

accessibility, visual impairment, and finance

**team b7g
secondary research report
spring 2017**

executive summary

This report reflects **five areas of research covered by literature review, talks with subject matter experts, and team exercises.**

First we describe an **overview of the spectrum of people with visual impairments (PWVI).**

Second, we address **five key insights with respect to PWVI and their technology needs.** Third we bring in a **broad picture of data visualization in the finance domain.** Fourth, we examine the **current state of accessibility technology for PWVI.** Finally, we present a **survey of potentially relevant emerging technologies.**

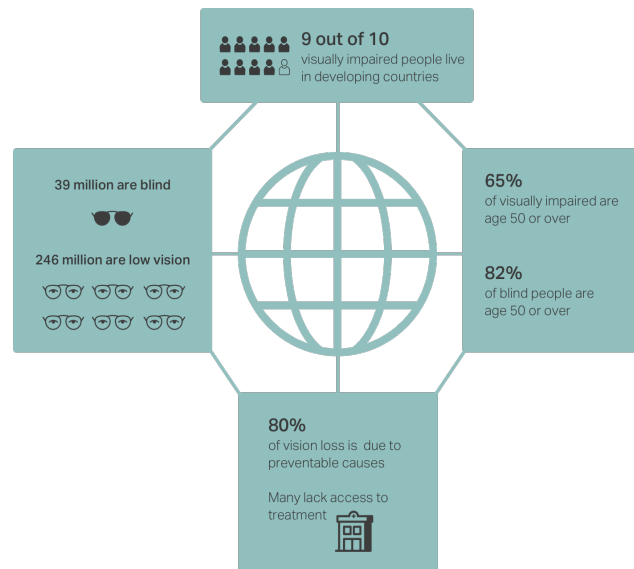
This research now guides our **contextual inquiry into visual accessibility and financial investments.**

table of contents

An Overview of People with Visual Impairments	1
Designing for People with Visual Impairments	2
Data Visualization in Finance	3
Accessibility Technology	4
Emerging Technology Survey	5

an overview of people with visual impairments

Prevalence of Visual Impairments



Global vision by the numbers²

Global View

Millions of people of all ages suffer from vision problems around the world. The causes are varied, from genetic and metabolic diseases to sudden eye or nerve injuries.¹ There are socioeconomic correlates of vision loss: 9/10 of world's blind are in the developing world. Many people are blind from preventable causes, most notably cataracts. Globally, WHO estimates that 80% of all visual impairment could be prevented or cured.² Almost half of global visual impairment are uncorrected refractive errors like myopia (nearsightedness), hyperopia (farsightedness)³. In particular, unoperated cataracts account for 33% of visual impairment.²

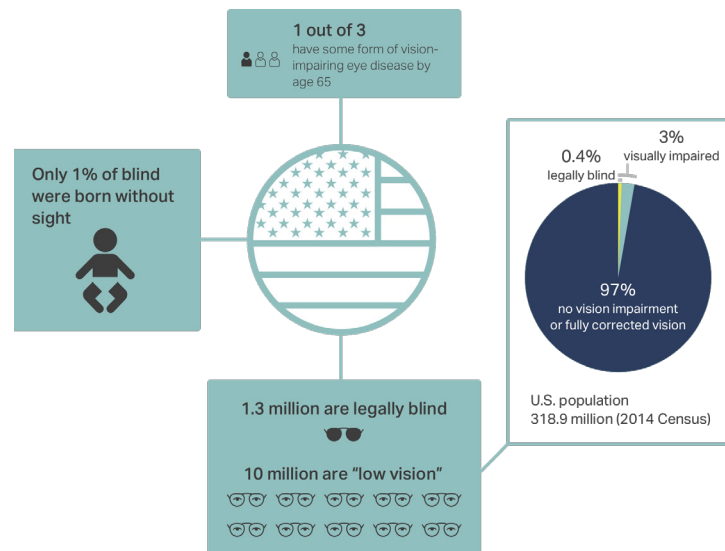
Leading causes of visual impairment worldwide:



- uncorrected refractive errors (43%)
- cataracts (33%)
- glaucoma (2%)

United States

In the United States, millions of people live with visual impairments that affect their daily lives.



US Vision by the numbers

Defining Vision

There are no generally accepted definitions for “visually impaired,” “low vision,” or “vision loss.”⁴ Measures to report vision loss may include both clinical (vision loss is determined by an optometrist or ophthalmologist using dilated eye exams and standard measurement tools) and self-reported vision loss.⁵

Measuring Vision

Vision level is measured clinically by assessing a variety of eye functions such as visual acuity, refraction, field of view, and color perception.⁷

Refractive Errors are the most common eye problems affecting people in the United States and can typically be corrected by eyeglasses, contact lenses, or surgery. Uncorrected, refractive errors result in blurred vision.⁷

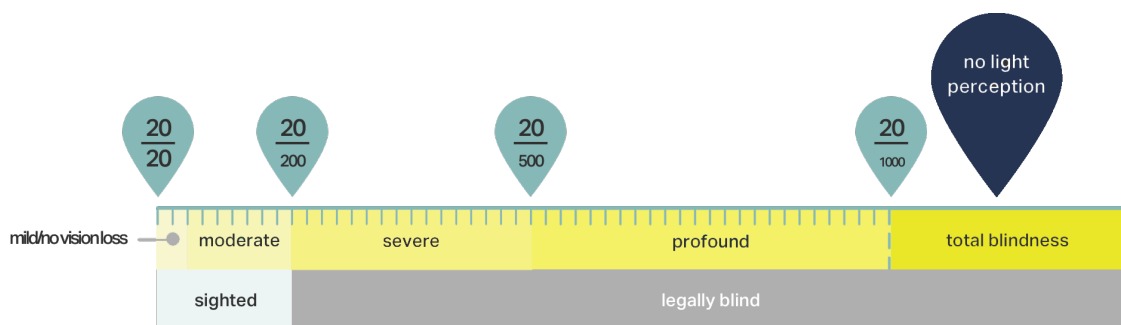
Visual acuity (VA) refers to clarity of vision. The US unit of measurement for VA is 20/x, where 20 represents a 20 foot distance and the denominator represents the number of feet at which a person with normal sight can see that same distance.⁸ For example, if a person has 20/100 vision, at 20 feet they can only see what a person with normal sight could see at 100 feet.

The legal definition of blindness is based on VA. People whose best eye when corrected has a visual acuity of 20/200 or greater are considered

legally blind. This means they do not qualify for a driver's license but do qualify for certain government disability benefits. It is notable that within legal blindness, people have a wide range of visual abilities.

