INSTITUT FÜR INFORMATIK
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SPREAD

A Game for Learning how Epidemics Spread

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Bachelorarbeit

Betreuer	Prof. Dr. François Bry
Abgabe am	18.09.2021

Erklärung

Hiermit versichere ich, dass ich die vorliegende Arbeit selbständig verfasst habe und keine anderen als die angegebenen Hilfsmittel verwendet habe.

München, den 18.09.2021

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Abstract

People experience a huge amount of confusion during the pandemic. For most of them it is really hard to understand why restrictions during pandemic are necessary and this is often perceived as very negative.

The main objective of this thesis is to simply convey the different models of spreading of a virus. With a mobile app that will help people to understand the concept of each spread model using: short text introduction, modelling, simulating and running a model with different parameters. The implementation of a mobile application ensures a good user experience independent from the screen size of the device. The layout and colors are based on the different parameters to make it easier for the user to understand.

A prestudy with paper prototyping provided early evaluation of the mobile application. After the implementation a group of students tested the mobile application SPREAD as part of a field study to evaluate the mobile application. An evaluation showed that the concept of the mobile application is successful as the overall design and simplified navigation proved to be useful.

Zusammenfassung

Menschen erleben während der Pandemie eine große Verwirrung. Für die meisten von ihnen ist es wirklich schwer zu verstehen, warum Einschränkungen während einer Pandemie notwendig sind, und diese wird oft als sehr negativ empfunden.

Das Hauptziel dieser Arbeit ist es, die verschiedenen Modelle der Ausbreitung eines Virus einfach zu vermitteln. Mit einer mobilen App, die den Menschen helfen wird, das Konzept jedes Ausbreitungsmodells zu verstehen, indem sie eine kurze Texteinführung, Modellierung, Simulation und Ausführung eines Modells mit verschiedenen Parametern bietet. Die Implementierung einer mobilen Anwendung gewährleistet eine gute Benutzererfahrung, unabhängig von der Bildschirmgröße des Geräts. Das Layout und die Farben orientieren sich an den verschiedenen Parametern, um das Verständnis für den Benutzer zu erleichtern.

Eine Vorstudie mit Papier-Prototyping ermöglichte eine frühe Bewertung der mobilen Anwendung. Nach der Implementierung testete eine Gruppe von Studenten die mobile Anwendung SPREAD im Rahmen einer Feldstudie zur Evaluierung der mobilen Anwendung. Die Auswertung ergab, dass das Konzept der mobilen Anwendung erfolgreich ist, da sich das Gesamtdesign und die vereinfachte Navigation als nützlich erwiesen haben.

Acknowledgments

I want to thank Professor François Bry very much for his dedicated supervision during this bachelor thesis and for the opportunity to write my work at the chair for Programming and Modelling Languages. I am especially thankful for his great advices and suggestions for improvements. He provided me with new ideas and the vision of how my project should be. He invested much time into the development of my thesis. The weekly meetings helped me to progress and improve my work. I was able to mature and grow as a result of his feedback. Unfortunately, due to the still ongoing pandemic, we were not able to physically meet but instead in video conferences.

I would also like to thank all the students who participated in the evaluation for their excellent feedback. I was able to learn a lot of things during the process.

Contents

CHAPTER 1

Introduction

For a lot of people, the beginning of the pandemic was a huge change in their life. Leaving many people without job, they suddenly have to face completely new challenges. More and more countries started adopting new strict rules which a lot of people didn't understand. With the increasing number of misinformation about the pandemic, more and more people have stopped trusting the restrictions by the government. Which led to many problems and protests among the public.

The question arises whether government is guilty for this misinformation among part of the population or many people just don't have enough knowledge to understand the current situation. Furthermore, the question arises whether, if it's too complex for average person to understand why we need to obey these strict rules and there is no short and easy way to learn more about it.

The main objective of this bachelor thesis is to simply convey the different models of spreading of a virus. For this purpose, a mobile app that will help people to understand the concept of each spread model using: short text introduction, modelling, simulating and running a model with different parameters. The implementation of a mobile application ensures a good user experience independent from the screen size of the device. The layout and colours are based on the different parameters to make it easier for the user to understand.

CHAPTER 2

Related work

To begin with, the mobile application SPREAD is introduced more closely. The application uses a concept that is key to this thesis - games with a purpose. Focusing on a specific implementation which brings together the underlying concepts of human computation and gamification. Followed by a closer look at the procedure for developing a game concept. Like a classic game, SPREAD aims to create an enjoyable user experience. However, the game concept of SPREAD puts additional focus on learning. The final section presents design specifications specific to mobile devices.

2.1 Games with a purpose

To motivate people to learn and understand the concept of difficult topics while having fun is the goal of ”games with a purpose” (GWAPs) [21]. This technique applies for various of different cases, such as educating a lot of people without need of a human interaction.

Through computer games, people can solve large problems or educate themselves in different topics. Such games are a common way of using brain power to solve open problems [28]. Designing such a game is similar to designing an algorithm - it must be proven correct [35]. Its efficiency can be then analyzed, allowing a more efficient version to replace a less efficient one [36]. There are a variety of applications for ”games with a purpose” in areas as education [35]. Any game designed to solve these and other problems must ensure that the game leads to a correct solution and is fun at the same time [6]. People play such games to entertain themselves, not to solve a problem - regardless how worthy its goal would be [28]. Using a game to educate people how main spread models work is the concept of SPREAD.

2.2 Models of the spread of infections

In the SPREAD mobile application only the main spread models are represented, such as SIR model, reproduction number and DOTS model.

2.2.1 SIR Model

One of the simplest spread models is the SIR model [37], and many models are derivatives of this basic form [26]. The model consists of three non-linear differential equations with no explicit formula solution [37]. The model consists of three parts:

S: Specifies the number of susceptible persons. It means that when a susceptible person and an infectious person come into "infectious contact", then the susceptible person obtains the disease and enters the infectious part of the population [19].

I: Specifies the number of infectious persons. In this case, these are persons who have been infected and are capable of contaminating susceptible individuals [29].

R: Specify the number of persons removed (and immune) or died. This part of the population may also be referred to as "recovered" or "resistant" [3]. These are persons who have been infected and have either recovered from the disease and passed to the recovered part of the population or have died. The number of deaths is assumed to be insignificant relative to the total population [33].

This model is well suited for predicting infectious diseases [39] that are transmitted from person to person and for which recovery confers durable resistance, such as measles, mumps, and rubella.

At a given time, these variables (S, I, and R) represent the number of individuals in every single segment. In order to be able to show that the number of susceptible, infectious, and removed individuals can fluctuate over time (even if the total population size remains constant), which leads to using exact numbers a function of t (time): S(t), I(t), and R(t) [3]. For a given disease in a given population, these functions might then be calculated to predict possible outcomes and help bring them under control [39].

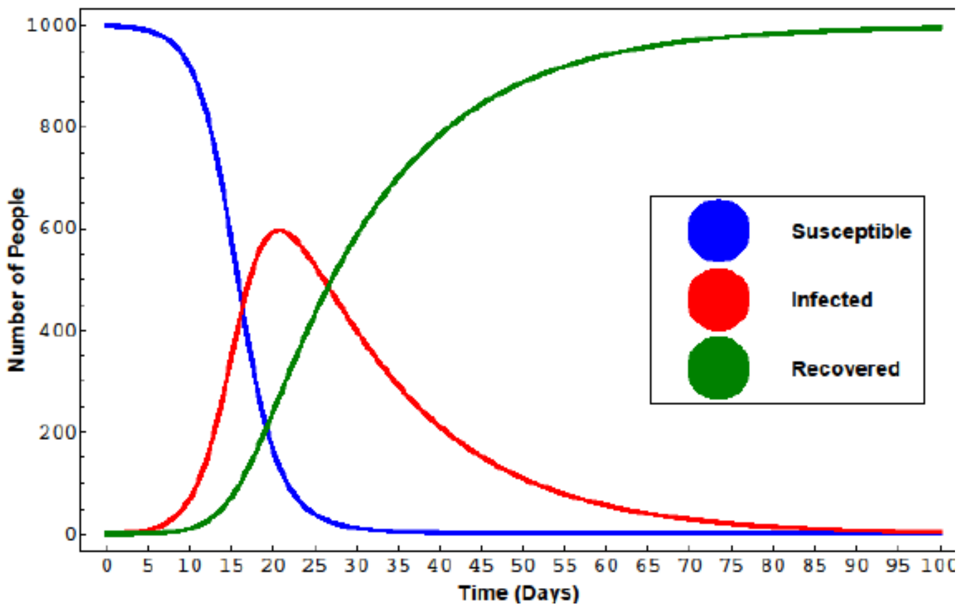


Figure 2.1: Typical SIR model solution showing progression of population disease [16]

Typically, each member of the population evolves from susceptible to infectious to recovered. This can be visualised as a Figure 2.1 [16] where the X axis represent the duration in days and the Y axis represent the number of people.

