

# Mobile Map Applications for Foldable Devices

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## ABSTRACT

As foldable mobile devices grow in popularity, they often feature two screens—a smaller cover screen and a larger inside one, accessible by unfolding the device vertically or horizontally. Despite this, most mobile applications, including map apps, have yet to be fully optimised for these interfaces. This paper explores adaptations of mobile map applications for foldable mobile devices to enhance usability and user satisfaction. In a user study with nine participants, we identify key aspects of mobile map app design for exploration and navigation scenarios. Our results show that in navigation scenarios, screens should provide complementary information, with turn-by-turn instructions on one screen and a route overview on the other. Furthermore, our results show that map views should maintain map alignment and orientation across screens during exploration to prevent disorientation. Ultimately, we find that the success of mobile maps on foldable devices rests on the role and importance of context and user preference in mobile map interactions. Foldable devices offer a valuable chance of improving the mobile map experience on mobile devices if designers find useful ways to make use of the two screens and the increase screen real estate.

## CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; *Usability testing*; *Interaction techniques*; *User studies*.

## KEYWORDS

mobile maps, foldable devices, navigation, mobile devices

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## 1 INTRODUCTION & BACKGROUND

Mobile maps, the digital evolution of traditional paper maps, have become an integral part of the daily lives of mobile device users [3, 12, 17, 19]. The functionalities offered by these applications cater to a wide range of users’ needs, including route planning for commuting or travel [8], local business search [4], real-time traffic

updates [6], location sharing [18], and even augmented reality navigation [22]. Unlike traditional paper maps, digital maps can be adapted and customised to fit specific contexts, offering a unique advantage for user experience and usability [10]. Depending on the requirements, adaptations can include points of interest, highlighted areas or other information not available on paper maps, which can drastically improve the interaction [23]. However, these adaptations need to be carefully designed to avoid overwhelming the user or reducing their confidence during navigation and spatial learning [10, 13, 14]. The design of mobile map adaptations, therefore, must consider the specific user, the use case, and especially the screen size of the device. With a range of mobile devices available, from small smartwatches to large tablets, screen size plays a vital role in mobile map design [10]. Especially for smaller screens, researchers have explored ways to convert maps to fit on this smaller form factor. For instance, StripeMaps [23] replaces the two-dimensionality of a map with a linear route on small smart-watch screens to adjust the interface to fit the smaller size.

Existing foldable devices in the market, such as the Samsung Galaxy Z Flip, the Motorola razr, or the Samsung Galaxy Fold, do not only come with multiple screen sizes but also incorporate different folding mechanisms. Each offering a novel approach to provide users with more screen space. However, due to the novelty of these devices, there is currently no research or guideline for mobile map applications on foldables. To effectively design and adapt mobile maps for foldable devices, understanding the diverse ways users interact with mobile maps is crucial. As mobile maps continue to evolve, becoming more information-dense and tailored to specific user groups [16], the interaction and user behaviour grow increasingly complex. Therefore, understanding this behaviour is a critical step towards adapting mobile maps for innovative platforms such as foldable screens [17]. Even though research focusing on map interaction and user behaviour is limited, some insightful studies exist [1, 15, 17]. For instance, Savino et al. [17] unobtrusively recorded user data, thus gaining insights about natural user behaviour. The study identifies four primary states of map usage – search, place, direction, and map-view manipulation. These represent the most commonly executed actions on mobile map applications and informed the design of our context scenarios during our study.