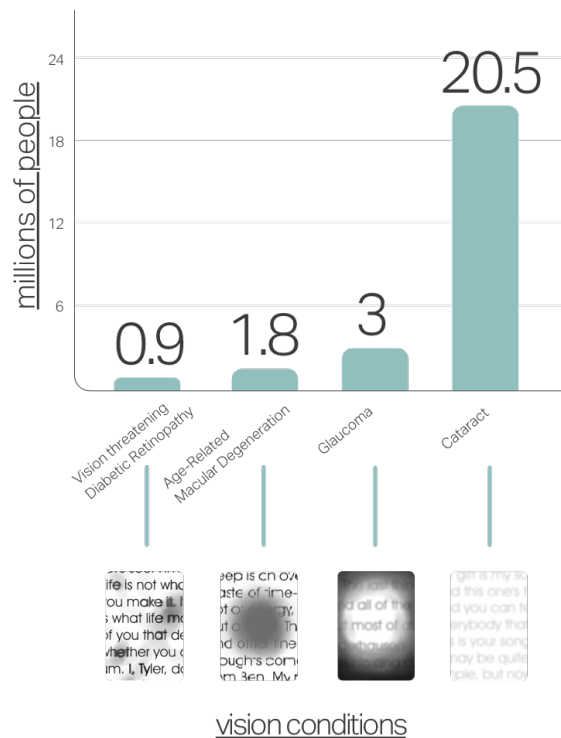
Another measure of vision is field of view, which measures the range of vision. Vision disorders like glaucoma and age-related macular degeneration may affect peripheral vision or result in blind spots that limit a healthy eye's range of vision.¹⁰

Finally, many people experience color vision deficiencies that result in different color perception than the majority of people. 8% of men and 0.5% of women have red-green color blindness which results in an inability to distinguish shades of red and green from each other. More rare forms of color blindness include monochromacy (no color perception) and blue-yellow color blindness.¹¹



Visual acuity scale⁶

Visual Impairments



Leading causes of visual impairment & blindness in the U.S.⁹

Age-Related Macular Degeneration

Macular degeneration, also known as age-related macular degeneration (AMD), is "an eye disorder associated with aging and results in damaging sharp and central vision. AMD is the leading cause of permanent impairment of reading and fine or close-up vision among people aged 65 years and older."⁹ There are two types of AMD: Wet AMD and Dry AMD. Wet AMD results in rapid central vision loss. Dry AMD is more common, accounting for 70–90% of cases of AMD. It progresses more slowly than the wet form. Central vision is gradually lost in the affected eye,

though generally affects both eyes.

Cataract

"Cataract is a clouding of the eye's lens. It is the leading cause of blindness worldwide and in the United States. Cataracts can occur at any age because of a variety of causes, and can be present at birth. Although treatment for the removal of cataract is widely available, access barriers such as insurance coverage, treatment costs, patient choice, or lack of awareness prevent many people from receiving the proper treatment."⁹

Diabetic Retinopathy

"Diabetic retinopathy (DR) is a common complication of diabetes. It is the leading cause of blindness in American adults, and it is the leading cause of blindness among U.S. working-aged adults aged 20–74 years. An estimated 4.1 million and 899,000 Americans are affected by retinopathy and vision-threatening retinopathy, respectively."⁹

Glaucoma

"Open angle, is a chronic condition that progress slowly over long period of time without the person noticing vision loss until the disease is very advanced, that is why it is called 'sneak thief of sight.' Angle closure can appear suddenly and is painful."

Comorbidity

Vision loss doesn't exist in a vacuum: many vision problems coexist with other health and mental health conditions. Studies find that "people with vision loss are more likely to report depression, diabetes, hearing impairment, stroke, falls, cognitive decline, and premature death. Decreased ability to see often leads to the inability to drive, read, keep accounts, and travel in unfamiliar places, thus substantially compromising quality of life."¹²

In addition to this, it's important to remember that a significant percentage of people with visual impairments developed their impairment later in life through conditions like cataracts and age-related macular degeneration. In these cases, vision loss must be considered alongside all of the other health considerations of an aging person: "Patients aged 65 years and older with visual impairment have a broad range of physical and mental health comorbidities compared to those of the same age without visual impairment, and are more likely to have multiple comorbidities."¹³

Accessibility and the Law

Two particular pieces of legislation affect businesses relating to visually impaired workers: the Americans with Disabilities Act (ADA) and the Section 508 Amendment to the Rehabilitation Act of 1973.

All US businesses are subject to Title I of the

Americans with Disabilities Act (ADA). Title 1 requires that employers accommodate employees with disabilities, within reason:

"Title I of the Americans with Disabilities Act (ADA) requires an employer with 15 or more employees to provide reasonable accommodation for individuals with disabilities, unless it would cause undue hardship. A reasonable accommodation is any change in the work environment or in the way a job is performed that enables a person with a disability to enjoy equal employment opportunities. There are three categories of "reasonable accommodations": (a) changes to a job application process ; (b) changes to the work environment, or to the way a job is usually done ;(c) changes that enable an employee with a disability to enjoy equal benefits and privileges of employment (such as access to training)."¹⁴

Additionally, all organizations in the public sector are subject to Section 508. Section 508 was first passed by US Congress in 1998 as an amendment to the Rehabilitation Act of 1973. The section requires that "all 'electronic and information technology' (EIT) developed, procured, maintained, or used by federal agencies must be equally accessible to persons with disabilities as it is to those who are not disabled."¹⁵

In January 2017, there was an update to the 508 Standards addressing international trends and standards in technology, which incorporates more modern accessibility practices from the International Web Content Accessibility Guidelines (WCAG), "updat[ing] and reorganiz[ing] the Section 508 standards and Section 255 guidelines in response

to market trends and innovations, such as the convergence of technologies." It remains to be seen whether this 508 "refresh" will sufficiently address the web technology concerns of visually impaired users. In general, as legal standards have fallen behind modern technology, there has been an uptick in lawsuits addressing the lack of online accessibility.¹⁶

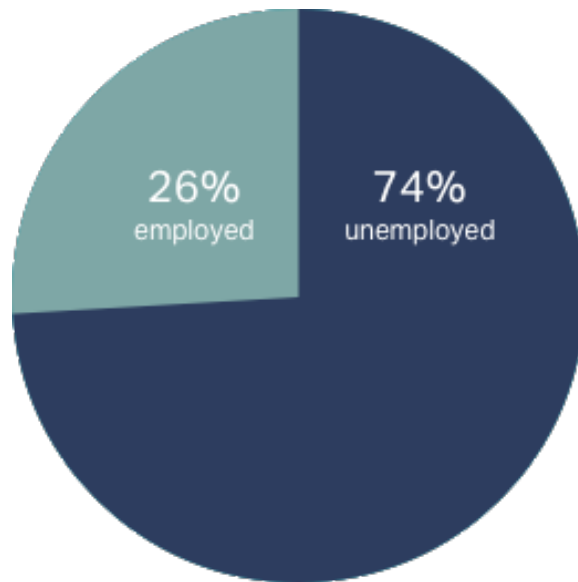
Professional Prospects

74% Unemployment Rate

People with visual impairments (PWVI) are at an extreme disadvantage compared to fully sighted workers: in general, workers with a disability are less likely to be employed and more likely to hold jobs with lower earnings.¹⁷ 74% of working age blind people are unemployed in the United States.

