *TripAdvisor*) for planning a holiday walk. For a local walk, participants may combine both their local knowledge and safety information from online local communities to plan a walk, as one participant noted "*Fundamentally, local knowledge having lived in my city for most of my life. Thus, I know what areas are potentially less safe than others, and what local events, etc. might increase risk (e.g., large sporting events, road conditions, weather, time of day, etc.). I supplement this with the use of a neighborhood social media website (Nextdoor), the relevant city page on Reddit, Twitter (local bus services, police, etc.).*"

4.2.3 Behavioral Strategies for Managing Pedestrian Safety. Findings indicate that participants adopted different types of strategies for managing safety before and during the journey, which we separate into two categories: *proactive* strategy (including *empowering*, *avoidance*, *disguise*, and *collective* strategy) and *reactive* strategy. The proactive strategy was used during both pre-walk planning and walking stages to increase pedestrians' perception of safety and prevent incidents and accidents from occurring during the journey. The reactive strategy was used to react to unexpected or threatened situations during walking. Participants may use multiple strategies at each stage of planning and walking.

Proactive Strategy: Empowering. Participants reported planning and memorizing the route before walking and carrying things that could increase their safety perception, such as bringing suitable footwear, reflective jackets, mobile phones, and self-defensive items (e.g., pepper spray, keys). As one participant mentioned, *"If I had to go on a walk at night, I might consider wearing a reflective jacket or attach something like that to my body, so that drivers might be able to see me better."* The street view of Google Maps was reported as helpful for understanding the walking route better. Participants reported familiarizing themselves with landmarks or main streets and road signs before setting off. As one participant mentioned: "*I look ahead at where the path* [on Google Street View] *is taking me and try to always stay in a residential area. I look out for landmarks or street and road signs to aid me in my journey.*" Participants reported ensuring their mobile phones were fully charged and easily accessible, so they could make an emergency call or ask family or friends for help and guidance. Some participants treated the mobile phone as a self-defense item, such as "*shining the torch in his eyes if confronted or attacked*". During walking, participants reported using map navigation to avoid getting lost in unfamiliar areas, and they kept alert to their surroundings.

Proactive Strategy: Disguise. The disguise strategy was often used by participants who walked alone, with the aim of demotivating potential perpetrators. Participants disguised the value of carried items, gender (mainly female), having a live remote witness, and being in unfamiliar places. For example, one participant reported "*carrying the laptop in an old non-descriptive bag*". Women disguised their gender to protect themselves from potential danger: "*I also wear a hat so nobody can spot my long hair and notice I'm female.*" "*I also dressed in a way that concealed most of me in a bid to look more threatening than usual in a bid to deter possible attackers from trying their chances with me.*" Pretending to be in phone calls was reported by both male and female participants. As one female participant shared: "*I was acutely aware that I could be a target as a lone female on foot late at night. . .I used my phone to pretend to be on a call when faced with a man standing on a street corner.*" One participant even highlighted having remote witnesses: "*I talked to a friend on the phone to show that I had a witness on the phone if anything were to happen to me.*" Some participants disguised their obvious use of navigation apps on the phone, to reduce being targeted. As one participant stated: "*I usually look at the route first and try to remember it so that I'm not obviously lost with my phone out if in an unfamiliar area.*"

Proactive Strategy: Collective. Collective behavior was found among many participants, who attempted to connect with a trusted person when feeling threatened before or during the journey. The collective strategies include collective information inquiry, walking-talking, walking with friends or family or the crowd, notifying others about the journey and arrival, regular check-in during the walk, tracking live location, and getting support from other pathway users. Collective strategies were used more often during walking in the dark or unfamiliar areas, or when people felt threatened or unsafe. As one participant reported: "*If I know I will be alone and* *after dark, I choose more crowded/main street areas."* By connecting with others, participants reported feeling "*comforted*" or less nervous or "*keep personal safety accountable*". A few participants mentioned using technology, such as social media platforms (e.g., *WhatsApp),* wearables, and personal safety apps (e.g., *Life360*), to virtually connect with trusted contacts by sharing location, regular check-in and/or chat. As one participant stated: "*I have a smartwatch that sends alerts to emergency contacts when triggered giving my live location and heart rate etc.*"

