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Mapping Deaf America: Visualizing American Deaf Sociality through Geographic Information Systems

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Visualizing American Deaf Sociality through Geographic Information Systems

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Abstract

In the study of the US deaf community, a noticeable gap is evident in the absence of an accessible map that presents current data about the community. This project takes an American perspective, embracing the term “Deaf America” as a framework that highlights the unique social network, geographic nuances, and sensory experiences of the deaf community in the United States. These elements are crucial to understanding the extensive network of the deaf community in the US. However, there is a lack of quality visual representations of these elements. This project seeks to bridge this gap by collecting data and leveraging the capabilities of ArcGIS to create a living document that reflects Deaf America and ensures the document is accessible to all. ArcGIS is a data management system and a powerful geospatial visualization software that allows spatial data analysis, map creation, and uncovering insights. The project’s accessible map is designed to serve both the general public and researchers, connecting multiple concepts relevant to the study of the US deaf community. By visually representing lived experiences, locations, and statistics, this project holds promise for future initiatives in understanding, researching, and supporting the deaf community.

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Literature Review

Introduction

The development of a tool that incorporates filters to explore different aspects of deaf sociality, particularly how deaf individuals connect and interact with one another in the United States, has the potential to enhance our understanding of this community. By visualizing the data generated by such a tool, we can gain insights into patterns and trends that inform more effective strategies for supporting the deaf community. This project has created a tool that reflects multiple aspects of deaf sociality, including statistical and cultural/social viewpoints, providing a comprehensive perspective of the American deaf network for researchers and the general public.

This project is built upon concepts and ideas such as Deaf Geographies, the Deaf-World, and sensescapes. However, the central concept falls with deaf sociality, which was created by Friedner in 2014. This term refers to the places where deaf people interact, as quoted by Friedner: “the norms of deaf sociality, which include identifying oneself in relation to the deaf world; sharing information, news, and stories; and desiring to contribute to "deaf development” (2014). The visualizations created in this project incorporate the foundations of deaf sociality, which is allowing oneself to understand their relation to the deaf world and sharing information about it, and enhances it with additions, including statistics and geospatial mapping of deaf people and their network in America.

There are published and researched data projects showing different framings of what deaf sociality (and related terms) is in America. The diverse perspectives on what represents deaf sociality in America and its characteristics make it a complex topic that can be framed in multiple ways. Visualizing the American deaf network can be a powerful tool for understanding it. However, there are no readily available interactive resources that allow for an easy understanding and the opportunity to interact with the data. The ability to do that is crucial in finding patterns and spatial relationships, as the accessibility of data has changed over the years. This was not possible thirty years ago, but it is now, thanks to technological advances and the Internet, making it just a click away. With that, the deaf research field needs accessible and visually clear information on various aspects of deafness and deaf sociality. As a result, a versatile system is necessary to collect and manage data and present it in different formats. In doing so, this project will address the lack of accessible and quality information about the American deaf community in a visual format. That is where ArcGIS, a geospatial mapping software, comes in as the core tool in creating a data-filled interactive map.

Deaf(ness) versus Deaf America

The primary goal of this project is to visualize the experiences, networks, and opportunities of both D/deaf people rather than solely focusing on the medical condition of “deafness.” However, it is crucial to establish and differentiate between the various uses of the term "deaf" and its related terms, as there is a need for a definition of deafness that aligns with the existing statistical data – but also allows for flexibility in reorganizing the data to include aspects of deaf sociality. In this context, “d” represents the general lowercase “deaf,” which encompasses the medical condition of partial or complete hearing loss and includes individuals across a spectrum of hearing loss. On the other hand, “D” refers to the cultural and social identity of Deaf individuals. This uppercase usage emphasizes a collective identity, encompassing shared language (such as American Sign Language), culture, and community experiences (Woodward & Allen, 1993; Napier, 2002). This project aims to visualize not just the medical aspect denoted by “d” but also the broader social and cultural dimensions represented by “D.” Since this paper involves multiple disciplines and fields of study, the terminology for D/deaf will be as follows:

capital “D” for already-defined terms relating to deafness such as Deaf-World, Deaf Studies, etc., and lowercase “d” for everything else regardless of cultural/social/statistical status. However, the term “deaf sociality” will also be lowercase, following Friedner’s usage in their articles. To arrive at this general framework, it is necessary to include the medical definition of deafness, as it will contribute significantly to the statistical side of the project and the overall goal of the project.

This project's statistical/overlay data section will utilize the medical definition of deafness, allowing it to be measured in numbers, which is also considered an operational definition (the ability to observe/measure something for data collection). According to the Western Interstate Commission for Higher Education (WICHE), the medical definition of deafness is:

> Medical – The term hearing-impaired covers the broad spectrum of any individual with a less-than-average hearing level. The term deaf is generally used to describe those who are unable to benefit from a hearing aid due to the severity of their hearing loss. It is important to note that the term hearing-impaired is only appropriate for use within the medical community. Most deaf and hard of hearing persons consider the term to be inappropriate for general use (Tate & Adams, 2006, p. 9).

Most of the collected data will use the medical definition to some degree, so for ease of collection and analysis, it will be used to measure the number of deaf people in all areas and age groups in the overlay data part. Different criteria will be used for the other parts of the data and map. Aside from the overlay data, the project will also focus on collecting data from a multitude of categories that create the deaf network. This part of the project is inspired by “Critically Mapping the Field” in the book *Innovation in Deaf Studies* (Kusters, Meulder, & O’Brien, 2017).

Different aspects of Deaf ontologies and Deaf epistemology will be combined and show the "deaf ways of being, and deaf ways of knowing," including areas like communities, networks, ideologies, language practices, and political practices (p. 3).

Since this project involves locations, it is necessary to have a term that will present the results of the data collection and is easy to refer to in other works or discourse. It also will address the lack of a singular operational definition in researching/measuring the deaf network and its aspects, as the related "deaf" term umbrella or the alternative term "the US deaf community" does not satisfy the above needs. Therefore, I propose the term **Deaf America** to describe the end product of this project. This term is inspired by Hoffmeister & Bahan's explanation of the Deaf-World:

> When we refer to the Deaf-World in the U.S., we are concerned with a group… possessing a unique language and culture… (p. ix) Signed language is the most important instrument for communicating in the Deaf-World… From the day Deaf Americans enter the Deaf-World, ASL becomes their primary language, and is, in itself, a big chunk of Deaf-World knowledge" (Hoffmeister and Bahan, 1996, as cited in Mitchell et al., 2006, p. 5).

Deaf America is a framework that describes the concept, statistical makeup, and visual representation of deaf people in the United States and its network. It incorporates several concepts to show how the deaf network exists in and influences a geographical area. The Deaf-World definition is overly broad – it can be used anywhere with a deaf community, which clashes with the American focus of this project. Some also consider the Deaf-World term to describe the "social network" in which the deaf community interacts, mainly through sign language. The Deaf-World definition also incorporates some data points that are not part of this project's focus, i.e., hearing children of deaf adults (CODAs) because they can also experience full acceptance in the Deaf-World due to access to sign language (Tate & Adams, 2006, p. 30). In addition, Deaf America is an all-inclusive term, as it includes every person, regardless of age, sex, race, etc., in the umbrella. However, this project acknowledges the issue of statistically essentializing a community that is diverse and multidimensional by nature, but ultimately, the goal is to present a statistical view of Deaf America. In addition, due to unavailable data and time constraints in attaining the necessary data, more extensive demographic information could not be included. At its simplest, this project aims to offer proof of concept and a starting point for a noticeable gap in the research of and understanding of the deaf networks in America. With that, this project allows space and encourages future expansion (see the Results/Discussion, Limitations/Further Research, and Conclusion sections) which would add more dimensions.

There are other keywords that frame the relationship between people in the subject of Deaf Studies, and such examples are deaf sociality, Deaf Gain, and Deaf Space (Kusters, Meulder, & O'Brien, 2017, p. 8). However, several of these terms are considered top-down concepts, causing people to be "thinking and structuring descriptions and analyses of deaf lives," which is detrimental to the experimentation of new concepts and collecting knowledge (p. 9 - 10). With that, it is essential to determine which concept correctly fits the goals of this project, which is to visualize the deaf network in America. The accurate collection of data and information relies on this keyword, so to filter out unnecessary data and summarize the terms mentioned above, Friedner's (2014) term "deaf sociality" is the most suitable. This concept focuses on the interaction and relationships between deaf people, making it broader and more inclusive than other concepts such as [deaf] identity, world, community, and culture (Kusters, 2014). Deaf sociality is created through spaces that provide deaf people with a "space to spend time with other deaf people, learn sign language, and learn deaf values and norms such as sharing knowledge and information, teaching each other, and engaging in 'help support'" (Friedner, 2015, p. 54). Such spaces can be churches, vocational training, and workplaces that allow deaf people to interact and increase connections between deaf people. All of these spaces combined help show the overall network of Deaf America.

The deaf sociality concept allows for a narrow but broad filter on what can be implemented on the maps of this project, helping define what type of data will be collected for the map. However, it is also important to include a term to describe the geographical features that the map contains. This is where the Deaf Geographies come in. Deaf Geographies is a sub-field in Deaf Studies that allows for the spatialization of the various approaches in Deaf Studies. This idea was born in the early 2000s and grew into the broad "Deaf Space" idea (Kusters, Meulder, & O'Brien, 2017, p. 16) before breaking into two separate ideas. The close parallels between Deaf Space and Deaf Geographies allow the "networks" concept to become another closely related idea.

Various Deaf Studies scholars have used all these ideas to dive into topics like mobilities and international deaf spaces (Kusters, Meulder, & O'Brien, 2017, p. 16). An example of a scholar doing so is Padden's (2011) summary of the history of deaf people, their mobility, and their language. She describes how deaf schools, associations, and other organizations in America formed and interacted with each other, allowing for connection and networking nationwide. Padden also points out the movement and connection between deaf people of the 1800s and 1900s as "sign language geographies" because the people traveled long distances to see other deaf people, creating a wider geographical spread of sign language users in North America (p. 27).

This project will omit the Deaf Space concept and instead focus on the deaf geographies/ "networks" parts of deaf people in America. As Gulliver and Kitzel (2016) describe it, Deaf Geographies is the combination of human geography and Deaf Studies. It shows how deaf people "encounter their environment and each other, produce interactive spaces through which they socialize and create/share knowledge and then begin to shape those spaces into their environment" (p. 1). There are many opportunities to study deaf people and their geography, but the field has not taken off until recently. Historically, human geographers' former belief was that the world was fixed, and their job was to collect this fixed information and map it out. However, over the years, they realized that their belief was untrue – the world is actually a living and interactable item, causing a shift in human geography to show that "life." Deaf Geography has followed a similar pattern, moving to show how deaf people produce Deaf Spaces by living within "visual bodies, rather than hearing ones" (pp. 1-2). Gulliver & Kitzel's (2016) work emphasizes Deaf Geography's ability to show the unique position of deaf people as social beings and how they create spaces as they live in the deaf and hearing worlds (p. 3). Factors like what/where Deaf Social Geographies emerge, what they look like, how Deaf Spaces are accessible/inaccessible to other members of the community, the interaction between deaf and hearing spaces, and how they interact with each other (p. 3) guide Deaf Geography and the emergence of spaces in it. Deaf Geography is divided into historical, urban, and Deaf Geographies. This project focuses on the Deaf Geographies field, which examines how buildings and environmental factors affect spaces for deaf staff and students (p. 3). This approach can benefit the analysis of community reach and the impact of deaf political/advocacy organizations in America on the deaf community around them.

This is where Rosen's (2018) work comes in. Rosen noticed that the social and cultural organizations of the American DeafWorld all had different approaches in what they offered to meet the various needs of the deaf community (p. Points of Interest). However, only the brick-and-mortar institutions were included because they are spaces where culture and body meet (p. 60). These institutions also influence the type of clientele that use them due to their different "cultural orders of the senses" (p. 64), which are priorities that these institutions deem important – such as sign language use, use of hearing devices, teaching philosophies, and more. These will influence the geographical layouts and the type of clientele that use them due to the scale of ease/difficulty accessing the institutions.

To describe these brick-and-mortar institutions that serve deaf people, Rosen coined the term "sensescapes," which are "the physical landscapes where the DeafWorld is instantiated" (p. 64). Rosen goes on to explain that sensescapes are "geographic model(s) of the sensory landscape that resulted from the imprinting of an institutional culture's ideological and practical order of the senses… scenescapes for the DHH (Deaf and Hard of Hearing) people are the institutional constructions of the DHH body in space" (2018, p. 64).

There are three aspects to an sensescape – visual, auditory, and mixed-sensory. A visual sensescape is a sensory landscape that "includes visual sensible objects and fields of sight." Examples of visual sensescapes are schools for the deaf, deaf clubs, and deaf organizations (pp. 66-67). An auditory sensescape is an institution whose "programs and services subscribe to the notion that DHH people are auditorially oriented" (p. 68). These spaces can be found in oral schools, various centers for hearing/communication, and speech centers (pp. 68-70). Mixed-sensory sensescapes are a combination of both visual and auditory sensory landscapes. These institutions prioritize accessibility due to diversity, which allows for visual and auditory objects to be combined to cater to a wide range of humans – examples of these spaces are found in common public spaces, such as airports or theaters (pp. 71, 73).

This project will use these sensescapes, focusing on the institutions that primarily serve the deaf community and allow for networking between deaf people in these spaces. The sensescapes also allow institutions to serve deaf people's needs. These spaces can evolve to "create, allocate, and imprint their sensory ideologies, sensible material objects and activities in their spaces. They 'paint' how they want their spaces to be 'sensed' to fit their ideologies, missions, purposes, programs, and services for certain DHH clienteles" (p. 74). This can be seen in the approaches of national/state associations for the deaf, political organizations, deaf schools, and clubs. Deaf people have different ways of thinking and beliefs. These institutions will help affirm or break down these beliefs via the deaf network, which allows deaf people to meet other deaf people and learn about themselves, the community, and so much more by simply just going to and existing in a sensescape.

There must be a term specific enough to incorporate the varying factors that make up deafness in America to ensure it is easy to understand in discourse. My proposed term, Deaf America, is an excellent fit. It removes some data points from datasets that would have used the Deaf-World definition. A combination of terms from Friedner (2014), Padden (2011), Gulliver & Kitzel (2016), and Rosen (2018) will complement the Deaf-World definition by Hoffenmeister & Bahan (1996) to help structure what makes up the Deaf America term. The concept of Deaf sociality shows the deaf network found within America. The Deaf America (inspired by Deaf-World, Deaf Geographies, and sensescapes) term will help narrow down the location aspect to just the United States.

This project aims to provide a visual representation of Deaf America by combining different definitions of deafness with the social network it offers. This visualization will incorporate various concepts from Deaf Studies scholars to help create a criterion of what constitutes Deaf America. Ultimately, the goal is to showcase a bigger picture of what makes up the American deaf network and identify any patterns that researchers can use for further study.

Software Use: R Programming & ArcGIS

The best software to showcase the approaches and analytics (including patterns) of Deaf America is the R programming language and the ArcGIS software through their Online (web-based) and Pro platforms (desktop-based). The data collection will be stored in Microsoft Excel, which can output the data in a .csv (comma-separated values) file. The file format allows both R and ArcGIS to read the data. R will then import the data and enable the user to analyze it. Once complete, the analyzed/cleaned data will be imported into ArcGIS to be visualized. The R and ArcGIS software are extensive with many parts, allowing for an advantage in utilizing these software.

The R programming language, called R in this paper, will be beneficial to wrangling the data and creating the initial visualizations to see the patterns of the data. This is because R is a "language and environment for statistical computing and graphics" (R Core Team, n.d.). Since one of the parts of this project focuses on the statistical analysis of the deaf network in the United States, R is a great tool to use. A second programming language, Python, can be used, but it does not have R's capability. Python is a "general-purpose, object-oriented programming language that emphasizes code readability through its generous use of white space" and R is "an open source programming language that's optimized for statistical analysis and data visualization" (IBM Cloud Team, 2021). R comes out on top because of its capability to expand its toolset, containing a plentiful library of various packages that users can mix and match to determine what they do with the data. Simply put, R's advantage over Python is that it has a better ecosystem with models and tools for data use and reporting.

In the Comprehensive R Archive Network (CRAN), more than 13,000 R packages are available for analytics (IBM Cloud Team, 2021). The dplyr, tidyr, forcats, tibble, readr, and ggplot2 packages will be used in this project. The tidyverse library contains packages that focus on data wrangling and transformation (dplyr, tidyr, stringr, forcats), data import and management (tibble, readr), functional programming (purrr), and data visualization and exploration (ggplot2) (Wickham et al., 2019). These packages will help clean up the data because this project will manipulate the data to create a “home” for each dataset to reside in for ease of access and use. The collected data has two parts to it – manual and automatic. The data collected manually from various groups, i.e., “custom put-together” data, is considered manual data. The automatic group has data already on a database or list and easily collected, such as the US Census data. This is where tidyverse comes in, combining both parts in one document (via commands and packages) without excessive manual work on Excel or other software to wrangle the data and allow initial analysis before moving on to ArcGIS.

Both programming languages are great tools to use in data science, but their goals of use are different. Again, Python is a general-use language, which allows for an easier learning curve. On the other hand, R has a steeper learning curve, but it was built by statisticians and relies on statistical models and specialized analytics. R is also designed to import data from Excel, .csv, and text files (IBM Cloud Team, 2021), allowing for better success.

After data cleaning, analysis, and visualizations are done in R, it will mark the end of R's capability to do more with the data. R can create quality visualizations in many forms, as seen in

Figure 1's graph of estimated excess mortality in 8 countries and Figure 2's map of various European wineries. These examples are random and have nothing to do with this project except to showcase R's visualization ability.