Education

There is more consistent funding and support for visually impaired people during primary education than advanced education. In the U.S., elementary and high school funding for assistive materials is determined by a quota system: "Each year, the American Printing House for the Blind polls each state for data on the number of legally blind children (through age 21) enrolled in elementary and high school in the US eligible to receive free reading matter in Braille, large print, or audio format. This is used to develop a "quota" of federal funds to be spent in each state for material



Professional prospects for PWVI

in each alternative format. These are probably the only exact numbers regarding blindness in the United States."⁴

Americans who have vision loss and are 25 years of age and over, 4.0 million have less than a high school diploma, 5.1 million have a high school diploma or a GED, 5.8 million have some college education, and 4.1 million have a bachelor's degree or higher. Of PWVI who pursue advanced degrees, they are rarely pursuing STEM fields: "If one uses the most recent number of 0.3% for the number of PWVI between the ages of 3 and 21, and then compares this number against the 0.06% of PhDs in STEM who identify as PWVI, a five-fold drop off is observed. In 2008, just 20 Ph.D.s out of 32,847 were awarded to PWVI."¹⁸

In the workplace

Amongst educated, Braille literate working age blind people, 44% are unemployed.¹⁹ From a 2012 CDC report, approximately 8.2 million Americans with vision loss are near or below the poverty line.⁵ Over the course of history, visually impaired citizens have clustered in certain industries. Some of these are culturally specific (for example, Spain has long offered employment opportunities for the blind in Once lottery sales²⁰), and others are found across cultures owing to the specific abilities of the visually impaired. For example, blind masseuses are very common in Southeast Asia because they allows visitors to undress without embarrassment.²¹

There are a number of professional development organizations geared specifically to people with severe visual impairments that are actively working to close this gap through vocational training and other services, such as the National Industries of the Blind²², DO-IT (Disabilities, Opportunities, Internetworking, and Technology)²³, Bureau of Blindness and Visual Services²⁴, and Lighthouse for the Blind and visually impaired.²⁵

Insights

In summary, there are several insights to take away from the statistics around low vision and blind populations:

One size does not fit all: consider the whole health profile of a visually impaired person.

- *"Visually impaired" encompasses a wide range of conditions and abilities.* The causes and effects for low vision are extremely varied, and often progress in severity over time.
- *There is no one definition of blindness:* Less than 0.5% of Americans are legally blind. Within this, many legally blind people still have some vision ability and light perception.
- *Age of onset for vision loss is an important consideration:* Approximately 1 million Americans are born blind, but many others have had their sight degenerate over time.
- *Mental health issues like depression are highly comorbid with vision loss.*
- *Hearing loss and joint issues are also highly comorbid with vision loss, often in older adults.*

Workplace accommodation relies on both the employer and the visually impaired employee.

- One struggle PWVI face in the workplace is overcoming the inability or unwillingness of employer to provide "reasonable accommodation" (ADA requirement) for a visually impaired applicant or employee to complete a job.

- Access to tech in schools is driven by funding based on number of disabled students in districts, whereas in workplace it's dependent on the employee to request AT.

Vision loss disproportionately affects people in developing countries with less access to treatment.

- There are socioeconomic correlates of vision loss: 9/10 of world's blind population is in the developing world, with many people blind from preventable causes, most notably cataracts.

designing for people with visual impairments

Disability Models

In creating accessible technology, there are a number of socio-cultural assumptions revolving around the word disability that influence the decisions designers make.

Medical Model of Disability

The most common model of disability is known as the medical model of disability.²⁷ The medical model asserts that the disabled individual is the problem, and the focus is on a cure, or at least an alleviation of the impairments themselves. Although this model boasts of a long tradition in modern society, the major assumption that the impairment resides as a problem of the individuals themselves ignores crucial elements of the human centered design process. A newer model has arisen to address this disconnect.

Social Model of Disability

The social model of disability takes a wider approach to the design of accessible technology.²⁷ The core tenet of this model is the idea that social barriers, in the form of inaccessible infrastructure, social attitudes, and organizational structure. The exclusion happens due to the interaction between individuals with disabilities and society. A very simple visual accessibility example can be made of crosswalks, which to this day often only provide visual feedback in the form of a walk sign. The decision to not include audio feedback shows the unnecessary creation of inaccessible infrastructure - a problem that has easily been mitigated by developing audio feedback systems that both individuals with visual impairments and sighted individuals can use. The solutions to this problem don't aim to single out people with visual

impairments, but rather, integrate their needs into the experience of crossing a street (all-way crossings, audio cues). And as a result, broader systems are more likely to be designed that can solve greater issues.

Social Model of Disability and Universal Design

As a team, we believe it is important to adapt the social model of disability moving forward with our primary research. We see this decision as a guiding factor in these future interactions with visually impaired users, who are more likely to embody the same ethos. It also keeps our design space more broad, as we are necessarily designing for people, as opposed to just an impairment. We plan to adopt this approach through the HCI concept of universal design. Universal design refers to broad-spectrum ideas meant to produce buildings, products and environments that are inherently accessible to older people, people without disabilities, and people with disabilities.²⁸ As universal designers, we will respect the needs and desires of all populations, recognizing that a solution is invalid if it is not accessible.

PWVI and Technology

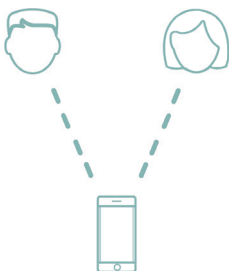
Throughout our literature review, chats with subject matter experts, and initial interviews with people with visual impairments (PWVI), we have uncovered five major themes relating to the interactions PWVI have with assistive technology.



“Don’t move my stuff!”

PWVI are very good at constructing spatial representations of an environment. These representations are reliant upon that environment remaining static, however, so moving things around is detrimental. There are many examples of this phenomenon in the physical world. Inside an apartment, the keys to the building might always be left on the corner of the kitchen table; but move that key to a counter, and the model begins to break down - a search for the keys must now occur as they aren’t where they are supposed to be.

