Improving Commuter Safety Through Geographical Crime Data Mapping

by

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Abstract

Due to the rapid increase in mobile technology, many people use a smartphone on a daily basis to commute. However, the current mobile map applications lack the ability to visualize how safe the route will be, especially for people who commute by walking. This research presents a prototype for a mobile application that can be used to combine geographical crime data with a map-based route, as well as research on the existing geographical crime data routing solutions, mobile usability issues, and data visualization methodologies. This research also includes a usability evaluation of the prototype to identify usability issues that can be improved. The results suggest recommendations on how geographical crime data can be used to improve commuter safety through map routes that are dynamically generated based on the crime statistics.

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Chapter 1: Literature Review

Introduction

Crime data is generally available to the public, though it is stored in large databases that are not easy to query. Recently, data visualization has become very important for usability. A recent example is the COVID-19 pandemic. People needed a way to quickly visualize statistics related to the pandemic. In order to create a mobile application that utilizes data visualization, it is important to analyze current examples to identify methodologies that can be applied. Additionally, it is important to research best practices for mobile design and location-based design. Ultimately, the research in this review will provide a foundation for designing and developing a mobile application that uses geographical crime data, such as Baltimore 311 and 911 data, to help commuters map the safest route possible.

Literature Review

Data visualization

In today's technologically advanced society, there is a plethora of data that is available to the public. More importantly, there is data that can be extremely valuable if it is consumed in a way that communicates the most important insights. The challenge of data visualization is to recognize what we are seeking, and to reduce the choices based on that (Kirk, 2012). Some examples of data visualization include tables, graphs, maps, and even images that are annotated based to highlight specific information.

Geographic data visualization. While people might be familiar with data visualization techniques used for applications that they use, there are specific techniques available when mapping geographical data. Each technique has benefits depending on the audience that is consuming the data, and each method has a specific type of data that it displays best. In some cases, the data might not be specific enough to plot points on a map, but rather it might be relevant to a large area on a map.

One data visualization technique is a choropleth map, which uses colors with differing saturation to display data based on quantitative values for geographic units, such as states or countries (Kirk, 2012).

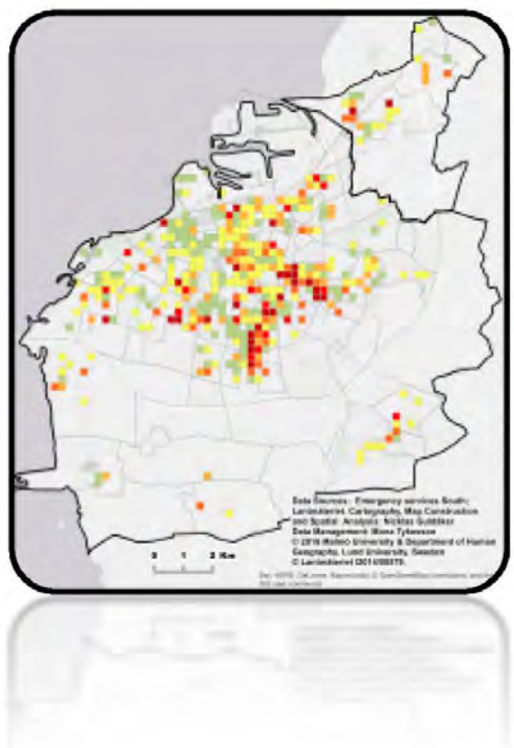

Figure 1. Geographical data based on fires displayed using a choropleth map (Guldåker, 2020).

A choropleth map could be used to display quantitative crime data for specific neighborhoods in Baltimore City, but it does not accurately represent the population data for each geographic unit. Choropleth maps are used mostly to represent large geographic areas, but another visualization technique is a dot plot map.

A dot plot map displays the geographical data as a scatter plot, based on longitude and latitude positions on the map (Kirk, 2012). One study on analyzing data visualization to prevent fires found that using a dot plot map can be difficult for emergency service personnel to interpret large amounts of points over large geographical areas (Guldåker, 2020).

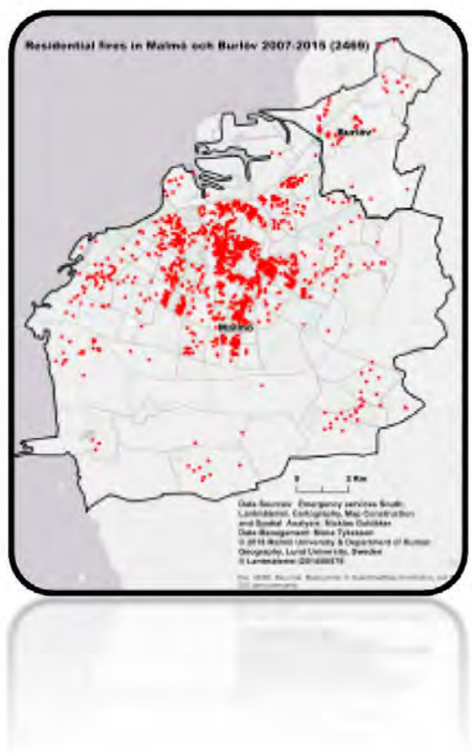

Figure 2. Geographical data based on fires displayed using a dot plot map (Guldåker, 2020).

A dot plot map would be more suited for mapping crime data to display specific events, but could be difficult to consume if there is a large data set and a large geographical area. For example, this method could be used to show specific locations where crime occurred in Baltimore City.

Another geographical data visualization technique is a bubble plot map, which uses differently-sized circular markers to represent quantitative data for a geographical location (Kirk, 2012). This technique is similar to a choropleth map, but instead of using color to show different quantitative values, it uses differently-sized circles. This technique has been used for mapping COVID-19 cases, specifically by Johns Hopkins University of Medicine (*COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)*, n.d.).

Figure 3. Quantitative data for emails per second displayed using a bubble plot map (Kirk, 2012).

A bubble plot map would be helpful in visualizing quantitative crime data for specific neighborhoods in Baltimore City, while providing a better differentiation between quantities than a choropleth map since it is relying on size rather than color.