Proactive Strategy: Avoidance. Avoidance strategies reported by participants for reducing the potential chance of victimization or injury, include avoiding walking alone, night walking, poorly lit or unlit areas, quiet areas, areas with low visibility during the day, areas with bad reputations, short-cuts, carrying valuable things, and staring at the phone. As one participant reported: "*If I'm on my own, I tend to walk quite quickly to avoid temptation from anyone nearby who could have nefarious intent. I usually stick to open areas with good lines of sight unless I know the area well.*" Avoiding the potential road safety risks was also reported, such as routes with bad road conditions, busy roads, shared pathways with other modes of travelers, or busy roads without pedestrian crossings. As participants suggested: "*I try to avoid the busiest roads even if it means a longer route." "I would try to avoid any areas where motorized transport is allowed... and to check any routes where cycling is allowed because of the danger to pedestrians."* Some participants avoided carrying valuable objects and visibly using their mobile phones to reduce the risk of being targeted victims. As one participant suggested, "*On the walk, I wouldn't use any technology as it might increase the risk - if I did refer to Google Maps, I would hide away to do it.*". Due to the risks of distraction, some participants attempted to minimize screen time by memorizing the route, taking a physical copy of the route, or using voice navigation instead. For example, the voice navigation was reported by some participants to mitigate risks introduced by mobile phones: "*I did not want this [Google Maps] to distract from my awareness of my surroundings, so I put some headphones on and used the voice navigation on Google Maps.*" However, other participants suggested avoiding wearing headphones or lower the volume to be aware of surroundings.

Reactive Strategy. Different from proactive strategies, reactive strategies were used by participants to react to ongoing unsafe or threatened situations during the journey. The most frequently mentioned reactive strategy is changing the route or walking speed based on the situation on the way. Additionally, participants judged the situations based on instinct (e.g., feeling and look of the place) and updated media information (e.g., *Facebook* or the local news). For example, one participant reported: "*If it's taking me somewhere I don't like the look of I take* [a] *detour where more people are walking or walk quickly if it's unavoidable.*" "*If a road looks very quiet, I will change my route and reset the route on my phone to make myself feel safer.*" As one participant suggested: "*The golden rule of any travel is that if you feel unsafe or attract unwelcome attention... LEAVE.*" "*If I see something in [the] distance I might pretend I forgot something and reroute if I think it's a necessity for safety.*"

4.2.4 Role of Technology in Safe Mobility Practices. Findings show that technology played important roles in supporting pedestrians' safe mobility practices, including walk planning, navigation, and enhancing safety measures. Participants reported the use of navigation apps, social media platforms (e.g., *Facebook*, *WhatsApp*, *Reddit*), and travel review websites (e.g., *TripAdvisor*). A few participants reported using wearables (e.g., smart watches) and personal safety apps (e.g., *Life360*) to mitigate their safety concerns during planning and walking. It was reported that different technology was used for different purposes. For example, one participant described: "*I usually check local Facebook groups for any detail in terms of landslide issues or traffic. I always check Google Maps for delays and quickest route options.*" One participant highlighted her experience of using *Citymapper* app to plan a safe walking route: "*I need to make sure that I am walking on main roads and not somewhere undeveloped or rural. In my Citymapper app, there is an option to choose 'main roads' and I would always go for that due to safety reasons.*"

The need for direction, guidance, and navigation was highlighted by participants, especially for walking in an unfamiliar area. It was found that participants used mainstream navigation apps for general route planning and navigation: 97.6% of participants used *Google Maps* and 25.8% used *Apple Maps* (as shown in Figure 3). Participant responses highlighted the value of GPS (global positioning system) locating. The navigation apps made pedestrians feel more confident, as one participant mentioned: "*I like the visual step-by-step display of the journey as knowing exactly where I am and where I'm going makes me feel more confident.*" Some other navigation apps specializing in walk planning and navigation were also disclosed, such as *Go Jaunty* and *All trails*. The satellite view and street view of *Google Maps* were favored by participants as they provided useful information in aiding pedestrians to know the route. For example, one participant stated: "I *usually look at the route on Google Maps and then look at Street View to get a better idea of what the route, roads, and walking paths look like.*"