Beyond how users interact with mobile maps on traditional smartphones, the emergence of foldable screens introduces new ways of interacting with mobile maps as they offer the unique advantage of dynamically resizable screens and increased mobility. Foldwatch [5], a paper prototype developed based on an origami folding technique, explores the potential for foldable devices by unfolding smaller screens (mostly used for passive information consumption) to larger screens for more complex interactions. A similar approach could be taken with mobile map applications. FoldMe [9] proposed principles for foldable designs and explored

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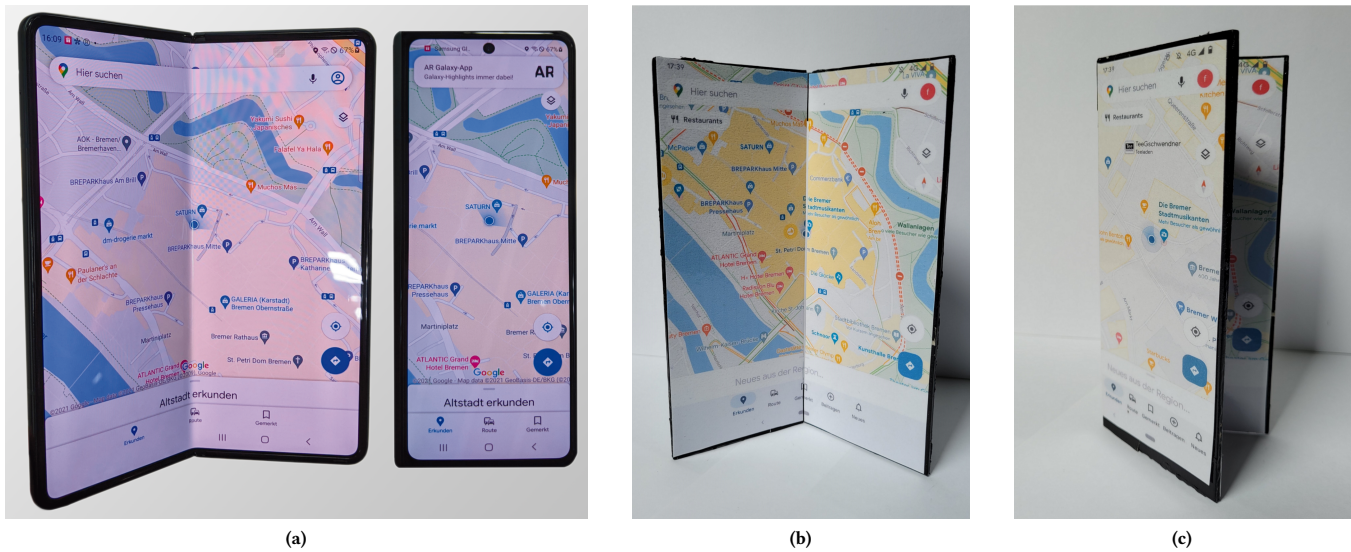


**Figure 1: The Galaxy Z Fold3 5G phone running Google Maps (a) and our paper prototype showing the cover screen (c) and the inside screen (b) of the paper prototype**

various folding techniques for flexible devices. One highlighted feature is the double-sided design, allowing developers to utilise both display sides for enhanced access and multitasking. The study suggests folding interactions are a natural addition to established touch gestures, enhancing user experience. Lee et al. [11] indicate users prefer a mix of folding, tearing, crumpling, and conventional touch gestures when interacting with foldable devices. Ultimately, while designing for novel form factors such as foldable devices, map customisation should be highly flexible and individualised, stating that there are diverse use cases with well-defined needs [2]. Specific guidelines, like those suggested by Höök [7], can help to ensure such map adaptations don't violate usability principles and maintain user autonomy.

Therefore, in this research, we investigated the design of mobile map applications for foldable devices with nine participants using paper prototypes with different context scenarios in a lab study. Our results highlight the importance of the context; during navigation scenarios, participants preferred different map views on the inside screen and cover screen of the foldable device, while inconsistencies between screens during exploration scenarios proved confusing. Participants also appreciated keeping the map orientation aligned between the screens and the larger screen space provided by foldables.

While existing literature provides valuable insights into the functionality and user behaviour associated with mobile maps, as well as design principles for foldable screens, there remains a gap in understanding how these two intersect. Our study aims to bridge this gap by investigating the impact of foldable screen designs on user interactions in mobile map applications.