Techniques for visualizing geographical data are important to understand in order to design and develop an application that will inevitably use one of these techniques. However, it is also important to analyze techniques for visualizing crime data, and research current crime data visualization applications to gain an understanding of how those techniques can be applied to the design and development of a mobile application.

Crime data visualization. The techniques used for geographical data visualization align similarly with techniques for crime data visualization. However, visualizing crime data requires the data to be more granular, typically at the census tract level (Jefferson, 2018). Considering the data for crime visualization is more granular, it is possible that a dot plot or bubble plot map would be the best choice in representing the data.

Another important factor to analyze for crime data visualization is predictive crime mapping. Using statistical crime data in order to predict future crime is one technique that could be important in understanding crime data visualization techniques. One study analyzed data collected by the Vancouver Police Department around where and when crimes occurred, then predicted future crime locations with that data (Fitterer et al., 2015). They found that there was strong spatial clustering of crimes over short periods of time. One important component to actually implementing a predictive crime mapping tool is automation of the predictive tool (Fitterer et al., 2015). In order to effectively predict future crime, the tool would have to automatically update the data that it is analyzing.

Crime data visualization already has some proven benefits, even without considering the ability to predict future crime. The NYPD uses CompStat 2.0, a geographical information system (GIS), in order to provide the public with a user-friendly map of crime data (Tewelow, 2018). With today’s technology, crime data visualization is possible through GIS platforms such as CompStat. Since CompStat was introduced, the average crime per month has decreased in New York City (Tewelow, 2018). It is important to consider that making crime data visualization available to the public can benefit society by decreasing the quantity of crime. In developing an application that utilizes geographical crime data, it is important to ensure that it is available to a wide audience and that it meets the usability needs for a wide range of users.

Another example of a crime data visualization app is *SpotCrime*, a mobile application that maps crime data to a *Google* map. *SpotCrime* collects crime data from police resources and other validated sources to plot the data on a map (*Find Crime in Your Neighborhood*, n.d.). *SpotCrime* also allows the ability to search from crime around an address (*Find Crime in Your Neighborhood*, n.d.).

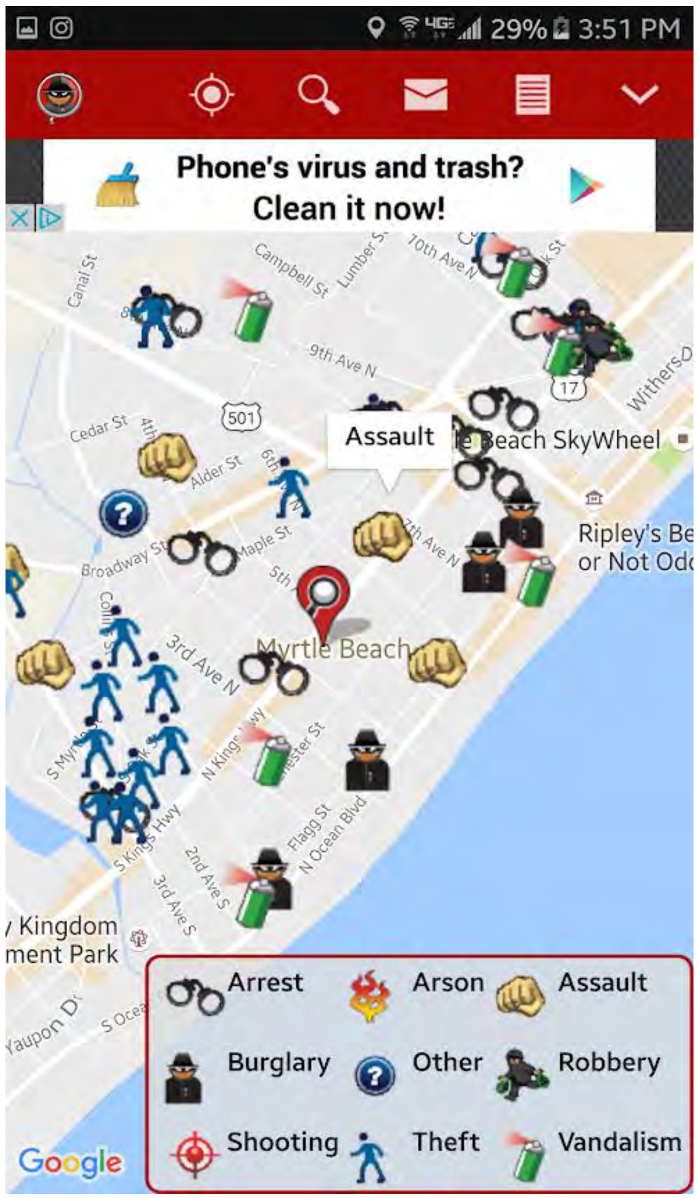

Figure 4. Screenshot from *SpotCrime*, showing the crime map and icons used for each crime (Obtained from the *Google Play Store*).

SpotCrime is an example that can be used when designing a mobile application that uses geographical crime data, especially the use of icons and location-based mapping.

Interactive data visualization. Creating interactive data visualizations can be extremely complex for the developer and designer. It is important to consider that an interactive data visualization should be used to enhance the clarity and accessibility to data perception, rather than compromise it (Kirk, 2012). Although there are a lot of possibilities when adding interactions to data visualization tools, it should be kept simple so that it only meets the needs of the user.

Another important aspect to consider when making data visualizations interactive is that users should have quick access to descriptive statistics for specific regions (Smith, 2017). For example, in a crime data map the regional markers should have the ability to show the numeric information for that region through an interaction. This information could be a description of the crime and location for a specific crime event, or it could be quantitative crime information for a region.

During a study that used interactive data visualizations to analyze undergraduate students in a genomics course, the researchers noted that the students primarily used the following operations when interacting with the map; panning and zooming to keep oriented, search to find elements of interest, and focus to select certain items (Mirel et al., 2016). These operations can be applied to the design of an application for mapping crime data as well. Panning, zooming, searching, and selecting are all common operations for interactive map tools. One usability issue that was found during that study was that students had trouble processing lengthy numerals in the descriptive data (Mirel et al., 2016). This is something to consider when designing interactive data visualization tools, because there is the possibility for large amounts of data to be consumed at once. Providing descriptive data that requires low cognitive processing can improve the usability of the application.