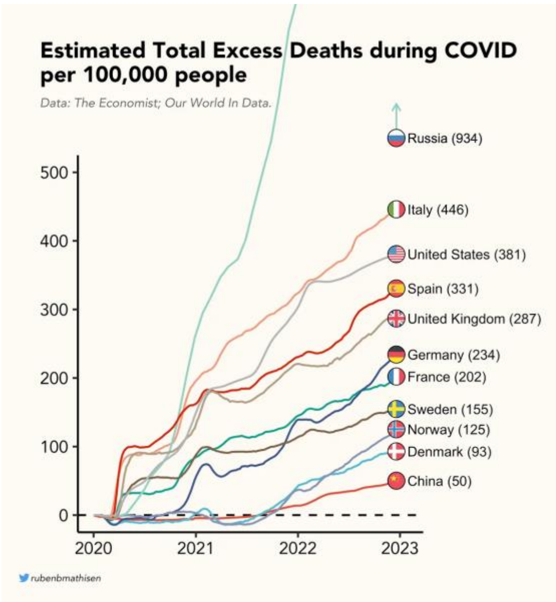


Figure 1

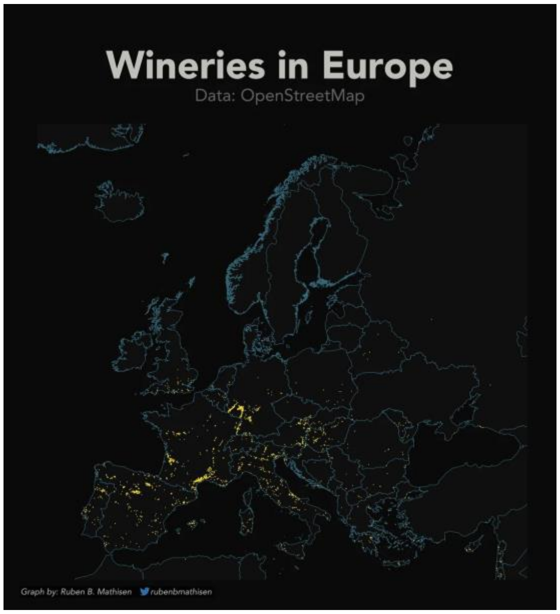


Figure 2

However, the primary goal of this project is to visualize the data collected geographically and in an interactive form, and this is where ArcGIS (powered by Esri) comes in. ArcGIS is a powerful platform, and it has the potential to address many issues relating to data collection. Due to its capabilities, it can also become a flexible repository for incoming data. At its simplest, ArcGIS is a geospatial software that collects, edits, analyzes, and views geographic data (What is ArcGIS?, 2023). The ArcGIS software can take many data points and layer them together on a geospatial canvas (aka maps).

ArcGIS maps can highlight previously unknown patterns, as seen in Angel's "Patterns of Hearing Impairment in Rural and Urbanized Texas in 2018" (2021). Angel's project mapped the patterns of hearing impairment in Texas utilizing census data in county- and state-level data. Angel wanted to find the reason for the hearing loss care discrepancy in Texas's rural and urban areas. GIS software was able to help them find the patterns on which to base the potential solution on. The main highlight of this article is the use of GIS software to map the results, showing how data visualization can offer a better understanding of the content over a typical table or .csv file. A bonus is that the data used in this project was publicly available – which is a critical element of this capstone project. This project emphasizes the accessibility of the data and the ability to source it from public databases. Angel's work shows that it is possible to create a map entirely in GIS that shows a pattern across an area, which is the goal of this project.

However, interactivity is a critical aspect of this project, so that is where the ArcGIS platform comes in. The ArcGIS platform provides the ability to deliver an interactive map, present data in data layers, and a way to tell a story within the same platform, which, if done right, becomes a powerful resource for the platform's users. Two examples of powerful interactive resources can be procured from Brianna DiGiovanni's *Deaf New York Spaces* StoryMap and the Public Religion Research Institute's (PRRI) *American Values Atlas*.

Brianna DiGiovanni's *Deaf New York Spaces* StoryMap was created for the Schuchman Center of Gallaudet University. It spotlights the Deaf New York community over a period of time. It also shows how the deaf people of New York City gathered and built schools, clubs, and so much more from the late 1800s to 2020. This project is a comprehensive look into the history, locations, and stories relating to these spots, preserving the important history of the deaf community. An additional bonus for this example is that it was built on the ArcGIS platform, which is one of the goals of this project. The story is interactive throughout the entire read, with maps embedded within the StoryMap, allowing for some necessary explanation of the data shown in the maps without taking too much attention away from the project's focal point, which is the maps. In the composite map of deaf spaces in NYC, the dots represent a location significant to the history of deaf people in New York City. They are all on one layer, using a light gray basemap, which makes it easy to see. The dots are colored, with each color representing a type of space – such as red for clubs/organizations/associations, blue for deaf schools, green for religious spaces, and so on. That makes the map easily readable and findable for various data. The *Deaf New York Spaces* StoryMap is an excellent example of combining a written work explaining the project and discoveries alongside the mapping/visualization aspect into one final product.

PRRI's *American Values Atlas* (AVA) is an interactive map showcasing Americans' answers to various questions asked by PRRI, such as "how much do you attend religious services?", "what political party do you identify with?", or measuring the support of same-sex marriage (favor, oppose, don't know/refused). It allows the user to arrange their lens of focus to see answers to what they want to know. An example of said interactivity is that the user can choose to see the answer to the demographics of each state in the 18-29 age group by clicking Demographics > Age > 18-29. The map then will return the results in each state, the national average, and the density of 18-29-year-olds in each state in the map (PRRI – American Values Atlas, n.d.). This map reflects the ideal perfect-world map of this capstone project, as the PRRI site offers a visualization of the cross tabulations between demographics and survey responses on various topics.

With the amount of possible data streams on deafness, deaf sociality, and Deaf America, a full, in-depth map can be built from scratch that includes a wide range of demographics, statistics, and topics, just like PRRI's *American Values Atlas*. This resource will allow for various uses and benefits, ranging from ordinary people seeking out deaf institutions close to them (hearing parents of a deaf child wanting to find a school), to researchers wishing to use statistics in their projects; which this map will help them find the information they need in "one click", place the information/data on a geospatial scale – which will allow the viewers to understand the world around them (aka deaf sociality) and how to utilize the world around them, and so many more. However, with the time constraints (a year to collect the data and create the maps) and the barriers in identifying good data sources, doing something large-scale like this map is not viable, so for this project, only a nationwide and one statewide map was created. The goal of this project, as a visualization of cross tabulation data (geographic and demographic datasets), is to eventually become a living document (map) and a centralized data repository relating to Deaf America. Data will be continually added as more research and information is found, allowing the map to evolve while maintaining historical layers of past information and data.

Methodology

This project differs from the usual methodology seen by deaf scholars, as it does not utilize usual visual methods such as drawings, photographs, or videos. Instead, the core part of the project is delivered through ArcGIS. This section will cover how the data was collected, cleaned, analyzed, and shown. ArcGIS provides many advantages in using its platform, and its incorporation into this project leads to a product that can be accessed and interacted with by the public.

Visualizing data of Deaf America at this depth has never been really done before, and it brings a whole new dimension in showcasing research on deafness. To encourage more visualizations, I will share my methodology and work done in ArcGIS below. With that in mind, it is important to look at other projects that have done something similar in visualizing data on the deaf network and population. The combination of Angel's (2021) study on hearing impairment in Texas and DiGiovanni's (2020) *Deaf New York Spaces* is very close to my project. The project has choropleth maps (filling areas with colors that correlate to different categories of data) like Angel's (2021) map, but also with geolocated institutions like DiGiovanni's (2020) locations of different deaf institutions in New York City. Angel argued that "it is well known that the Geographic Information System (GIS) and spatial epidemiology have unique methodological expertise in evaluating geographic data. However, its application in assessing hearing census data has not been thoroughly investigated" (2021, p. 2). Angel shows that there is a need for more data relating to deafness in general to be visualized and describes their study as an "attempt to assess the GIS capabilities using publicly available data," (2021, p. 2) and they are successful in showing the capabilities of GIS to visualize data and its patterns.

Due to their success, this project is modeled after their idea of assessing hearing census data in GIS form.

Another great approach to analyzing data patterns in GIS work is the “Regional Patterns and Trends of Hearing Loss in England” study (Tsimpida et al., 2020). Their study used prevalence and hot/cold spot analysis to determine the density and number of people with hearing loss in England. The reasoning behind the hot/cold spot analysis was to “indicate unexpected spatial spikes of high or low values, respectively, showing that the distribution of these values in the dataset is more spatially clustered than would be expected if underlying spatial processes were truly random” (Tsimpida et al., 2020). This study’s GIS figures are not interactive, but they present a good inspiration for the analytical approaches used and a layer in this project.

Thanks to the works mentioned above, the methodology of this project is firmly based on the goal of gathering publicly available data on the American deaf network and its patterns through overlaying other types of data (i.e., institutions) atop the Census data. There are two prongs to this fork; the first is determining what missing data is not currently available to create a fuller project for future additions. The second prong is the proof of concept, reflected in the ArcGIS maps that use the collected data. Therefore, ArcGIS is attempting to visualize Deaf America and its patterns within.

ArcGIS Work

The art of using ArcGIS is relatively new in the mainstream media and research outside of the specialized field, so it is important to touch base on what approaches will be used in this project and the different parts of the end product.

The project contains two maps: a simplified nationwide map and a detailed Maryland (state) map. My reasoning behind doing this is due to time constraints and the difficulty of finding good nationwide data. From the day I came up with this project, it has always been thought of as **proof of concept**. This project is not as detailed or accurate as if I had decided to follow a standardized method of creating GIS maps with one's research. I had only a year and a half to develop, work on, and complete this project, so it has always been viewed as an innovative idea/starting point in encouraging further research or work on this topic. The maps intend to show what is possible with a singular state's more in-depth data on the state's deaf community/numbers (due to time constraints) and encourage thinking on the "what if we applied this to all fifty states?" question, essentially making ArcGIS attempt to visualize Deaf America and its patterns, starting with the layering of the maps.

The layers of the nationwide map largely follow these guidelines (but keep in mind that all layers except for the base map can be rearranged in different orders):

Base Map: This map is visually appealing and easy to reference due to the layering of the data. I chose the light gray canvas map (Esri, n.d.-a), as it is easily viewed without straining and allows for adding different colors atop it. The map also has major interstates and cities already shown on the map, which helps the viewers to understand the spatial relationships of the data to the area around them.

Overlay Layer: This layer shows the overall number and percentage of people with hearing difficulty in different age groups for each state. This allows for seeing the differences between the states and using color saturation to represent the density of people with hearing difficulty in America. This layer uses choropleth maps, filling the states with different colors representing the breaks in the dataset, showing where more people with hearing difficulties are.

This part will not be 100% accurate due to 1) the undercounting of disabled people in the American Community Survey (ACS) (Swenor & Landes, 2023) and 2) not having an “official” count or census of deaf people in America; the last one was in the 1940s.

Deaf Academic America (DAA) Layer: This layer highlights the various academic institutions for deaf people in America, ranging from primary to post-secondary and everything in between. This layer also includes clickable pop-ups with information about the institution (i.e., address, statistics, website).

Deaf Political America (DPA) Layer: This layer covers the political institutions for deaf people in America, ranging from advocacy to state organizations to actual political organizations. The national/state associations, state agencies, and other organizations are included here. Some examples of such organizations are the National Association of the Deaf (NAD), states’ Deaf and Hard of Hearing offices, and the Center for Democracy in Deaf America (CDDA). Similar categories and pop-ups from the DAA layer are used here.

Now, the layers of the Maryland map also largely follow these guidelines (but keep in mind that all layers except for the base map can be rearranged in different orders):

Base Map: This is a visually appealing map for easy reference due to the layering of the data. I chose the light gray canvas map (Esri, n.d.-a), as it is easily viewed without straining and allows for adding different colors atop it. The map also has major interstates and cities already shown on the map, which helps the viewers to understand the spatial relationships of the data to the area around them.

Overlay Layer: This layer shows the overall number and percentage of people with hearing difficulty in different age groups for each census block area. This allows for seeing the differences between the states and using the color saturation to represent the density of people with hearing difficulty in Maryland. This layer uses choropleth maps, filling the census block areas with different colors representing the breaks in the dataset, showing where more people with hearing difficulties are.

Institutions Layer: This is a combination of both the DAA and DPA maps of the nationwide map, following the same color scheme for each category. However, all these fall under one group for easier mapping and layering, as Maryland is not a large state.

With the layers set, the general rundown of what my procedure in creating this project looks like this:

1. Collected data sets relating to the project from publicly available and accessible databases such as Esri, US Census, etc.
2. Manually found and collected data from various deaf associations, clubs, schools, and other social institutions that interconnect and make up Deaf America.
    a. This was done by finding data from publicly available databases online, such as the IES/NCES National Center for Education Statistics database.
    b. Some groups (such as the National Association for the Deaf) were contacted for inquiries regarding membership/people numbers.
        i. The data requested will contain NO personally identifiable information, as this project is focused on only the statistics of the various aspects of Deaf America.
3. Utilized Microsoft Excel and R programming to clean up, analyze, and visualize the data before moving to ArcGIS.
    a. Part of this process is defining what criteria must be met for Deaf America.

4. Visualized what makes up Deaf America in two areas of focus:
   a. Nationwide snapshot of Deaf America, which includes its sensescapes (Rosen, 2018, p. 64) and its overlay data. Buildings known to belong to the deaf community will be geolocated. This map is simple in comparison to the second map. It consists of just the spatial information and the statistics (if applicable) regarding each institution. Numbers of people with hearing difficulties across four age groups (0-17, 18-34, 35-64, and 65+) in each state are visualized through a choropleth map.
      i. If there is no building or a physical location, the information is still collected as long as that group is contained within a single U.S. state (applies mainly to the state associations).
   b. A state-level snapshot of Deaf America, which in this case, is Maryland (and some parts of DC/Virginia, if applicable). This map is more detailed, as the overlay data with the same age groups was split into census block areas, giving a more detailed look at where the people are. The sensescapes are also included, following the same criteria as the nationwide map.
5. Utilized nation-level, state-level, city-level, and census block-level mapping techniques to visually show data using GIS.
   a. Captured patterns of hearing difficulties and the deaf network in various areas, comparing the city and rural areas.
   b. Differences in data in regions were shown due to the density of the people with hearing difficulties in these regions.

   c. Included the institutions of the Deaf-World or Rosen's sensescapes, which can be deaf schools, clubs, organizations, etc., to indicate possible hot/dense spots as a result of these institutions.

6. An analytic mapping technique called hot/cold spot analysis was used to identify critical areas of interest.
7. Density/weighted overlay analysis was used to create optimal visualization of the highest deafness density in specific areas.
8. Incorporated all of the data and discoveries during the process above into a one-stop place for all of the visualizations and explanations to reside online, like DiGiovanni's *Deaf New York Spaces* and PRRI's *American Values Atlas*.

During the process of working on this project, one of the largest parts was geoprocessing. Geoprocessing is the framework and set of tools for processing geographic and related data. In this project, I used these geoprocesses:

- Table to Geodatabase
- Join data
    - Joined tables of collected data with the Living Atlas (online repository for polygon features)
- XY Table to Point
- Calculate Fields
- Apply Symbology from Layer
- Buffer, Merge, Dissolve and Clip
    - For populations within 10 miles of institutions

These geoprocesses above are just some examples of the work done in ArcGIS to transform the data from its raw format to the end product. The rest depends on the different features of the map that tell the story/information of the data. The following information explains the different decisions I made in telling Deaf America to my audiences.

The foundational part of a map is its spatial reference, which determines how the map appears. For this project, the WGS 1984 Web Mercator (Auxiliary Sphere) is used, as it is the accepted standard across the map-making world, and no matter where you are on the map, up is north, down is south, and west and east are always left and right. The same spatial reference is used on Google Maps and many other online maps, which means the viewer can understand the map and the sizing without much difficulty.

As for the styling of the maps, they follow the tips and guidelines from Esri, who is responsible for the ArcGIS software. Lavery's (2019) article discusses the best approaches to creating a demographic map, from the basemap to the color usage. To present the demographic data clearly, the basemap should not be busy, so either the gray canvas (light/dark) or the human geography (light/dark) basemaps should be used. I chose the light gray canvas basemap because it was important that the cities, roads, and landmarks were represented on the map in an easy-to-read way to allow for a better spatial understanding of the locations on the map. Since this project maps the numbers and the percentage of people with hearing difficulty, the high-to-low color ramps are the best course of action for the coloring. The darker a color is, the higher the percentage of incidence the data is. These choices allowed for more people across a spectrum of academic knowledge to understand the maps.

The data is presented in a normalized format, as it is important that the data is shown in a more commonly used way. The normalization method used for the data in the overlay layer is as follows:

$$\frac{Total\ of\ People\ (Age\ Group)\ with\ Hearing\ Difficulty}{Total\ of\ People\ (Age\ Group)} \cdot 100$$

This normalization method outputs the number that represents the percent of people with hearing difficulties in a specific region/area following guidelines from the Esri Education Program (2005). Normalization is important, especially in visualizing demographic data, because it is different from just comparing numbers. This normalization method will show the likelihood of finding a person that matches the characteristics of the criteria. This is good for someone wanting to know the chance or incidence rate of finding a person with hearing difficulty in America. Another reason for utilizing a normalization method is the population dependence phenomenon – the idea that bigger states will have more counts of something over smaller states. Take California or Texas, for example. There will be more people with hearing difficulties than in states such as Connecticut or Delaware. The density, if depending on raw counts, will show larger population centers as having a higher incidence rate of a specific demographic. Normalization eliminates this phenomenon and focuses on the intensity of something happening in an area. This is explained via a guide on normalizing data on Esri's website, stating, "normalizing data factors out of the size of areas by transforming counts (measure of magnitude) into ratios (measures of intensity)" (Dailey, 2006).

This project has a distinctive approach that is different from typical methodologies used by deaf scholars, as it is centered around the ArcGIS software. ArcGIS is a powerful resource that can take on many hats at once, including database management and visualization. ArcGIS' power allows for workarounds with gaps in the data and inaccessible data and appeals to the visual world many deaf people reside in.

Data

Existing Datasets and Gaps

The main goal of this project is to show a snapshot of a relatively recent year in Deaf America. It will show the deaf sociality aspect of Deaf America, i.e., the deaf capital/network – which comprises data consisting of several categories and criteria. This project will hopefully turn into a yearly progression, leading to a living interactive document of Deaf America in the 21st century (2020s and on) both in visual and spatial forms. There is a good deal of data on deafness in America. It ranges from statistical data on hearing loss to information on spaces that serve the deaf community. It is important that this project acknowledges historical trends in connecting statistics' roots to eugenics (Davis, 2014). Statistics for deaf and hard of hearing populations are often not used objectively. Data provided by this project is intended to be used to **understand**, **support,** and **elevate** the deaf community, NOT for contributing to its eradication, cure, or other harmful efforts. It is strongly encouraged that the data, maps, and results of Deaf America provided from this project are used ethically.

