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# Use of Notebooks and Role of Map features in Mapping Minority Women Bicycle Riding

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**Abstract**

*Visualization has greatly enhanced our understanding of cycling trends [fL18], enabled the depiction and analysis of large-scale cycling data [BWB14, RMGZALD18], and facilitated the tracking and interpretation of personal behaviour through the dashboards of personal tracking devices [NKKW20]. Data and visualization can be either vast and generalized or intimate and personal. There are significant challenges associated with big data as certain subgroups are underrepresented in data collection, making their presence difficult to detect and more targeted and smaller data collection can complement and expose facets of the population that are not visible in big data. Ethnic minority women cyclists are one such group. Research into their attitudes and cycling habits is often outdated [Lim10] or originates from contexts where their ethnicity is the majority [GOF*22].*
*This study aims to shed light on the experiences of Muslim and BAME women cyclists, uncovering hidden realities and challenging dominant narratives. A small group of ethnic minority women participated in the research, keeping diaries of their cycling experiences and using GPS trackers. The collected data was presented back to them in the form of individual data notebooks, combining technology, visualization, and ultimately qualitative analysis. This empirical work provides a fresh perspective on how female cyclists interact with their environment and offers valuable understanding of the preferences and challenges faced by this growing and vibrant group. This paper builds upon the previously published work [RDWT23], shifting the focus away from the methodological execution of the study and instead emphasizing the participants' interactions with the maps and the unique insights gained.*

**CCS Concepts**

• ***Human-centered computing*** → ***Empirical studies in visualization; Geographic visualization;***

## 1. Background

The persistent gender disparities and ethnic minority challenges in cycling, highlight how societal expectations, infrastructure limitations, and underrepresentation in data and research influence these issues. In order to capture and better understand these experiences, we need a methodology that combines technology and qualitative approaches. Gender differences in cycling uptake have been a steady topic of research covering barriers to cycling [RBS20], female adolescent cycling [SD22] and cycling preferences [AEWG17] to name the few. While teens appear to be susceptible to the influences of society and peer groups [SD22], lack of infrastructure and road safety concerns tend to be among the primary barriers for female cycling [Puc01]. However, work by Aldred [AD17] finds that in London, the increase in the infrastructure is not a sufficient factor for increasing the diversity of the cycling cohort. Lam [Lam19] challenges the very organisation and layout of the London cycling infrastructure and proposes that its radial layout, aimed at the economic centres, serves as a barrier to female cycling. This assertion is based on female travel being tied in with societal expectations of women having caring duties and undertaking a greater number of 'encumbered' journeys as well as their travel being formed as trip-chaining [SW14], a practice where travel from A to B incorporates X, Y and Z of daily obligations. The issues present in cycling, which manifests themselves in the overt gender disparity, align with other manifestations of societal inequality regarding presence and representation. These are eloquently presented in Caroline Perez's work on data, gender and the impact of gender bias in the data-led society [CP19]. Without data to inform, anecdotal discussions about ethnic minority women cyclists often rely on preconceived notions and narratives drawn from general observations and popular media. The most scientific and relevant body of work regarding ethnic minority cyclists is the research currently emerging from the Westminster University, Active Travel Academy (ATA). Osei and Alderd [OA23] analysed the outcomes of a BAME male cyclists focus group, and found the lack of status, increased visibility of being a minority and fear of police prosecution are dominant narratives for black, male cyclists. On the other hand, Chowdry [CU20] conducted interviews with Muslim women cyclists and non-cyclists. The aim of the work is to identify barriers and as such, most of its findings relate the attitudes of



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non-cyclists and outline the actions to mitigate them. One of the recommendations is behaviour modelling and normalising cycling for everyone. As mentioned previously, there exists a considerate body of research which explores barriers to cycling but we know almost nothing regarding the cycling likes, dislikes and habits of minority women who cycle.

Urban environments and mapping have historically had a relationship that extends far beyond mere orientation and navigation. Starting with John Snow's Cholera Map, used to identify sources of infection, maps have been used to make sense of and communicate the interactions with our environment. Maps continue to serve as a bridge between lived experiences, their representation, and the practical application of that representation. In their work, Loukissa [LN21a] places physical maps in opposition to civic algorithms and the Explainable AI in order to address the shortcomings of automation. This exploration is a continuation of their previous work [LN21b] on the use of maps to open urban data collection by directly involving subjects in the interaction with maps and data using sketching and projection. Feminist voices, such as Joni Segal [Sea18] and Doreen Massey [Mas13], have significantly contributed to the comprehensive exploration of the representation, distribution, and intricate relationships of women with, and within the field of geography. Through their influential works, Segal and Massey have delved deep into the multifaceted aspects of gender and its intersectionality with space, place, and the broader sociopolitical context. By critically examining the experiences and perspectives of women, they have shed light on the often overlooked or marginalized aspects of geography, bringing to the forefront the importance of gender analysis in understanding the intricate dynamics of human-environment interactions. Our work continues on the principles of Loukissa, Segal and Messey and its contribution is a methodology for the examination of mobilities that joins technology with qualitative methodologies to help us explore how, when and why ethnic minority women cycle as well as how their environment facilitates their mobility.