The interface complexity is an important factor when designing interactive data visualization applications, especially for a user who is not familiar with interactive map tools. One study on the usability of an interactive map found that showing a simple view of the map without any extraneous views was the best experience for new users (Roth & Harrower, 2008). Users who have more experience using map tools might prefer an initial map view with menus and legends already open, but this would be too complex for a new user. Another finding from that study was that users thought that the look and feel of the map was different from the look and feel of the interface and menus (Roth & Harrower, 2008). Consistency is extremely important when designing an interactive data visualization tool, so that users are able to recognize the actions associated with specific interactions.

Location-based design

Location services, specifically on mobile devices, enable developers to utilize the real-time geographic location of the user. Global Systems for Mobile (GSM) and Universal Mobile Telecommunications Systems (UMTS) can be utilized to obtain location information without the need for external hardware (Jafaar & Nema, 2019). Although location information is accessible through GSM and UMTS, it is important to consider the ethical implications of being able to access location information. User privacy is becoming an extremely important topic in web development. In developing an application that utilizes personal data such as location, it is important to understand the best way to handle the data while keeping the user's privacy in mind. The limitations of the device are also important when doing location-based design. Constantly requesting location data can be a large consumer of a device's battery power (Jafaar & Nema, 2019).

Location-based services. Many mobile device users are using applications that utilize location-based services on a daily basis. Location-based services work by offering context-based assistance to users based on their current location (Gamarra et al., 2019). location-based services are being used in many common applications such as a Google search or a social media post. When Google asks the user for permission to use their location and social media applications allow an option to share the user's current location on the post, it is using location-based services to identify the user's current location.

One example of a mobile application that uses location-based services and utilizes geographical data is the *Citizen* application. Citizen started in 2017, specifically in New York City, but it has since expanded to San Francisco, Baltimore, and Los Angeles (Herrman, 2019). The *Citizen* application gets information for events through a team of people who listen to police, fire, and emergency radio transmissions, as well as users who document and record events through the application (Herrman, 2019).

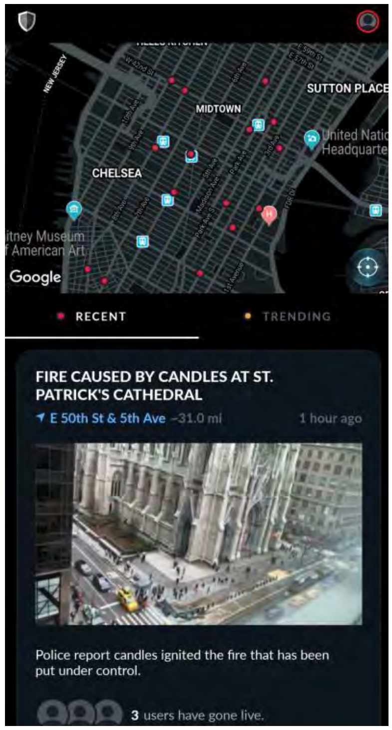

Figure 5. A screenshot of the *Citizen* app, showing a specific event and the map with other relevant events (Herrman, 2019).

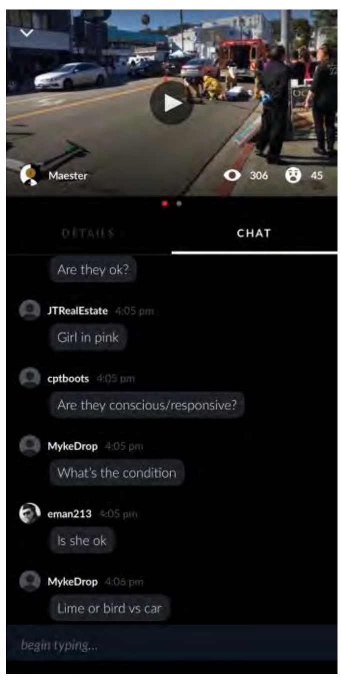

Figure 6. A screenshot of the *Citizen* app, showing the chat and video options available for an event (Herrman, 2019).

The *Citizen* application is a good example of how geographical data can be presented to the user. The map shows pins where there are events, and it allows the user to view details about each event by selecting the pin. Also, *Citizen* implements a social media aspect by allowing users to communicate through a chat and record events as they happen.

User privacy. Inevitably, location-based design is going to have privacy and security risks for the user. However, user privacy should not just be an afterthought when designing a location-based application. User privacy should instead be the primary focus of the design. User privacy and security is not limited to just their location either, but rather it consists of location privacy and query privacy (Cui et al., 2020). it is important to consider both of these factors from the beginning of the design phase.

When a user opens an application that uses location-based services, the device submits the user’s exact location and queried interest to an untrusted server (Cui et al., 2020). That information that gets sent to the server can be sensitive information. Theoretically, someone could obtain that information and they would know the exact location of the user. Some current solutions to this issue are false locations, spatial cloaking, and space transformation (Cui et al., 2020). These approaches are designed to protect a user’s location privacy, but fail to address a user’s query privacy. In other words, these approaches hide the user’s specific location but they do not hide the queried interests of the user.

Ethics are another important factor in user privacy, especially when using location-based services. Most users are not aware or even interested in the fact that their location can be stored and sold to third-party companies (Gamarra et al., 2019). Not only do users need to be notified when their location is being accessed, but they also need to be notified about what happens to that data. Although it might not be illegal to store users’ location information, it is unethical to store that information and sell it without their consent. One study did a survey that asked about which situations users consider an invasion of privacy on their location (Gamarra et al., 2019). The survey found that the majority of users in the survey group that were between 19-25 years, male gender, bachelors and students answered that selling their location data to third parties without being informed was an invasion of privacy (Gamarra et al., 2019). In the event that the location information needs to be stored, it seems that the best solution to protect the user's privacy is to inform them and get permission first.

Device limitations. Most location-based services are used on mobile applications, where the mobile devices have a finite amount of battery power. Applications that use location-based services can cause heavy battery consumption when updating the location information, although this can be lowered by setting a longer interval for how often the location information is being requested (Jafaar & Nema, 2019). it is important to take this into account when designing location-based applications, especially when it makes frequent requests for the user's location information. Battery consumption can also be impacted when the device is on a slow connection, such as a 2G or 3G network (Jafaar & Nema, 2019). Slow connection is more difficult to manage for the developer, but any measures that can be taken to reduce the data size for network requests in an application that uses location-based services should be implemented.