The statistical data on hearing loss will make up the overlay section of the dataset, allowing for comparison between states on the numbers and percentages of deaf people. The data will come from the US Census Hearing Difficulty dataset (2021b). Accessing data easily is a significant aspect of this project; therefore, this table was chosen specifically due to the accessible nature of the data, as it is easily viewed online and downloaded. However, it comes with the limitation of an overly broad definition of hearing loss/deafness. In the table, there was a note explaining that it had asked respondents if they were "deaf or… [had] serious difficulty hearing" (U.S. Census Bureau, 2021, p. 63). Factors of hearing difficulty can vary greatly, which means that some of the respondents in this survey may not be a part of the Deaf America definition, skewing the results. The US Census' approach to counting disability in America is done through the American Community Survey (ACS), which provides more consistent estimates of the disabled population in America. However, it still fails to accurately count large groups of disabled people (Swenor & Landes, 2023), which will create a barrier to collecting accurate data. During the data collection process, I noticed that the states' estimates were far greater than the ACS estimates despite having a similar population count. For example, Indiana's estimate for deaf and hard-of-hearing people in the state was 542,842 (Indiana FSSA, 2020). The ACS estimate for people with hearing difficulty was 252,797 (US Census Bureau, 2021b). This disparity in the data between the US Census and the other datasets is noticeable, indicating that Swenor and Landes' (2023) explanation is true. However, despite the undercount of numbers, the US Census data will still be used in consideration of its accessible nature and the project's time constraints to collect everything. The straightforward point here is that this project is considered a starting point for this type of work in deaf studies - aka proof of concept/a big picture. Hopefully, this project will encourage researchers to collect more compatible, accurate, and accessible data.

To reach the goal of having a suitable data repository, there is a need for a standard definition of deafness for survey and research purposes. Too many surveys cannot corroborate each other due to their differences, creating additional headaches for the researchers and the deaf community in understanding the statistics of their people. This shows a much larger issue at play here. The surveys (i.e., NHANES, SIPP, NHIS) do not measure deafness and Deaf America as a cultural or social statistical category. It also does not measure an important aspect of the Deaf-World -- the people who are “functionally deaf,” meaning they do not use any hearing to communicate (i.e., signing) (Tate & Adams, 2006, p. 30-31), so not including these leaves out a critical area of study and data collection.

There is also a lack of initiative in collecting data related to the demographics of deafness, or what I have termed Deaf America. With the issues already discussed in defining deafness, a common suggestion would be to create a singular national survey that measures deafness and base the demographics on that. That is not possible, as WICHE explains, "creating a national survey that incorporates all definitions to meet everyone's epidemiological needs would likely be cost-prohibitive and unwieldy. As such, the statistics on deafness in America currently need to be painstakingly pieced together to create a tentative picture." (Tate & Adams, 2006, p. 11). WICHE attempted to visualize and organize the data with deafness in 2006 but focused only on the WICHE states, and the attached table is below for observation.

WICHE States	Total Population 2004 U.S. Census	Deaf & Hard of Hearing	Deaf	Hard of Hearing
	100%	**8.6%**	**0.9%**	**7.7%**
United States	293,655,404	25,254,364	2,642,898	22,611,466
WICHE States				
Alaska	655,435	56,367	5,899	50,469
Arizona	5,743,834	493,969	51,695	442,274
California	35,893,799	3,086,866	323,044	2,763,822
Colorado	4,601,403	391,359	40,956	350,403
Hawaii	1,262,840	108,604	11,366	97,238
Idaho	1,393,262	119,821	12,539	107,282
Montana	926,865	79,710	8,342	71,368
Nevada	2,334,771	200,790	42,026	158,764
New Mexico	1,903,289	163,683	17,130	146,553
North Dakota	634,366	54,555	5,709	48,846
Oregon	3,594,586	309,134	32,351	276,783
South Dakota	770,883	66,296	6,938	59,358
Utah	2,389,039	205,457	21,501	183,956
Washington	6,203,788	533,526	55,834	477,692
Wyoming	506,529	43,561	4,559	39,002
Total WICHE States	**68,814,689**	**5,913,698**	**639,889**	**5,273,810**

Figure 3

Tate & Adams say that "it is important to note that while these numbers are based on the best information available and can be stated with some confidence, they are still rough estimates based on debatable definitions of deafness as discussed… Individual states will need to take the initiative to reliably determine the numbers of deaf individuals within their borders" (2006, p. 14). Thus, the data in the table above is not 100% accurate because of the lack of a standard definition.

In one of the best available visualized demographics of the statistical number of deaf people in America (Holt, Hotto & Cole, 1994) (Tate & Adams, 2006, p. 13), it was also pointed out that there is a need to have a standard definition of the cultural aspect, too, for visualization purposes. That is where the Deaf America term comes in. The visualizations, which are the GRI publications of Holt, Hotto, and Cole in 1994, used the NHIS (National Health Interview Survey) results to create the table/visualization below.

Age Group	Population	Number of Hearing Impaired	Percent of Population	Percent Urban	Percent Rural
TOTAL	235,688,000	20,295,000	8.6%	7.9%	11.1%
3-17 years	53,327,000	968,000	1.8%	1.8%	2.0%
18-34 years	67,414,000	2,309,000	3.4%	4.2%	5.5%*
35-44 years	38,019,000	2,380,000	6.3%		
45-54 years	25,668,000	2,634,000	10.3%	11.8%	15.4%*
55-64 years	21,217,000	3,275,000	15.4%		
65 years & older	30,043,000	8,729,000	29.1%	27.4%	33.7%

* In computing rural population estimates, the age groups 18-44 years and 45-64 years were not broken down.

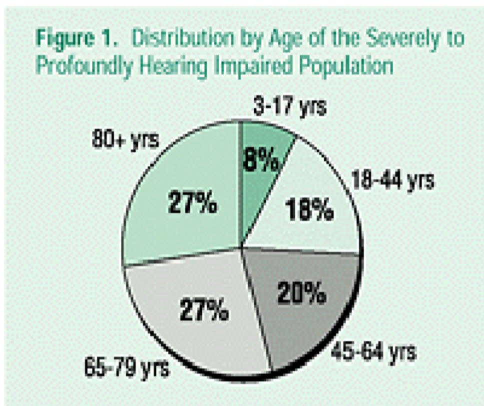


Figure 1. Distribution by Age of the Severely to Profoundly Hearing Impaired Population

Figure 4

There are immense benefits from having visualizations with the already known/collected data, as the data will allow for more informed decision-making for various situations, such as deciding how to spread out support for deaf people in different locations or figuring out where to add a new institution and many more. However, there is so much data with different definitions and/or relying on outdated data, as explained in the abstract of *How Many People Use ASL in the United States?*. The authors point out that “all data-based estimates of the number of people who use ASL in the United States have their origin in a single study published in the early 1970s… There has been neither subsequent research to update these estimates of the prevalence of signing nor any specific study of ASL use” (Mitchell et al., 2006).

No other studies have been done at this level since at least 2003, and the technology has transformed in the last 20 years. This indicates a need to create updated visualizations to show the demographics and the network of deafness in America. With some research, there are already national surveys, some data, and even a couple of maps on deafness. However, the data is inaccurate or cannot be combined to create a larger picture due to different definitions of deafness or data inaccuracy. There is no visualization on the general American deaf network. Another issue is the availability of accurate data; many are considered "old," which shows a lack of initiative in collecting and combining data related to the numbers and demographics of the American deaf network. For example, there is no living document exclusively for Deaf America to show the variances of deaf people and the various social institutions that make up Deaf America. However, there are two maps available through ArcGIS: the PLACES: Hearing disability and ACS Disability by Type Variables - Boundaries maps. The PLACES map is based on the crude prevalence of hearing disability (%), and the ACS map is a compilation of various disabilities in one map, but each disability is shown in a map pop-up. It is nice that there are some maps out there, but these maps do not satisfy the needs of this project at all. There is not a singular map easily accessible to the deaf community, and it does not allow for more "factors" to be added to give a bigger picture of Deaf America. Therefore, the goal of this project is to, again, provide a map that is easily accessible to everyone and focuses on Deaf America and its aspects only.

As society and technology advance, people in Deaf Studies have been calling for innovation in research and approaches due to the changes the field has accumulated from its birth in the 1970s to the present. The editors of the book *Innovations in Deaf Studies* (2017) explain that the changes that the field has seen can be attributed to the "decline of deaf schools, normalization of cochlear implants, multiplication of pathways into deaf communities, increased virtual and transnational contact, diversification of intersectional backgrounds, and growing numbers of hearing people who learn/use sign language" (Kusters, Meulder, & O'Brien, pp. 3-4 & 39). The deaf way of being relies on visual representations in everyday life, so why should this project be any different? Geospatial Information Systems (GIS) relies on visuals to create and make maps work. This is a great combination for deaf people - it allows us to use our strength in our visual abilities to pick out patterns and discover things that would otherwise be overlooked in a regular table format.

This approach will also allow us to have a dynamic view of Deaf America that includes many aspects of deafness and deaf sociality that do not fall under the "general" umbrella. Turner (1994) proposed the idea that the view of deaf culture should be "anti-essentialist, fluid, dynamic, and processual," arguing that it should be a verb instead of "consolidating representations of dominant deaf groups" (Kusters, Meulder, & O'Brien, 2017, p. 8). This map will combine strategic essentialism (a tactic by marginalized groups to temporarily emphasize common identity traits for mobilization) and fluidity to create a dynamic view, including choosing specific layers to view and seeing various viewpoints of Deaf America. Researching and visualizing deaf people in the 21st century can become complex due to the multifaceted nature of it and technological advancements, and that is why this project needs to and will be fluid and dynamic, allowing for the recognition of the complexity of the deaf network.

To bring in new ideas and approaches, it is important to understand what the current datasets offer. During the data collection process, the inaccessibility of some data created a barrier. In the end product, some of the data will have NAs, which stands for not available in R. NA is a null value, meaning there is no data or information for this data point. Essentially, NA means nothing to show for, meaning no information was found or calculated. That can be attributed to inaccessible data, the age of the data, and/or a lack of initiative for consistent data collection. Another contributing factor is the unwillingness of organizations to share current data publicly. I (the author) contacted a major organization for the deaf in America and requested membership numbers for the various deaf associations in America. The organization responded by saying they do not share their database, rendering this potential dataset unavailable. Personally identifiable information should stay anonymous, which the organization has the right to keep private. However, non-identifying data should be made available for the public to utilize. Hans Rosling, a Swedish physician and statistician, emphasized the importance of having accessible data so the general public can put them together, play around with them, and, most importantly, **understand** the world around them. Hans, in 2006, said:

> But I think it's very important to have all this information. We need really to see it… And the thing would be to get up the databases free, to get them searchable, and with a second click, to get them into the graphic formats, where you can instantly understand them… Everyone says, “It's impossible. This can't be done. Our information is so peculiar in detail, so that cannot be searched as others can be searched. We cannot give the data free to the students, free to the entrepreneurs of the world.” But this is what we would like to see, isn't it? (Rosling, 2006).

Most of the data in our extremely data-driven society is hard to understand, and if they are put behind walls, that takes away opportunities for people to analyze the said data, understand what is going on themselves, and eventually share that understanding with others. One of the key goals of this project is to allow everyone – regardless of their walk of life -- to understand what resources are available and how many deaf people are around them. Having data hidden away is not the answer to this issue, and I implore deaf organizations nationwide to reconsider their stances on the privatization of databases. The United States Census data is a great example of publicly available data, but it may be hard for the average person to understand. That is where this map comes in – transforming said data into a visual representation, which is a great way for people to connect the data with their understanding of the world and, hopefully, allow them to come to their own conclusions.

Accessing the Maps

To access the maps, click on the hyperlinks provided below. These hyperlinks will direct you to the ArcGIS website, which is a comprehensive platform for various maps and related features.

Nationwide Map Link

Maryland Map Link

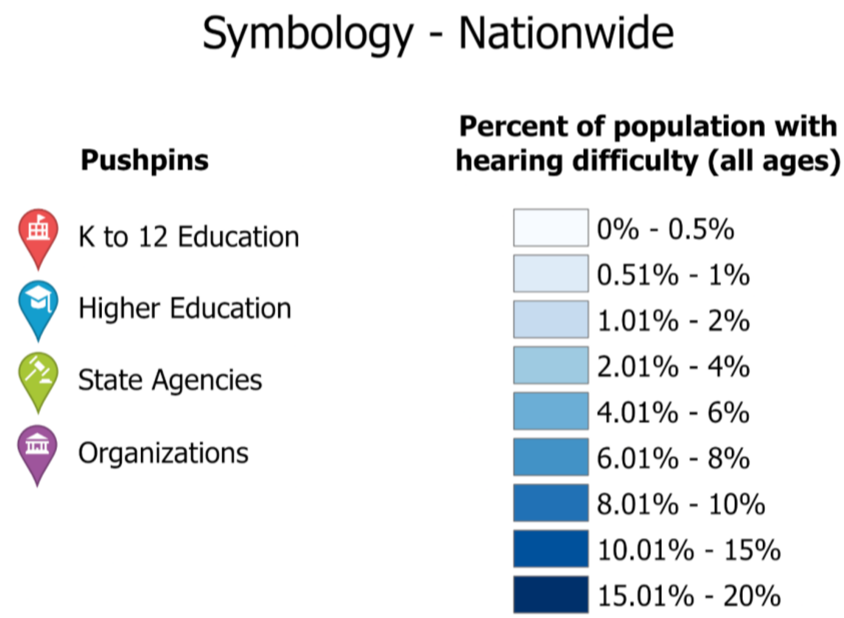
StoryMap Link

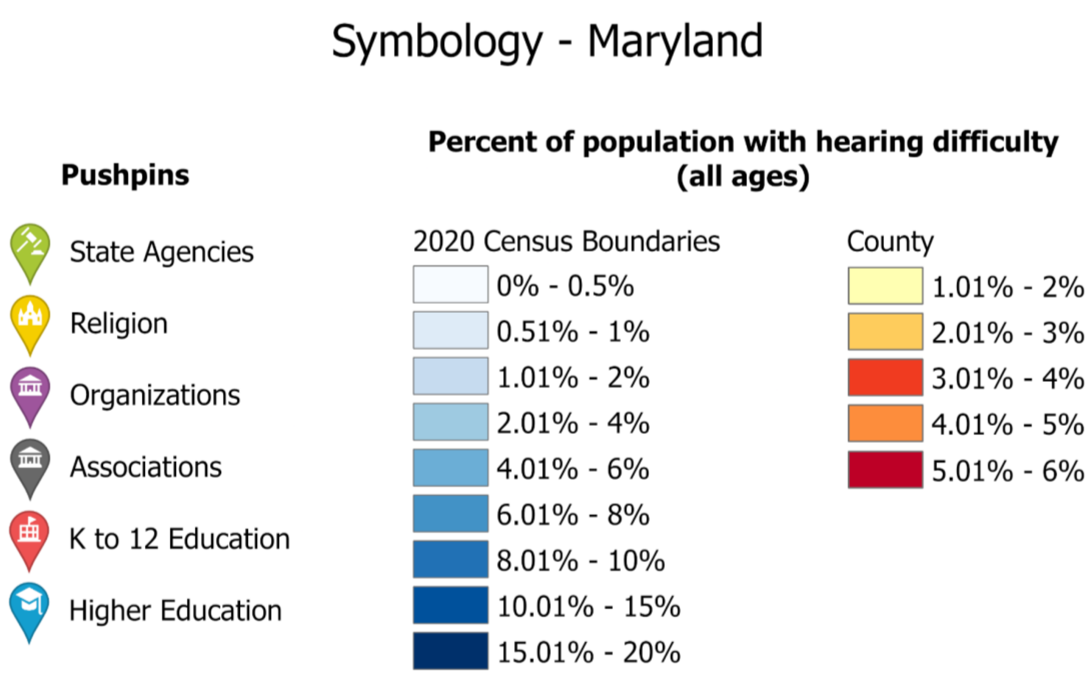
Further instructions on interacting with the map will be provided in the introduction pop-up on the maps' web pages. However, you can navigate the map like Google Maps. Scroll in/out to navigate the map, and click the objects on the map to view their information. There are buttons on the sides of the map to assist in viewing the map (bookmarks, legend, etc.). For the reader's convenience, the legends/symbols of the data on the maps will be shown below, as these will be discussed in the following sections. These legends and symbols will also be accessible on the maps.

It is important to note that the scaling of the legend does not follow one approved method (i.e., linear, exponential, etc.) due to the limitations of the appearance and aesthetics of the map.

ArcGIS allows up to nine color classes (or “steps”) to be shown on the map. More color classes can be added, but it becomes increasingly difficult to differentiate between each step. As this project is also geared towards the general public, I am sticking with nine steps for ease of use. In order to accommodate the extensive range of percentages involved in the data, I am using a combination of linear and exponential increases for the scaling. Intervals of 0.5%, 1%, 2%, and 5% are used in the scales, creating a mixture of linear and exponential increases to allow for the fullest representation of the data.

Map Legends


Symbology - Nationwide
Pushpins
K to 12 Education
Higher Education
State Agencies
Organizations
Percent of population with hearing difficulty (all ages)
0% - 0.5%
0.51% - 1%
1.01% - 2%
2.01% - 4%
4.01% - 6%
6.01% - 8%
8.01% - 10%
10.01% - 15%
15.01% - 20%


Symbology - Maryland
Pushpins
State Agencies
Religion
Organizations
Associations
K to 12 Education
Higher Education
Percent of population with hearing difficulty (all ages)
2020 Census Boundaries
0% - 0.5%
0.51% - 1%
1.01% - 2%
2.01% - 4%
4.01% - 6%
6.01% - 8%
8.01% - 10%
10.01% - 15%
15.01% - 20%
County
1.01% - 2%
2.01% - 3%
3.01% - 4%
4.01% - 5%
5.01% - 6%

Results and Discussion

The maps offer valuable information regarding understanding where the people and institutions are located in Deaf America. Looking at the Deaf Academic and Deaf Political America maps, most institutions are located near a reasonable distance from major cities and hubs, as seen in Figure 5.