## 2. Methodology

The study addresses the limitations of survey data due to conformity bias by collecting and analyzing participants' cycling data over two weeks using stand-alone devices, presenting the findings in interactive data notebooks, and contextualizing the information with maps, temporal scatterplots, and personal metrics to better understand the movement patterns of a small and specific group of ethnic minority women cyclists. Survey data can be unreliable due to conformity bias [MF72] where participants align their answers with the popular view or provide answers that will promote the common goal. Hence, we have decided to collect the movements and the data surrounding them, then present it to participants contextualised with spatial (four possible base maps), temporal (temporal scatterplot of the journeys) and personal metrics (daily meta-data collected via messaging service). In order to account for changes in personal schedules and mitigate the impact of unsuitable weather, each volunteer was asked to participate in the data collection for two weeks. Rides were recorded passively, using a cycling computer that volunteers self-managed, giving them control over what journeys to share. Despite a wealth of tracking mobile applications, a stand-alone device was chosen as it did not rely on a specific mobile OS system; this ensured that there was no data leakage to third parties and that the study was economically accessible (no need for an up-to-date phone). Two devices were purchased, which due to time constraints, limited the number of participants to seven. Finding participants from small, dispersed groups is challenging for outsiders, but active minority advocacy groups can serve as valuable gateways, facilitating sensitive access and enabling targeted thoughtful research. We engaged with one such group and participants were recruited from their community.

As well as recording the journeys, participants received a daily survey-diary in order to record the purpose of the trips, whether they rode in the company and the number of significant stops during the cycling journey (in order to identify trip-chaining). The device collected the longitude, latitude and time, a combination of which was later used to extrapolate speed. The collected data was exported in the form of .fit files, which were then transformed into a suitable format for loading into the canvas data platform Observable, where we cleaned, aggregated and presented it in the form of individual data notebooks. Notebooks are interactive computing environments that combine code, text, and visualisations, allowing for multiple processes in a single environment and supporting branching narratives and dependencies [WKD18].

In the images Figure 1b, we can see different prompts that the maps provide for the user. The cycle map is showing cycle furniture, the humanitarian map is showing local utilities, the transport map the bus routes and the Stamen light has the main roads clearly marked.

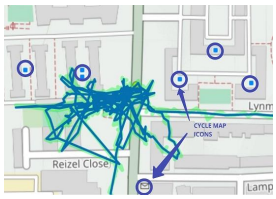
### 2.1. Data Notebook Components and the Interaction

Observable data notebooks are data-driven, reactive, and interactive. A notebook contains inter-referencing cells, but since it is fully compiled before running, the order of the cells is flexible, allowing the designer to adapt and optimise the notebook for their specific task. The content, including interactive views linked to HTML inputs like sliders or colour pickers, enabled us to create a flexible, interactive dashboard that incorporated all the collected elements.

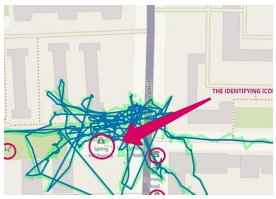
The time-series scatterplot provided participants with a temporal display of their cycling activities, showing the days, times, and durations of their rides. This allowed both participants and researchers to uncover movement habits and patterns. The markdown capabilities of Observable let us incorporate meta-data we collected on a daily basis. The display of the text was seamlessly interconnected with the journey selection, as choosing a specific journey would dynamically showcase the relevant meta-data.

The main focus point of the notebook was two canvases for displaying the journeys. Both canvases contained drop-down menus that enabled the user to control which base map and the personal journey were displayed. Each facilitated a distinct approach to exploration and discovery. Canvas 1 used radio buttons to select a single recorded journey, paired with a speed-tracking line chart that allowed participants to follow their progress along the route. This also allowed for the identification of stops and served as an indicator of trip-chaining. Canvas 2, used a checkbox that let the user select, and display multiple options, thus allowing for comparison

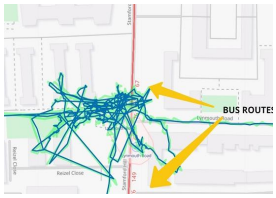
and overview of multiple outings in one display. The users could compare multiple journeys performed; in a single day (such as to and from the commute); compare different types of journeys (eg. leisure vs commute); compare weekdays vs weekends; or the same day in different weeks.