Mobile design

Most people have some exposure to touch-screen mobile devices in some capacity. In order to design a mobile application, it is important to first understand the best practices that the industry already implements. Rather than create new mechanisms for mobile design, it would be best to follow current mobile design standards so users can quickly use the application and become familiar with the user interface.

Touch gestures. One of the most important aspects of mobile applications is the ability to quickly navigate or complete actions with touch gestures. Mobile devices have the ability to capture gestures such as a quick tap, swipe from left to right, tap and hold, etc. Designing for touch gestures is not simple, though, due to variability during user's interactions with their phones (Kim & Jo, 2015). For example, users may have different hand sizes or different positions for holding a phone. Some users may use their thumb for interacting with the screen while other users might use a finger.

There are some commonly used and understood touch gestures that users expect when using mobile applications. One of those gestures is the tap gesture, which happens when a user comes into contact with the screen (Mendoza, 2013). The tap gesture is commonly used to click on a button or to initiate another touch gesture. The drag gesture is another common touch gesture that is used to scroll or pan the user interface (Mendoza, 2013). This could also be used to drag a slider that increments and decrements an input, or to drag an item to another location on the screen. Similar to the drag gesture, another common touch gesture is the flick gesture, which allows the user to quickly tap and flick up or down to scroll or pan quickly (Mendoza, 2013). This gesture can be used to quickly scroll on the page or to flip through screens. An example would be flipping through images. The flick gesture is primarily for vertical flicks, but another touch gesture is the swipe gesture, which happens when the user flicks horizontally on the screen for directed on-screen movement (Mendoza, 2013). The swipe gesture is commonly used for flipping between screens or flipping between images. An example is the home screen on the iPhone, which allows the user to move to the next or previous screen by swiping right or left. Lastly, the pinch gesture is another commonly used touch gesture, which is used to control zooming in and out based on two contact points that move together or away (Mendoza, 2013). This gesture is used in map applications to zoom in and out on the map.

Speech input. Today’s technology has provided the ability to incorporate speech input into mobile applications. One common example is being able to search through speech input. Many smart televisions allow the ability to search for shows and movies through speech input, mobile devices have Siri and other speech input tools built-in, and desktop computers have speech input tools built-in such as Cortana in Windows computers. There are already a vast number of devices that support speech input, but it is important to understand how it can be used when implementing it into a mobile application.

Speech input can also be used to overcome cognitive skill limitations. One study researched the effect of speech input on multi-touch gesture systems for children and it found that the use of speech input as an alternative mode for multi-touch gestures is beneficial for children to overcome their cognitive skill limitations (Hussain et al., 2018). The study was done specifically with children, but the same conclusion would apply to adults with cognitive skill limitations.

One limitation of mobile devices is that it can be difficult to type a search and sometimes the user needs to get information quickly. There are some examples of mobile applications that allow users to quickly get information about nearby businesses and other resources, such as TellMe and OneSearch (Arar, 2008). Speech input can be used to help users quickly access information on mobile applications, especially if they struggle with typing on mobile devices.

Screen size. An obvious limitation for mobile design is the screen size, which is inherently smaller than desktop computer screens. This means that mobile applications have to follow different principles than desktop applications, because there is less space for the interface.

It is important to show only the most important information on the screen at a given point in mobile design. One example is the common use case for a map application. The pattern for a map application on a mobile device is to search for an address, preview the map, and view further details on that location (Mendoza, 2013). In the example in Figure 7, it shows how a common map application can use the available screen size in a way that only shows the information that the user needs at that phase in the user flow. These same principles can be applied to mobile design.

Figure 7. The user flow of a common map application (Mendoza, 2013).

Conclusion

Data visualization, location-based design, and mobile design are important aspects of geographical data mapping and mobile application development. More specifically, the guidelines and best practices can be used to design and develop a mobile application that meets the usability needs of the users. Since there are already existing applications that combine crime data with data visualization, those examples can be used to further research the possibilities in regards to visualizing crime data in a meaningful way. The existing examples and current design guidelines in this review will provide a basis for future research on improving commuter safety through geographical crime data and development on a mobile application solution.

Chapter 2: Methodology

Overview

The focus of the research was to gather feedback through usability testing on a prototype of a map-based mobile application. The application was built using the research in the literature review, in order to create an application that follows current standards and patterns for map-based design. The prototype includes a map that shows geographical crime data, and the ability to show a route on the map between two locations. During the usability testing, a facilitator asked the user to perform specific tasks using the prototype. While the user performed the tasks, the facilitator observed their interactions to understand what areas of the application can be improved. Additionally, the facilitator asked the user questions about their current usage of map applications and their direct thoughts on how the prototype could be improved.

Participants

The participants for the usability testing were contacted by email and asked to voluntarily participate in the study. A total of 10 participants were recruited to participate in the usability testing. Each participant was asked to answer questions about their current occupation, age, and mobile device usage. The participants were between the ages of 21 and 31, residents of Baltimore, and owners of mobile devices.

Table 1

Participants and their age, gender, occupation, mobile device, and primary map application

Participant	Age	Gender	Occupation	Mobile Device	Map Application
1	21	Male	Student	iPhone	Google Maps

2	26	Female	Student	iPhone	Google Maps
3	26	Male	Reporter	iPhone	Google Maps
4	24	Female	Accountant	iPhone	Apple Maps
5	24	Male	Retail	iPhone	Apple Maps
6	24	Male	Student	iPhone	Apple Maps
7	24	Male	HVAC Technician	iPhone	Apple Maps
8	31	Male	Student	iPhone	Waze
9	22	Male	Student	iPhone	Apple Maps
10	26	Male	Student	iPhone	Apple Maps

Materials

The usability testing sessions were conducted through remote video calls on *Zoom*. The sessions were about 20 minutes each and consisted of background questions, tasks for the usability test, and follow-up questions about the prototype. The prototype for the usability testing was a high-fidelity version that is built with JavaScript, using the React framework. The prototype was hosted through the *Expo Client* app that the participants were able to download on their own mobile devices to access the prototype for the usability testing sessions. The participants were given a username and password to login to the *Expo Client* app in order to access the prototype. Each participant used their own device to access the prototype and shared their screen through *Zoom*.