These representations are raft in the digital world, as well. Many PWVI use screen readers to hear the contents on a webpage or app. Screen readers traverse pages based on the DOM structure, a hierarchical approach far different to the visual exploration html code begets. What seems like a simple UI change to a sighted user (say, moving options from a screen to a nav bar) can totally change the structure of a webpage; in other words, constant software updates should be evaluated in part by the work they will cause users of assistive technology.



“I want to use the same stuff as everyone else.”

Having to use special tools makes people stand out - by and large, PWVI don’t want to stand out more



than they need to. Rather than designing standalone technology for PWVI, universal design dictates that tools like VoiceOver (Apple's built-in screen-reader) are integrated into the operating system at all levels. The code that screen-readers interpret should be clean, succinct, and consistently labeled. Additionally, these tools should provide support to third party developers to exploit these capabilities.²⁹

"Don't fix what isn't broken."

Learning new technologies takes a great deal of time - leave PWVI the opportunity to leverage their existing skills. Take obstacle avoidance, for example: the ubiquitous white cane is sufficient in outdoor environments. Not only are canes cheap and replaceable, they are effective at doing their job. This idea gains support in studies that evaluate the design of smartphone-based navigation technology for the visually impaired. Not only were participants not bothered by the occasional contact with an external object, they were quick to point out that the existing physical technologies indeed work well enough in their current state.³⁰ New products should serve to supplement existing skills and solutions.



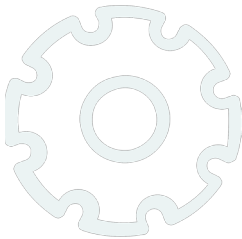
"So what product are you making?"

People with visual impairments have a tendency to approach user studies with the assumption that they are testing a final product, as opposed to having a conversation about research, or giving feedback on a prototype. Although our team was warned in advance about this pattern,³¹ it took on new meaning during our first in-person chat with a blind professional. We had planned on a casual interview

discussing accessibility at universities, as well as trying to make inroads with the blind community of Pittsburgh. When we sat down and introduced our project, however, our interviewee promptly asked, “So what are you making?”

Put in context with the desire to use the same technology as everybody else, the skepticism is understandable, and the onus is on us as designers and researchers to explain the design process and keep the conversation focused on the relevant tasks.

“I do a lot of additional work others don’t know about.”



Accessibility researcher Stacy Branham sets forth the concept of invisible work: a visually impaired person necessarily conducts additional work to create an accessible space.³² This work frequently involves researching and learning assistive technology that best solves a problem. Such a problem might involve gaining access to visual content in a room like signs or flyers, being able to better collaborate with sighted peers, or bringing everyday technology to a sufficiently accessible level. Invisible work shows up again when technology breaks, as PWVI often have more experience debugging assistive technology.

Empathy Exercises and Design

Empathizing with Users with Visual Impairments

We are five sighted designers trying to understand the perspective of users who cannot see, or have great difficulty doing so. A natural first step in relating to our users involves developing empathy for the challenges they face. Empathy exercises are a classic, but controversial way of trying to reduce prejudice by understanding the world from a disabled person's point of view. They commonly occur in the form of disabled simulations that boil the experience of, say "being blind" to blindfolding oneself, and attempting to navigate.

Critiques of Empathy Exercises

Many studies boast of positive results from empathy exercises, but they tend to be qualitative in nature. On the other hand, many academics (especially those in the accessibility domain) are vocal opponents of disability simulations, on the basis that the experiences encountered during these exercises can reinforce negative prejudices of the pain and sorrow disabled individuals must feel, or they can promote the hero syndrome the accessibility community is trying to defeat.³³ The few quantitative analyses of disability simulations paint a very neutral picture, however, suggesting that disability simulations have very little effect one way or the other.³⁴

Other researchers make the case that empathy exercises that are well-designed and evaluated can be effective.³⁵ For the purposes of our project, we believe the value of empathy exercises is limited to better understanding our users as researchers and designers. Even though we cannot understand exactly what

it is like to be blind, we can use currently available assistive technology (e.g., screen readers) to better understand the barriers people with visual impairments face. This form of empathy is very specific to the human centered design process - the goal is to understand our users so that we can make more informed design decisions.

Empathy with Context

A 2015 CSUN lecture offered a template for running empathy exercises that overlapped very closely to our vision for designing one of our own.³⁶ The speaker emphasizes the importance of preparation and scope of how to use exercises. Specifically, he says: "you want to understand the specific barriers people face, perform predefined tasks onsite, prepare, perform common tasks, encourage discussion." At the end, hopefully we will experience frustration and think about accessibility a little differently.

Finding Finances Without Eyes

We designed an empathy exercise that required us to complete a task using financial data. In this exercise, we familiarized ourselves with the Mac OS screen-reader VoiceOver so that we could use it to check our personal finances without using eyesight. Specifically, our task was to navigate to a bank account balance, and have VoiceOver read it back to us. Each team member performed this task on both desktop and mobile devices.

To stay within the financial context, a team member logged into their online banking service before beginning the simulation. Only just before the team

member saw the visual layout of the page did they put on a blindfold. Past experience with the interface served as the foundation for a mental representation of the site's spatial layout, since our users would also not be using personal banking for the first time. An unimpaired teammate took notes and stepped in to keep the exercise on track. In this way, we focused our efforts on navigating personal finances, rather than becoming frustrated with elements of Voice-Over as inexperienced users (for example, navigating out of the Internet browser and onto the desktop).

Simulation Insights

As pseudo-impaired users, we felt frustration in the following areas:

navigating hierarchy - personal finance interfaces offer a wide variety of options. While simple to check a variety of dropdown menus visually, it can be very confusing to remember not only in which menu an option resides, but also in which submenu it may be nested. Also, as there is an additional level of selection with screen-readers (e.g., one must select a link with which to interact before they can actually indicate they wish to proceed to the page to which that link points). It was quite confusing to figure out if we had actually made active an element of information originally obscured by progressive disclosure, or if we had simply navigated into a submenu instead.

bloated alt-text - alt-text is a word or phrase that can be inserted as an attribute in an html document to tell Web site viewers the nature or contents of an image. On personal banking pages, there was a lack

of attention given to image and banner elements. The alt-text being read would include outrageously long sequences of letters and numbers representing the file name, which would immediately disrupt our memory of where [we believed] we were on the page.

unsure of what is relevant - personal finance pages consistently advertise other features their company offers - it quickly became confusing as to whether or not what we had just heard was something to which we had access, or if it was just an ad that was wholly unrelated to the task at hand.