2.2.2 The reproduction number

The reproductive number (R) is often used to describe the contagiousness of a disease. The reproduction number R (for a disease) expresses how many persons are likely to get the disease from a person who has this disease [9].

For instance, if the R for Ebola in a population is 2, then it is expected each new case of Ebola to produce 2 new secondary cases on average (supposing everyone around the case was susceptible) [2]. This can be visualised as a chart [31], where the red persons represents the infected and black persons are the susceptible.

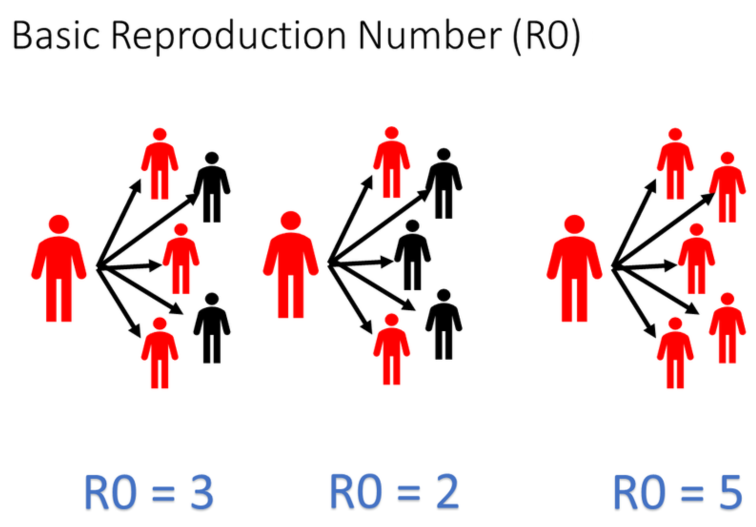


Figure 2.2: How R0 works [11]

In the absence of immunity due to previous exposure or vaccination, or intentional interference with disease transmission, basic reproductive number (R0) is the reproductive number which occurs [12]. In a population where everyone is susceptible, (R0) represents the average number of secondary infections caused by an infectious case [2]. (R0) does not include new cases caused by secondary cases.

- If $R < 1$, then the number of infected persons decreases exponentially over time.
- If $R > 1$, then the number of infected persons increases exponentially over time.
- If $R = 1$, then the number of infected remains constant.

A few features of a reproduction number are useful to remember, as their interpretation is not always straightforward. An epidemic begins when $R0 > 1$ in a susceptible population, i.e., the number of cases is increasing [4].

For individuals being homogeneous and mixing uniformly, R is defined as the average number of infections occurring during the infection period of a single infected individual [10]. Allowing individuals to vary in the number of infections they have due to chance, the average number of infections is R [15]. The occurrence of epidemics cannot be achieved if R is less than 1 at the time of the starting of the epidemic. With established epidemics declining when either public health interventions keep R below 1 or the susceptible fraction of the population has been reduced to a level high enough to keep R below 1 [12].

The basic reproductive number for each location could fluctuate as contact levels between people may vary due to variations in population density and cultural diversity [15].

The actual reproductive number may also fluctuate because the immune response of populations in different locations varies [22].

2.2.3 DOTS Model

The (D), (O), (T) and (S) originate from what Adam Kucharski of the London School of Hygiene & Tropical Medicine refers to as ”DOTS” in his book Rules of contagion [14].

The base reproduction number R zero is the number of new cases that one case could cause in a population that would normally be susceptible and not immune. Where its value is greater than one ($R0 > 1$), transmission is occurring, i.e., an infected individual is transmitting the disease to more than one individual. For example the reproductive number (R0) for COVID-19 is estimated to be around 2.2 [14] (higher than seasonal influenza). In terms of public health measures to both prevent and limit transmission, the value itself is less important than understanding and influencing the four components that all combine to estimate the value.

The first component is the duration (D) of infectivity-not of the disease itself-but of transmission from a diseased person to an apparently healthy person. This is even more important when infectivity begins before the end of the incubation period, that is before the person has symptoms [4].

Its second element is the opportunity (O) to spread the virus to another individual. It is highly dependent on the social and community interactions of the infected person with that person’s family, community, workplace, or school while traveling by air, sea, or land, or attending another mass event (soccer game, pilgrimage, rock concert, to name a few) while infected and contagious. If the person remains completely isolated because they are very sick or in the hospital, (O) has a value of zero, which means no transmission! However, this could only be true for a few of the infected people [5].

Its third parameter is the transmissibility (T) of the virus. Presuming that there is a possibility of transmission, the dynamics of the virus’s transmission and the nature of human interaction must be taken into account. Respiratory viruses are transmitted from one person to another by airborne droplets released during coughing or sneezing or by contaminated objects (e.g., faucets, handrails, doorknobs, or bus grab bars). The probability of effective transmission depends on the type of contact as well as environmental parameters such as air pressure, humidity, and temperature, which affect how long droplets remain suspended in the air and how far they travel [14].

The last component of model of transmission rate is the susceptibility (S) of the person being exposed to the virus. Whether the person is an infant, a child, a pregnant woman, or an elderly person. Whether the person already has a health problem or a weakened immune system, or whether the person has already been infected with the virus and has become immune as a result [14].

CHAPTER 3

The SPREAD App

In this chapter, the approach of the technical implementation is discussed to show the software structure and architecture.

3.1 Technical implementation

The smartphone application is based on the Android OS version 11 which is equivalent to the API level 30. SPREAD is also compatible with the Android version 5.1 or newer, which is equivalent to the API level 21. The operating system was selected, due to the market share dominance of the operating system Android [23], as it is shown in Figure 3.1.

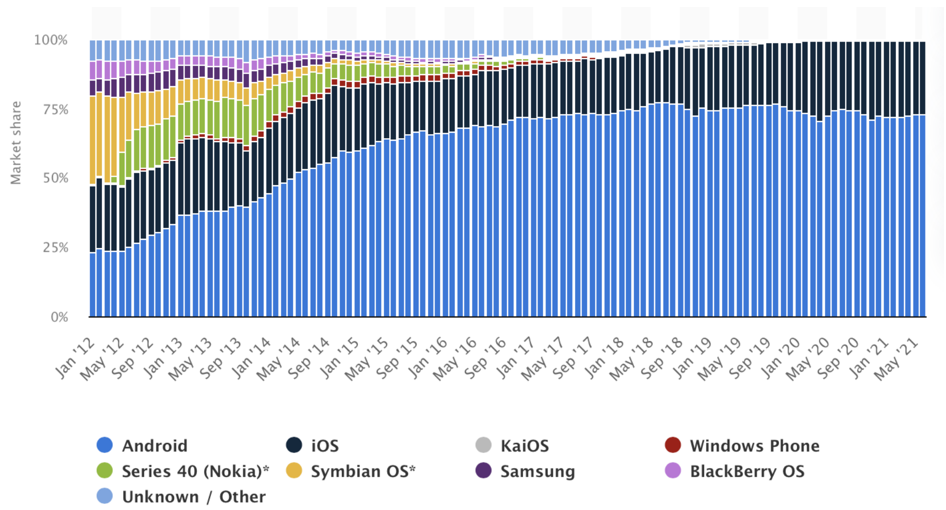


Figure 3.1: Mobile operating systems' market share worldwide from 2012 to 2021 [23]

Android achived its position as the leading mobile operating system worldwide in June 2021 [23], controlling the mobile OS market with a close to 73 percent share [23].

Which makes the application available to more than 250 million users[24] who are using the matching platform version.

The app is written in Kotlin, because today it is the recommended language for Android development [13]. Both Java and Kotlin could be used to create powerful, useful applications, but Google's libraries, tools, documentation, and learning resources continue to take a Kotlin-first approach, making it the better language for Android today [8].

3.2 User Interface

The mobile application SPREAD is structured into activities which can be described as different screens or entry points of the app with a user interface and other interaction possibilities. Each of them serves an organisational or game-play purpose.

SPREAD UI is simplistic and features no styled animations. The color of parameters consists of four distinct colours (red, green, blue and black), which are toned to represent red equals infected, green equals recovered, blue equals susceptible and black equals death. The whole application consists of Android activities (Android's implementation of views). The main activity is used as a start menu activity. While introduction activities are used to concisely explain the purpose and functionality of the app. Configurations activities offer parameter adjustments to the users simulations models for the other activities.

3.2.1 Start menu activity

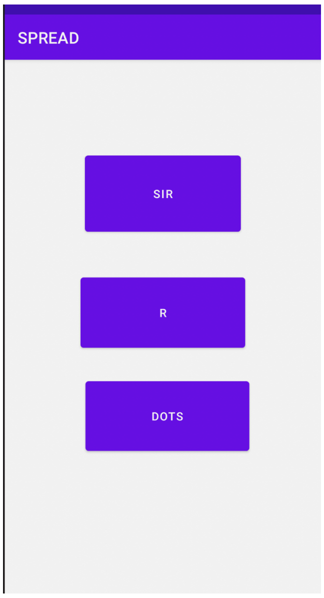


Figure 3.2: Main menu of SPREAD

SPREAD's main activity, as displayed in Figure 3.2, is the starting point for user interaction with the application. It shows the different models which could be chosen. If users want to learn more about one of the models, he should just click the button of the model. Overall, there are three interactive buttons in the activity. The "SIR" button leads to the SIR introduction activity, while the "R" button leads to the reproduction number introduction activity. The "DOTS" button, forward user to DOTS model explanation activity.