During the usability testing sessions, the users were first asked to answer background questions about themselves and their mobile device.

Table 2

Background questions for the usability testing

Questions
What is your occupation?
What is your age?
What do you currently use to map a route?
What mobile device do you use?

After answering the background questions, users were asked to complete tasks using the prototype. The tasks were created to test the usability of specific areas in the prototype. As the user completed the tasks, the facilitator observed their interactions and helped guide the user if they were unable to complete a task. While completing tasks, the participants were asked to narrate their thoughts so the facilitator could understand their thought process.

Table 3

Tasks for the usability testing

Task Order	**Question**
1	You're planning on walking to Patterson Park in Baltimore, but you want to take the safest route. Find the safest route to Patterson Park based on your current location.
2	You're planning on walking from Patterson Park to Madison Square Park and you want to find the safest route ahead of time. Find the safest route to Madison

	Square Park from Patterson Park.
3	You want to see a map of recent crime around your current location. Find recent crimes around your current location.
4	You only want to see crime that is assault or robbery. Filter the map to only show crime that is assault or robbery.
5	You want to see crime that occurred in October of last year. Filter the map to only show crime that occurred in October of last year.

Each participant was asked to sign a consent form before participating in the usability testing. Out of the 10 participants, 9 gave consent for the session to be recorded so the facilitator could observe the session more closely. The consent form was sent to each participant through email, and then returned through email after signing.

Chapter 3: Results

Overview

During the user testing, each session was recorded so they could be observed independently. After observing each session, the prototype was updated and more user testing sessions were conducted. As changes were made to the prototype, those differences were closely examined in the sessions that followed to ensure that the changes resulted in the desired usability improvements. The most common points of feedback were around data visualization and consumption, memory and recognition, ease of navigation, and visual defects.

Data Visualization and Consumption

All 5 of the tasks required the user to interact with the visualization of crime data. For tasks 1 and 2, users were asked to find the safest route to a specific location. Task 1 required the user to find a route from their current location, and task 2 asked the user to find a route from one specific location to another. In each task, the user was asked to find the safest route possible. Task 1 and 2 both had a success rate of 80%. One of the failures was due to the user not realizing that they had to type the from and to location. Instead, the user zoomed into each location and said they would find the route themselves using the map. The other failure was because the user did not notice that the route was placed on the map with a blue line.

One recurring point of feedback for the data visualization and consumption tasks was that users were not sure what filters were successfully applied. After selecting filters, the map would refresh but there was no indication of the selected filters unless each filter button was expanded. The suggested change to improve this experience is to show a count for the selected filters, but the level of effort to implement that was too high for the prototype used during user testing and may not have increased usability. Another similar point of feedback was that users were not sure what happened if no data was shown on the map due to filters. For example, if a user selected a filter that returned no crime results, it was difficult to understand what happened. A possible solution for this is to show a message that says “No results were found”.

Users also found it difficult to quickly understand the icons on the map. Initially, the icons were all the same color and shape (see Figure 8), so they were updated to have icons that were specific to the type of crime. This partially solved the issue, but the map would only ever show a maximum of 50 icons due to performance constraints. In order to improve the ability of users to quickly consume the crime data, the map was updated to show a heatmap of all available data, rather than specific icons for a limited amount of data (see Figure 10).

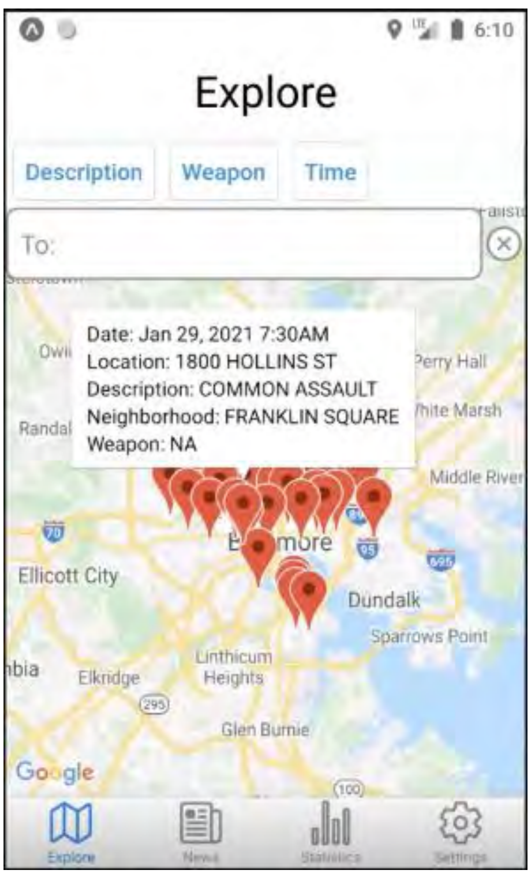

Figure 8. Initial map with icons.

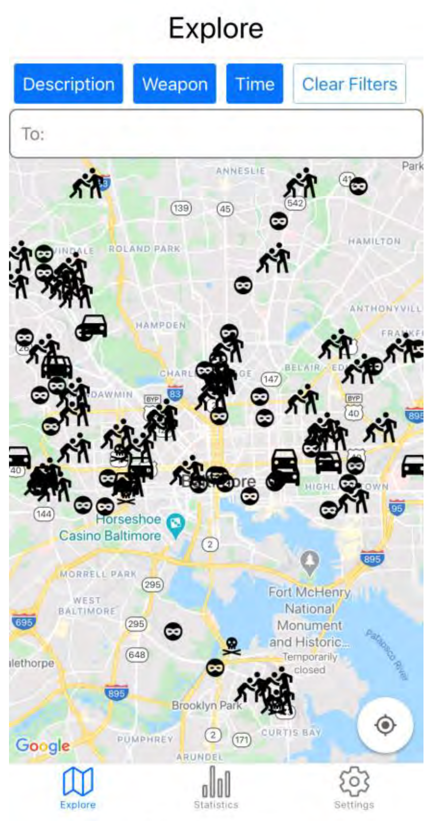

Figure 9. Updated map with specific icons.