Technology was reported to bring virtual layers of safety measures. A few participants shared their positive experiences of using in-app maps of social media platforms (e.g., *WhatsApp*, *Snapchat*), personal safety apps (e.g., *Life360, HollieGuard, Safe and the City*) to connect with friends or family by sharing live location and live conversations. Examples include "*I share my location with someone via WhatsApp so they can follow me." "Whenever I am going to a new location, I always ensure friends or family are aware of my location through the Life360 app or having my location turned on in Snapchat maps.*" "*Using Google Maps allowed me to find a faster route so that I wasn't stuck in that area for a long time. To make myself feel safer during this walk, technology contributed by allowing me to share my location with my friends and family and I also ensured I stayed on the phone with my sister so she could accompany me and feel less nervous.*"

Some participants reported that bringing mobile phones made them feel safe while walking. Mobile phones' ability to connect with others remotely and confident navigation were highlighted. As reported by some participants: "*I felt much safer being able to have someone on the other end of the phone should anything happen.*" "*I felt I could also call 999 in an emergency, so my phone helped give some level of protection.*" The navigation technologies reassured participants' walking directions hence people feel more confident and safer on the journey. As one participant mentioned: "*I like the visual step-by-step display of the journey as knowing exactly where*

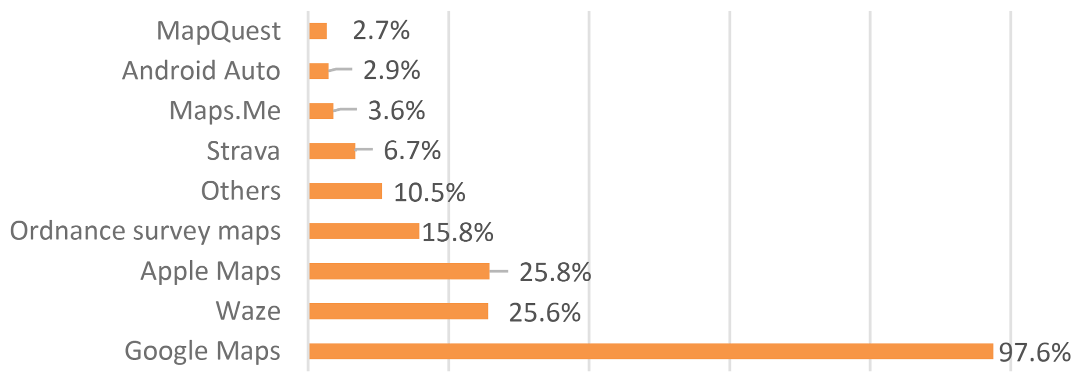

Figure 3: The route planning and navigation systems used by participants

I am and where I'm going makes me feel more confident." "*I feel safer using Google Maps as I know that I am walking towards the right place instead of taking a wrong turn and getting lost.*" The importance of mobile phones was also reflected by participants preparation of extra phones: "*One thing that helped me feel safe was to have a spare phone, in case of loss of main one or battery giving out.*"

4.3 Challenges and Barriers

Findings show that there are several barriers to planning safe walking routes, including a lack of information and tools for planning safe routes: lack of safety information, outdated information, biased safety information, lack of knowledge or technology in finding specific information, and the time-consuming planning process. Technology failures and risks introduced during the journey are also highlighted.

4.3.1 Lack of Information/tools for Planning Safe Route.

Lack of safety information. Participants reported that it is difficult to readily get available information online about the safety of routes, especially when people don't know the area. It was found that participants did not know where and how to get safety information when planning safe pedestrian journeys. As one participant stated: "*It is easy enough to plan a route online, but I don't know of anywhere that would help with safety.*" The difficulty in finding specific information was also highlighted by participants. For example, one participant mentioned: "*There isn't really anywhere to find very specific information about an area (e.g., antisocial behavior hotspots or incidences of dog fouling) when planning a route in a new area.*" A female participant complained: "*It's hard to find information specifically for women.*"

Outdated information about the pathway. The outdated information used by existing route planning systems might lead pedestrians to some inaccessible areas, such as road closures, road construction, private land, bad road conditions due to weather, or a new layout of the road. As one participant highlighted: *"A big concern is that the road up for path may be closed off and also that the map may not be up to date, or it may be difficult to access on foot and the map does not show me this."* Another participant also mentioned road closure: *"There could be work being done or something like that which you just have no way of knowing about until you are already there and it's too late to change route/do anything about it."*