3.2.2 Introduction SIR menu activity

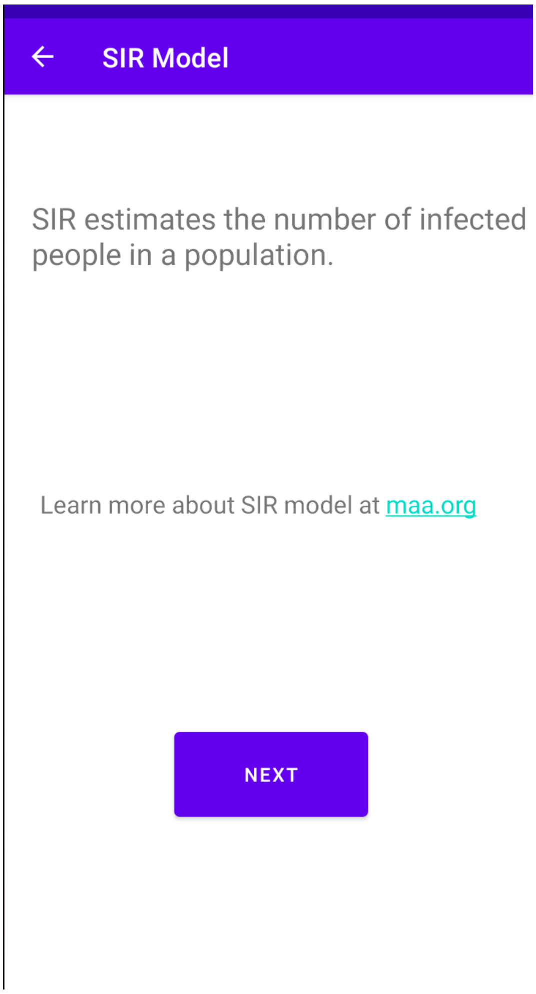


Figure 3.3: Introduction of SIR

SPREAD's SIR introduction activity, as displayed in Figure 3.3, is the starting point for user in SIR model. It shows a short description of the model. If users want to learn more about one of the SIR model, he should just click the link provided in the activity of the model. Otherwise user could continue using "Next" button which takes the user to the configuration activity. The upper left counter contains back button which returns the user in the main menu activity.

3.2.3 Configuration SIR activity

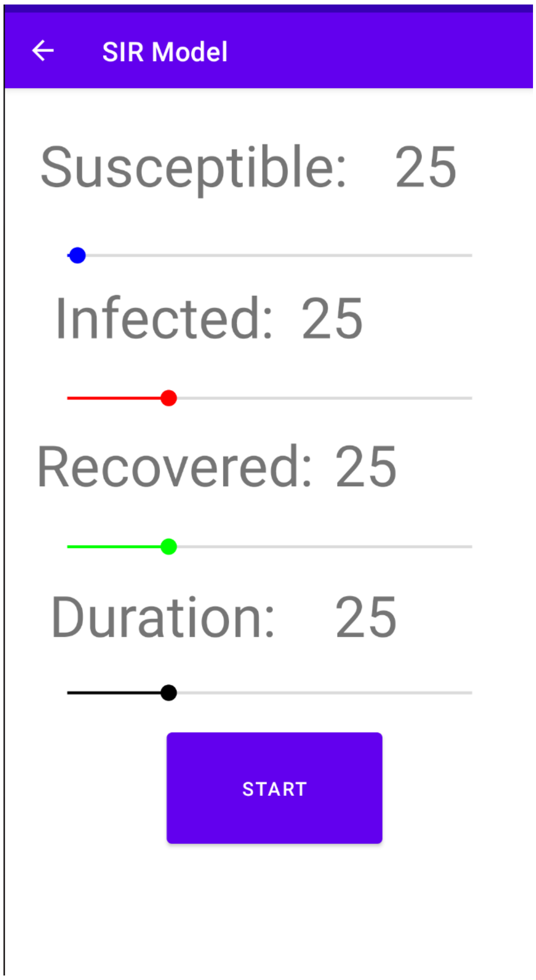


Figure 3.4: Configuration of SIR

SPREAD's SIR configuration activity, as displayed in Figure 3.4, is the configuration menu of SIR. It shows a four sliders toned with the colours red, green, blue and black. These colours represent: red equals infected, green equals recovered, blue equals susceptible and black equals duration in days. If the user wants to return in the introduction activity, the upper left counter contains back button. Otherwise user could continue using ”Next” button which takes the user to the simulation activity.

3.2.4 Simulation SIR activity

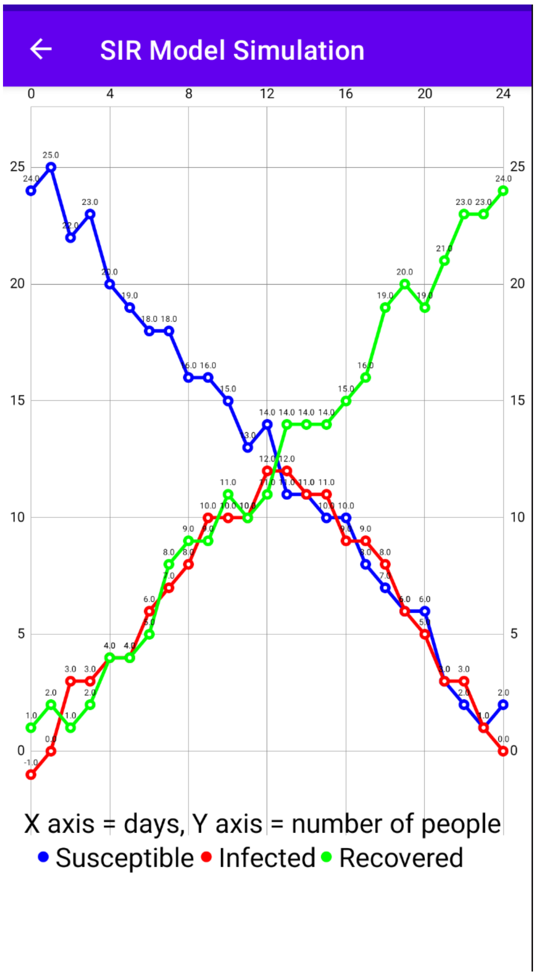


Figure 3.5: Simulation of SIR

SPREAD's SIR simulation activity, as displayed in Figure 3.5, is the simulation graph of SIR. It shows a three lanes toned with the colours red, green and blue. These colours represent: red equals infected, green equals recovered and blue equals susceptible. The graph contains of two axis:

- X axis equals duration in days

- Y axis equals the number of people

The graph also have legend of the colours and axises. If the user wants to return in the configuration SIR activity, the upper left counter contains back button.

3.2.5 Introduction R activity

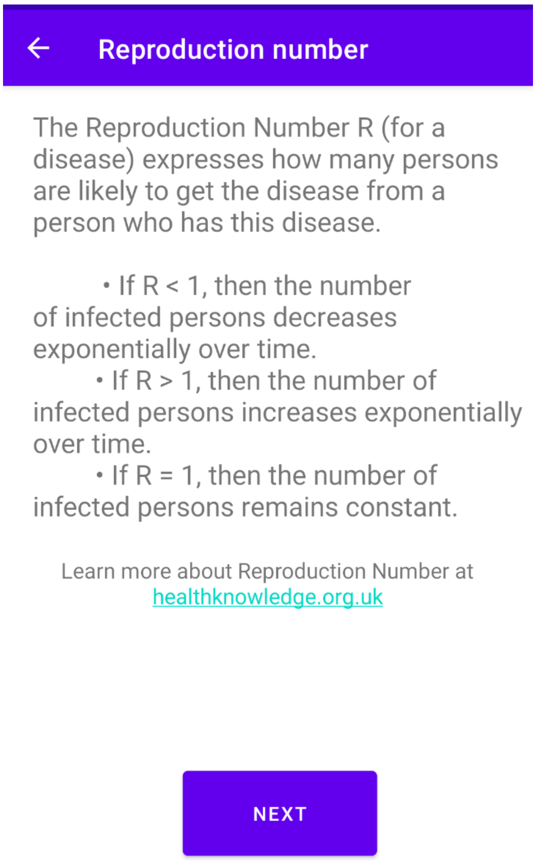


Figure 3.6: Introduction of reproduction number

SPREAD's R introduction activity, as displayed in Figure 3.6, is the starting point for user in reproduction number. It shows a short description explaining how reproduction number works. If users want to learn more about one of the R number, he could just click the link provided in the activity of the model. Otherwise user could continue using "Next" button which takes the user to the configuration activity. The upper left counter contains back button which returns the user in the main menu activity.