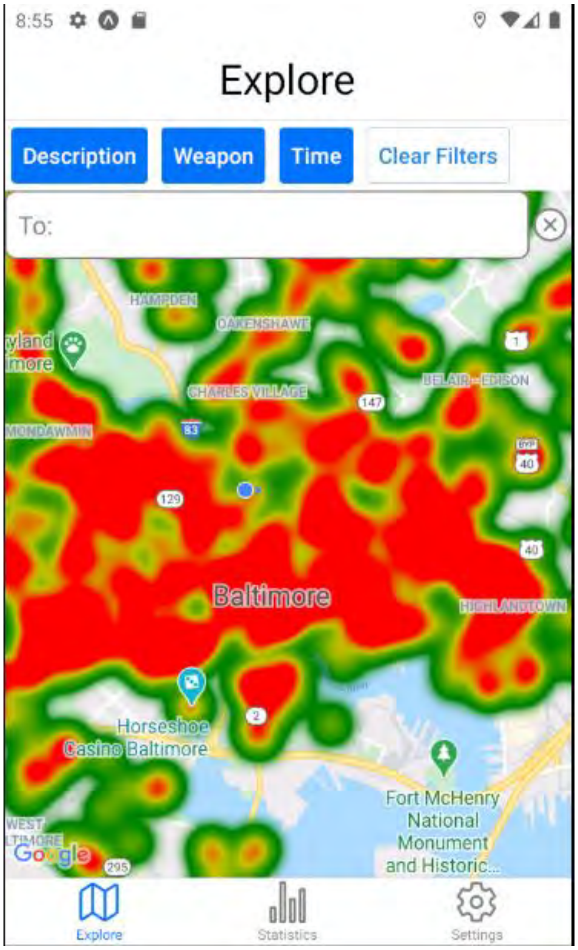

Figure 10. Map with heatmap.

There was some feedback around the statistics screens even though those were not directly tested in the tasks. Initially, the statistics screen had a list of individual crime events, but some users did not understand what the screen was showing or what any of the text meant (see Figure 11). This was updated to be pie charts that show crime counts based on specific categories such as time or type (see Figure 12). This change involved substituting the initial listing visualization with the pie chart visualization. The pie charts still caused some confusion so they were updated to bar charts that better represent the data (see Figure 13).

Figure 11. Initial statistics list.

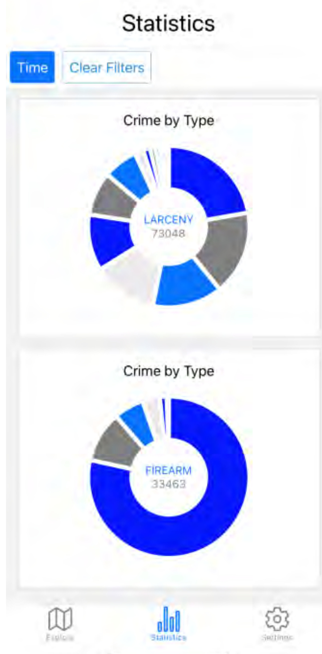

Figure 12. Pie chart statistics.

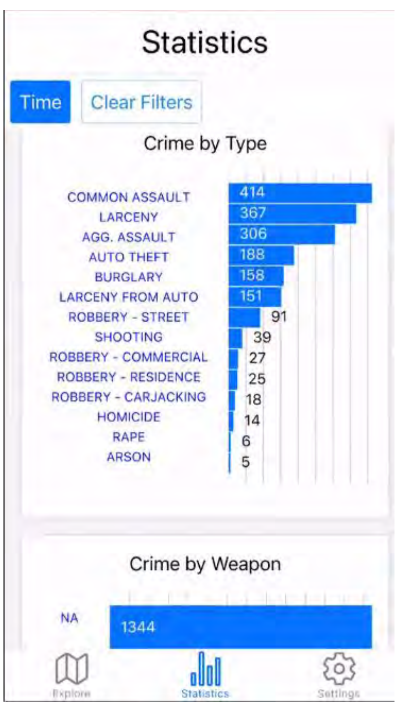

Figure 13. Bar chart statistics.

Memory and Recognition

Tasks 3, 4, and 5 focused on the memory and recognition of mobile design patterns. Each task required the user to select specific filters for the data on the map. The success rate for tasks 3, 4, and 5 was 100% for each.

When selecting filters, one user struggled with selecting a time filter because the button was a checkbox, even though only one option could be selected. This was addressed by changing the filters for time to be radio buttons (see Figure 14). Another observation around memory and recognition was that some users did not understand why the map was resetting its position after a filter was changed. This was frustrating for users who zoomed into an area on the map and were zoomed out to the initial map zoom after changing a filter. The level of effort in preventing the map from resetting was too high for the prototype, but this was an important point of feedback if the prototype is developed further.

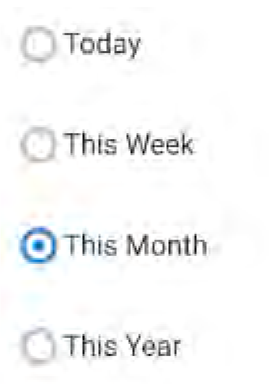

Figure 14. Updated time filters with radio buttons.

Ease of Navigation

Navigation was tested to some extent in all 5 of the tasks. For the tasks that required the user to find a route, the navigation of selecting the “to” and “from” locations was tested. For the tasks that required the user to change filters, the navigation of the filter buttons was tested.

Most of the feedback for ease of navigation was related to the filter menu. One point of feedback was that there was no way to clear all filters at once. A few users mentioned that it was difficult to have to individually unselect each filter. To resolve this, a "clear filters" button was added to the filter menu. Another frustrating experience of the filter menu was that the button dropdown would close after selecting a filter. This meant that if a user opened the button dropdown and selected a filter, they would have to open it again to select a different filter. In order to make selecting filters easier, the dropdown buttons were updated to only close after the user clicked outside of the dropdown, or if they clicked the "close" button.