Biased online safety information. Another barrier is biased information online. It requires the critical thinking skills of participants to judge the reliability of online information, especially opinions or reviews. As participants mentioned: "*It can be hard to find reliable information about places easily by using Google*"; "*To determine if a route were safe, I would have to Google it first. This would return several results for which I may struggle to know what to read or believe.*" One reason could be that safety is a subjective matter, thus different people have varied levels of safety perception and experience. As one participant was concerned "*There may not be any information online or I may not know whether online opinions are biased or not. Some opinions may come from people who would have a more relaxed view about safety than I do so wouldn't be applicable to me.*" "*People's perception of risk (and actual risk) varies so advice from others might not be suitable.*" Therefore, it is usually hard to determine the safe area before starting the walk. As one participant stated: "*One block away from a safe area can be a less safe area, and there is usually no quick way of determining this. And some run-down areas are actually quite safe, despite their appearances.*"

Lack of safe route planning technology. Participants reported difficulty in finding useful safe route planning technology. Current mainstream navigation systems only suggest the fastest route without considering and do not consider safety information and lack details about the route (e.g., street lighting, crossings, underpass, crime). Examples reported by participants include: "*I cannot find useful tools to help identify where the best and safest pedestrian-only routes may be located, away from traffic.*" "*I have never used any digital technologies to determine safety factors. To keep myself safe I tend to keep alert and use my senses to make judgments in real time about the directions I go in and the posturing I take while walking. I am not aware of any online sources or technologies that assist in any of this.*" "*Not knowing an area or the best way to get around, where* *might* [be] *safer, or well lit. Maps will usually give me the most direct route regardless of the area the route may pass through.*"

Due to the above-mentioned factors, participants indicated that extra effort was needed when collecting information about safety and making decisions, thus planning a safe walking route was time-consuming. For instance, one participant stated: "*The most annoying aspects of planning would be the extended time it takes to plan these safe routes and trying to gather information around the area you will be going in order to plan is very difficult as well.*" Similarly, one participant highlighted: *"the time it takes to plan a route safely, as there are no 'Google Maps' style directions from point a - b, or a way you can draw with your finger the route you want to take, and it pulls up any safety concerns in the areas."*

4.3.2 Technology Failure and Risks. Technology failure was reported by participants regarding incorrect routes, misleading navigation, weak signal, and no battery. For example, Participants reported that sometimes navigation apps guided them to unmapped routes: "*Incorrect routes shown on maps such as private property or paths that don't exist.*" Misleading navigation caused by bad design of navigation technology: unclear or difficult to follow navigation guide: "*I had concerns that we would get lost due to being in an unfamiliar area, and the instructions given on the route not being overly clear, which led us to take a few wrong turns.*" One participant reported the bad signage of the map: "*The hardest bit is where the map doesn't have very good signage, so it is hard to know where to go*". The importance of strong signals to make phone calls or use digital maps was also highlighted by some participants.

Participants also mentioned the potential risks of using navigation technology. Participants reported that some navigation systems suggested risky routes or guided them to unsafe places. For example, "*Technology didn't really help with my safety concerns and would have taken me through the subway*"; "*The route had to take me through some deprived areas where it was known for the crime, so I was concerned about my safety.*" On the other hand, navigation technologies may make people over-reliant on technology or pedestrians got distracted from being alert of actual risks during walking: *"I rely upon a live update direction app which means that I constantly have to be attentive to my phone; this means that I am less attentive to my surroundings and therefore more worried about being snuck up on."* Some participants felt vulnerable when using their phones in unfamiliar areas, because "*staring at the phone"* can "*look obviously lost*" and attract unwanted attention. Participants also reported the privacy issues of using digital technology. As one participant spotted: *"Google Maps and other apps and websites use my personal data in ways that I am not happy with*". <strike/>

5 DISCUSSION

This study was conducted to explore people's pedestrian safety perceptions and safe mobility practices. In this section, we address our research questions and identify two design implications to inspire HCI researchers and designers to better support pedestrians' safety. Both the contributions and limitations of our work are also discussed.