Figure 5

However, there is a pattern of having deaf schools located pretty far from these hubs, except for what is considered the “Big Six,” a group of deaf schools that usually have large enrollment numbers and are conveniently located near cities. This group includes these schools: California School for the Deaf - Fremont, California School for the Deaf - Riverside, Indiana School for the Deaf, Maryland School for the Deaf, Model Secondary School for the Deaf, and Texas School for the Deaf. The nationwide map will reveal the benefit of location to these said schools. These schools are close to major cities, including some critical institutions that serve the deaf community there. California School for the Deaf - Riverside is a great example of that.

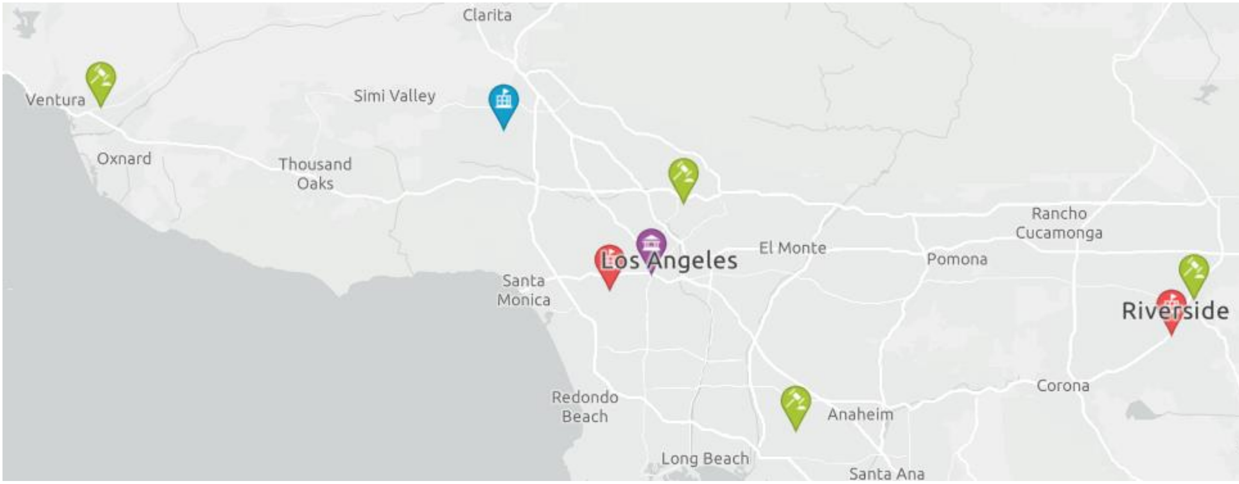


Figure 6

California School for the Deaf - Riverside (CSDR) is an hour from downtown Los Angeles by car. Within an hour's drive westward, the CSDR community can access seven different institutions (shown in Figure 6) that range from state agencies serving the deaf to another K-12 school and a university that has a deaf program. CSDR has an enrollment of almost 300 students, which is pretty significant compared to other smaller deaf schools. Let us take a look at the Midwest region of America, which is shown in Figure 7.

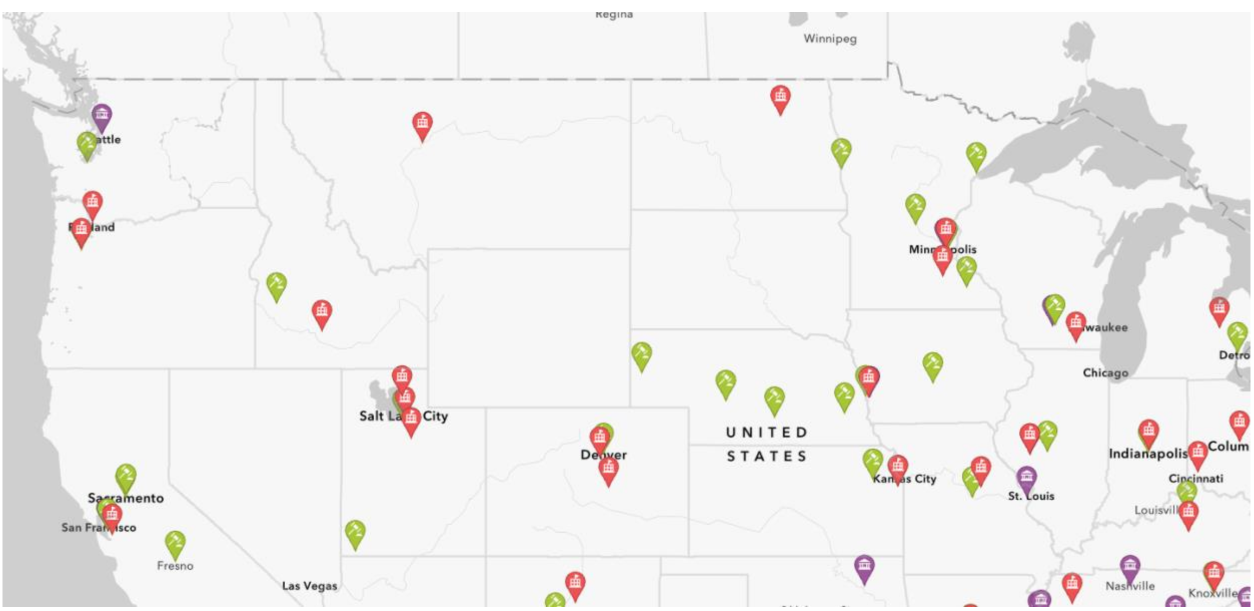


Figure 7

It is interesting to note that the region that includes the Dakotas, Montana, and Wyoming has practically zero resources other than the school for the deaf, according to the National Association of the Deaf's State Agencies of the Deaf and Hard of Hearing resource list. Upon further research, Montana does have a Deaf and Hard of Hearing Services (MDHHS) office in Great Falls, but it is not listed in NAD's directory. This, again, is an issue of incentive to collect up-to-date information on resources or the privatization of resource locations and data from deaf people. Wyoming does not have a deaf school that is operating, as their school for Deaf shuttered its doors in 2000 due to declining enrollment (Alliance For Historic Wyoming, 2015). Similarly, South Dakota's school for Deaf shuttered its main campus doors and redelegated the students to neighboring school districts due to low enrollment (The Daily Moth, 2019), leaving the state without an official school for Deaf.

North Dakota, fortunately, has a school for the Deaf in Devils Lake.

Figure 8

However, in my hypothesis, its location greatly contributes to its struggle to maintain a good enrollment rate, with approximately 20 students from K-12. As seen in Figure 8 above, the closest state agency serving the deaf community in North Dakota is almost three hours away by car in Fargo. It would be recommended that the school relocate to Fargo, as it is a far larger city than Devils Lake. However, one of North Dakota School for the Deaf's (NDSD) statutory/constitutional responsibilities is to "**25-07-01. School for the Deaf – Maintained – Location – Purpose.** There must be maintained at Devils Lake, in Ramsey County, a school for the deaf, which may provide education and training and serve as a resource and referral center for individuals who are deaf or hearing-impaired" (Sorensen & Frelich, 2023, p. 8). There is legislation that requires the school to be in Devils Lake, a very rural area, which creates barriers to higher enrollment numbers, alongside various laws (IDEA, etc.) that redirect students to mainstream schools. With that being said, the bar chart in Figure 9 will show the differences of enrollments in the K-12 institutions across the country.

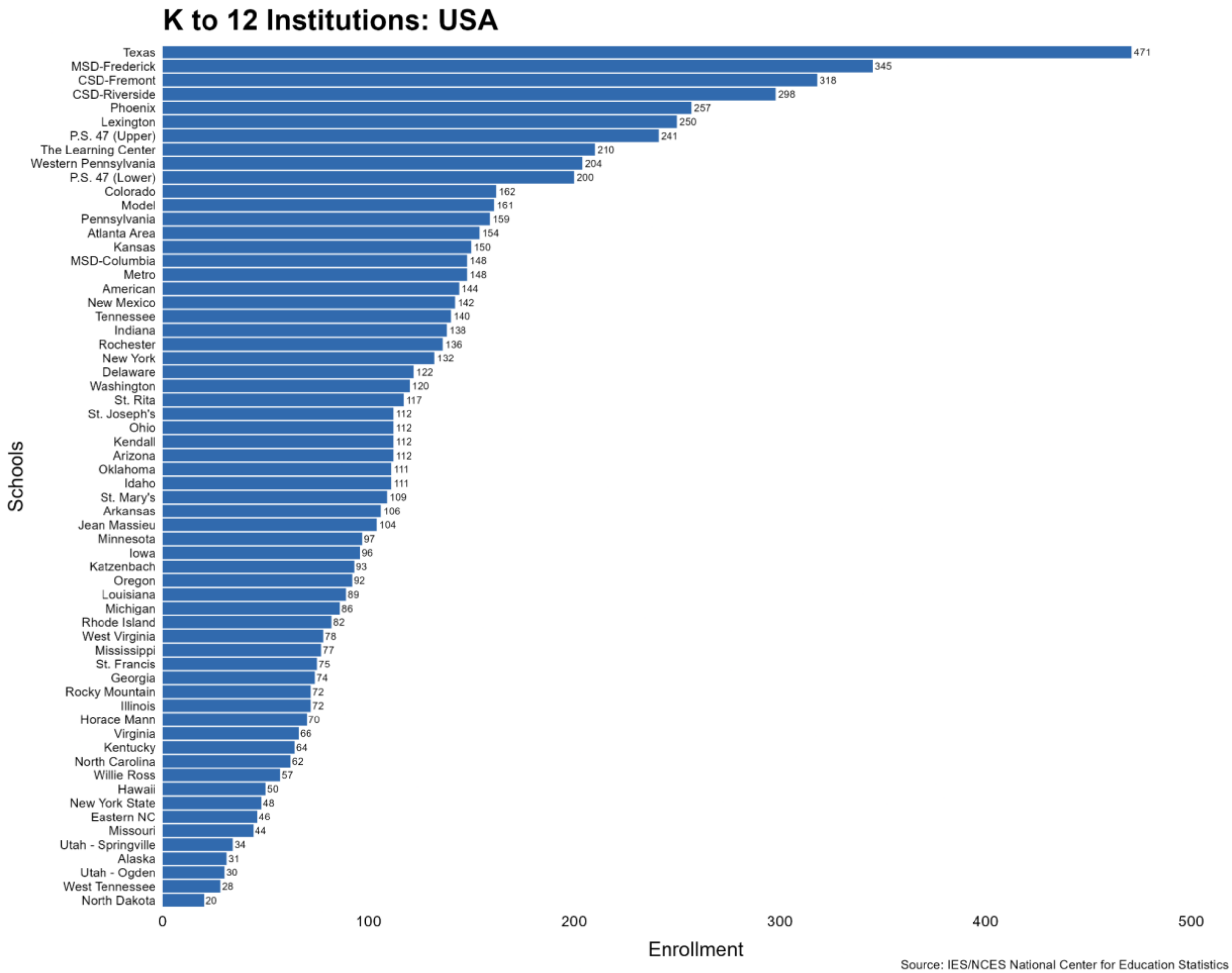


Figure 9

This shows the different enrollment numbers of students at each school in the United States. 9 schools are omitted as they have no data for their enrollment numbers. (Wisconsin, South Carolina, Montana, Marlton, Gov. Baxter, Florida, Bruce Street, Florida, Beverly, and Alabama).

Therefore, it is essential to have resources like this map to point out patterns and help us understand where the resources and institutions are for Deaf America. Having a visual image of where things/places are spatially located allows for innovation in ideas that may help the states in need, such as those mentioned above (WY, MT, ND, SD). Utilizing an overlay layer of statistics on the number of people with hearing difficulties creates a clearer picture of which states have the densest population and if the resources there are sufficient. The following figures (10 to 14) will show the percentage of people with hearing difficulties in the US mainland. To view Alaska and Hawaii, please visit the maps via the links in the **Accessing the Maps** subsection.