One observation during the first couple of user tests was that the user could only close the keyboard if they click the "done" button on the keyboard. This was confusing to some users because they could not cancel the keyboard changes. The keyboard interaction was updated to close when the user clicks outside of it in order to make this a better user experience.

The last point of feedback around ease of navigation was that there were some areas that did not have a loading state. This was apparent when users started typing in the search boxes and nothing happened immediately on a slow network connection. To resolve this, a loading spinner was added in the dropdown area for the search text boxes. A loading spinner was also added anywhere that data is fetched; this includes the map and the statistics charts.

Chapter 4: Discussion

Discussion

Interpretations

The user testing identified many areas of the prototype that could be improved to create a better user experience, but the results also provided some correlations with other research for data visualization apps. One of the most important changes to the prototype was updating the map type from a dot plot map to a heat map. This was a challenge for many users because they could not quickly consume the data and identify patterns. During the initial research about map types, one study found that a dot plot map can be difficult for emergency service personnel to interpret large amounts of points over large geographical areas (Guldåker, 2020). This aligns directly with the results that were observed for the prototype in this study.

Another alignment that was observed in the user testing was that participants were familiar with the pinch to zoom interaction. All 10 participants used the pinch interaction to zoom into the map during the user testing sessions. This correlates with a study that noted students primarily used the following operations when interacting with the map: panning and zooming to keep oriented, search to find elements of interest, and focus to select certain items (Mirel et al., 2016). Searching was also observed by 8 of the 10 participants when trying to find a specific location on the map.

Some other general correlations between the user testing results and the initial research were around navigation. Most of the studies for data visualization mentioned that the interactions need to be kept simple and that the amount of information on the screen should be minimal. During the user testing, participants mentioned that the prototype was very “simple” and easy to navigate. This was one of the main focuses of the design, so it was important to get that feedback from users.

The goal of the user testing and the purpose of the application is to help improve commuter safety through geographical crime data mapping. The results indicate that it is possible to improve commuter safety or plan for a safer trip, but only through better awareness. The data is not being updated in real time, so users are not able to see crime that happened in the last hour, for example. However, participants mentioned that they would feel more aware of their surroundings in areas that show high crime rates on the map. The initial hypothesis was that the application could prevent people from walking in areas that recently had crime, but after user testing it appears that the application would be better for improving awareness of geographical areas with high crime so users can be more prepared if they need to walk near those areas. Another possible use could be for determining the risk for delivery drivers.

The results of the background questions indicate that most users surveyed have iPhone devices, rather than android. The prototype for this study was created to work for Android or iOS operating systems, but in the future, it might be better to prioritize iOS over Android. More research would need to be done in order to definitively determine that the majority of users have iPhone devices over Android, but this study showed that all 10 participants have iPhone devices.

Implications

The results indicate that preventing crime based on statistics might be outside the scope of a map with data visualization. Additionally, a heat map proved to be the best solution for visualizing large amounts of data. The heat map provides users with a quick way to visualize areas with high crime rates, which is essentially the most important piece of information that users were looking for. This should be considered when creating a data visualization map for large amounts of data. The initial dot plot map was too complex and confusing for users, but the heat map was easier for users to understand.

The user testing results also build on the theory that new users benefit from a simple interface with a small number of options. One focus of the application was to make the interactions minimal so new users could quickly become familiar. One study on the usability of an interactive map found that showing a simple view of the map without any extraneous views was the best experience for new users (Roth & Harrower, 2008). The results of the user testing support this theory, because users were able to quickly understand what they needed to do and none of the users were ever lost while navigating.

Limitations

Due to some constraints, there were limitations that impacted some of the user testing data. The methodology was impacted by the constraint of remote user testing sessions. Each session had to be conducted remotely through *Zoom* calls due to the Covid-19 pandemic. This meant that the observer could not see the user's facial expressions or hand motions. The observer could only see the screen of the user's device.

Additionally, the reliability of the user testing data was impacted by the demographic of the participants. The prototype is designed specifically for Baltimore City crime statistics, but all of the participants for the user testing study live in Baltimore County. The participants were also 80% male participants and 20% female participants. This could also impact the reliability of the user testing data since the demographic was not evenly spread across genders.

The available crime data is another limitation for this study. The crime data was accessed from https://data.baltimorecity.gov/, and the database is usually 2-3 weeks behind. This meant that the prototype could not access crime data in real time, so users could not see crime that happened recently. Additionally, the data was limited by how the database stored fields. Some fields include “time”, “description”, “neighborhood”, etc., but the data provided to the user was limited by what was available from the database.

One of the most notable limitations of this study was the available time to build the prototype. The prototype was built with JavaScript, but there were only about 7 months to develop it. This meant that some features, such as dropping a pin for a location, could not be implemented or tested for the study. Additionally, the functionality was prioritized over the visual elements. The prototype was high fidelity, but there was a lack of styling for some components.

The study only tested the usability of finding a route and filtering statistics, but it did not actually have any participants use the prototype during a walk in Baltimore City. This is one constraint that could not be overcome due to the pandemic, and it likely impacts the results as well. The user tests required users to find a route as if they were hypothetically about to walk from one location to another, but most users would likely use the app while walking in Baltimore City.

Recommendations

Future research is needed to determine whether commuter safety can be directly improved by geographical crime data mapping. The prototype that was developed for this study could be used to track changes in crime rates after making the prototype publicly available. Alternatively, other prototypes could be created and used to track changes in crime rates.

Another opportunity for future research is observing users actually using the prototype in Baltimore City when walking. This could be achieved through surveys that ask for feedback after users take a walk using the prototype. Commercial uses might also be worth observing. This could include delivery drivers for food services or ride sharing services.

Future research might also include a different way of visualizing the crime data. This study focused on a map as the approach, but other visualization techniques such as charts and graphs could be explored.

Future research should also focus on recruiting participants that include a more diverse audience than the one used in this study. This study lacked diversity of the participants, so this should be considered in any future research. Also, it is important to select participants that live in the area where the crime data is associated with. This study had participants from Baltimore County, but the crime data was specifically for Baltimore City.

One area that the user testing could be improved for future research is the background questions. In this study, the participants were asked what apps they currently use to find a route, but they were not asked how they would find crime data. It would be helpful to know how users get crime data so those apps can be used to identify patterns that can be shared for all crime mapping apps.