3.2.6 Configuration R activity

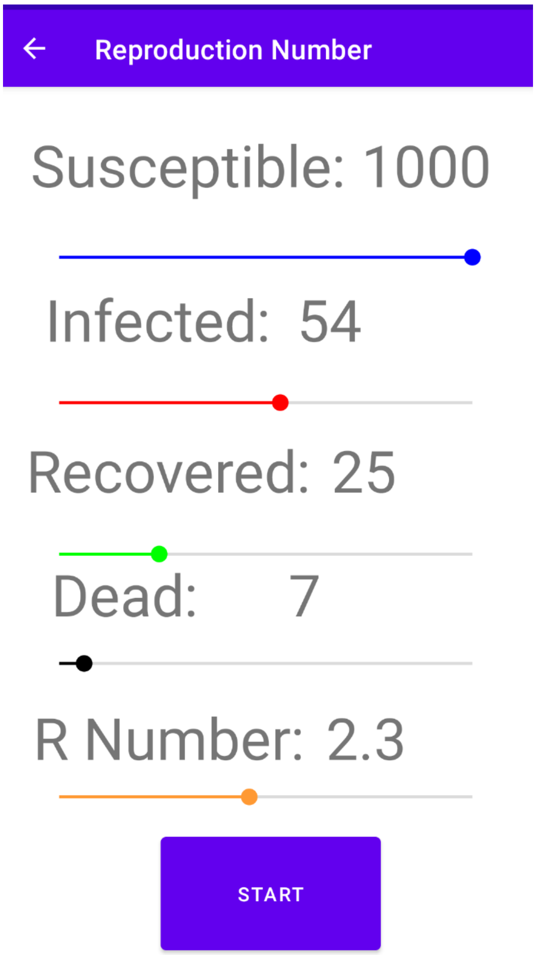


Figure 3.7: Configuration of reproduction number

SPREAD's R configuration activity, as displayed in Figure 3.7, is the configuration menu of reproduction number. It shows a five sliders toned with the colours red, green, blue, black and orange. These colours represent:

- red: infected people at the beginning
- green: recovered people at the beginning
- blue: susceptible people at the beginning
- black: dead people at the beginning
- orange: the reproduction number

If the user wants to return in the introduction activity, the upper left counter contains back button. Otherwise user could continue using "Next" button which takes the user to the simulation activity.

3.2.7 Simulation R activity

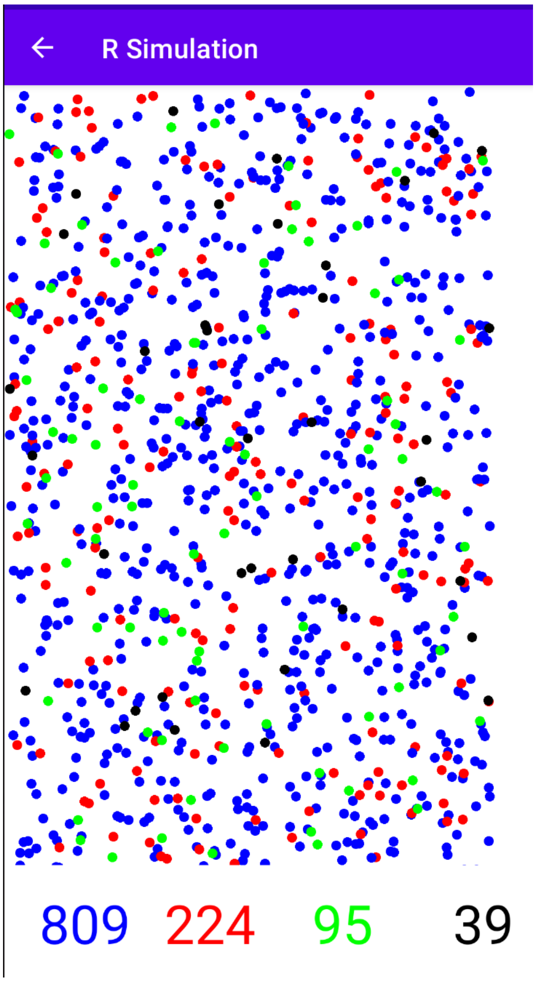


Figure 3.8: Simulation of reproduction number

SPREAD's R simulation activity, as displayed in Figure 3.8, is the running simulation showing how reproduction number works with different parameters. It shows small dots that are coloured with the red, green, blue and black. These colours represent:

- red: infected people
- green: recovered people
- blue: susceptible people
- black: dead people

The graph also shows as a number in the bottom the sum of each group in the same colour as the dots If the user wants to return in the configuration R activity, the upper left counter contains back button.

3.2.8 Introduction DOTS menu activity

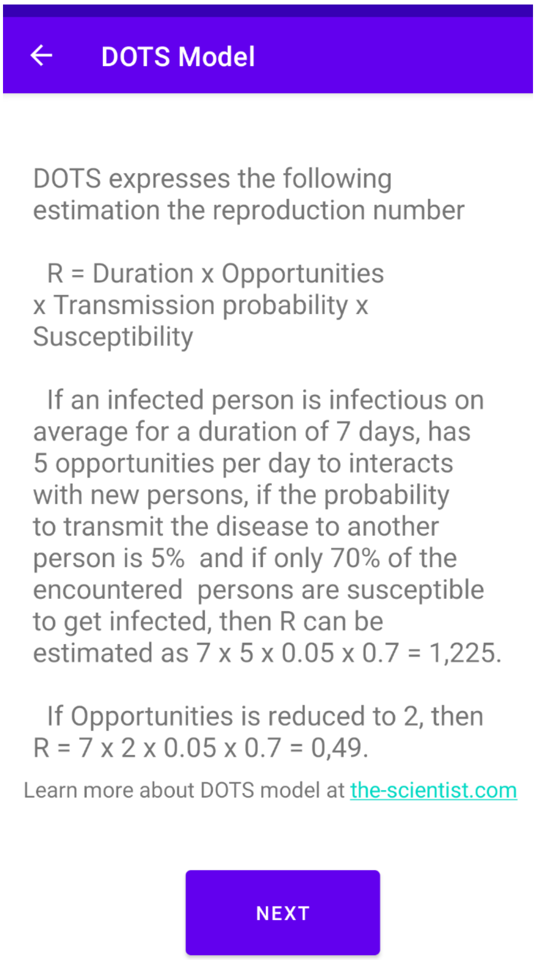


Figure 3.9: Introduction of DOTS

SPREAD's DOTS introduction activity, as displayed in Figure 3.9, is the starting point for user in DOTS model. It shows a short description explaining how DOTS model works. If users want to learn more about one of the DOTS model, he could just click the link provided in the activity of the model. Otherwise user could continue using "Next" button which takes the him to the configuration activity. The upper left counter contains back button which returns the user in the main menu activity.

3.2.9 Calculate R using DOTS activity

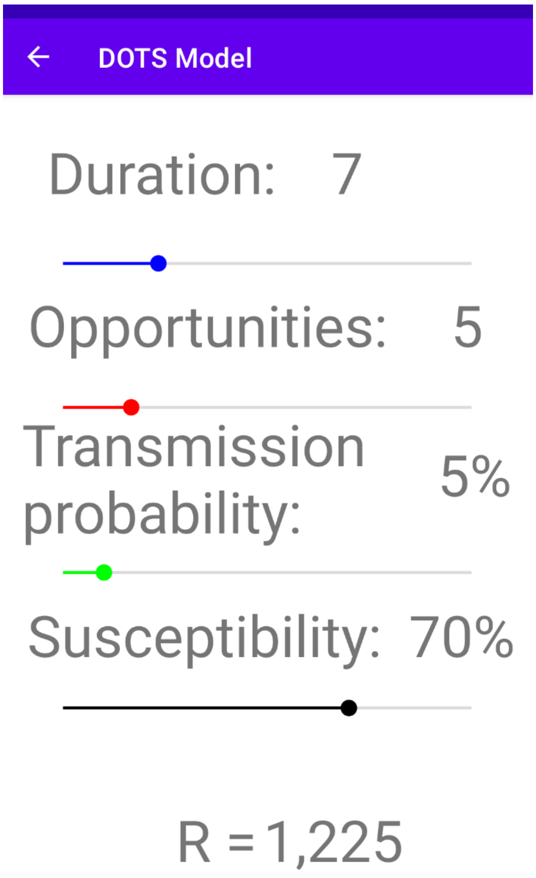


Figure 3.10: Calculate R using DOTS

SPREAD's DOTS configuration activity, as displayed in Figure 3.10, is the configuration menu of DOTS model. It shows a four sliders toned with the colours red, green, blue and black. These colours represent:

- red: opportunities - new persons to interact per day
- green: transmission probability - probability to transmit the disease to another person
- blue: duration in days
- black: susceptibility - percentage of the encountered persons are susceptible to get infected

At the bottom of the screen, represents the calculated reproduction number based on the given parameters. If the user wants to return in the introduction activity, the upper left counter contains back button.