## 2 METHOD

We collect qualitative and quantitative data to gain insights into device usability and user preference when adapting mobile maps for foldable devices.

### 2.1 Participants

The study involved nine participants (5 males and 4 females) aged 22 to 30. Eight participants had no prior experience with foldable devices, and one had a single encounter in a store. None had used a mobile map app on foldable devices before. Three participants used regular mobile map apps several times a day, two used them weekly, three bi-weekly, and one monthly. All participants primarily use Google Maps for navigation.

### 2.2 Prototype

To conduct the study, we developed a paper prototype based on the Samsung Galaxy Z Fold3 5G (see Figure 1). It consists of two black-painted cardboard pieces taped together in the middle to open and close the prototype. Laminated screenshots glued to the cover and inside screen of the prototype imitate the cover and inside screen of the device. The prototype's dimensions correspond to the actual device: the inside screen is 158.2 x 128.1 x 6.4 mm in size, and the cover screen is 158.2 x 67.1 mm. The paper prototype was used to explore different map adaptations during various context scenarios.

### 2.3 Procedure & Measures

The user study consists of three parts and was conducted in a lab setting. In parts 1 and 3 of the study, participants are asked to describe useful adaptations to the user interface while exploring and sketching on the paper prototype [21]. This is done at the beginning (part 1) and repeated at the end of the study (part 3). Part 2 of the study explores multiple mobile map adaptations along three

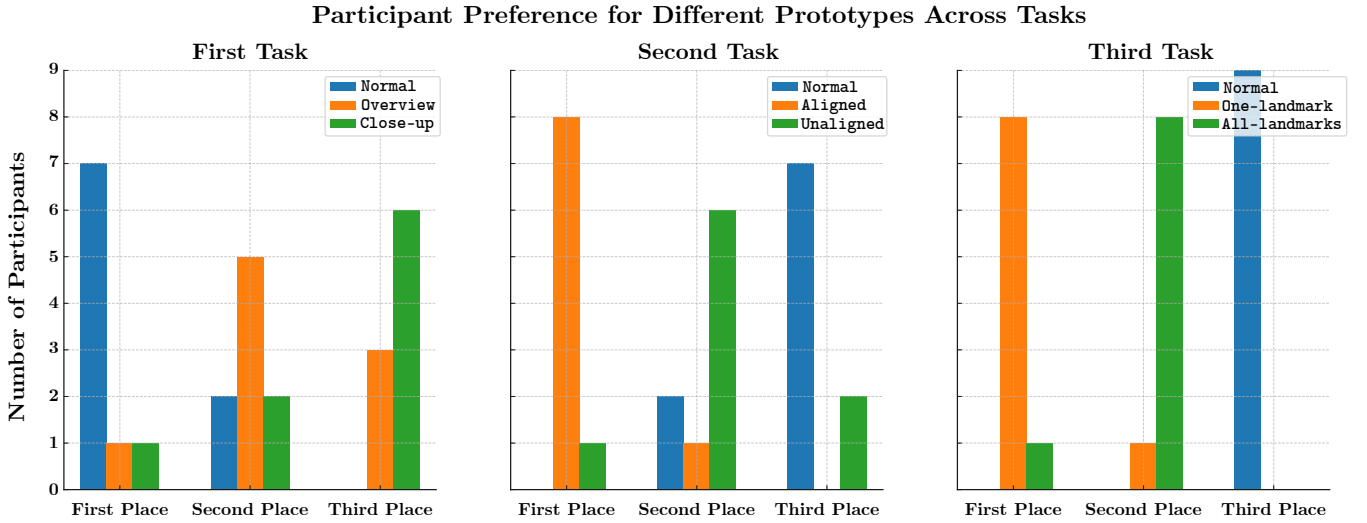


**Figure 2: Rank order results of the interface alternatives for the three different tasks.**

different tasks addressing a distinct aspect of user interaction with mobile maps. For each task we designed three alternative interfaces (visualisations of the interfaces can be found in the supplementary materials) [20]. The cover screen of the device always showed the default view of the mobile map application without any adaptations. Users were presented with one of three alternative interfaces on the inside screen when unfolding the prototype. Users went through all three interfaces for each of the tasks and were primed with a suitable context scenario for the task. During each task participants were asked to think out loud and were asked to rank the three different interfaces per task in the order of their preference.