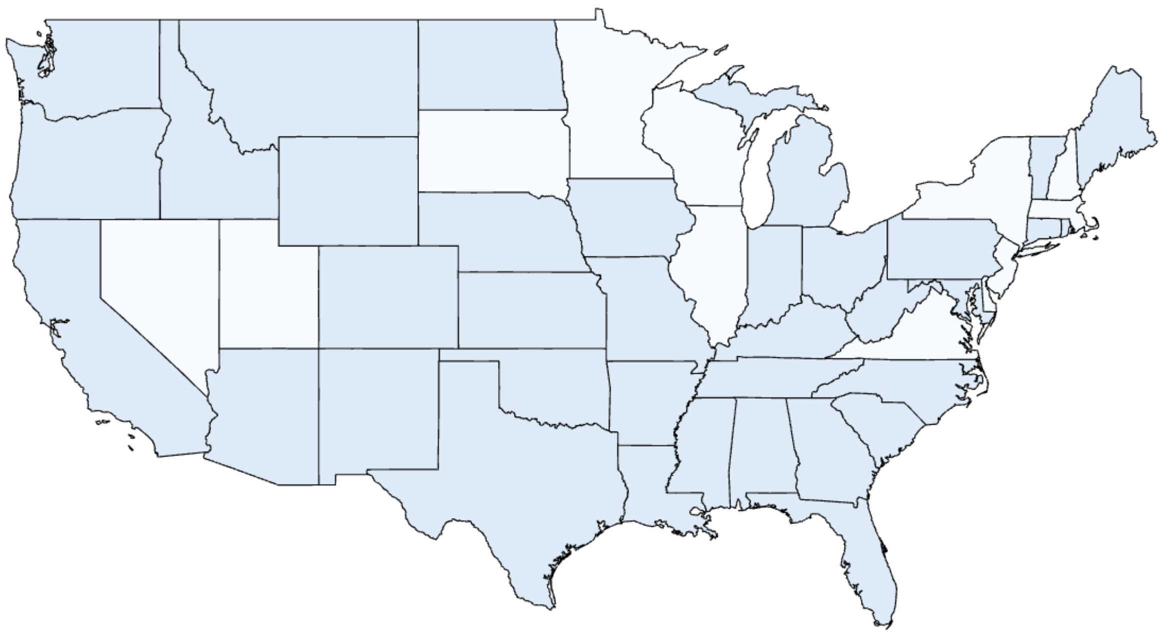


Figure 10: Percent of Population with Hearing Difficulties Ages 0-17

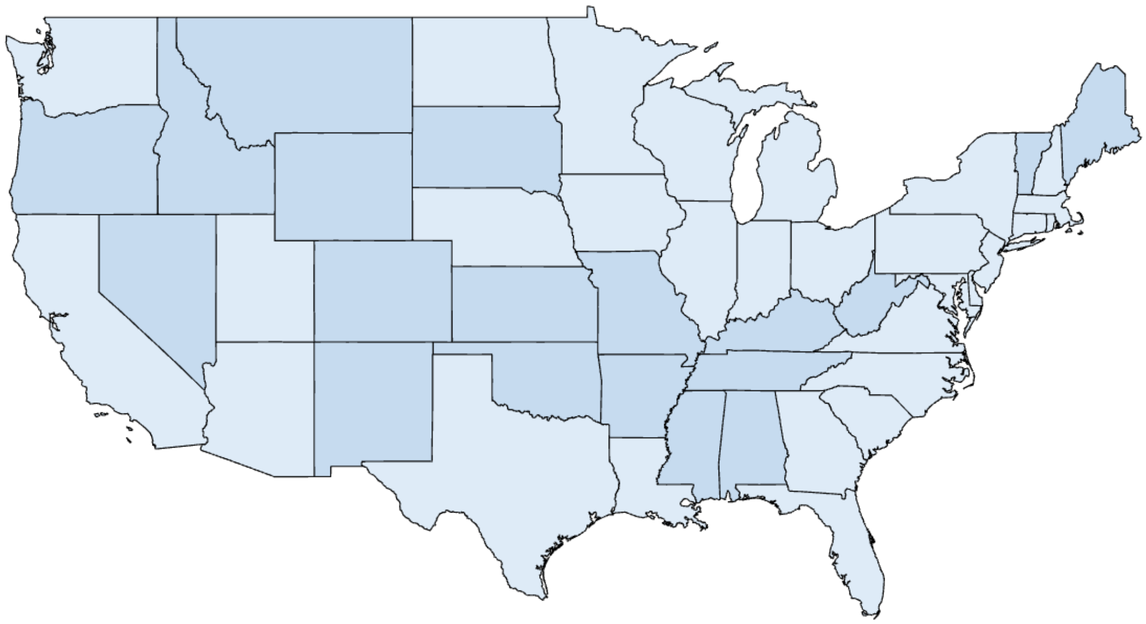


Figure 11: Percent of Population with Hearing Difficulties Ages 18-34

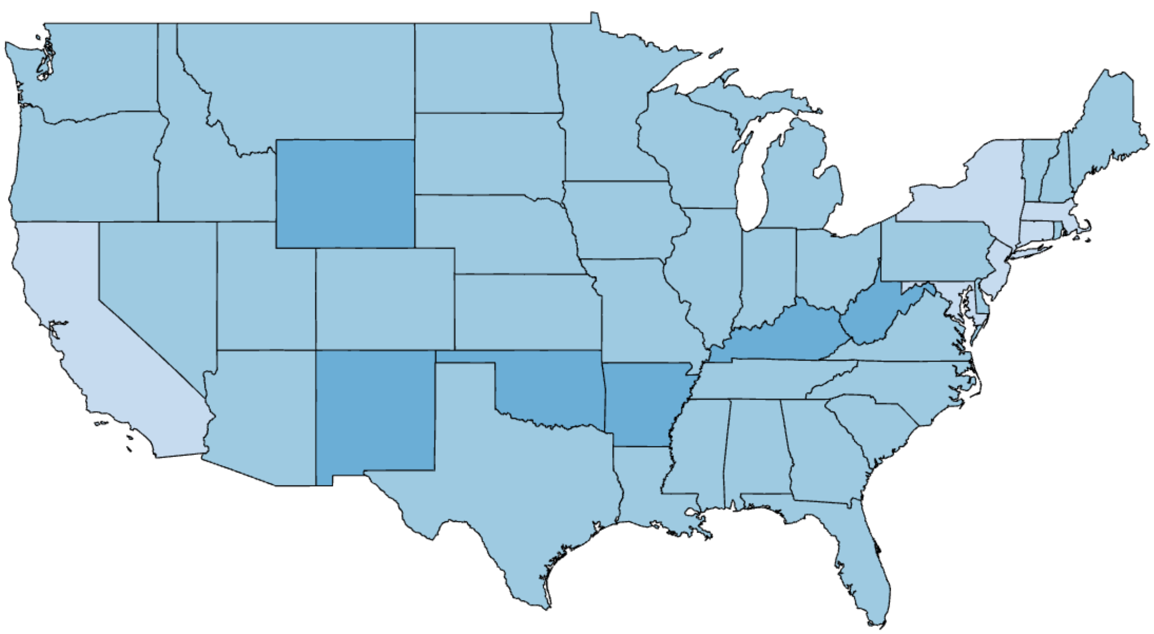


Figure 12: Percent of Population with Hearing Difficulties Ages 35-64

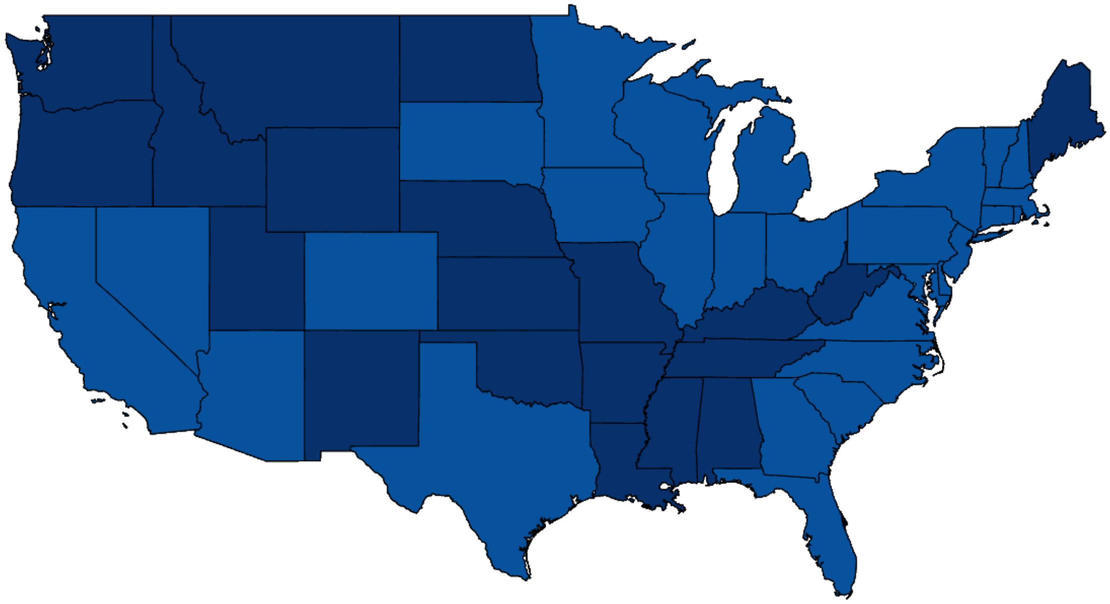


Figure 13: Percent of Population with Hearing Difficulties Ages 65 and Over

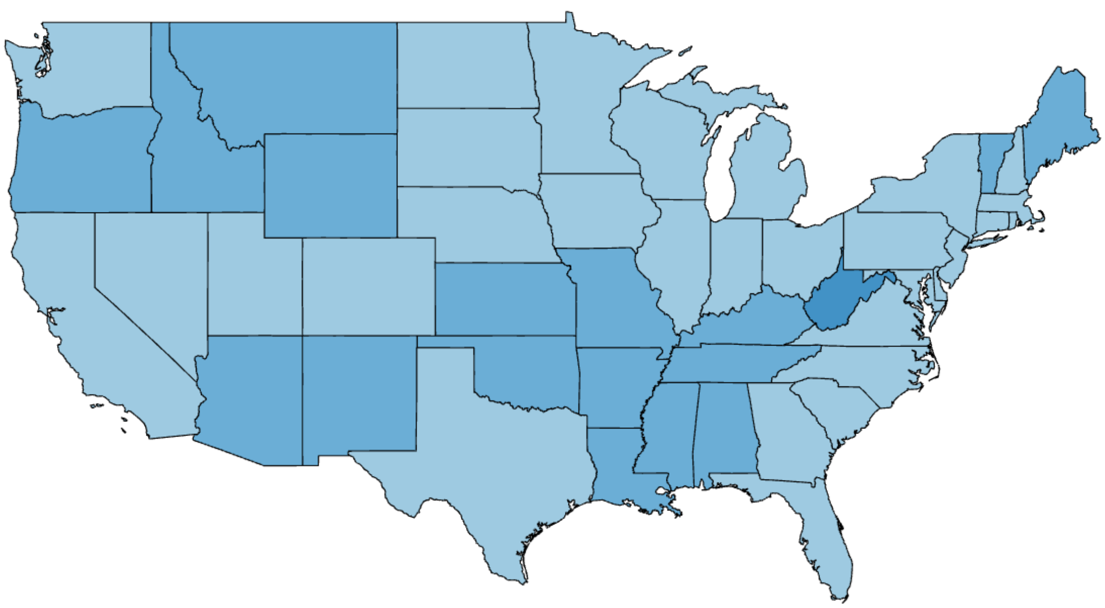


Figure 14: Percent of Population with Hearing Difficulties All Ages

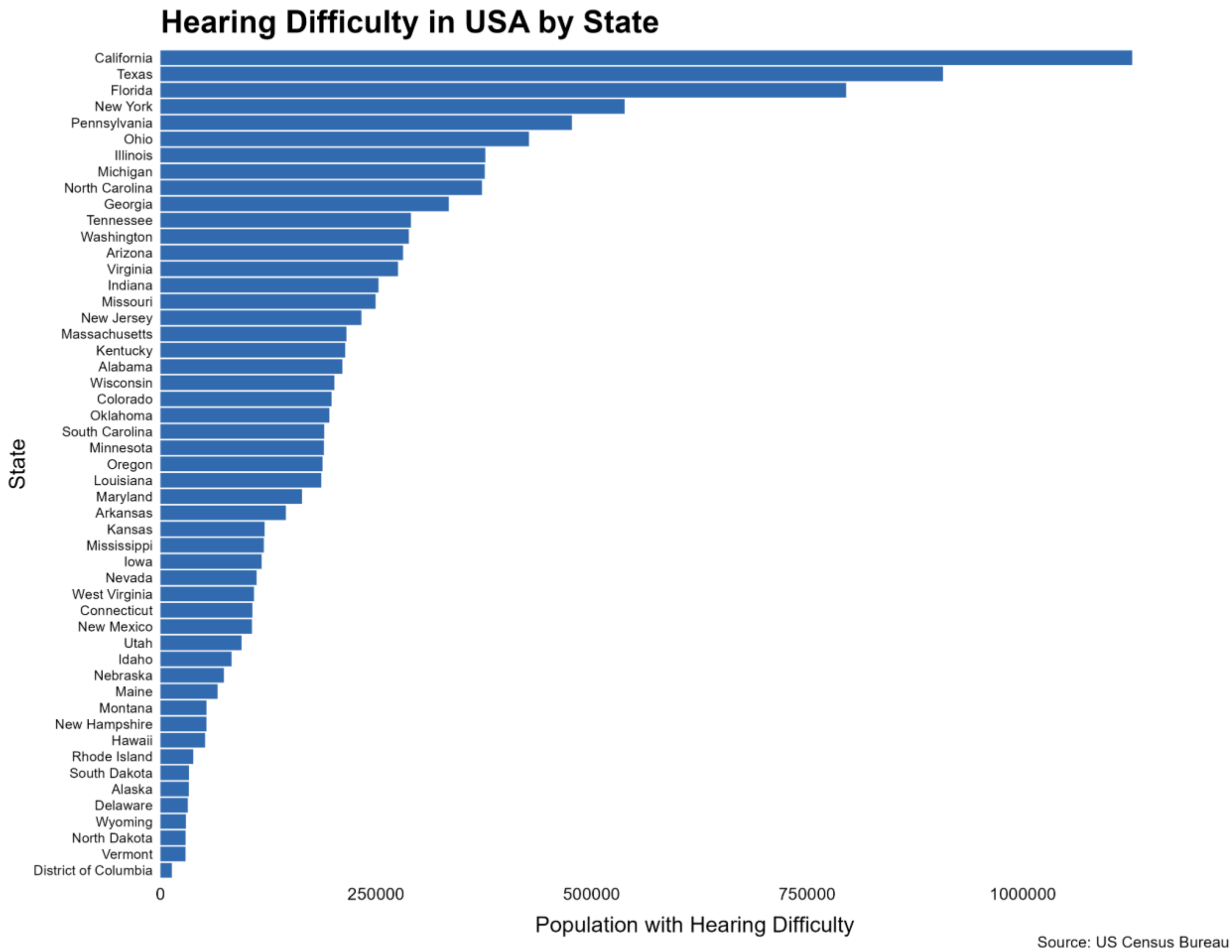


Figure 15: Bar Chart of Percent of Population with Hearing Difficulties All Ages

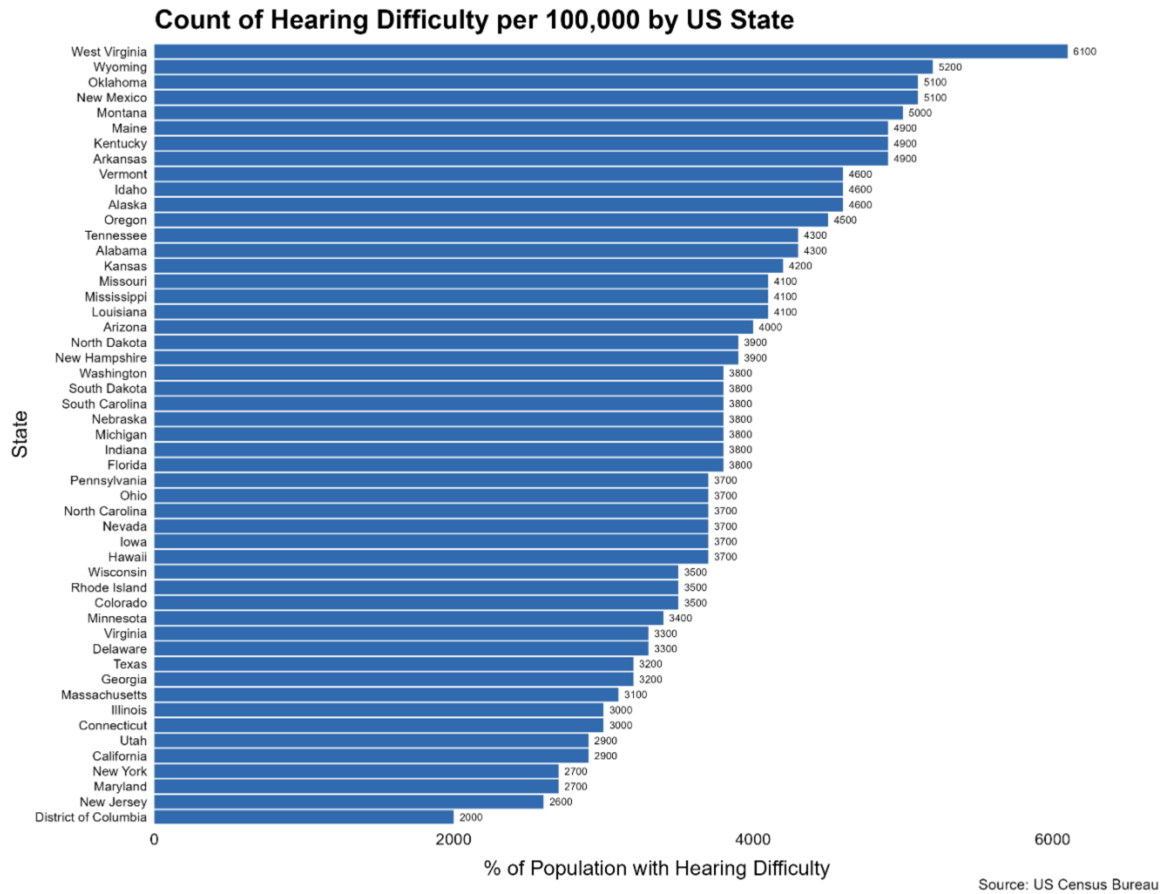


Figure 16: Bar Chart of Count of Population with Hearing Difficulties per 100,000 – All Ages

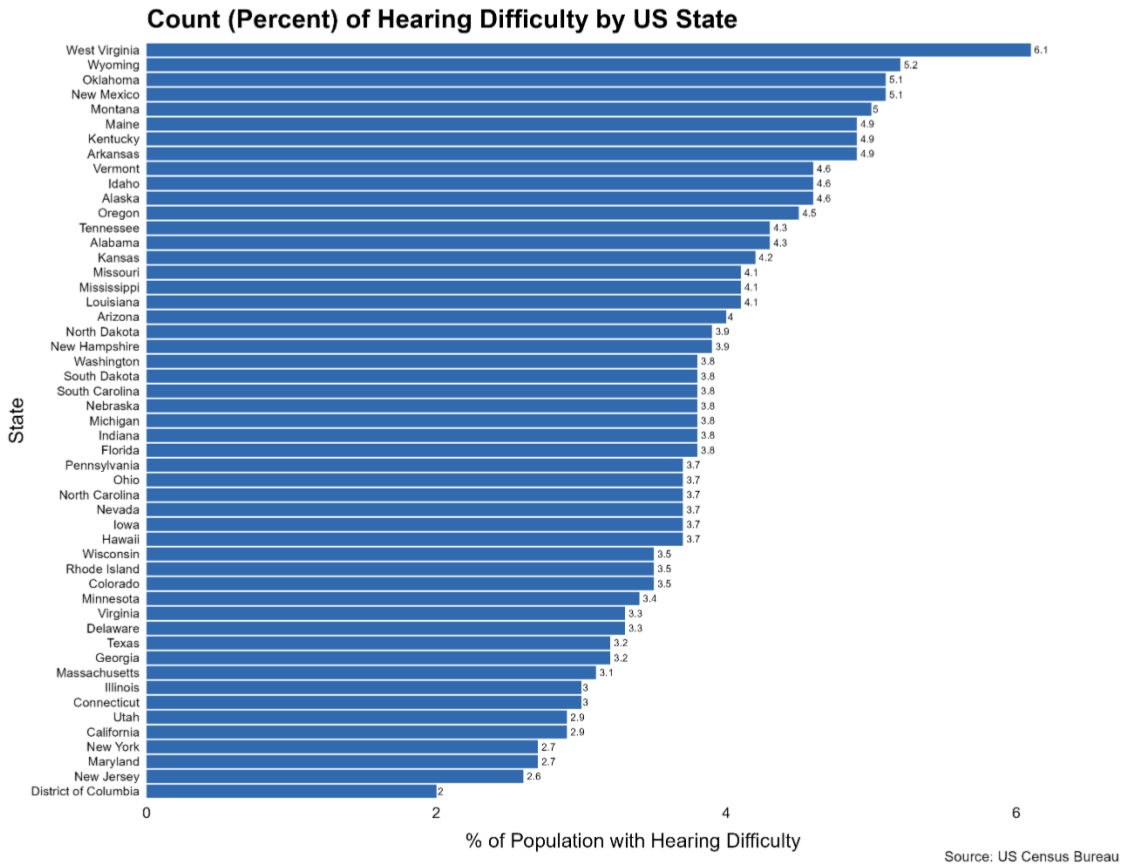


Figure 17: Bar Chart of Count (Percent) of Population with Hearing Difficulties All Ages

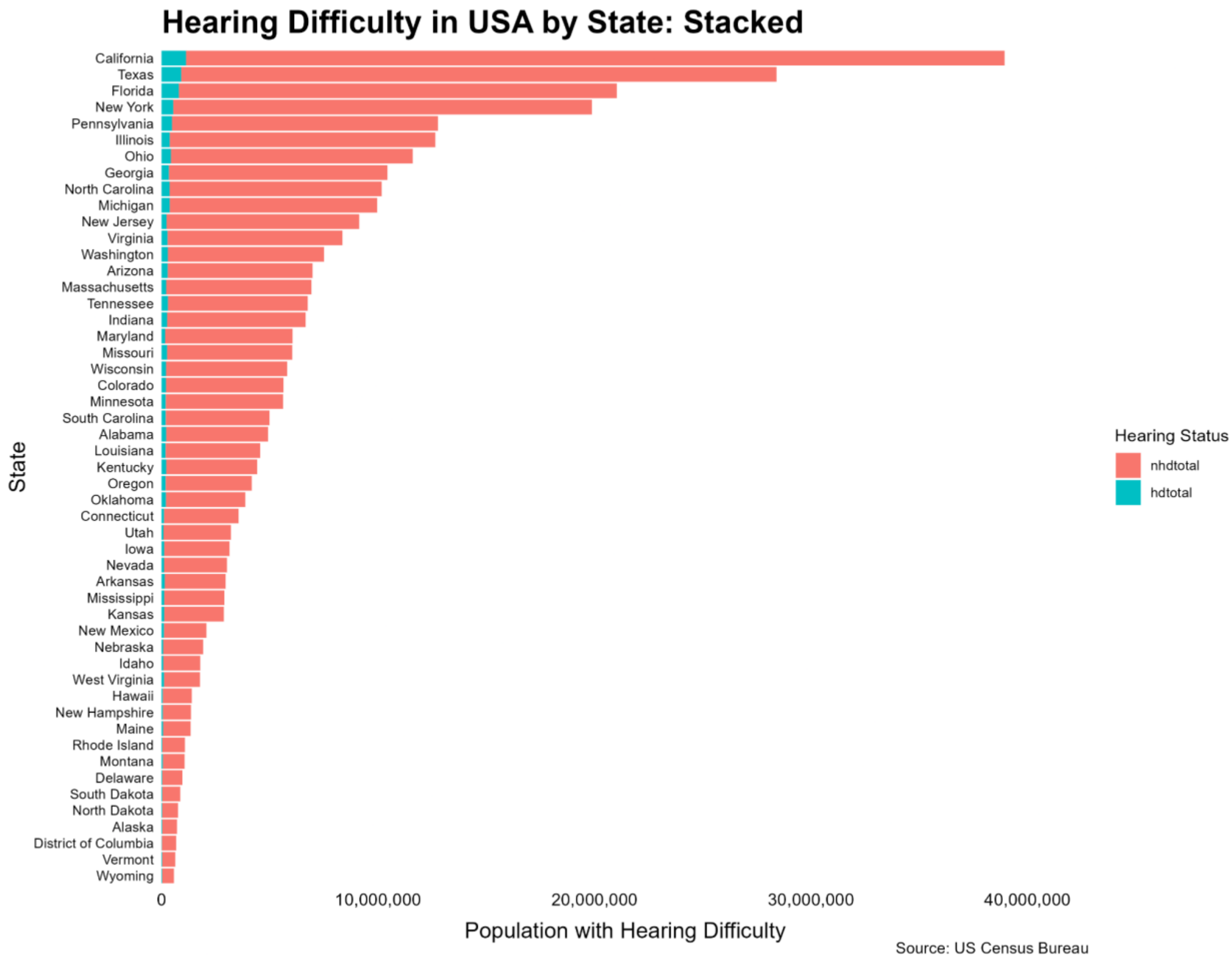


Figure 18: Comparisons of States' Populations with Hearing Difficulty/No Hearing Difficulty

The patterns noticed throughout Figures 10 to 14 show a typical pattern of having a higher incidence of hearing difficulties in the older population. This matches the idea that older people lose their hearing as they age. However, looking at the all-ages map (or the bar charts in Figures 15, 16, 17, and 18), one state stands out with the densest population of people with hearing difficulties – West Virginia. 6.11% of the population there has hearing difficulty. This is interesting, as it would be assumed that states like California (2.9%) and Texas (3.2%) would have a higher percentage. This is where the population dependence phenomenon occurs again – large populations tend to lead to a higher incidence rate, but it does not necessarily mean the density is larger. California was #1 in Figure 15, with about 188,000 people with hearing difficulties, but it dropped to #47 in Figures 16 and 17 (2,900 per 100k or 2.9%), proving the population dependence phenomenon true. A significant factor to the 6.11% having hearing difficulties can be attributed to West Virginia having the worst healthcare in the nation (WV Department of Health, 2018 & Kercheval, 2022), which leads to the people not having access to the right resources to treat their health. Therefore, the higher density of hearing difficulties in West Virginia makes sense. West Virginia only has two resources (a school for the deaf and a state agency) on opposite sides of the state (seen in Figure 19), which does not help either. This pattern can be seen in other states all over the country, with the higher-density states having fewer resources.