3.3 Distribution

The game is freely available on the Google Play Store https://play.google.com/store/apps/details?id=com.favoway.spread, so during the evaluation phase testers could download it. Also the source code of the mobile application was additionally published on GitHub https://github.com/marto97/SPREAD.

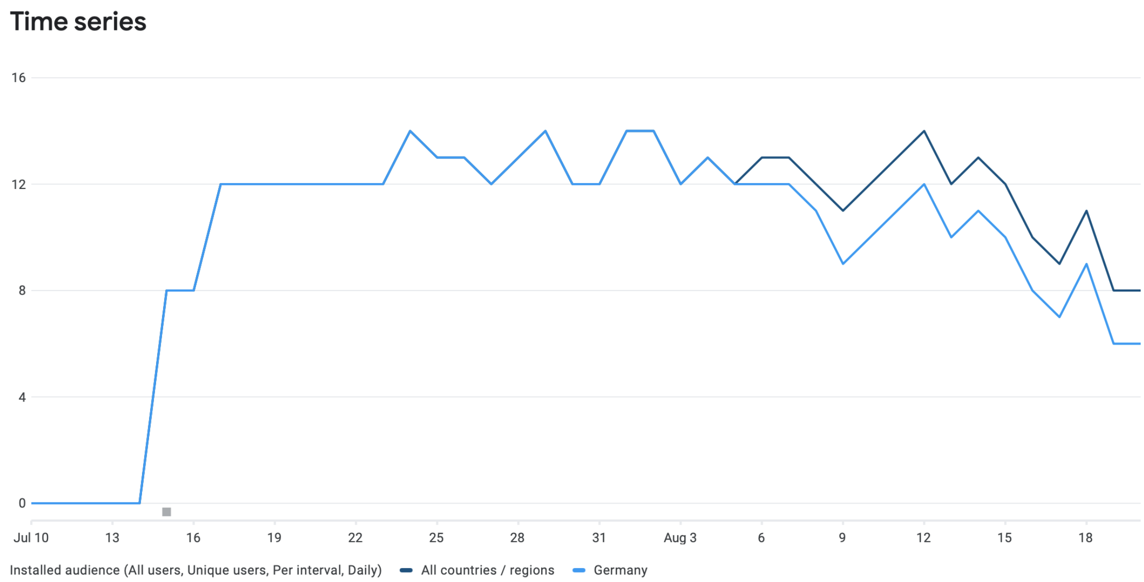


Figure 3.11: Google Console Statistic for SPREAD from July 2021 to August 2021

The Google Play Store registered at its peak 14 unique installs users during the evaluation period (see Figure 3.11).

CHAPTER 4

Evaluation

The main reason for SPREAD's existence is to help people to understand the concept of the main spread models. SPREAD testers could use the app for a 30 day period, between 15.07.2021 to 15.08.2021, during which all useful interactions were recorded by the Firebase server. These contributions can be measured in type, quantity and quality and will be evaluated in the following.

4.1 Testers

The number of testers can not be determined, as the mobile application SPREAD was freely available for download during the evaluation period. Most of them were probably acquired through a general email looking for people interested in testing the application, while the others were reached by their personal contacts. Since the number of testers is too small to draw any conclusions about the group's characteristics, the only metric that is available and can be used is location.

4.1.1 Tasks during evaluation

Testers to participate in the app evaluation from 15th of July 2021 till 15th of August 2021 they had to:

- download the Android app from Google Play Store and install the app SPREAD
- give SPREAD the permission to collect usage data for analysis purposes
- use the app daily for at least 5 minutes over at least 2 weeks period
- check every 3-5 days for possible updates of SPREAD and install them if available. As the app was still improving with updates that include whole new versions of the app, which usually involve new apps interface, look and feel as well as new features.
- give feedback for app problems and crashes, which were fixed with minor updates. Removing bugs that impact user experience what should otherwise be an enjoyable and intuitive.

- after two weeks, to complete the survey at https://docs.google.com/forms/d/e/1FAIpQLSeO85QtFxNvbuF7OrPfZpYteZlaVQyRUkj4KMuZMJtQnWBI0Q/viewform. Where the results are explained in details later.

The reward for media informatics students was 6 MMI points.

4.2 Data Collection

The data was collected using the Android app and saved in the Firebase database. Firebase provides also tools for tracking analytics, reporting and fixing app crashes. The users agreed to share their app data usage data for analysis purposes.

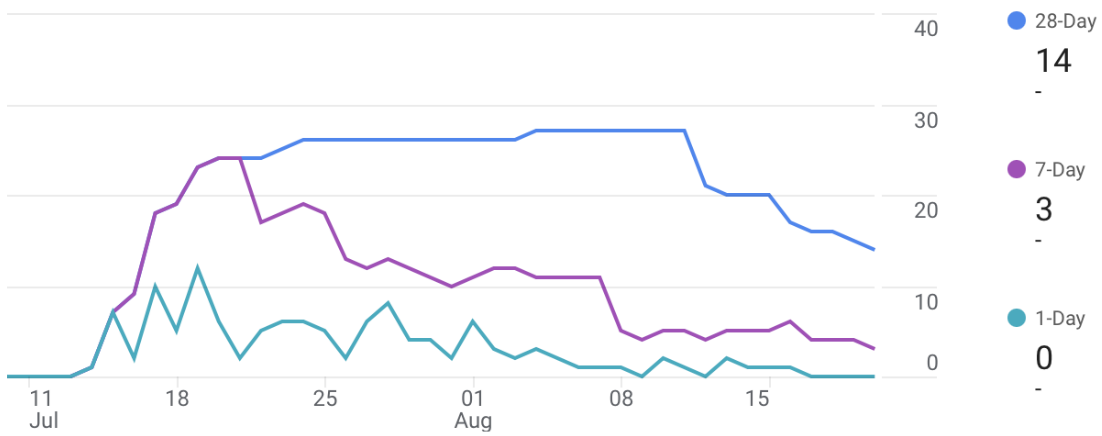


Figure 4.1: Firebase data for active users during evaluation period

The graph shows 1-day, 7-day, and 28-day active users, plotted over time between 10th of July 2021 and 20th of August 2021 (see Figure 4.1). The summarized values on the right represent the number of unique active users on the last day of the time period.

Figure 4.2: Firebase data for user engagement during evaluation period

The graph (see Figure 4.2) displays average daily engagement trends for the time period between 10th of July 2021 and 20th of August 2021. It is clear that the average app usage per day for all users is a little more than five minutes which is

Screen class	% total	Avg. time
CanvasViewR	71.74%	1m 27s
CanvasViewSIR	11.45%	0m 16s
Configure...lActivity	6.21%	0m 05s
MainActivity	3.93%	0m 03s
Configure...lActivity	2.52%	0m 02s
Configure...Activity	2.02%	0m 11s
RModelActivity	0.95%	0m 01s
IntroDotsModel	0.67%	0m 01s
SirActivity	0.52%	0m 00s

Figure 4.3: Firebase data for user engagement in different activities during evaluation period

The table (see Figure 4.3) shows the name of the activity, the percentage that screen accounts for in engagement time, and the average amount of time that screen was used for the time period period between 10th of July 2021 and 20th of August 2021.

It it clear that the most used and time consuming activity is "CanvasViewR" which represents the simulation activity of reproduction number with almost 72% time usage from total with average usage time 1m and 27s. Followed by "CanvasViewSir" which is the SIR simulation activity with around 11% time usage from total. The least used activity with just 0.52% seems to be "SirActivity which represents SIR introduction activity.

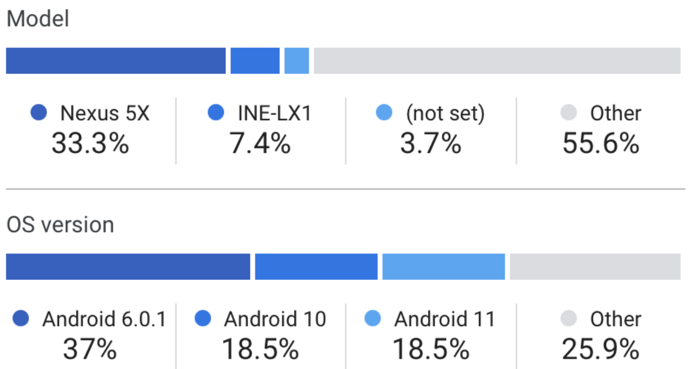


Figure 4.4: Firebase data for top three device models and top two OS versions during evaluation period

The bar chart (see Figure 4.4) from Google Firebase represents percentage of users on each ot the top three device models(plus all other devices) and percentage of users on each ot the top two OS versions(plus all other OS versions). It shows that most of testers have been testing the app on Nexus 5X with 33.3% of all devices. And also the chart states that most testers used older version of OS operation system - Android 6.0.1 with 37%. Followed by Android 10 and Android 11 with both around 18%.