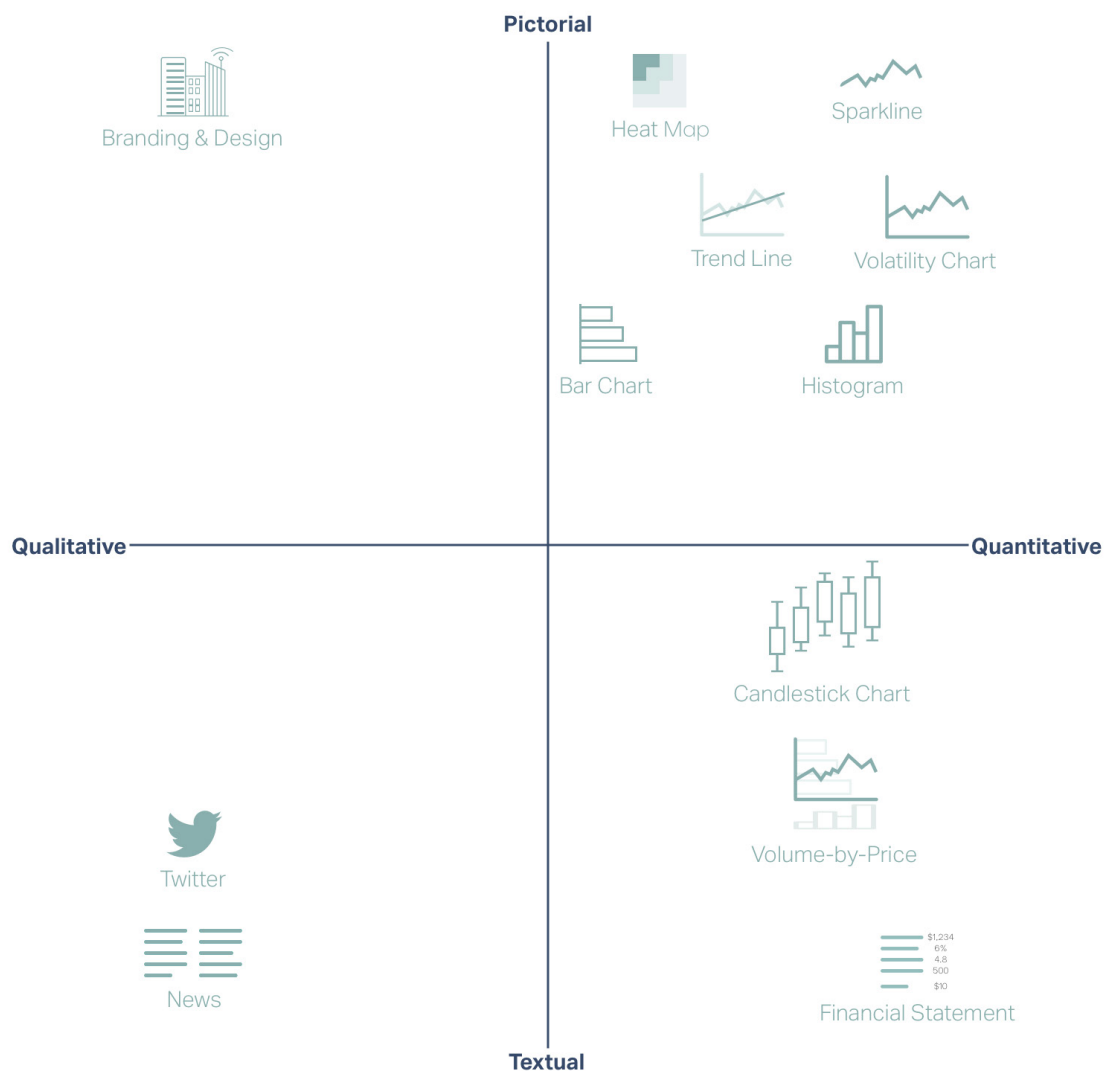
desktop versus mobile experience - hierarchy is often much simpler on web apps or mobile apps because screen real estate dictates how much information can be included on a page. Although these limitations may make screen-readers more efficient in mobile contexts, it doesn't mean that desktop should make for an inferior experience.

The "finding finances without eyes" empathy exercise was useful to our team because it forced us to develop some proficiency with common visual assistive technology. This baseline knowledge allowed us to understand the difficulties of performing financial tasks online, as opposed to being stuck on the barriers of entry screen-readers require, a challenge outside of our project's scope.

data visualization in finance

Data in Finance

Financial experts use many forms of information to make decisions. When investigating a security, buy or sell recommendations are based on qualitative and quantitative data. Data can be either entirely text or heavily pictorial. The below chart depicts data commonly used to make investment decisions and illustrates where each form falls along these scales.



Data Commonly Used to Make Investment Decisions

A deeper dive into the some of the most common visualizations of financial data. Across the many different kinds of visualizations, all data visualizations simultaneously communicate the higher level trends and stories of the data through visual patterns and shapes (e.g., the curve of a sparkline), as well as detailed information that can be drilled down into and is typically portrayed via text (e.g., the exact date and value of a data point).

Heat Map

A graphical representation of data where individual values are represented as colors³⁷

Histogram

A graphical representation of quantitative data that shows the distribution of variables in rectangular bins. The entire range of values is divided into bins.³⁹ Values are represented as colors³⁷

Bar Chart

A graphical representation used to compare categorical data in rectangular bins.³⁹

Sparkline

A very small line chart drawn without axes or coordinates. Frequently used to show stock market prices over time.⁴²

Candlestick Chart

A visualization for financial data that contains open, high, low, and close values for each time period. The "wicks" on the top and bottom represent high and

low prices. If the body of the candlestick is hollow, the stock closed higher than its opening price. The bottom of the body represents the opening price and the top of the body represents the closing price. If the the body of the candlestick is filled, the stock closed lower than its opening price. The top of the body represents the opening price and the bottom of the body represents the closing price.³⁹

Table

Text and numbers in a multicolumn and multirow display. Frequently used in the form of financial quarterly reports.⁴⁴

Volume By Price

A visualization that shows the amount of volume for a specific price range. Volume-by-P rice bars are horizontal and laid against stock prices over time.⁴⁵

Volatility Index

Measures the volatility of put and call options related to a specific index or ETF.⁴⁶

Trend Line

A straight line that connects two or more price points and extends to the future. Trend lines will indicate whether net-demand or net-supply are increasing.⁴⁷

Having explored these common forms of data, in our upcoming primary research we are interested in pinning down exactly how they are used for decision-making in finance. Specifically, how do users decide when to drill down from a big picture pattern

to a finer level of detail? What level of detail is needed and what details are ignored? When do users move on from one visualization to a next? For historical data, are different time scales used more frequently than others? How important are real-time updates to data? Do users switch back and forth between different data sets, or examine them sequentially? Our next steps include conducting contextual inquiry to examine our users' processes to answer these questions.