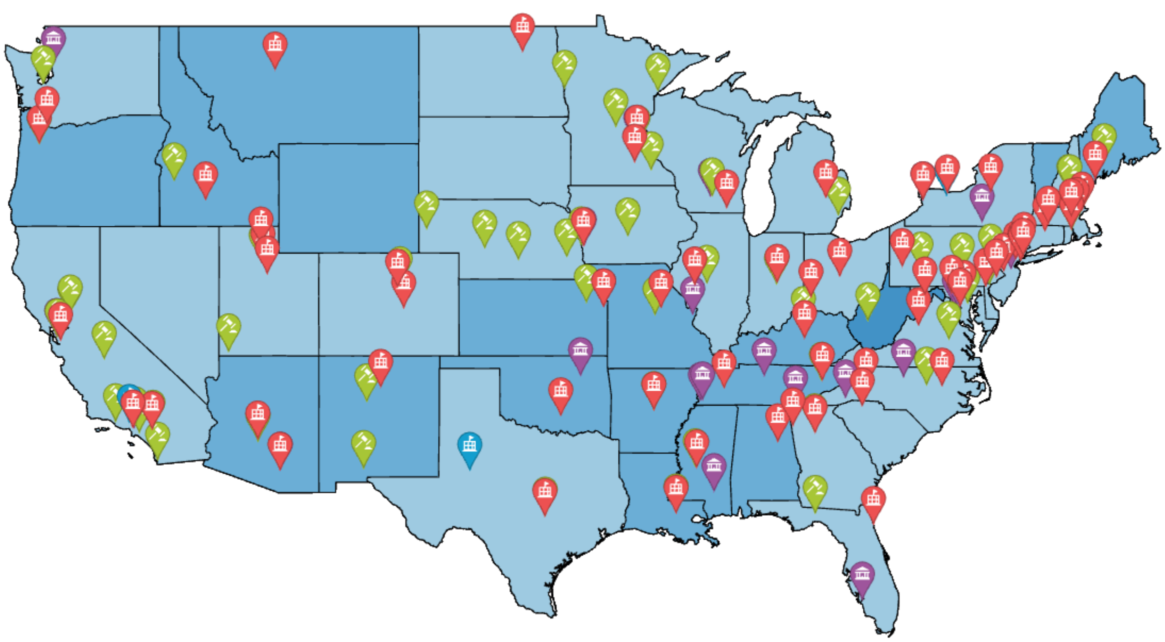


Figure 19: Percent of Population with Hearing Difficulties All Ages with Institutions

Even with its simplified data presentation, the nationwide map's immense benefits show how much it can offer the research field and the general public in terms of having a clear centralized data hub and visualizations, which will allow for quick reference and usage in everyday situations such as a person seeking out a resource near them, or research situations where a person is seeking out data that would help solidify a research project or paper that will support the deaf community. There is not one that exists today – which shows that there is a gap in having a centralized and visualized place for Deaf America and its data. In order to allow for an insight into how a more detailed map may work with the nationwide map, a snapshot of the state of Maryland was created. This map has the same institutions (albeit adding more, such as churches) but shows the data differently – at the county and census tract levels. The data on Maryland's hearing difficulty population can be seen in Figures 20, 21, and 22 below.

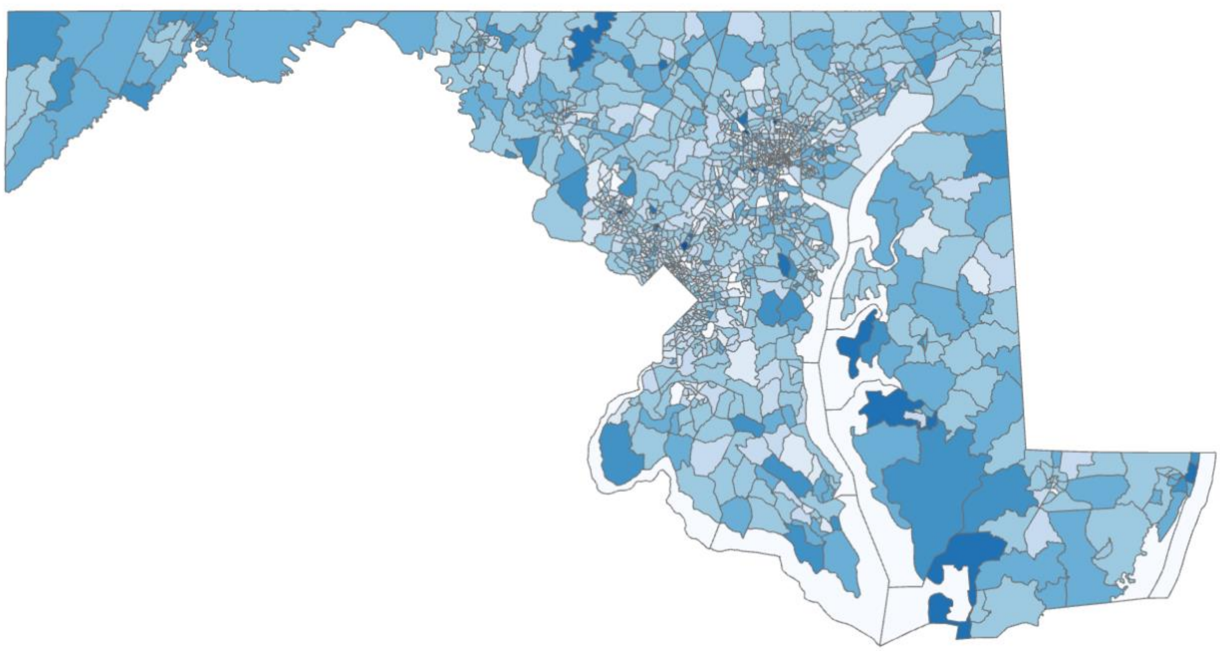


Figure 20: Percent of Population with Hearing Difficulties All Ages by Census Tract

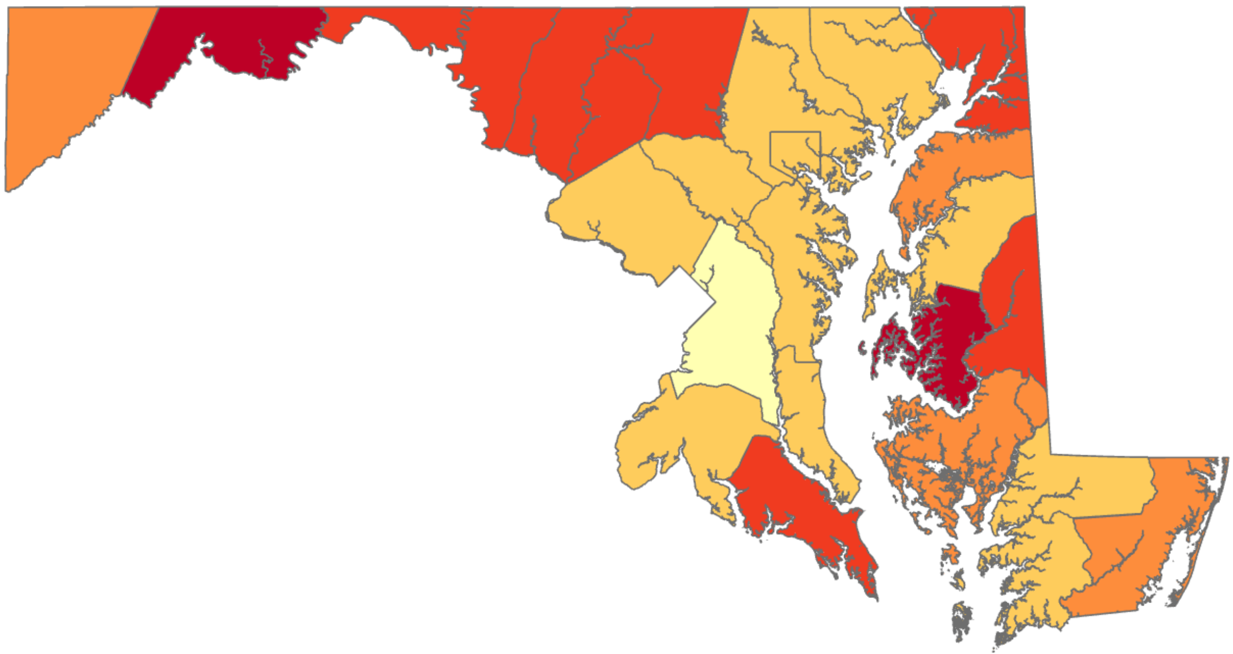


Figure 21: Percent of Population with Hearing Difficulties All Ages by County

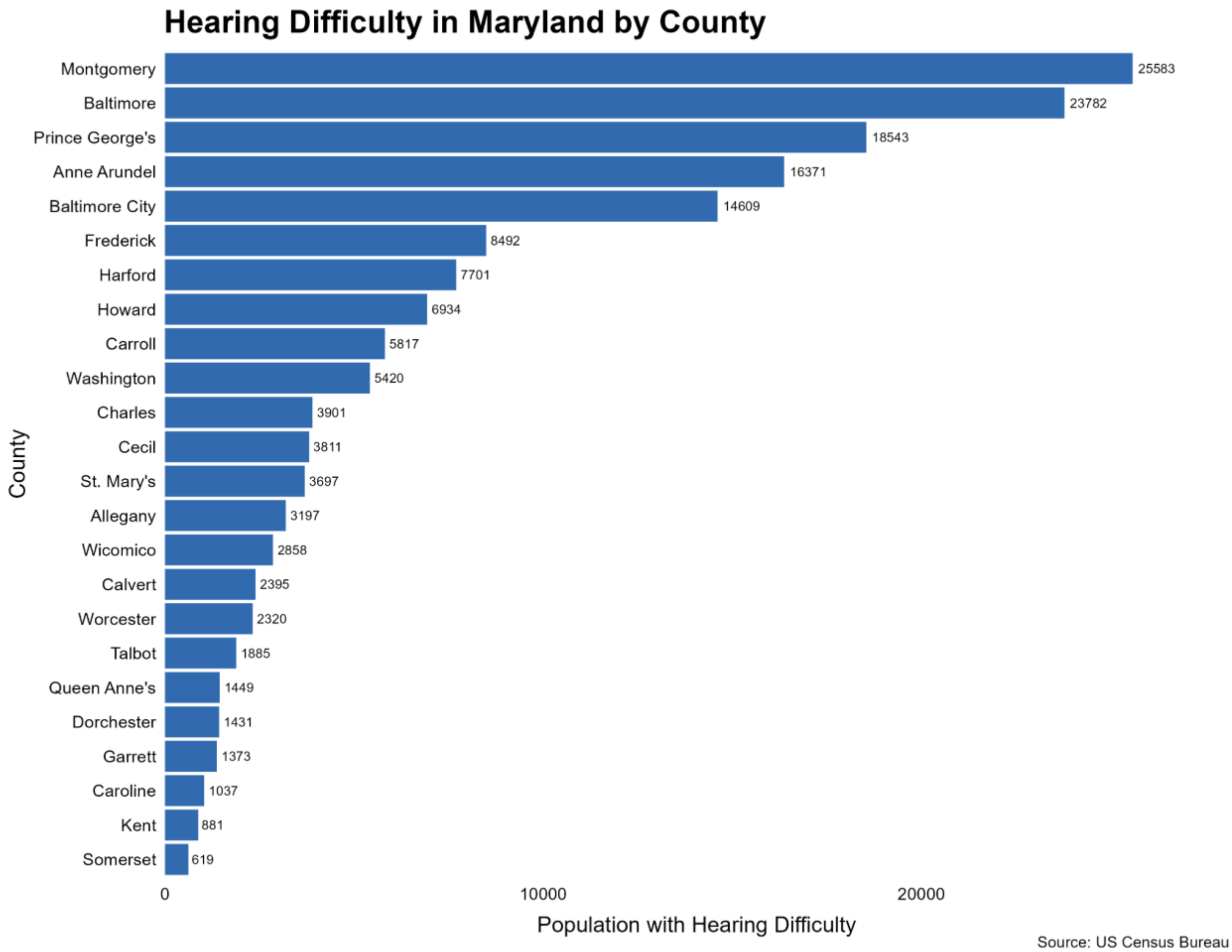


Figure 22: Bar Chart of Population with Hearing Difficulties All Ages by County

The Maryland map revealed that a higher percentage of people with hearing difficulties were in the more rural countries, away from the institutions. Most of the institutions serving the deaf community are clustered in the middle of the state, as seen in Figure 23.

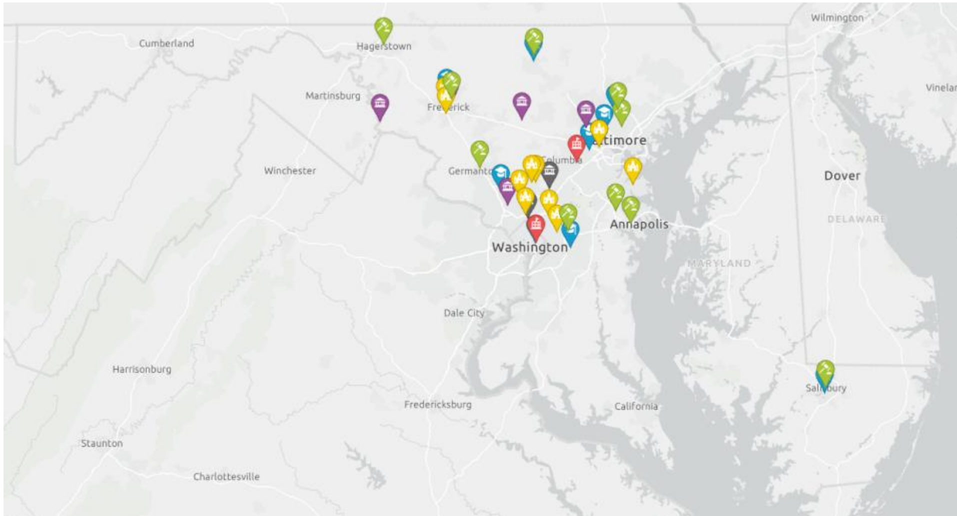


Figure 23

A more in-depth look at the percentage of people with hearing difficulties was done by creating a 10-mile buffer around the various institutions that serve the deaf community and clipping the census tract data within these 10-mile buffers, which can be seen in Figures 24 and 25.

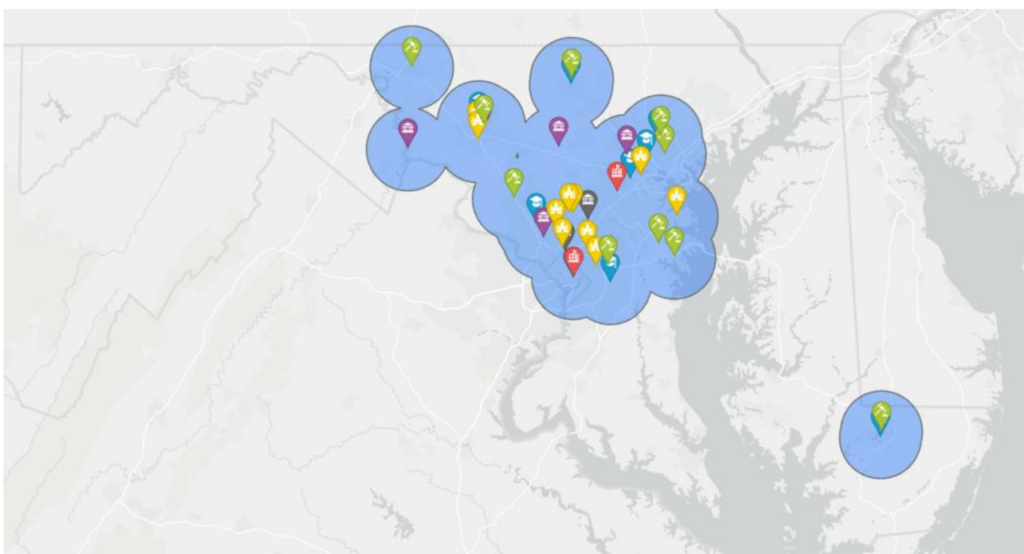


Figure 24

These maps show that the population within these buffers has the most benefit from these resources and services, as they are located within a 20 to 25-minute drive (approximately 2 minutes per mile) to these institutions. Could a lower incidence of hearing difficulties be due to the accessibility of resources? Looking back at Figures 20 and 21, the denser areas are in the rural areas, and they are the furthest away from the cluster of institutions in the middle of the state.