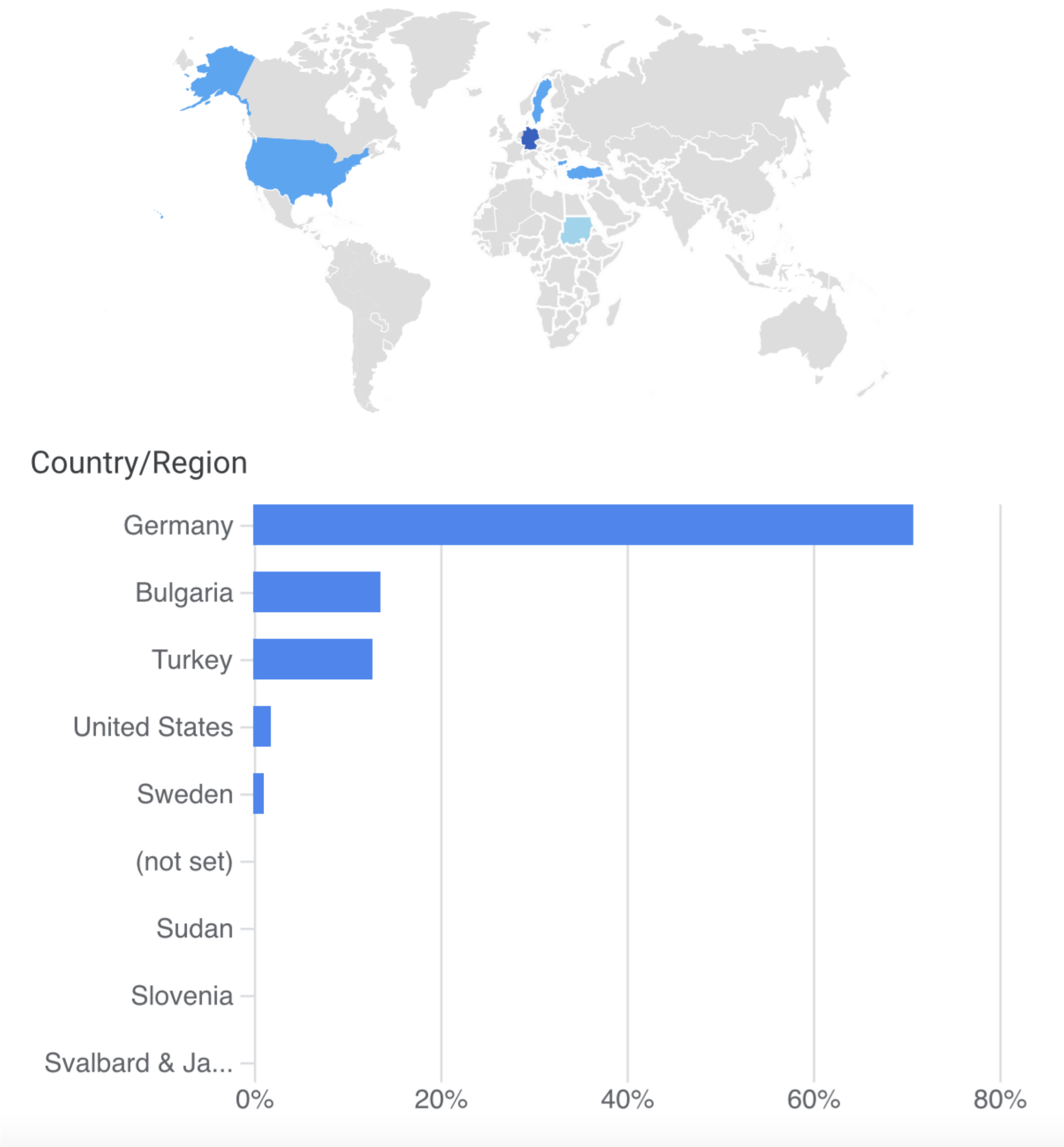


Figure 4.5: Percentage of sessions from each of countries during evaluation period

The bar chart (see Figure 4.5) from Google Firebase represents percentage of sessions from each of countries. It shows that 70% of testers have been testing the app from Germany. Followed by Bulgaria and Turkey with both around 13%. And USA and Sweden are accountant for only around 1-2%.

4.3 Results

After the testing phase of the app, testers had to fill out a survey. The responses of the survey will be represented as a summary in this section.

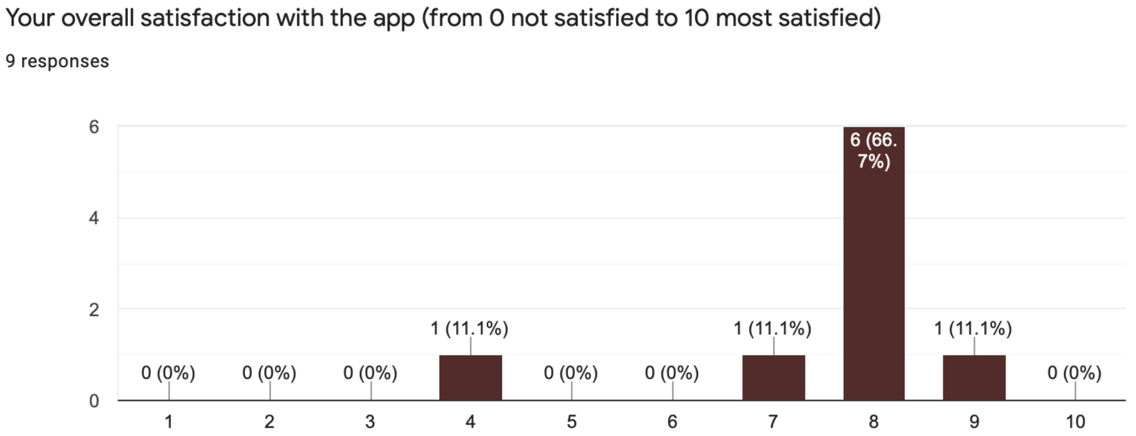


Figure 4.6: Google Form responses summary for overall satisfaction

The bar chart (see Figure 4.6) from Google Forms shows that 90% of testers have been satisfied with the app. They rate the app with more than 7 out of 10. Only one person was not so satisfied with the app rating it with 4 out of 10.

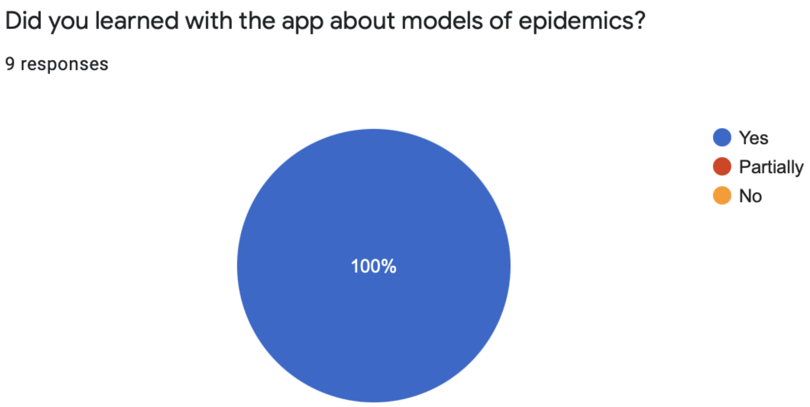
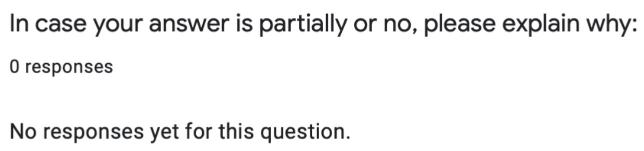


Figure 4.7: Google Form responses summary for learning about models of epidemics

The pie chart (see Figure 4.7) from Google Forms shows that 100% of testers have learned with the app about the models of epidemics.


In case your answer is partially or no, please explain why:

0 responses

No responses yet for this question.

Figure 4.8: Google Form no responses

There are no responses for question in Figure 4.8 becouse there are no answers "partially" or "no" in previous question.

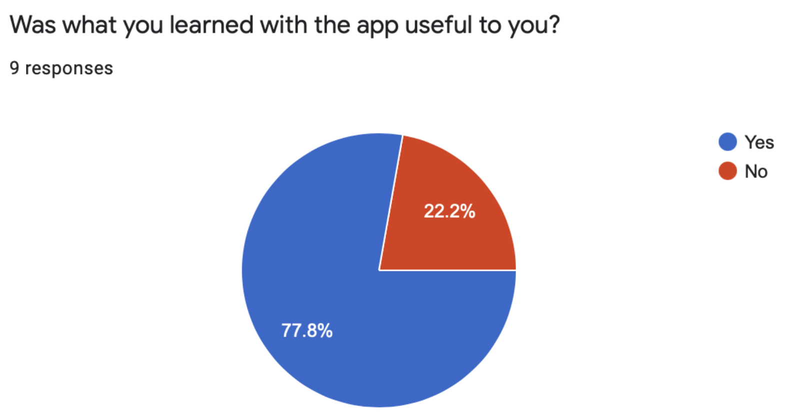


Figure 4.9: Google Form responses is the app useful

The pie chart (see Figure 4.9) from Google Forms shows that 77.8% of testers say that the app was useful for them. And the other 22.2% think the app was no useful for them.