Information of Interest

"Anything you say about an investment you need to back up"⁴⁸

Financial experts work in such a large number of different industries. Although we cannot be exhaustive in our catalogue of every job role and responsibility in the financial domain, in speaking with Tepper Business School students, we found the following sample of some of the important kinds of information used in their previous jobs to make buy/sell recommendations and providing ratings for a sector/industry:

- Commodity prices
- Stock prices
- Currency trading
- Country GDPs
- Trade imbalances
- Growth rates

Through contextual inquiry with financial experts, we hope to expand on both the types of information of interest and the ways they are used to make decisions.

Considerations Going Forward

"There is no such thing as an "at-a-glance" chart... everything has to be learned"³¹

- Information can change in real time
- People will view the same information in chart and table form
- Quantifying visual contrast is difficult³¹
- Interaction may be able to enhance contrast³¹
- The same visualization & data may be used by different people for different tasks³¹
- Can we customize an individual graph for different scenarios of use?
- How can we use the principle of under-design to allow for our product to be used for unanticipated tasks?⁴⁹

| accessibility technology

Screen Readers

Presently, there are many solutions available for people with visual impairments (PWVI) to navigate screen-based interfaces. There are many screen readers which translate visual and text elements to speech or outputs them to refreshable braille displays. There are several popular options on the market, such as Microsoft Narrator for Windows, Apple VoiceOver for iOS and macOS, Text-To-Speech for Google's Chrome OS and Android, as well as 3rd party offerings such as JAWS.

Screen Readers work by reading the text that is present on screen. In addition, they handle graphical elements by reading labels (known as alt-text or accessibility labels) that are provided by the developer of the software product. Some screen readers let users caption their own images. In addition, websites have options to add ARIA Landmarks which allows visually impaired users to better navigate web pages and understand content without having to go through each individual element. ARIA Landmarks allows developers to categorize content and for users to better discern what is actually on a web page. For example, a developer could add an ARIA Landmark for the navigation on the website and another for the content.

While screen readers are great for text-based content, they're not so great for media based content. If developers do not provide alt-text or accessibility labels, then vision impaired users do not have access to that content. For example, with major social media websites such as Twitter encouraging more video and visual content, visually impaired

users feel as if they are no longer able to be a part of that network⁵⁰. Finally, screen readers can't read any form of graphs without developer intervention. Some companies have focused on making screen reader compatible graphs, but, currently, there are no standards or ubiquitous way of implementing graphs for the visually impaired.

There are several emerging solutions for data visualizations out there. For example, SAS's screen reader solution uses sonification to visualize the graph for users. In addition, Describler (<http://describler.com/>) is another solution that uses screen reading to give users the gist of the data as well as other statistical information about graphs. While these solutions are not universally accepted, they give us a good idea of what people in industry are using and trying to solve this complicated problem.

Typing Feedback

Some systems give feedback when typing. For example, on iOS, when a person type letters, the system reads the words out loud.

Speak Screen

In iOS, users have the option to select an area on the screen and have it be read out loud. This feature is very useful for reading passages in a book or reading your notes out loud again.

Embossing

Another technique in the accessibility space is to use Embossing for content. Embossing allows you to create raised or depressed surfaces on content such as paper. There are some exciting applications for this in the accessibility field. For example, LightHouse SF is creating embossed maps of the BART train system in San Francisco for the blind⁵¹. Learning these maps helps visually impaired users navigate the world and travel to places like never

Dynamic Braille Displays

One new creation is the use of Dynamic Braille displays. These displays have a row of braille that is dynamically generated to fit content and is used in conjunction with screen reader products such as JAWS or VoiceOver. These displays can be quite expensive and can vary from \$3500 to \$15000 depending on the number of characters displayed in the charts. These devices are more prevalent among the deaf-blind community where text-to-

speech really isn't an option. These dynamic displays are fantastic for type but still aren't great for visual content like graphs.



A dynamic braille terminal

Haptics and Sonification Literature

Researchers are working to help improve the current situation and better bring visual content to the visually impaired. Many Researchers are focusing on using haptic and sonification technology to bring more content to the visually impaired. For example, researchers at the University of Toronto have worked together to create a haptics system for smartphones that can give users locational feedback as well as intensity. This means that users can get haptic feedback to turn left on the left side of the phone when their maps app tells them they

need to turn or that their swipe gesture feels like it's following them along the page. In addition, there have been other projects that have used haptic feedback to give visually impaired users access to something akin to a dynamic braille display. In addition, researchers have created solutions to help visually impaired people navigate spaces using their smartphones. One set of researchers at University of Toronto created a GPS system that uses relative haptic feedback to give blind users a way to navigate their surroundings. In addition, another set of researchers at UMBC used sonification for the same task and found promising results as well.

We found some key insights from these systems, mainly that:



It's hard for me to keep track of a large set of sound

"You have to listen to the feedback multiple times to make a correction"



It's hard for me to make complex gestures and shapes

Visually Impaired users are able to perform simple one handed gestures on smartphones



I have more privacy when I use haptic features

Haptics can allow for more discrete forms of communication



I need to pay more attention when I use sound-based solutions for work

"Focusing on two things [pitch and stereo] at the same time was hard"

emerging technology survey

Designing with Emerging Technology

As Gordon Moore predicted in 1965, computer chips are continuously getting smaller, cheaper, and more accessible everyday.⁵² With that comes a burst of innovation that at times can seem overwhelming with a constant influx of new products and services. Many new startups seem to be producing what seems like trivial and unnecessary products: rings that buzz when you get a text message, VR consoles, an endless number of different courier services etc.⁵³

The problem with this assumption is that often we think of the standard user as an able-bodied, not impaired individual. In doing this, we forget that the world is filled with differently abled people to which these products might not be used for laziness and entertainment but for essential daily activities.⁵⁴

What we have learned so far in our research on the visually impaired community is that most often, those who are differently abled prefer to use existing, ubiquitous technologies, instead of technologies specially tailored to them. We have also learned that in order to ensure that new assistive technologies are maintained, updated, and profitable, the technologies are designed for the disability first, but then are scaled to make them useful to everyone. We hope to explore existing emerging technologies to see how they can be beneficial to someone who is visually impaired. In doing this, we hope to design a product that the visually impaired community wants to use and that will continue to be well supported and pervasive in society.