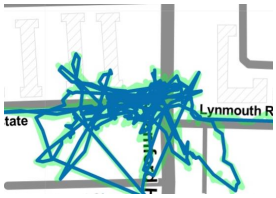

**(a)** *Cycle map with icons for cycle parking and letterbox.*



**(b)** *Humanitarian map with icons for human resources.*




**(c)** *Transport map with public transport routes and services clearly marked.*




**(d)** *Neutral map containing names of the roads and no buildings.*

**Figure 1:** *Four base maps at maximum zoom. This example illustrates different aspects of the same geographical area that each map provides. In the image (b), we can see an arrow pointing to an icon which acted as a memory jogger for one of the participants. In this case, the humanitarian map was the one with the right information.*

Our previous work has demonstrated that map selection directly impacts the associations and recollections of the reader. To better situate participants in their environment and offer a range of stimuli, we provided them with a choice of four maps. When choosing the maps we have taken into account two categories of map attributes

1. **Information map relates** - all the maps differ in what they capture as each one is compiled with a single, specific purpose in mind.
2. **Visual Clutter** - Clutter can be calculated in a number of ways (such as the number of distinct objects, number of contrasting hues, number of vertices in an image, etc.). Visual clutter is important for this task, as the number of features can have an influence on segmenting a scene and performing a visual search [RLN07].

Based on those criteria, we used the following maps:
Stamen Light Toner, toner black-and-white maps maps are particularly suitable for overlaying data and visualizations. These maps are widely used in web applications, and data visualisations, and are favoured by designers and developers due to their high-quality designs and accessibility.
The OSM transport map [Ope21] focuses on transportation infrastructure like roads, highways, railways, buses, and subways. It is especially relevant for cyclists transitioning from public transport to cycling, as they often follow public transport routes, but the map is important for all cyclists as they frequently share lanes with buses.
The Humanitarian map is created to aid in humanitarian efforts and disaster response. It provides detailed information on infrastructure, resources, and transportation routes. The map's muted colours make it suitable for displaying tracks and and inclusion of local features enables orientation.
The OSM Cycle Map is specifically tailored for cyclists. While the map displays cycle lanes, cycle parking, A-roads, high roads, and cycle-specific icons such as bike repair, water stations, cycle furniture, and rain shelters, it exhibits the highest visual clutter, strongest hues, and greatest contrasts [LGMR05].

The maps increase complexity from the Stamen Light map (this map will also be referred to as 'neutral' in the following text) to the OSM Cycle map. Each map presents a different environment. Stamen Light offers freedom from distraction. Transport offers connections to the public transport infrastructure that might serve as a reminder or a locator. The humanitarian map contains local resources and municipalities. The cycle map presents the classification of the roads and cycle-friendly features 1.

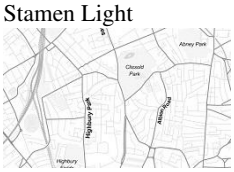
| Maps and their features | |
|---|---|
| **Map** | **Information** |
| Stamen Light  | Roads, road names, natural features, area names |
| Transport OSM  | Roads, road names, natural features, area names, public transport routes, and stops. Neutral background with a strong contrasting colour for the bus routes. One item (bus routes) draws attention. |
| Humanitarian OSM  | Roads, road names, natural features, area names, icons for local resources and transport. The harmonised colour scheme in terms of saturation. Icons draw attention but are not in high contrast. |
| Cycle OSM  | Roads, road names, natural features, area names, icons for cycling resources, and colour classification of roads. Icon-rich map with contrasting colours and many items that draw attention. |

**Table 1:** *Basemap options and their features.*

**2.1.0.1. Interviews** For data collection, individual interviews were conducted with each participant using the chauffeured inter-

action method [WBD14]. This method involved participants providing researchers with prompts for interactions with the interface. This was a necessary modification due to the COVID restrictions. The sessions averaged approximately one hour in duration and were recorded on Zoom. To analyse the interview contents and the participant's interaction with the components, a thematic analysis approach [BC13] was used for identifying themes and uncovering patterns within the collected data.

## 3. Findings

The study had a range of findings, some of which might have an explicit impact on our understanding of how ethnic minority women approach cycling. Those findings are being published in a separate publication [RDWT23]. This publication showcases a selection of our results, specifically focusing on elements of the maps that enhanced the discovery process for both participants and researchers.