5.1 RQ1: Identity-situated Pedestrian Safety Perceptions

Our findings indicate pedestrian safety perceptions consist of both road-related safety and crime-related safety concerns, and such perception of safety depends on an individual's identity and walking situations, we refer to this as *identity-situated safety* perception. Our findings confirm the complexity of safety perceptions [18, 75] and are consistent with prior work in exploring the impact of gender [62], crime [79], and darkness [83] on pedestrians' safety perceptions. Findings demonstrate a wide range of built environmental factors [27] affect pedestrians' perceived safety or safety concerns, such as road infrastructure [7] and landmarks [6, 31]. Our work extends the existing literature on pedestrian safety perception by considering more nuanced situations and providing empirical evidence on which safety factors play significant roles in people's safety perception. For example, previous studies [64] show that pedestrians' familiarity with the place affects their safety concerns, our work mirrors this but further explores the nuances in the impacts of familiarity with the starting place and the destination and their combinations. Moreover, our findings highlight the significant differences in safety concerns when comparing walking with strangers and walking with friends, walking with strangers in the dark and walking with strangers under the daylight, and walking with a few strangers could trigger significantly more safety concerns than walking with many strangers. This suggests the need to reconsider the concept of '*natural vigilance'* [42] which refers to the presence of other pedestrians on the street as '*effective surveillance*'.

Our findings highlight the intersections [25, 104, 106] among social identities and/or situations in shaping safety perception. Like Williams et al.'s qualitative work [104], we find the intersectionality of identity (gender, age) in shaping pedestrians' safety perception. However, our quantitative data provides different insights about how age intersects gender: the gender difference in safety concerns was not significant among the older people, who are concerned about crime more than other age groups. Compared with road safety, older people have significantly higher crime-related safety concerns. This is contrary to Williams et al.'s work [104] that suggested that older people's safety concerns when walking are shaped mainly by the risk of injury due to physical limitations. Also different from prior work [104], our findings suggest that the difference in safety perceptions among different racial groups is not statistically significant. Most prior studies indicate that increasing walking traffic density can encourage people to walk more [48]. This is true for some participants of our study; however, it is also found that populated areas might also discourage walking by increasing the fear of crime, pollution, and risk of injury, especially among pedestrians who identify themselves as vulnerable. This is because individuals who perceive themselves as being vulnerable, such as the elderly [13] or lone females [26, 63], typically have lower levels of self-efficacy [24] and thus are more concerned. This identity-situated safety explains the subjective nature of safety perception [84], for example, a place perceived as safe by one may feel unsafe by others, likewise, a crime hot spot may not invoke fear if people are not aware of historical crime incidents [10]. This suggests that pedestrian safety perception is not fixed but fluid based on perceived identity and situations.

5.2 RQ2: Diverse Practices in Pedestrian Safe Mobility

Our findings highlight the diverse practices in pedestrians' safe mobility, including multiple factors considered for route planning, hybrid ways of getting information, and a variety of strategies to manage safety during planning and walking (see Table 6). Our findings verify the previous research on pedestrian route choice [61] which highlights that people consider various safety factors when planning their walks. This could be explained by using Tong's essential principles of pedestrian route choice [99]: pedestrians *perceive* their walking situations selectively and purposely, so they *integrate* selective information and *construct* subjective cognitions to *make decisions*, and each stage of safe mobility (planning and walking) could be affected by different walking situations, such as the type of walk, the familiarity of the place [91], and the crime rate of the area [24].

Our findings indicate the new insight into strategies adopted by pedestrians to manage safety before and during the journey: *proactive* strategy (*empowering, avoidance, collective, disguise),* and *reactive* strategies. Pedestrians' responses to safety information may depend on individual characteristics, previous experience, and context [27]. Pedestrians may use multiple strategies to keep safe during planning and walks. These safety strategies are consistent with prior work [36, 39] and extend it further by looking at broader populations and differentiating pedestrians' *proactive* strategies from *reactive* strategies during walk planning and walking. For example, our work confirms the *avoidance* and *collective* strategies in Gates and Rohe's model [39] of people reacting to fear of crime, but our data suggests more granularity than their *protective* strategies such as the empowering strategy and disguise strategy. García-Carpintero et al. [36] only explored the safety strategies used by the youth during recreational nightlife. Moreover, our findings elaborate on the pedestrians' strategies used during the safe route planning before walking.