**2.3.1 Task 1: Zoom Levels and Map Views.** With this task, we examine the user preferences regarding spatial orientation in unfamiliar urban environments, specifically comparing the default broader spatial overview to a more detailed map view. Users are initially presented with their current location on the cover screen, followed by three distinct options on the inside screen:

- (1) **Normal:** The map with the default zoom level
- (2) **Overview:** A zoomed-out overview of the map
- (3) **Close-Up:** A zoomed-in view of the map, providing more detail, such as nearby points of interest

**2.3.2 Task 2: Map Alignment and Zoom Levels During Navigation.** In this task we examine user preferences in navigation scenarios, whether users favour a larger map overview or the default zoomed-in view while following a route, as well as determining the preference for map alignment in route overviews. The cover screen displays an active route with the default zoom level, while the inside screen presents users with three alternative choices.

- (1) **Normal:** An aligned view of the map with the default zoom level
- (2) **Aligned:** An aligned view of the map displaying the entire route
- (3) **Unaligned:** An unaligned view of the map displaying the entire route

**2.3.3 Task 3: Use of Landmarks in Navigation.** The task investigates zoom levels and the size of map sections during route following using landmarks. The cover screen provides the default view of an active route passing a landmark. Users are given three options on the inside screen:

- (1) **Normal:** The map with the default zoom level
- (2) **One-Landmark:** A larger map section showing the user's distance to the next landmark
- (3) **All-Landmarks:** An overview of the entire route highlighting all landmarks along the way.

## 3 RESULTS

This chapter presents the results of the ranking task and the qualitative findings from the think aloud protocols.

### 3.1 Prototype Preferences

Figure 2 illustrates the participant preferences across three different tasks, each exploring a unique aspect of mobile map applications for foldable mobile devices. For the first task focused on general map exploration, the *Normal* prototype was the clear favourite, with being ranked on the first-place seven times. The *Overview* prototype also received some attention but was largely placed in second or third place. In the second task, which aimed at evaluating the map alignment during navigation, the *Aligned* prototype was overwhelmingly favoured, with being ranked on the first-place eight times. In contrast, the *Normal* prototype, which dominated the first task, was ranked primarily on third place, indicating that alignment is a critical feature for user satisfaction in the navigation context. The third task highlighted the importance of landmark representation during navigation. The *One-Landmark* prototype was almost universally chosen as the best, with being ranked at the first-place eight times. Interestingly, the *Normal* prototype again was the least favoured, emphasising that additional screen space should be utilised effectively for information that enhances user navigation experience. Our results highlight that for task two and

three, alternative designs to the normal design were favored, indicating room for improvement in terms of mobile map design for foldable devices.

### 3.2 Qualitative Findings

Beyond our ranking analysis, we analysed the think aloud protocols to collect additional insights into participants decisions and design choices.

During the first part, participants expressed that they would like for the inside screen to display more contextual information, such as POIs and other people's locations like those of friends and family. They also suggested UI changes, including more customizable settings to display additional information. Generally, most participants liked the bigger screen after unfolding the device, "it could help a little better as compared to a smaller screen" (ID 6). Others, however, considered it redundant to have another bigger screen when the smaller cover screen sufficed for their needs.

In the third part, participants were not only more experienced regarding foldable devices they were also more open to express their ideas. Participants mentioned that the ideal zoom level would be context-dependent. As one participant put it, the zoom level is a "double-edged sword" (ID 8). Most of the times the standard zoom level was just fine, but for specific actions (like for example in task 3 of part 2) a more zoomed out view could be more beneficial to get an overview over the route. Another topic that emerged was the display of more relevant points of interest, as one participant noted, "In any case, I think I would have drawn in even more places, i.e., more POIs... that there is much more to explore in my direct surroundings" (ID 7). Currently mobile map applications on foldable phones do not take advantage of the larger screen size. For mobile maps participants often highlighted that a lot more information could actually be shown than was visible on the normal view in our prototype.