The inclusion of temporal scatterplots in the notebooks helped reveal that a significant portion of the journeys occur early in the morning—specifically, 42% (31 out of 73 recorded trips). Excluding commutes, the percentage of early-morning trips increases to 60%. The participants reflected on the times they cycle, with two out of three beginner cyclists stating that early mornings are the times they feel safe cycling as it is the time they have the road to themselves. Further, the participants differed in cycling ability as the two were cycling advocates, three cycling beginners and two occasional riders. The visualisation of the routes covered by the advocates showed that they took longer trips regularly and had more diversity in their journeys, often modifying the established routes. The novice cyclists were more adventurous on weekends and when not cycling alone. When preparing the routes for visualisation, we applied the Kalman smoothing algorithm [CC79] on all tracks but allowed a higher level of noise for the tracks in the second canvas Figure 2. Also, the notebooks had a slider which allowed participants to adjust the opacity of the route renderings. The combination of these two features enabled participants who took the same route repeatedly to differentiate individual days and to see the cumulative effect of their movements, thus mitigating the reductionist effects datafication and visualisation can sometimes have [Boe16]. This resulted in participants discussing the more holistic aspects of their activities, such as time-saving, fitness and the benefits of routine. Visualisation of the routes revealed unusual events in the journeys of beginners and the occasional cyclists. These were excursions to, or encompassing, areas lacking notable significance or discernible destinations. Participants were routinely unable to recall what motivated these behaviours despite the access to the daily metadata. Figure Figure 1 shows one such instance. It also shows the view of it on all four base maps and the memory jog prompts [Bar88] maps provide. The ability to display different aspects of the environment by varying the maps provided context and stimulated recollection. In the majority of cases, beginner cyclists were getting lost in the pursuit of the routes that would enable them to develop their skills and confidence.

Our analysis revealed interesting patterns, particularly among beginner cyclists. We found that they tend to ride early in the day, with a higher proportion of cycling trips occurring during the morning hours. This finding aligns with previous studies [AEWG17]


**(a)** *The track detail in the single-journey cell.* **(b)** *The track detail in the multiple choice cell.*

**Figure 2:** *The depiction in the single journey cell is smoothed using the Kalman filter to facilitate easy tracking by participants. The track in the multiple choice cell has a higher level of noise, which allows for better segregation of individual laps.*

which indicate that women may prefer to cycle during quieter times of the day when traffic volume is lower.

Furthermore, our study uncovered distinct patterns of behaviour among beginner cyclists compared to experienced cyclists. Beginner cyclists were more likely to exhibit cycling patterns that differed from those of experienced cyclists. These patterns suggest that the environments surrounding beginner cyclists do not adequately support their development and confidence building. This finding underscores the importance of creating supportive cycling environments for novice riders, such as implementing dedicated cycling infrastructure, providing cycling education programs, and improving road safety measures. The failure of the urban space to enable women who try to gain cycling independence aligns with observations by Lam [Lam19] and Massey [Mas13] on gendered politics of place.

## 4. Discussion and Conclusion

Data notebooks have emerged as a powerful tool in the field of GIS, enabling the creation of reproducible and scalable analytics [YLH*19]. Tools such as Jupyter Notebooks, R-markdown, and Observable facilitate the integration of software code, output, explanatory text, and diverse media resources within a single document [Per18]. The application of data notebooks incorporating GIS is widespread across disciplines such as economics, biology, and astronomy [Per18].

While the utilisation of notebooks in the context of active travel is still in its early stages, there are notable examples of their emerging use. For instance, Sin [Lau20] implemented a routing algorithm within a notebook, and Zhenlong conducted an analysis of origin-destination flows [Lau20].

In the present study, the data notebook served as a versatile platform for integrating multimodal personal data. It provided a structured environment for performing various operations, both manual and automated [WGK10]. The use of visualisation data notebooks enabled us to explore the mobilities of an underrepresented subgroup of people who cycle in an intimate and immediate manner as it both preserved the idiosyncrasies of their individual movements and provided aggregation and refinement of some aspects (such as temporal). It allowed us to explore the data interactively, uncover

forgotten instances, and gain a richer understanding of the participants' behaviours and needs. By combining quantitative data with qualitative insights, we were able to develop a more nuanced understanding of the challenges faced by this sub-group of riders and the factors that influence their cycling behaviour.

These findings highlight the need for targeted interventions and infrastructure improvements to create a supportive and inclusive cycling environment, especially for women and beginner cyclists [Lam22]. By increasing our understanding of the specific needs and concerns of these groups, we can promote their confidence, enhance their riding experience, and ultimately create social environments and urban infrastructures that will help minority women adopt cycling as a sustainable mode of transportation.

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