Findings highlight both the supportive role of technology in safe mobility and its hindrance. Findings indicate pedestrians use existing technologies (such as social media platforms, travel websites, navigation apps, and personal safety technology) and traditional ways to plan, navigate, and connect with others during the journey. Digital support including navigation and connecting with others, especially in emergencies, is also suggested in our data. People feel more '*confident*' to navigate with their mobile phones. The mobile phone is considered an object that could magnify or extend a human's physical or mental ability, as suggested by technology extension theory [57]. However, lack of live trustworthy information and safe route planning technology are the most-mentioned barriers to planning safe walking. Technology failure and increased risks are also highlighted as making pedestrians feel vulnerable or putting them in danger during the journey. For example, existing navigation apps suggest incorrect routes or risky routes, especially for certain groups of people in certain situations (e.g., lone women who have to walk at night). Our work suggests the need for navigation technology to consider identity-situated pedestrian safety, which is absent from current mainstream navigation apps. Moreover, our findings highlight mobile phone use while walking could reduce situation awareness, which was found in the literature that could lead to injury or death [56]. Constantly checking navigation apps in unfamiliar areas was perceived as representing vulnerability and may attract unwanted attention. This suggests a design opportunity that balances technology-facilitated empowerment against exposing potential vulnerability (cf. 'not to design' [8]). It opens opportunities for HCI designers and practitioners to learn from existing best practices to bridge the sociotechnical gap [1, 66] in safe mobility.

5.3 Design Implications

Our empirical findings about pedestrian safety perception and practices highlight how identity and situations intersect to affect safety perception and safe mobility practices. Our work has the potential to provide empirical evidence for authorities to develop suitable pedestrian facilities that could increase physical activity and avoid social isolation [6]. It also suggests the general considerations for nudging designers, digital innovators, and HCI researchers to better understand the problem space [105] at the ideation stage However, moving from problem framing to design solutions is not a trivial task. Rather than providing '*prescriptive*' implications about a specific design solution [82], we propose two implications for design with additional guidance to inspire designers to support safety practices through design.

5.3.1 Design for User Autonomy. Our study highlights the intersectional nature of safety perception and diverse safety practices in route planning and walking. Safety perception and reactions are informed by individuals' identities and situations. This suggests one of the most important safe walking requirements: user autonomy [31], that individuals are able to plan, decide, and react in ways that they believe to be useful and protect them from potential harm. Design for user autonomy requires technology to provide users with the necessary technological capability to achieve their goals. One way of enabling user autonomy is through customization [65]. The customized safe walking technological interventions could include but are not limited to, allowing users to choose which safety factors to consider, which crime information to see and in which level of detail, or providing alternative walking routes, which safety measure to be provided for certain walking situations (see Table 7). Prior work has investigated the technical implementation of multi-preference navigation technology [58]. For example, Quercia et al. [78] proposed a route planning algorithm that recommends the shortest and most emotionally pleasant route based on user-rated beauty, quietness, and happiness scores. However, tensions between control and autonomy [16] are worth consideration. For instance, people with low self-determination or *non-power users* might show negative attitudes toward customized interfaces [95]. There are still gaps in the HCI literature for understanding identity-situated user requirements and designing effective multi-criteria route planning systems based on empirical evidence [67].

5.3.2 Mechanisms to Adopt Situated Data. This empirical study has demonstrated current challenges and pedestrians' need for updated trustworthy safety information. First, our findings indicate that road safety concerned most pedestrians but there is a lack of updated information about road status and/or infrastructure; Second, our survey data also show people's concerns about the

Table 6: Summary of practices and strategies for pedestrian managing safety in planning and during the walk

Stage	Route Choice Factors	Barriers (objective)	Concerns (subjective)	Technology	Behavioral strategy
Planning	•Weather •Familiarity •Reviews •Time of the day •Traffic density •Pathway infrastructure/facilities •Accessibility •Route characteristics: o Type of walk o Length of the journey o Effort o Scenery •Safety – accident blackspot, crime hotspot	•Lack of info/tool for safe route planning: o Lack of info about route safety o Outdated info o Biased online info o Lack of knowledge/tech for safe route planning •The time-consuming process of planning	•Pre-journey anxiety: o Safety cannot be planned or guaranteed.	•Phone call, •Maps (paper/digital) •Social media platforms •Websites (e.g., travel websites, local council websites) •Walking apps	•Walk planning: o Get info online & offline. o Plan different walks by using different technologies o No planning o Plan by using local knowledge •Empowering strategy: e.g., memorize the route. •Avoidance strategy (avoid certain areas or times of the day) •Collective strategy
During the walk	•Other pathway users •Built environmental factors •Weather •Traffic •Crime	•Technology failures: o No signal or mobile data o Technology distraction o Map leads to unsafe/inaccessible routes	•Road safety concerns: o Hazards/dangers on the road o Risk of injury or collision o Animals o Weather •Crime safety concerns: o Fear of victimization (violence, mugging, sexual harassment, etc.) o Social barriers (gendered safety concerns, racism, bystanders) •Spatial anxiety: o Getting lost in unfamiliar areas	•Maps navigation •Phone call •Portable alarms/GPS •Social media platforms •Personal safety apps	•Avoidance strategy (e.g., phone distraction) •Collective strategy •Disguise strategy •Reactive strategy