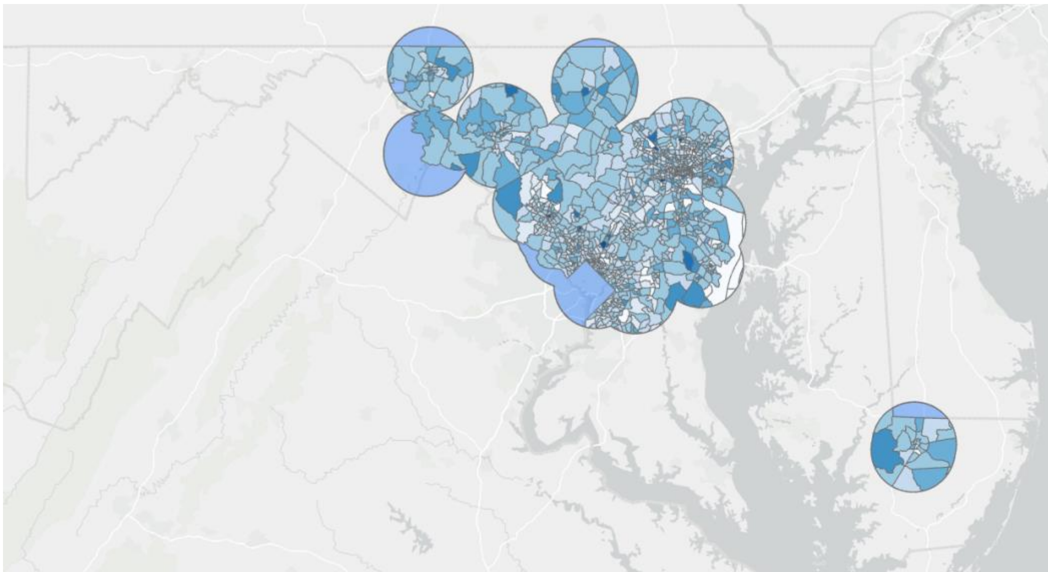


Figure 25

Additionally, in Figure 26, the enrollment numbers of the students at the four deaf schools in the area are shown to compare the numbers of students. This bar chart also includes the Clerc Center because it also enrolls a large number of students residing in Maryland. The colors of the bars themselves represent each school's color: orange for MSD (orange/black), red for MSSD (red/white/blue), and blue for KDES (blue/yellow). Both MSD campuses have significantly higher enrollment numbers than the Clerc Center, which makes sense. The counties in which both campuses are located (Frederick and Howard) have a higher incidence of hearing difficulties compared to Prince George's and Montgomery, where many Clerc Center students come from (keep in mind that MSSD also has students from other states). MSSD's enrollment is capped at around 160 or so students due to availability in the dorms, but it matches up with the high school enrollment of other schools in the nation.

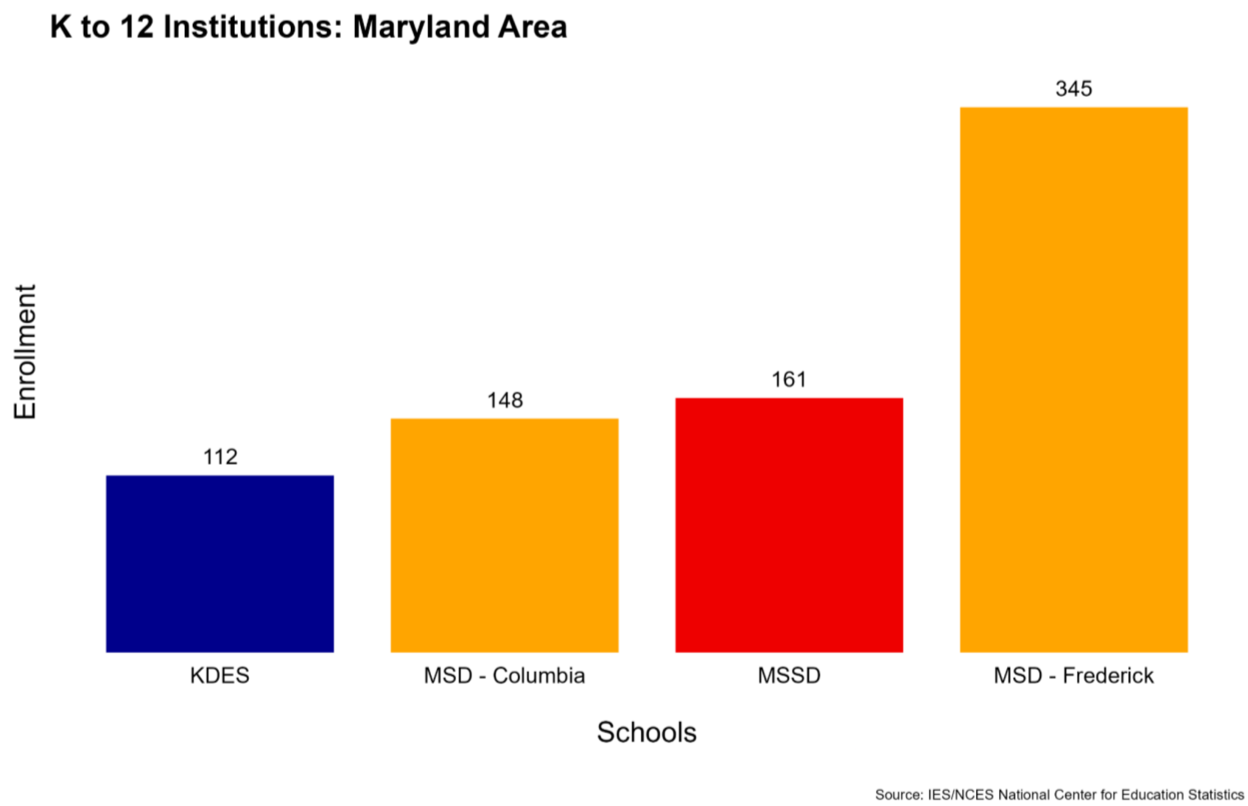


Figure 26

The nationwide and Maryland maps and the corresponding R visualizations show many insights into what makes up Deaf America and how its network is connected (or disconnected). The visualization of the data in ArcGIS allows us to analyze the spatial relationships between the institutions and the statistics of Deaf America. Once again, this project is "proof of concept," which means it is an innovation hoping to bring new insights and approaches to something. Both maps show the possibilities of having a full nationwide map that includes data from the state level, county level, and down to the census tract block areas, allowing us to see where the people are located and how the institutions serve the population around them. In the future, I hope to apply what is on the Maryland map to all fifty states, allowing for far greater insight into Deaf America for **everyone**.

Limitations of Study and Directions for Further Research

Based on the results section, it is clear that having a visual representation of Deaf America offers many insights and benefits. That being said, everyone must join together in sharing the information needed to create a more in-depth map that allows people of all backgrounds, such as researchers or parents of a deaf child looking for resources, to look at and take away something for themselves. Barriers faced in data collection for Deaf America must be taken down, and that begins with going back to the 1970s.

The Deaf Census of 1974, as presented in *The Deaf Population of the United States* by Jerome D. Schein and Marcus T. Delk, Jr., stands as a cornerstone in understanding the demographics of the deaf community. It was the first national study of the "numbers and characteristics" of deaf people in 40 years (Schein & Delk, 1974) at the time of publication in 1974. However, the age of this research raises concern. It does provide invaluable information and insights into data on deaf people in the 1970s. However, fifty-plus years have passed, and the necessity for a newer and updated version becomes clear. As societal structures, communication methods, and the landscape of deaf education evolve, a modern collection of the numbers and characteristics is imperative to accurately reflect the current state of the deaf population. Having a resource like this study by Schein and Delk is indispensable as it captures the nature of the community at a specific time and enshrines it in history.

It is perplexing that, despite recognizing the value of historical data in the past, there seems to be a reluctance to share current information publicly. For example, the National

Association of the Deaf, which published this book in 1974, did not agree to share their database despite receiving requests from myself and many other researchers. They did guide me to their web pages of affiliated organizations, which I have incorporated into my project, which was greatly helpful and appreciated. However, the web pages already contain outdated information in the form of broken links, which posed an additional challenge to my research. The obsolete information within the tiny slice of NAD's databases available to the public poses a substantial challenge to the overall integrity and reliability of the provided data. A considerable portion of the database exhibits signs of obsolescence, with many entries reflecting old information and broken links. The database also does not provide physical addresses, which creates yet another barrier in my research as I have to seek down the addresses and attach them to each entry. In the Internet age, it is crucial to maintain up-to-date information, especially with the importance of the information that resides on NAD's website, which serves the role of providing critical information to the deaf community.

It is contradictory that there is a book focused on the data of deaf people published by the same organization that now refuses to share its database. The same goes for many other organizations and companies, such as Convo. Convo allows its consumers to access their "Deaf Ecosystem" directory within its application, but it is not accessible to people who do not have a Convo account or are not associated with them. This directory is also a long list, which is not visually accessible nor spatially accessible; the people using it need to do further research to see if one of the list items is local to them. Should the various organizations and/or companies revisit their data policies, this data would be extremely valuable.

Gallaudet University has created and uploaded an Apple Maps Guide named Schools & Programs for the Deaf/HH, which seems extensive at first glance, with 174 places included.

However, by the criterion of Deaf America, it is not comprehensive enough. There is the issue of accessibility, as the Apple Maps guide is limited to Apple devices. People with Android, Windows, or any non-Apple devices can still access the map via the Internet, but in today's world, fast and easy accessibility is crucial. The guide is slow, sluggish, and unclear on non-Apple devices (as confirmed by comparing the author's own Windows laptop and Apple iPhone/iPad). Zooming in and out requires more work by mandated clicking the zoom in/out buttons, not by scrolling. Viewing the areas of the map requires manual clicking and dragging of the touchpad/mouse, not scrolling or light dragging. The quality of the map is subpar compared to the ArcGIS maps on non-Apple devices, as seen in Figure 27 below. Cross-platform support is a must in today's world, as people have varying types of devices, and to receive equal access to the data, all the devices should offer the same product. In Apple Maps' case, it does not. The information on each school on the map is minimal, offering just the website, phone, and address. The ArcGIS maps of this project include far more information that will benefit the viewer.

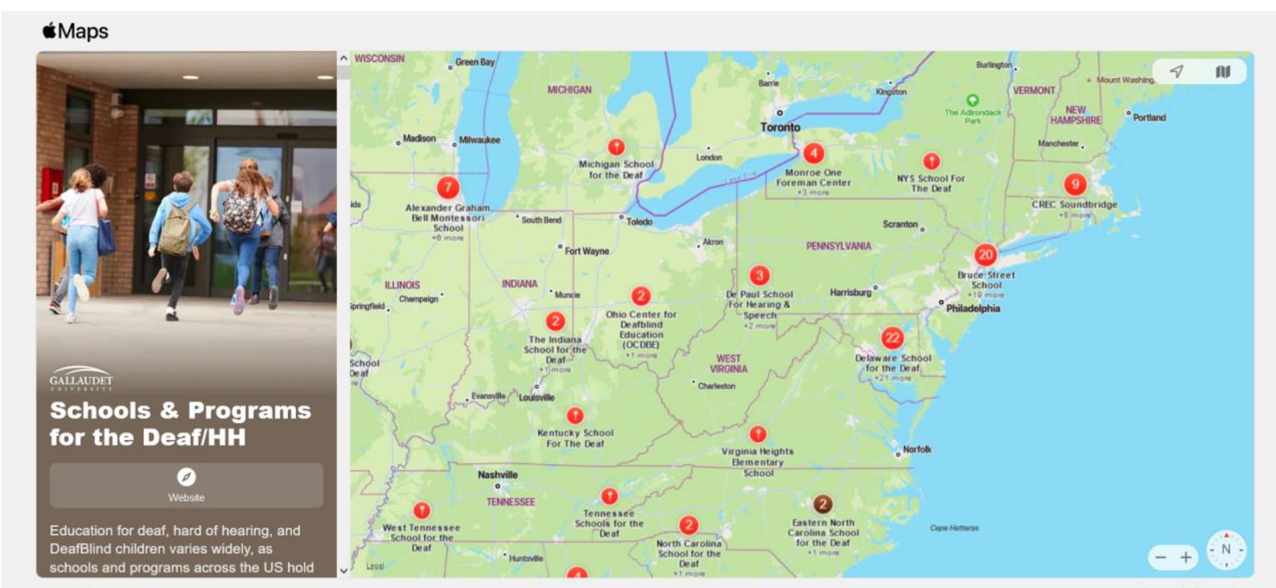


Figure 27

The opening up of data of deaf people and its network, that is, Deaf America, would not only address this temporal gap but also serve as an enduring testament to the importance of maintaining a comprehensive and accessible repository of data for the benefit of the entire community.

With the above discussion of the results and the barriers to continuing this research, it is important to note some approaches that would greatly benefit this project in the future, along with some ways to future-proof it to allow for continued work and expansion. The current version of the project is proof of concept, which means that it is not perfect. The main aim of the whole project is to create and showcase an idea that can lead to further innovations. Some examples will range from utilizing the National Deaf Center, expanding the demographic data of the project, collecting more spatial data, adding more layers, and creating a way to maintain the documentation each year.

The National Deaf Center's (NDC) Research & Data page has some wonderful and accessible resources relating to the research and data collection of deaf people in America, but it is limited only to the educational achievement data, job data, and related fields (National Deaf Center, 2023). This project differs from the NDC's data collection as this focuses on the demographics of deaf people in America and the network around them, but a suggestion for a future research project would be to find a way to utilize the ArcGIS map with its demographics and layers and combine it with the data that NDC currently houses to discover possible connections between the number/demographics of Deaf America and educational/career opportunities/outcomes. It would be worthwhile to attempt this project, as it will allow the incorporation of NDC's static data in PDF formats, which is not exactly 100% accessible to everyone, and turn that into a publicly available and accessible database.

The next suggestion is the expansion of the demographic data aspect, which will allow for a more detailed analysis of Deaf America. The current nationwide map utilizes just the U.S. Census numbers of people with hearing difficulties split into age groups, which does not introduce a detailed look at Deaf America, but it is a starting point. In the Maryland close-up view, a chart with hearing difficulties was used alongside the numbers and age groups, allowing for greater insight into how the Deaf America population is made up. To continue from the starting point, it is encouraged that this project's demographic data is expanded to include more detailed information such as age, sex, race, signing/non-signing, and much more. This does bring challenges in terms of how to define the more nuanced characteristics of Deaf Americans, especially with regard to sign language use and the amount of involvement with the deaf community. This will bring up some sensitive discussions, but that is something that is encouraged to be done, as it will allow for a better understanding of the deaf community (deaf sociality) in America.

Another barrier this project encountered was that a large majority of the essential deaf organizations or resources did not have a physical address. Some of them had a P.O. box, but it was not productive in terms of helping establish a physical presence within the area that it serves. Some large and well-known organizations, such as Sorenson, Convo, National Black Deaf Advocates, and others that serve the deaf community, did not end up on the map due to not having an official "office" address. Another critical missing element was the New Jersey agency for the deaf not having any clear physical address. I (the author) am pretty sure that the office is located in one of New Jersey's offices for human services or a related department, but there is no physical office address on the webpage for the agency. This is a glaring omission, as it prevents the deaf people in the state from being aware of the resource. That is where the next suggestion comes in -- encouraging the organizations to have ONE physical address that the map can affiliate them with spatially. This will allow more organizations to be represented on the map because their location (or headquarters) can be pinned down spatially.

The final suggestion is finding a way to "future-proof" the project, as technology and data changes constantly. There is a two-tiered approach: 1) adding more layers and 2) figuring out a data management system. Adding more layers will incorporate the "other" institutions that were unable to be categorized or deemed not as critically important as the categories in this project, but these institutions are still essential to the map and Deaf America. Such institutions include deaf clubs, interpreting organizations/businesses, deaf churches, and the Deaf Queer Resource Center. This layer will, too, show information categories similar to those of the previous layers. With further research, more layers or institutions can be added to the map to further our understanding of the many varieties of deaf experiences in America. Now, where will all this data reside in the future?

Throughout the entire project, I encountered many different databases and datasets for deaf people in America. This is a great thing, as it provides a home for the data to reside in, but it is imperative that all of the data are incorporated into a robust data management system. There is a need for a centralized database/hub for information on Deaf America. The overlay data part was downloaded from the US Census website and easily modified. For the remaining data in the project, the data input process was undertaken individually, with the information meticulously collected from the Internet and imported into comma-separated values (.csv) files. This approach shows a high level of dedication in creating a data hub, but it also increases the risk of human error, which may jeopardize the accuracy of the data, as encountered during the process of creating R visualizations. It is important that the data is presented correctly, and some formatting issues appeared, such as sizing and labeling, but it was resolved with the help of the Director of this project. However, this risk must be reduced by creating a one-stop data management system that not only consolidates information but also introduces efficiency and reliability into the process. There is a need for a comprehensive and streamlined solution, and that begins with ArcGIS.

In the pursuit of creating said data management system, ArcGIS is a great starting point for a centralized data hub on deaf Americans. With its powerful geospatial analysis capabilities, ArcGIS is a tool to visualize and comprehend the data stored in our files. An example of its capabilities is its ability to create charts within pop-ups, as seen in the maps in this project. This ability can be expanded further in the future to create fast and accessible comparisons of hearing difficulties versus no hearing difficulties for each state with easy exporting, which I (the author) hope to utilize Structured Query Language (SQL) for, as it is commonly used in the data science and programming worlds to create, access, and maintain databases. By integrating ArcGIS, we not only eliminate the unnecessary clunkiness of storing data for deaf research but also gain a dynamic platform for insights. This will allow for interpreting complex information more efficiently and making informed decisions/research. Within the ArcGIS system, it is possible to build a data management system where the data resides and use it seamlessly and efficiently without outsourcing to another data management system (Esri, n.d.-b). However, ArcGIS can also work with SQL within the ArcGIS software. Within that data management system, it is possible to maintain a “living” data file, ensuring that the data remains current and accurate. It will also be able to store historical data by archiving each year’s data and putting it out into different tables for each year. That will foster adaptability and responsiveness to changes and make this project sustainable for long-term use in this ever-changing technological environment.