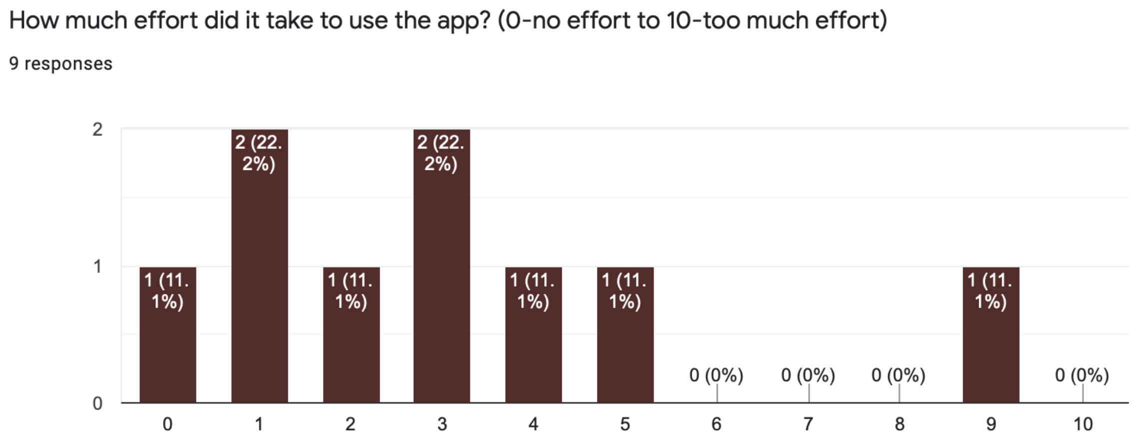


Figure 4.10: Google Form responses for how much effort

The bar chart (see Figure 4.10) from Google Forms shows that everyone has experienced different level of effort using the app. But overall around 90% of the testers answered with 5 or less, which means for most of people the app was pretty easy to use.

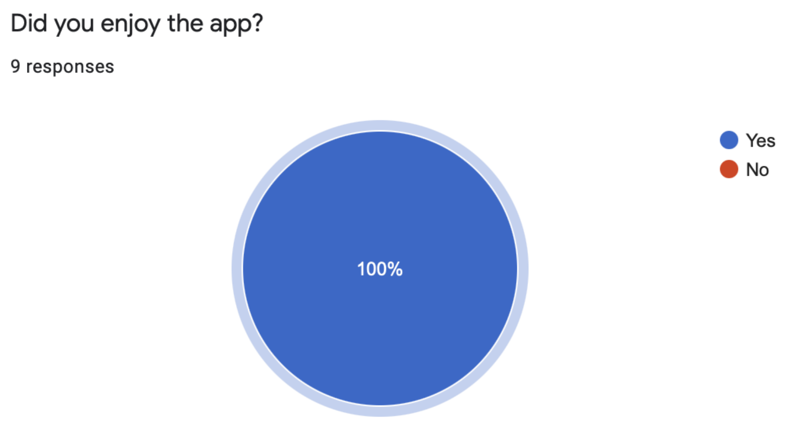


Figure 4.11: Google Form responses for enjoying the app

The pie chart (see Figure 4.11) from Google Forms shows that 100% of testers enjoyed using the app during evaluation period.

CHAPTER 5

Perspectives for future work

Overall, the implementation of SPREAD described in this thesis is still only a prototype. Therefore, it is important to consider the results of the study in future developments. Participants in the study suggested adding more explanations with examples, better UI Design with more colours to improve the user experience. Specifically, participants wanted more information in the beginning of the app about the the gist of the application they were dealing with, as well as more custom settings and better app performance and faster loading time between activities. Participants also suggested adding a proper tutorial when user opens for first time the app, which would be especially important for future implementations of the app that increase its complexity.

5.1 Time forward and motion speed

The simulation interface implemented in this bachelor thesis can only represent how pandemic is progressing and is mostly for proof of concept. It could be further improved by adding the ability to use slider near the simulation screen with which user could forward in time the pandemic progress without waiting too long. Additionally, support for custom motion speed could be added so that the speed of pandemic process can be adjusted by the user. For example ”x days simulated every second”, where user can input the number of days represented every second. This feature will let users to simulate more different parameters without losing a lot of time.

5.2 Different cases

Another feature that could be implemented is to have separate communities, with transit between them. Every day, each person will have some probability of traveling to the centre of an another community, and then going about the usual routine from there. So future work would add the choice for the user to select from three different cases:

- Simple Case which is the default of the mobile application. In this case during the simulation people have random direction and random speed.

- Central Location Case: having a public place such as at public gatherings, on an airplane, at school, or in the workplace in the simulation where people could be exposed to the same source of disease. In the SPREAD app could be shown as a central square or circle during simulation, where higher percentage of people move through it.
- Community Travel Case: every community, such as a neighbourhood, household and etc., during the simulation could be represented as a different square. Where each person will have some probability of traveling to the centre of an another community.

5.3 More configuration settings

5.3.1 Death rate

Currently the death rate in the app is fixed in a proportion 1:2 where as 1 is for death rate and 2 is for recovery rate. This is done only for proof of concept. Additionally, having a choice to adjust the proportion death:recovery after getting infected would be much better for users. As they will have more control to test different type of viruses.

5.3.2 Infection Radius

Based on the size of the initial droplet distribution [20]:

- most of the virus content settles in the first 1-2m
- all virus is airborne on dry cores or on liquid droplets
- small droplets settle slowly on the ground, covering less than 2.5m or more than 7.5m

The app focus is on the airflow generated by the cough. And the infection radius parameter is fixed to a few pixels around the infected. Further work would add possibility to change this parameter to show the effects of ventilation in the environment, especially over long periods of time.

5.3.3 Social Distancing Factor

Social distance is proved to be one of the most effective preventive measures and an immediate solution to prevent or slow down spreading a virus [32].

The app currently doesn't give the user the possibility to simulate social distancing. Further work would add the possibility to change the parameter of what percentage of the population obeys social distancing. And as well to automatically change the social distance parameter in the population if the reproductive number is higher than 1.5. But when the reproductive number during the same simulation got lower than 1, the restrictions such as social distance in the population to be removed.

5.3.4 Quarantine after x days of Infection

One of the oldest, most effective, and most commonly misunderstood methods of controlling transmissible disease outbreaks is quarantine [17]. The term quarantine is used to describe the restriction of people who are considered to have been exposed to a contagious disease, but who are not ill [18]. On an individual, group, or community level, it can be applied and usually involves limiting people to their homes or a specific facility[27]. Such quarantine could be voluntary or mandatory [7].

Having group quarantine refers to quarantining people who have been exposed to the same source of disease such as at public gatherings, on an airplane, at school, or in the workplace [30]. According to the HHS (U.S. Department of Health and Human Services) plan [17] , the following is stated: Quarantine's goal is to protect the public by separating those exposed to a dangerous transmissible disease from the rest of the general population. Therefore, it is a collective action for the public good based on helping those already infected or exposed and protecting others from accidental exposure [30].

Modern quarantine and social distancing principles limit its application to situations involving highly dangerous and contagious diseases and where resources are available to implement and maintain the measures confidently [34]. Quarantine involves a wide range of transmission reduction strategies that can be used depending on the phase and intensity of an outbreak [1].

Further work would add the possibility to simulate spreading a virus and infected people to be in quarantine. The user could select after how many days an infected person must be isolated from the rest part of the population during the simulation. Also user could choose if only infected people to be isolated or also the people who had contact with.

5.3.5 Additional parameters

The lack of data makes difficult to precisely simulate spreading a virus. Simplified versions of reality are mathematical models of the spread of infection [25]. Based on their design, they emulate the main characteristics of real-world disease spread with sufficient accuracy to make predictions that can be trusted, at least in part, to inform decision-making [38]. The COVID-19 predictions, which have been widely debated in the public press, are based on mathematical models that have been implemented in computer simulations [25]. For instance, a model might use a variety of real-world data to predict a date (or set of dates) for the maximum number of cases in a city [40]. By adding more input parameters to the simulator, it will represent the spread of a virus more precisely. Such parameters could be:

- Percentage of the infected, don't show symptoms, hence, won't be quarantined.
- Percentage chance that an individual visits the central location in any given hour.
- Percentage chance of travel by an individual on a given day to another community.
- Number of individuals per community.
- How many communities has an infected person?
- How long (in days) is the infection duration?
- Percentage of the population obeys Social Distancing.
- Quarantine after how many days of infection.
- How many days after the beginning of the epidemic to start the quarantine zone?