Table 7: Implications for designing customized safe walking technological interventions

Implications	Questions to ask
Ability to support users in making informed decisions	*Which safety factors fed into the route planning algorithm?* *What safety information is to be included or displayed?*
Ability to manage the walking route	*How could technology support users to memorize walk routes, e.g., customized landmarks?* *What options could be provided to allow users a sense of control? e.g., options of saving route and comments (for private or public use), or manually changing the route.*
Getting support from others and supporting others	*Which safety measure/strategy will be provided for specific walking situations?* *How to support other walkers to feel safe – e.g., positive walk experience.* *How to get support from others, e.g., walk share* [10], connect with designated contacts

Table 8: Implications for encouraging adopting high-quality crowdsourced situational data.

Implications	Questions to ask
Design to encourage users to create high-quality situational data	Which situational data should be crowd-sourced? Road safety or crime safety-related information, or others? Which gamification mechanism or other mechanisms could help to motivate users to report accurate situational data, or encourage peer review? Design for increasing motivation [71]
Mechanisms to valid user-reported data	*How to use device-based situation data to validate user-reported information?* *Will peer reviews help with accuracy?* *How to implement it with democracy and inclusivity?*
Mitigate potential risks for users who report	Which interventions for privacy and security could be designed?

quality of user-reported data and misuse of the crime reporting function. Third, our findings suggest a lack of ways of finding identity-specific information such as safety information for women. Moreover, previous research has demonstrated that the absence or lack of relevant situated temporal data in existing route planning and navigation systems has limited applicability of these systems [68]. Prior work also shows that it is challenging and unrealistic for local authorities to mitigate all road facility-related issues [11] and the value of high-quality crowdsourced data was highlighted (e.g., pathway accessibility [80], crime [22]). This suggests a critical design opportunity to better design crowdsourcing technology [71, 86] to collect situated spatial-temporal information [10]. Further, mechanisms will be needed to verify the validity, accuracy, and relevancy of user-reported data, and ensure the democracy and inclusivity of participation. For instance, the gamification mechanism [100] could be designed to encourage peer review of user-reported data, especially for subjective crime information; users' mobile sensor data such as GPS location might be used to validate the genuineness of the location of reported issues. Furthermore, there is a broader range of sociocultural factors which may affect people's willingness to report crimes or incidents [17]. Therefore, the safety measure of safe route planning and navigation technology requires a broader perspective considering multiple socio-cultural-technical factors.

5.4 Limitations & Future Work

Although it is cost-efficient and beneficial to use an online survey to recruit a large population in a short time, self-reported data may suffer from memory biases [6] and potentially poor quality of data due to different motivations for participating in the survey. However, this online survey helps to collect the opinions of large representative populations with diversity, and our study still contributes to the HCI community in the initial empirical understanding of pedestrians' ecological way of walking planning and safe walking strategies, barriers and safety concerns. It is also important to note we depended on the Prolific platform to recruit a representative sample of the UK population. There may be inaccuracies in the demographic information regarding their participant pool, which affects the sampling accuracy. It is recommended to embed certain mechanisms such as attention checks [89] when designing an online survey. Additionally, to gain a deeper understanding of walking practices and barriers to walking that affect specific groups, e.g., women, older people, people with disabilities, and ethnic minorities, further research that focuses on these groups will be needed.

6 CONCLUSION

This paper reports findings from an online survey with a representative sample of 449 participants from the UK population, with the aim of understanding pedestrian's safety perception and safe mobility practices. Our findings extend previous HCI research by highlighting the intersectional nature of pedestrian safety, including identity-situated safety perceptions, multiple factors and strategies considered for route planning and walking, the role of technology, and current challenges in safe mobility practices. Our work contributes to broader insights into pedestrian perception of safety by adding empirical evidence from UK representative samples and more nuanced contexts. Two design implications and limitations have also been discussed.

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