If applications are made for visualizing crime data, some recommendations can be supported by this study. For example, crime data maps should use a heat map if there is a large amount of data. If there is not a large amount of data, then a dot map could be used. When using a dot map, the dots should be unique so users can distinguish the different types of crime. In this study, the initial prototype had a dot map with red pins for every crime. Users found this to be confusing so the dot map was updated to have unique icons for each type of crime. This improved the usability and made it easier for users to understand the data, but eventually this was changed to a heat map based on user testing results.

Future applications that visualize crime data should request permission before getting any data from a user, specifically when using the user's current location. In this study, a few of the users mentioned that they felt more comfortable using the prototype after it requested permission to use their current location. They also mentioned that it was helpful for the permission request to say specifically why their current location was needed.

Chapter 5: Conclusion

Usability tests were conducted on a high fidelity prototype to determine if commuter safety could be improved through geographical crime data mapping. The crime data was specifically for Baltimore City, and the prototype was designed for mobile devices. A total of 10 participants were asked background questions and to complete 5 tasks with the prototype. Though there were some limitations with the study due to the lack of diversity in the participants and the constraints of the Covid-19 pandemic, the study still provided useful data about the impact of geographical crime data mapping.

The usability tests focused on the ease of use to find a route in Baltimore City. The results of the usability tests showed that there were some areas of the prototype that could be improved. Specifically, the type of map had to be changed to a heat map and the filters had to be changed a few times so they were easy to select. The prototype was updated after each user testing session so the changes could be tested in the next session. The user testing sessions provided helpful information about how users are currently mapping routes for walking. It also provided helpful feedback about how the usability of the prototype could be improved.

While the prototype received good feedback from the user testing and users mentioned that it was easy to use, the initial hypothesis was not directly confirmed. Initially, the goal was to create a prototype for an application that could improve commuter safety through geographical crime data mapping. The prototype and the results from the user testing support that awareness can be improved, but it did not prove that commuter safety could directly be improved. Further research would be necessary to determine conclusively that commuter safety could be improved, but this study did support the theory that awareness about crime trends, relevant to specific geographic areas, could be improved through geographical crime data mapping. There would need to be statistical evidence about crime rates in order to determine if they can be improved by crime data mapping, and that would be out of scope for this study.

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Appendix A: User Testing Script

Introduction (2 minutes)

- My name is Adam Mizell and I'm a graduate student at the University of Baltimore. I'm working on a study to examine the user experience of a mobile application in order to gain feedback on how it can be improved. I'll be asking you to complete a few tasks using the mobile application. I encourage you to think aloud while completing the tasks and to provide feedback if any parts seem frustrating or confusing. The goal of this session is not to test you, but rather to test the usability of the application.

Background interview (2 minutes)

- What is your occupation?
- What is your age?
- What do you currently use to map a route?
- What mobile device do you use?

Tasks (15 minutes)

- You're planning on walking to Patterson Park in Baltimore, but you want to take the safest route. Find the safest route to Patterson Park based on your current location.
- You're planning on walking from Patterson Park to Madison Square Park and you want to find the safest route ahead of time. Find the safest route to Madison Square Park from Patterson Park.
- You only want to see crime that is larceny and the weapon is fire. Filter the map to only show crime that is larceny with fire as the weapon.
- You only want to see crime that is assault or robbery. Filter the map to only show crime that is assault or robbery.
- You want to see crime that occurred this month. Filter the map to only show crime that occurred this month.

Tasks (5 minutes)

- Is there anything that could be improved?
- Did you find any part of the tasks frustrating?
- What did you like most about the tasks?

Appendix B: Consent Form

CONSENT FORM

TITLE OF STUDY: Improving Safety Through Geographical Crime Data

PRINCIPAL INVESTIGATOR: Adam Mizell

STUDY PURPOSE/SUMMARY:

The purpose of this study is to examine the user interaction on a mobile application in order to gather information on how the usability of the application can be improved. The mobile application is a map-based application that focuses on suggesting walking routes based on geographical crime data.

PROCEDURES

The facilitator will ask users to perform simple tasks with the mobile application, while observing your decisions and interactions. You will be asked to think out loud as you complete the tasks. It will take about 30 minutes to complete the tasks. After completing the tasks, you will be asked to answer some questions about your current experiences with map-based applications. The session will be conducted through a Zoom meeting so participants can remain remote.

CONFIDENTIALITY

Your name and personally identifiable information will not be used in the data that is collected during this study, nor will it be stored with any images or yourself. Because your data is anonymous, responses that could be linked to you as an individual will not be revealed. This data will be destroyed. Storage of the observation notes, survey answers, and video recording will all be stored on a password protected computer.

POTENTIAL BENEFITS

There are no direct benefits to you for participating in this research. However, you may find it interesting to talk about the issues addressed in the research and it may be beneficial to the field and to future clients or individuals who have experienced similar concerns.

POTENTIAL RISKS AND DISCOMFORTS

There are no known risks in participating in this study.

VOLUNTARY PARTICIPATION

Your participation is completely voluntary. You can withdraw from the study at any time. You do not have to answer any questions that you do not want to answer. If you choose not to participate, there will be no penalty or loss of any benefits for not participating**.**

WHO TO CONTACT WITH QUESTIONS?

"If you should have any questions about the research, please feel free to call or email the Principal Investigator, Adam Mizell at adam.mizell@ubalt.edu or Faculty Sponsor, Greg Walsh at gwalsh@ubalt.edu."

"If you have questions regarding your rights as a research subject, or if problems arise which you do not feel you can discuss with the Investigator, please contact the UB Institutional Review Board at: irb@ubalt.edu 410-837-4057"

SUMMARY

I understand the information that was presented and that:

I am 18 and older and my participation is voluntary.

Refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

I may discontinue participation at any time without penalty or loss of benefits.

I hereby give my consent to be the subject of the research.

If applicable, I give permission to audiotape or videotaping my interview. Yes__ No___

Name (please print): ____

Signature: _______________________Date: ________________________

Interviewer Name (please print) __________________________________

Signature________________________ Date:_______________________