We asked participants specifically about how they felt about the fold/unfold gesture and how they would utilize it. Some participants criticized the need for using two hands to unfold the device: "I always find it nice when you can do things with one hand. That's why my mobile phone is also rather small so that you can still use it well with one hand" (ID 2). However, the fold gesture found favour for specific scenarios such as zooming into the map during cold weather: "It's cold, you're wearing gloves. You want to pinch to zoom, and it's so annoying" (ID 5). In direct comparisons between traditional pinch gestures and folding interactions, reviews were mixed. While some found folding more precise and efficient, others preferred the familiarity of traditional gestures. Especially for rotating the map they disliked the unfold to rotate feature in task 2 of part 2: "I know that automatic rotation means mental effort for me [...] I don't think I would actually use it like that in a foreign city, for example, or when I'm really pressed for time, or I just have to go somewhere quickly" (ID 2).

## 4 DISCUSSION & CONCLUSION

Our study reveals that the optimal map design for foldable devices is highly dependent on the context and user preferences. In navigation-oriented tasks (task 2), the *Normal* prototype was less favoured, both in ranking and qualitative feedback, as it did not

offer any additional utility. On the other hand, during exploration tasks (task 1), this prototype was often ranked first, and participants wanted a stronger mental correlation between the cover and the inside screen. Opinions about zoom levels were mixed during exploration tasks, but there was a general preference for mid-range zoom in both exploration and navigation scenarios. This mid-range zoom was considered to display the 'right' amount of information which was also somewhat personal to the different participants. Participants also expressed a desire for more relevant or personalised information and less irrelevant data, a sentiment particularly strong in the explorative parts of the study. Aligned map views were overwhelmingly preferred over unaligned ones, described as less intuitive and more irritating. This was supported by the rank orders. The preference for unaligned maps appears to stem from a minority of participants who wish to challenge their sense of orientation rather than merely follow directions.

Regarding foldable interactions, the findings were inconclusive. While some advantages over traditional pinch gestures were noted, particularly in terms of precision and time efficiency, participants also voiced reservations. The primary benefit of foldable devices was the increased screen real estate when unfolded. However, its usefulness is tied to personalisation and map designs that align with user expectations. Some participants indicated that they would prefer foldable gestures like unfold-to-zoom or unfold-to-rotate if the expanded screen displayed precisely what they desired. In essence, the success of foldable interactions as a replacement for conventional touch inputs relies on personalisation and contextual utility.

Our results underscore the role and importance of context in mobile map interactions on foldable devices. The study identifies key areas such as map alignment, zoom level, and user interface gestures, thereby contributing to an understanding of the challenges and opportunities for future design strategies in foldable mobile map applications. Participants differentiated between navigational and exploratory scenarios, showing a preference for different map views on the foldable device's screens. Our results suggest that designers should consider the context when determining map features and that personalisation becomes especially important in exploratory scenarios, presenting a design opportunity to adjust, for example, zoom levels based on user behaviour or settings.

Though foldable interactions were appreciated for their efficiency and precision, participants generally favoured conventional pinch-to-zoom and pinch-to-rotate gestures. This may be attributed to familiarity, highlighting the importance of user adaptation over time, as foldable technology becomes more mainstream. Furthermore, participants highly valued the larger screen space offered by foldables. The foldable device's larger screen offers more room for displaying important information like Points of Interest (POIs), landmarks, and potentially even advertisements. While our study focuses specifically on foldable devices, our results show that personalisation and context-specific behaviour are what users expect from a next-generation mobile map application. Foldable devices are in a particularly interesting position regarding this potential development as the multiple screens these devices provide can be used flexibly instead of the static behaviour they show today.

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