	Input			Output			
	Touch	Voice	Position or Rotation	Haptics	Sound	Visual	
HTC Vive	•		•	•	•	•	Virtual Reality
Oculus Rift	•		•	•	•	•	
Samsung Gear VR	•		•		•	•	
Playstation VR	•		•	•	•	•	
Daydream	•		•		•	•	
Google Cardboard	•		•		•	•	
Hololens		•	•		•	•	Augmented Reality
Google Tango	•		•		•	•	
Perception Neuron Suit			•				Gesture
Leap Motion			•				
Tanvas	•			•			Haptic Touchscreens
Senseg	•			•			
HAP2U	•			•			
Ultrahaptics			•	•			Mid-air Haptics
Lamsaptic			•	•			
Microsoft Surface Dial	•			•			Tactile Computer Accessories
Dell Totem	•						
PowerMate Media Control Knob	•						
X-keys® XK-12 Jog & Shuttle	•						
Ringly	•			•			Haptic Wearables
Navigate Jacket			•	•			
Apple Watch	•		•	•	•	•	
Fan Jersey				•			
HP Sprout	•					•	3D Scanning
RealSense	•		•				
Structure Sensor	•		•				
Amazon Echo/Dot/Tap	•	•			•	•	CUIs
Google Home	•	•			•	•	

Virtual Reality

VR Technologies

Many virtual reality headsets utilize position tracking, positional/3D sound, and controllers with haptic feedback. After reading several papers, we hypothesize that we can leverage these non-visual aspects of a traditionally visual platform to convey complex data.



- The **HTC Vive** is Valve's high fidelity tethered VR headset. The headset comes with two tracked controllers with haptic feedback. Additional accessories are available for audio and object tracking. \$800.⁵⁵



- The **Oculus Rift+Touch** is Facebook's consumer grade Oculus VR headset. The headset comes with two haptic feedback controllers. Additional accessories including earphones and a remote are available. \$600.⁵⁶



- The **Samsung Gear VR** is Samsung's tether-free VR headset. This headset runs on 6 different models of Samsung phones. While it doesn't have a controller, the headset has a touch pad and two buttons on the side for more complex interfacing. \$100 + phone.⁵⁷



- **Playstation VR** is Sony's high-resolution tethered headset. \$400.⁵⁸



- **Daydream** is Google's VR headset for their Pixel phone. The headset comes with a remote. \$80.⁵⁹

- **Google Cardboard** is Google's open source spec for a mobile phone VR viewer. Premade versions



can be purchased at around \$10+ for a cardboard version and \$20+ for a plastic version.⁶⁰

Relevant VR Experiences

- Jamie Soar, a legally blind man from England who suffers from Retinitis Pigmentosa, was able to use the HTC Vive to see clearly for the first time because the headset put two 1200 x 1080 screens with a 90 Hz refresh rate close enough to his eyes to overcome his extreme nearsightedness.⁶¹
- Vivid vision uses a number of different headsets

Augmented/Mixed Reality Devices

AR/MR Technologies

Like Virtual Reality, Mixed Reality devices can use input such as position and rotation to get data, and haptics and 3d sound to display data. In addition, AR/MR experiences utilize the visual data from the world around the user.



- **HoloLens** includes a Locatable Camera world-facing camera mounted on the front of the device which enables apps to see what the user sees.⁶³ HoloLens also includes Cortana, Microsoft's virtual assistant.⁶⁴
- **Google Tango** is an augmented reality computing platform which "uses computer vision

to enable mobile devices, such as smartphones and tablets, to detect their position relative to the world around them without using GPS” allowing “experiences that include indoor navigation, 3D mapping, physical space measurement, environmental recognition, augmented reality, and windows into a virtual world.”⁶⁶

Relevant AR/MR Experiences

- Using the camera on the back of a phone, devices like Google Cardboard can deliver “see-through” augmented experiences. Many people have used this to relay the incoming camera data from the phone, but with magnification distortions overlaid.

	Company	Haptic Controller	Wireless	Position Tracking	Tracking system	Built-in camera	Built in Sound	VR	AR/MR
HTC Vive	Valve	•		•	Lighthouse		Additional Audio Strap	•	
Oculus Rift+Touch	Facebook	•		•	Optical		•	•	
Samsung Gear VR	Samsung		•	Head Only		•	Phone Only	•	
Playstation VR	Sony			•	Optical			•	
Daydream	Google		•	Head Only			Phone Only	•	
Google Cardboard	Google		•	Head Only			Phone Only	•	
Hololens	Microsoft		•	•	Inside-out	•	•		•

Motion/Gesture Capture

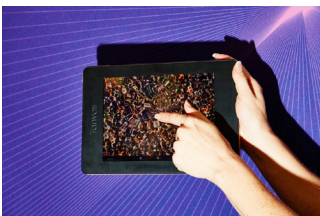
Gesture input might provide a different way of exploring data.



- The **Perception Neuron Suit** provides fine grain positional and gesture input. The gloves can be worn independent of the full body suit. This is solely an input device.⁶⁷
- The **Leap Motion** is a small, usb device that plugs into computer and can provide gesture input through hand tracking. It can also be mounted to a VR headset.⁶⁸

Haptic Touchscreens

We have discovered that iPhones are popular in the visually impaired community because they have tactile edges which provide context to their users. However, iPhones only have binary haptic feedback (off and on). We have requested several development kits from startups who are creating touchscreens that provide detailed haptic feedback so that we can explore this modality of delivering data.



- **Tanvas** uses "electrostatics to control friction [to] create virtual touch." Tanvas can recreate the feeling of "the edges of keys, the snap of a toggle switch, the swipe of a turned page, the direction and magnitude of impacts in a game." (Dev Kit Requested)⁶⁹



- **Senseg** is a display that can “reproduce the texture and ‘feel’ of surfaces, apart from reproducing moving images” by “making and manipulating an attractive force between the finger and that electrostatic field. The screen can reproduce surface textures and create the sensation of vibrations” (No Dev Kit Available)⁷⁰
- **HAP2U** enables the use of textures and “finger force” through the use of “ultrasonic vibration generated thanks to piezoelectrical actuators” (Development Kit Requested)⁷¹

Haptic SDKs

Although phones only contain on and off modes for vibration, we might want to explore what information we can provide using this approach.

- **TouchSense** gives developers “full control over haptic playback in Android devices.” It provides a library of effects and the ability to create your own. (Free to try)⁷²
- **Vibration API** allows web applications to access the existing haptic hardware in devices if it already exists and does nothing if it doesn't.⁷³

Haptic Consoles

Many gaming consoles provide haptic feedback to enhance the experience. We wanted to look at the newest innovations in these technologies.