Conclusion

This project hopefully fills the holes in research on the deaf network, deafness, and Deaf America – and encourages further research to reinforce the data we already have. The problems in currently doing so are a lack of initiative in collecting data related to Deaf America and the privatization of more updated datasets. Many aspects of the existing data are also complex and confusing due to their differing criteria and other factors. Some datasets have been regularly updated, but their conflicting definitions of deafness and/or not easily accessible render them moot for meaningful use within the deaf community. I (the author) plan to continue this project in the future by collaborating with others who are interested in building and expanding this project. That will start with creating the SQL database with the already-confirmed accurate data and then figuring out how to create a continually updated database between SQL and ArcGIS so it will output to a map on ArcGIS Online without too much work, allowing for the viewers to enjoy up-to-date information on a regular basis.

A key aspect of being deaf is living in and using visuals every day – American Sign Language (ASL) is a visual language, and there are not enough visualizations of deafness in America. The last meaningful visualization was in the 1990s and early 2000s, but they were tables/pie charts – which does not meet today's standards. In the years since no visualizations have utilized our technological advancements. Why have we largely neglected the collection and visualization of Deaf America in the 21st century? It is time to get on with our technological advancements, create a living document, and visualize the collected data. The social institutions of Deaf America need to be geolocated – which this project has incorporated and shows the statistical information (number of enrollment or members, etc.) in each geolocation. This project focused on creating proof of concept using current data on Deaf America to show the beautiful possibilities that can be created if we decide to take the initiative to create a database and visualizations. The project aims to provide a comprehensive view of Deaf America, enabling a better understanding of deafness in the country and how the deaf community serves its people. This allows for a better understanding of and more informed decision-making in supporting the community.

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Appendix – Data

The data used in the project ranges from feature layers, individually collected data, Esri/ArcGIS, or Maryland’s data portals, to actual statistical data from the US Census. The summaries of the information and procedures used to collect and use them are explained below.

Individually collected data:

This part was the most arduous, as many deaf-related institutional data were scattered all over the internet. I had to collect them and move them to a table before doing anything with them. A significant part was the Deaf schools, which had their enrollment information on the National Center for Education Statistics’ pages, but I had to search for them individually. The NCES had three different pages for three different categories of schools: public, private, and higher education. An example of a search page was:

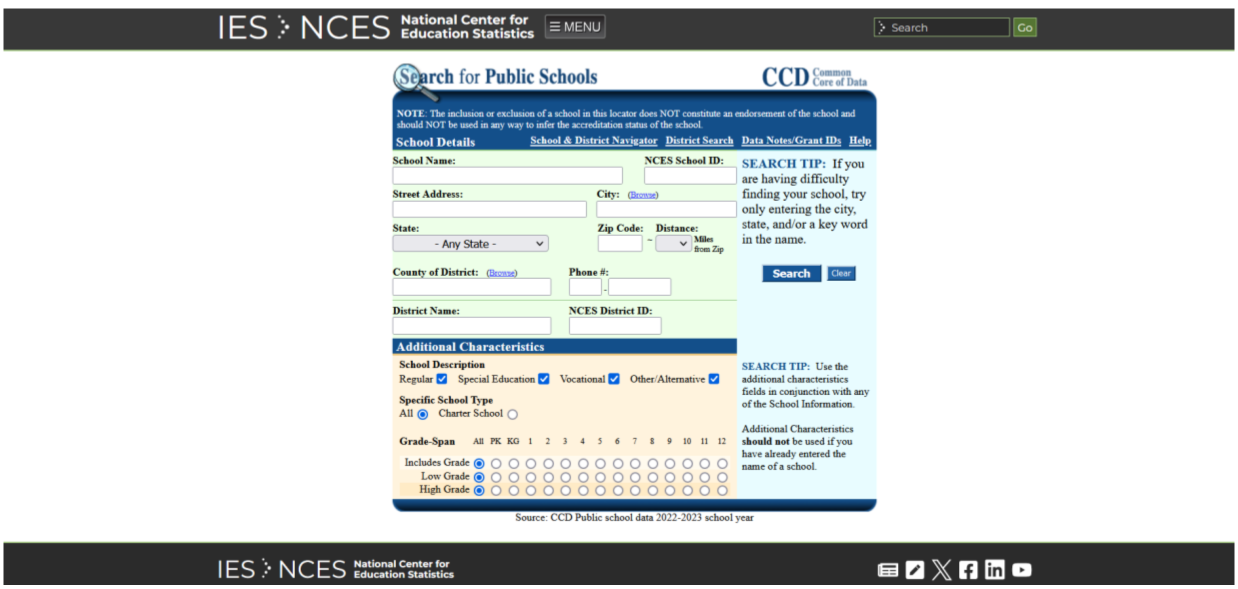

Figure 28

I searched for the school’s name individually, and sometimes I came up with nothing because the school was not registered with the NCES for either public or private schools. These schools received an NA on the table of school information, which can be seen in Figures 29 and 30 below.

	A	B	C	D
1	***DAA DEFINITIONS***			
2	**name**	Name of school		
3	**yr_est**	Year of establishment for school		
4	**yrs_opr**	Years operated		
5	**address**	Road address of school		
6	**city**	City location of school		
7	**state**	State location of school		
8	**zip**	ZIP code of school		
9	**enrol_nbr**	Number of students enrolled at that school		
10	**mascot**	Mascot of the school		
11	**gr_served**	Grades the school serves		
12	**deg_served**	Degrees the school awards (Higher Education only)		
13	**day_or_res**	Indicates if school is a day or residential school		
14	**address**	Physical address of school		
15	**phone_nbr**	Voice number for school		
16	**vp_nbr**	Videophone number for school		
17	**website**	Link to school's website		
18	**lat**	Latitude		
19	**long**	Longitude		

Figure 29

1	**name**	**yr_est**	**yrs_opr**	**address**	**city**	**state**	**zip**	**enrol_nbr**
2	Alabama Institute for the Deaf and Blind	1858	165	205 South Street East	Talladega	Alabama	35160	NA
3	Alaska State School for the Deaf and Har	1973	50	5530 E Northern Lights Blvd	Anchorage	Alaska	99504	31
4	American School for the Deaf	1817	206	139 North Main Street	West Hartford	Connecticut	06107	144
5	Arizona State Schools for the Deaf and B	1912	111	1200 W Speedway Blvd	Tucson	Arizona	85745	112
6	Arkansas School for the Deaf	1849	174	2400 W Markham St	Little Rock	Arkansas	72205	106
7	Atlanta Area School for the Deaf	1972	51	890 N Indian Creek Drive	Clarkston	Georgia	30021	154
8	Beverly School for the Deaf	1876	147	6 Echo Avenue	Beverly	Massachusetts	01915	NA
9	Bruce Street School for the Deaf	1910	113	333 Clinton Place	Newark	New Jersey	07112	NA
10	California School for the Deaf, Fremont	1860	163	39350 Gallaudet Drive	Fremont	California	94538	318
11	California School for the Deaf, Riverside	1950	73	3044 Horace Street	Riverside	California	92506	298
12	Colorado School for the Deaf and Blind	1874	149	33 N Institute Street	Colorado Springs	Colorado	80903	162
13	Delaware School for the Deaf	1929	94	630 E. Chestnut Hill Road	Newark	Delaware	19713	122
14	Eastern North Carolina School for the Dea	1964	59	1311 US Hwy 301 South	Wilson	North Carolina	27893-6621	46
15	Florida School for the Deaf and Blind	1885	138	207 San Marco Avenue	St. Augustine	Florida	32084	NA
16	Georgia School for the Deaf	1846	177	232 Perry Farm Road SW	Cave Spring	Georgia	30124	74
17	Governor Baxter School for the Deaf	1957	66	1 Mackworth Island	Falmouth	Maine	04105	NA
18	Hawaii School for the Deaf and the Blind	1914	109	3440 Leahi Avenue	Honolulu	Hawaii	96815	50
19	Horace Mann School for the Deaf and Har	1869	154	40 Armington Street	Allston	Massachusetts	02134	70
20	Idaho School for the Deaf and the Blind	1906	117	1450 Main Street	Gooding	Idaho	83330	111
21	Illinois School for the Deaf	1839	184	125 South Webster Avenue	Jacksonville	Illinois	62650	72
22	Indiana School for the Deaf	1843	180	1200 E 42nd Street	Indianapolis	Indiana	46205	138
23	Iowa School for the Deaf	1855	168	3501 Harry Langdon Blvd	Council Bluffs	Iowa	51503	96

Figure 30

A similar process was used for the other parts of the manually collected data, such as the Deaf Political America. Once the tables were collected and set up, I moved them into R for initial visualizations, such as for the enrollment numbers and more. Once that was completed, they were moved to ArcGIS Pro to start visualizing the geospatial locations of each institution listed on each table (Deaf Academic America and Deaf Political America). These results can be seen in the final maps of this project.

Esri/ArcGIS and Maryland:

Feature layers:

- USA States Generalized Boundaries (Esri)
- Maryland County Boundaries (MD iMAP Data Catalog)
- Maryland Census Boundaries (MD iMAP Data Catalog)

The above are feature layers, which are a grouping of similar geographic features that I used in my project. These are feature layers of boundaries that I needed to assign data to, so I used these already-established boundaries, which are based upon the official Topologically Integrated Geographic Encoding and Referencing (TIGER) files that the US Census maintains. The features layers may look like this:

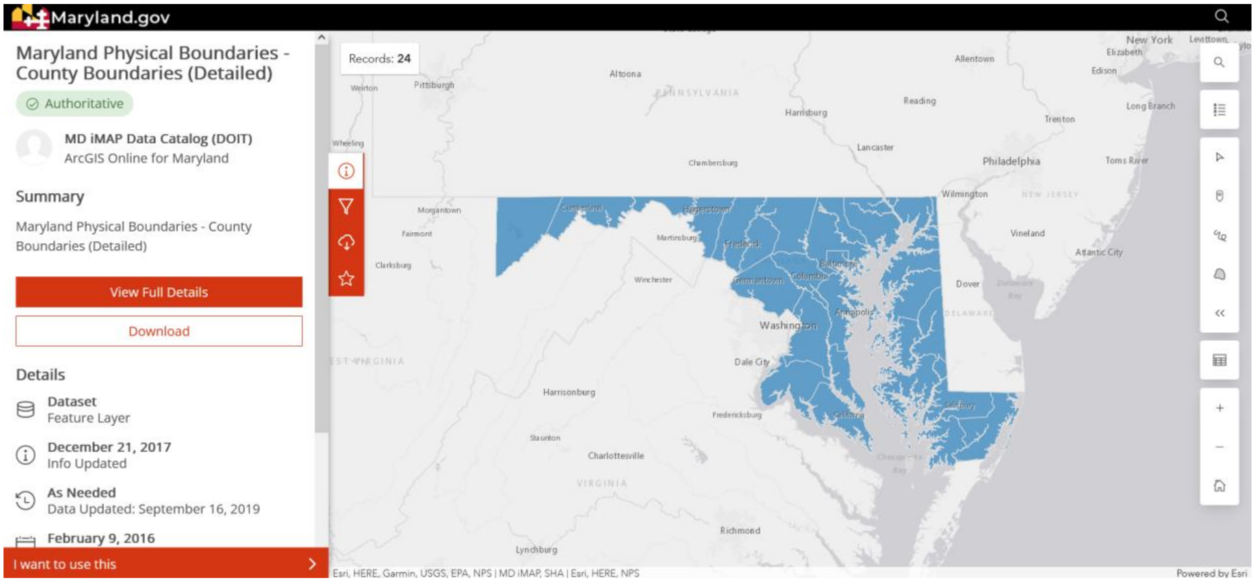

Figure 31

The feature layers on the Maryland iMAP Data Catalog were merged with Esri's Living Atlas, which is an online hub for all types of data and feature layers used in ArcGIS maps, but they were on separate websites. I decided to use/download the Maryland feature layers from the iMAP Data Catalog because I knew they were the "official" feature layers, which would add credibility to my project. The Esri state boundaries feature layer is official, too, but it came from their website as it is a "national" map, which no one state can claim and use on their website/data portals.

US Census data:

Definitions of terms used in the dataset came from this document on the US Census Bureau's website: *American Community Survey and Puerto Rico Community Survey: 2021 Subject Definitions*, which helped inform how I used the data and tables attained from the US Census Bureau. The two tables I used for the data in this project came from **Table B18102**, which was named Hearing Difficulty. The tables can be viewed from many points of view, from nationwide to city area data. However, for this project, I utilized the general state counts and Maryland census/county counts through the Hearing Difficulty: All 50 States table and the Hearing Difficulty: Maryland table, respectively, and downloaded it as a .csv file, which I then uploaded and cleaned in R and Excel before moving to ArcGIS. An example of the R cleaning code I used to rename all the columns from numbers to clearly defined ones is shown below in Figure 32:

```
#Now let's rename the columns to a more readable one. This will be a LONG
#command, but I'll try to keep it all in one line instead of having 39 lines for
#the 39 columns that need renaming. I will rename them by index because I don't
#want to copy it all again and again.
deafusa <- deafusa %>%
  rename("STATE" = 2, "TOTAL ESTIMATE (TOT_EST)" = 3, "TOT_EST MALE" = 4, "TOT_EST MALE UNDER 5" =
           5, "TOT_EST MALE DEAF UNDER 5" = 6, "TOT_EST MALE NOT DEAF UNDER 5"
         = 7, "TOT_EST MALE 5-17" = 8, "TOT_EST MALE DEAF 5-17" = 9,
         "TOT_EST MALE NOT DEAF 5-17" = 10, "TOT_EST MALE 18-34" = 11,
         "TOT_EST MALE DEAF 18-34" = 12, "TOT_EST MALE NOT DEAF 18-34" = 13,
         "TOT_EST MALE 35-64" = 14, "TOT_EST MALE DEAF 35-64" = 15, "TOT_EST MALE NOT DEAF 35-64" =
         16, "TOT_EST MALE 65-74" = 17, "TOT_EST MALE DEAF 65-74" = 18,
         "TOT_EST MALE NOT DEAF 65-74" = 19, "TOT_EST MALE 75+" = 20,
         "TOT_EST MALE DEAF 75+" = 21, "TOT_EST MALE NOT DEAF 75+"
         = 22, "TOT_EST FEMALE" = 23, "TOT_EST FEMALE UNDER 5" = 24,
         "TOT_EST FEMALE DEAF UNDER 5" = 25, "TOT_EST FEMALE NOT DEAF UNDER 5" = 26,
         "TOT_EST FEMALE 5-17" = 27, "TOT_EST FEMALE DEAF 5-17" = 28,
         "TOT_EST FEMALE NOT DEAF 5-17" = 29, "TOT_EST FEMALE 18-34" = 30,
         "TOT_EST FEMALE DEAF 18-34" = 31, "TOT_EST FEMALE NOT DEAF 18-34" =
           32, "TOT_EST FEMALE 35-64" = 33, "TOT_EST FEMALE DEAF 35-64" = 34,
         "TOT_EST FEMALE NOT DEAF 35-64" = 35, "TOT_EST FEMALE 65-74" = 36,
         "TOT_EST FEMALE DEAF 65-74" = 37, "TOT_EST FEMALE NOT DEAF 65-74" =
           38, "TOT_EST FEMALE 75+" = 39, "TOT_EST FEMALE DEAF 75+" = 40,
         "TOT_EST FEMALE NOT DEAF 75+" = 41)
```

Figure 32

I renamed each column all in one line by index number to streamline the process because if I had decided to rename them individually, it would have been a long process due to 40+ existing columns. The code is not shown, but I then reduced the number of columns by merging the aggregated age groups to only four and then renamed these columns. Another example of a script is Figure 33, which visualizes per capita and percent data:

```
#Now running the tidyverse library, which will install the following packages:
#tidyverse, ggplot2, tidyr, readr, purrr, dplyr, stringr, forcats, lubridate
library(tidyverse)

#Setting my working directory to the folder on my desktop that contains
#the data I need for this project
setwd("C:/Users/Emily GU/Desktop/Capstone/Nationwide data")

#I am loading in the R and Excel wrangled data.
df <- read_csv("OverlayDataDraft2Copy.csv")

#Checking if the data has the right stuff I need for this part
head(df)
colnames(df)

#Creating the simple ggplot2 barplot for USA numbers
ggplot(df, aes(x=regPC, y=reorder(name, regPC))) +
  geom_bar(stat = "identity", fill = "#316aae") +
  labs(title = "Count of Hearing Difficulty per 100,000 by US State",
       x = "% of Population with Hearing Difficulty",
       y = "State",
       caption = "Source: US Census Bureau") +
  scale_x_continuous(position = "bottom", expand = expansion(mult = c(0, .1)))+
  geom_text(aes(label=regPC), hjust= -.25, color="black", size=2.5) +
  theme_minimal() +
  theme(axis.text.x = element_text(color='black', size=11),
        axis.text.y = element_text(color='black'),
        plot.title = element_text(size = 18, face="bold"),
        axis.ticks.y = element_blank(),
        axis.title=element_text(size=14, color='black'),
        axis.title.x.bottom = element_text(vjust=-1),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        plot.caption = element_text(size=10))


#Exporting the plot now
ggsave(filename = "PerCapitaCount.png",width = 11, height = 8.5, bg = "white", dpi = 300)
```

Figure 33

I used this script to create Figures 16 and 17 in the Results and Discussion section. I used the already cleaned data (using the script in Figure 32), read it in the script, and then utilized the tidyverse library to allow me to use the ggplot library to create the visualization. I could customize it using labs to label the parts of the graph and fine adjust the labelings or colors of the bars and labels via the axis.text.x, and other lines. This process was repeated for the Maryland data and many other R visualizations throughout the paper.