5.4 More live data and control

The SPREAD mobile application currently represents the number of susceptible, infected, recovered and dead people during the simulation. Adding additional live data, such as the live reproduction number during the simulation, will help the user to understand what action will help to stop this spread. Also having more control, like changing the social distancing factor, lowering the percentage of people with access to public places, adding or removing quarantine during the simulation. This will help the user to understand more deeply how the viruses are spreading and what could help preventing them.

5.5 Agent-based model

Having additional button ”Agent-based”, which by clicking it could combine the SIR and DOTS models using:

- A few types of agents based on the following parameters.
- A few types of ages (like young, middle-aged, old)
- A few types of mobility (public transportation commuters, etc.)
- Generation time
- Population size

Using simple but attractive visualisations for both setting parameters and displaying the results.

CHAPTER 6

Conclusion

The number of testers and duration of the test are not enough to provide a definitive conclusion. Also, solving a sense is not an accurate indicator of its descriptiveness.

Since the game is designed to be simplistic, only two choices were used to evaluate how the senses performed. The results of this study suggest that the app's usability is on a good level, and its underlying methods for learning could be used to improve the knowledge for people who are interested in the topic.

Due to the simplicity of its features, most of the tools and options are used. Additionally there is also short descriptions for each model and parameters. This is also the reason why SPREAD is so easy to use.

Bibliography

[1] Cécile M Bensimon and Ross EG Upshur, *Evidence and effectiveness in decisionmaking for quarantine*, American journal of public health **97** (2007), no. Supplement_1, S44–S48.

[2] Gerardo Chowell, Hiroshi Nishiura, and Luis MA Bettencourt, *Comparative estimation of the reproduction number for pandemic influenza from daily case notification data*, Journal of the Royal Society Interface **4** (2007), no. 12, 155–166.

[3] Ian Coopera, Argha Mondal, and Chris G. Antonopoulos, *A SIR model assumption for the spread of COVID-19 in different communities*, Chaos, Solitons and Fractals **139** (2020), 1.

[4] K. Dietz, *The estimation of the basic reproduction number for infectious diseases*, vol. 2, Statistical Methods in Medical Research, 1993.

[5] Donaldson, Liam J., and Paul D. Rutter, *Donaldsons' essential public health*, Chemical Rubber Company (CRC) Press LLC, 2017.

[6] Benjamin M Good and Andrew I Su, *Games with a scientific purpose*, Genome biology **12** (2011), no. 12, 1–3.

[7] Lawrence O Gostin, Steven D Gravely, Steve Shakman, Howard Markel, and Marty Cetron, *Quarantine: voluntary or not?*, Journal of Law, Medicine & Ethics **32** (2004), no. S4, 83–86.

[8] Daniela Gotseva, Yavor Tomov, and Petko Danov, *Comparative study java vs kotlin.*, IEEE, 2019.

[9] Fiona M Guerra, Shelly Bolotin, Gillian Lim, Jane Heffernan, Shelley L Deeks, Ye Li, and Natasha S Crowcroft, *The basic reproduction number (r0) of measles: a systematic review*, The Lancet Infectious Diseases **17** (2017), no. 12, e420–e428.

[10] Saran Shantikumar Helen Barratt, Maria Kirwan, *Epidemic theory (effective and basic reproduction numbers, epidemic thresholds) and techniques for analysis of infectious disease data (construction and use of epidemic curves, generation numbers, exception reporting and identification of significant clusters)*, Public Health Action Support Team CIC **1** (2009), 1.

[11] Arne Holst, *Understanding the Numbers Behind COVID-19* `https://www.methodsman.com/blog/understanding-the-numbers-behind-covid-19`, accessed on 2021-09-07 (2020).

[12] Heesterbeek JAP and Dietz K., *The concept of R0 in epidemic theory.*, vol. 50, Statistica neerlandica, 1996.

[13] Dmitry Jemerov and Svetlana Isakova, *Kotlin in action*, vol. 1, Manning Publications, 2017.

[14] Adam Kucharski, *The Rules of Contagion: Why Things Spread–And Why They Stop*, Hachette UK, 2020.

[15] Pellis Lorenzo, Frank Ball, and Pieter Trapman, *Reproduction numbers for epidemic models with households and other social structures. I. Definition and calculation of R0.* , vol. 235.1, Mathematical biosciences, 2012.

[16] Charles M. Macal, *To agent-based simulation from system dynamics*, no. 1, Proceedings of the Winter Simluation Conference (WSC), 2010.

[17] Cetron Martin and Landwirth Julius, *Public health and ethical considerations in planning for quarantine.*, The Yale journal of biology and medicine **78** (2005), no. 5, 329.

[18] Cetron Martin, Maloney Susan, Koppaka Ram, and Simone Patricia, *Isolation and quarantine: containment strategies for SARS 2003*, Learning from SARS: Preparing for the Next Disease Outbreak (2004), 71–83.

[19] Kröger Martin and Reinhard Schlickeiser, *Analytical solution of the SIR-model for the temporal evolution of epidemics. Part A: time-independent reproduction factor.*, no. 53, Journal of Physics A: Mathematical and Theoretical, 2020.

[20] WRosti M.E., Olivieri S., and Cavaiola M, *Fluid dynamics of COVID-19 airborne infection suggests urgent data for a scientific design of social distancing.*, vol. 10.1, Scientific reports, 2020.

[21] Christopher Thomas Miller, *Games: Purpose and potential in education*, Springer Science & Business Media, 2008.

[22] Hiroshi Nishiura and Gerardo Chowell, *The effective reproduction number as a prelude to statistical estimation of time-dependent epidemic trends*, Mathematical and statistical estimation approaches in epidemiology, Springer, 2009, pp. 103–121.

[23] S. O'Dea, *Mobile operating systems' market share worldwide from January 2012 to June 2021* `https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/`, accessed on 2021-09-07 (2021).

[24] Android Developer Platform, *Distribution dashboard (2021)*, `https://developer.android.com/about/dashboards`, accessed on 2021-09-07 (2021).

[25] Bastian Prasse and P Van Mieghem, *Fundamental limits of predicting epidemic outbreaks*, Delft University of Technology, Delft (2020).

[26] Beckley Ross, Weatherspoon Cametria, Alexander Michael, Chandler Marissa, Johnson Anthony, and Batt Ghan S., *Modeling epidemics with differential equations*, no. 1, Tennessee State University Internal Report., 2020.

[27] Mark A. Rothstein, *From SARS to Ebola: legal and ethical considerations for modern quarantine*, Indiana Health Law Review **12** (2015), 227.

[28] Doris C Rusch, *Making deep games: Designing games with meaning and purpose*, CRC Press, 2017.

[29] Kröger Martin Schlickeiser Reinhard, *Analytical solution of the SIR-model for the temporal evolution of epidemics. part b: Semi-time case*, no. 54, Journal of Physics A., 2021.

[30] Sara D Schotland, *A plea to apply principles of quarantine ethics to prisoners and immigration detainees during the COVID-19 crisis*, Journal of Law and the Biosciences (2020).

[31] David L. Schriger, *Modern epidemiology*, vol. 52, University of California, Los Angeles, Los Angeles, CA, 2008.

[32] Alicia Elena Suarez and Deidre Redmond, *Desired social distance from people who have hepatitis c virus: An exploration among staff in health care, dentistry, drug treatment, and tattoo/body piercing*, Substance Use and Misuse **49** (2014), no. 4, 466–474.

[33] Harko Tiberiu, Lobo Francisco S. N., and Mak M. K., *Exact analytical solutions of the susceptible-infected-recovered SIR epidemic model and of the SIR model with equal death and birth rates*, no. 236, Applied Mathematics and Computation., 2014.

[34] Kim Usher and Bhullar N, *Life in the pandemic: Social isolation and mental health*, https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/jocn.15290 (2020).

[35] Luis Von Ahn, *Games with a purpose*, Computer **39** (2006), no. 6, 92–94.

[36] Luis Von Ahn and Laura Dabbish, *Designing games with a purpose*, Communications of the ACM **51** (2008), no. 8, 58–67.

[37] Howard Howie Weiss, *The SIR model and the foundations of public health.*, Materials matematics, Georgia Institute of Technology. Mathematics Department, 2013.

[38] Claus O Wilke and Carl T Bergstrom, *Predicting an epidemic trajectory is difficult*, Proceedings of the National Academy of Sciences **117** (2020), no. 46, 28549–28551.

[39] Yang Wuyue, Zhang Dongyan, Peng Liangrong, Zhuge Changjing, and Liu Liu, *Rational evaluation of various epidemic models based on the COVID-19 data of china*, no. 54, Zhou Pei-Yuan Center for Applied Mathematics, Tsinghua University, Beijing, 2020.

[40] Danqing Xu, Yiqun Liu, Min Zhang, Shaoping Ma, Anqi Cui, and Liyun Ru, *Predicting epidemic tendency through search behavior analysis*, Twenty-Second International Joint Conference on Artificial Intelligence, 2011.