- The **Nintendo Switch** is Nintendo's newest gaming console which boasts the ability to be both a home and mobile console. The controllers contain a new technology called HD Rumble that provides high fidelity haptic feedback. The touch-screen uses the TouchSense SDK to provide haptic feedback on the 10-point capacitive touch display.⁷⁴

Midair Haptics

Mid-air haptics provide haptic feedback without the limitations of a controller or wearable.



- **Ultrahaptics** "enables users to receive tactile feedback without needing to wear or touch anything." Using the table-top device, "users can 'feel' touch-less buttons get feedback for mid-air gestures or interact with virtual objects." (Dev Kit Ready, Cost: \$2000)⁷⁵
- **Lamsaptic** creates "holographic touch" through "high resolution air pressure fields"⁷⁶

Tactile Computer Accessories

These accessories provide alternate ways of interfacing with traditional platforms.



- Microsoft's **Surface Dial** is recognized by Surface devices when it is placed on the screen. It uses haptics to provide feedback as the dial turns.⁷⁷
- Dell's **Totem** is similar to the Surface Dial but comes in two sizes. It was released at CES 2017⁷⁸
- Griffin's **PowerMate Multi-Media Control Knob** is an affordable usb dial. It does not provide haptic feedback. There are lots of similar products.⁷⁹
- The **X-keys® XK-12 Jog & Shuttle** is a device with 12 programmable keys (can be taken out), an infinite rotating Jog wheel with 10 indents,



Wearables with Haptic Feedback

These devices provide real time data through nonvisual means.



- **Ringly** is a connected jewelry device (ring or bracelet) that provides haptic feedback and light notifications. Ringly connects to your phone via Bluetooth and lets you "receive customized mobile notifications through vibration and a

subtle color-coded light.” Users can program up to 7 different combinations⁵³

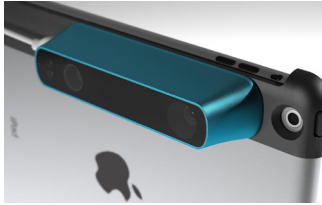
- The **Navigate Jacket** syncs with your phone’s navigation and taps your shoulders to give you directions.⁸¹
- Among the **Apple Watch**’s sophisticated features, it includes haptic feedback for notification and force touch.⁸²
- The **Fan Jersey** “communicates when there are interceptions, turnovers, touchdowns, fumbles from the other team,” etc. using haptic

3D Scanning



These devices allow for 3D inputs.

- The **HP Sprout** is a desktop computer with a 20-point capacitive Touch Mat and RealSense sensor meant to make 3D scanning everyday objects seamless.⁸⁴
- The **RealSense** “technology uses various sensing technologies to achieve depth perception, 3D imaging, interior mapping, and feature tracking.” It can be used to capture and scan 3D objects and environments.⁸⁵
- The **Structure Sensor** “adds precise 3D vision



to your mobile device, giving it a new way of understanding the world around it." This enables a "growing set of advanced capabilities like 3D scanning, indoor mapping and mixed reality experiences."⁸⁶

3D Sound Software

This technology allows for the sculptural creation of 3D sound.

- **Auro 3D** "creates a spatial sound field by adding a height layer around the audience on top of the traditional 2D surround sound system."⁸⁷

Conversational User Interfaces

These physical connected devices allow for audio commands as inputs.



- **Amazon Echo** is a hands-free speaker you control with your voice that connects to the Alexa Voice Service.⁸⁸



- **Google Home** is a voice-activated speaker powered by the Google Assistant.⁸⁹

| references

References

1. Common Eye Conditions and Causes of Blindness in the United States. (n.d.). Retrieved March 23, 2017, from <https://nfb.org/images/nfb/publications/books/books1/ifbld10.htm>
2. Visual impairment and blindness. (n.d.). Retrieved March 23, 2017, from <http://www.who.int/mediacentre/factsheets/fs282/en/>
3. Facts About Refractive Errors. (n.d.). Retrieved March 23, 2017, from <https://nei.nih.gov/health/errors/errors>
4. Blindness Statistics. (n.d.). Retrieved February 24, 2017, from <https://nfb.org/blindness-statistics>
5. Key Definitions of Statistical Terms. (n.d.). Retrieved February 24, 2017, from <http://www.afb.org/info/blindness-statistics/key-definitions-of-statistical-terms/25>
6. Visual impairment. (2017, March 23). Retrieved March 23, 2017, from https://en.wikipedia.org/wiki/Visual_impairment
7. Vision Tests. (n.d.). Retrieved March 23, 2017, from <http://www.webmd.com/eye-health/vision-tests#1>
8. Visual Acuity: What is 20/20 Vision? (n.d.). Retrieved March 23, 2017, from <http://www.aoa.org/patients-and-public/eye-and-vision-problems/glossary-of-eye-and-vision-conditions/visual-acuity?sso=y>

9. Common Eye Disorders. (2015, September 29). Retrieved March 23, 2017, from <https://www.cdc.gov/visionhealth/basics/ced/index.html>
10. Marilyn Haddrill; contributions and review by Charles Slonim, MD. (n.d.). Visual Field Testing. Retrieved March 23, 2017, from <http://www.allaboutvision.com/eye-exam/visual-field.htm>
11. Facts About Color Blindness. (n.d.). Retrieved March 23, 2017, from https://nei.nih.gov/health/color_blindness/facts_about
12. The State of Vision, Aging, and Public Health in America: How Are We Doing? (n.d.). Retrieved March 23, 2017, from <http://www.visionaware.org/blog/visionaware-blog/the-state-of-vision-aging-and-public-health-in-america-how-are-we-doing/12>
13. Court, H., McLean, G., Guthrie, B., Mercer, S. W., & Smith, D. J. (2014, October 17). Visual impairment is associated with physical and mental comorbidities in older adults: a cross-sectional study. Retrieved March 23, 2017, from <https://www.ncbi.nlm.nih.gov/pubmed/25603915>
14. W. (n.d.). What are the laws that cover digital accessibility? Retrieved March 23, 2017, from <http://www.rehab.cahwnet.gov/DisabilityAccessInfo/What-are-the-Laws-that-Cover-Digital-Accessibility.html>

15. Section 508 Compliance. (n.d.). Retrieved March 23, 2017, from <http://www.afb.org/info/programs-and-services/technology-evaluation/section-508-compliance/125>
16. Lewis Wiener and Alexander Fuchs, Sutherland Asbill & Brennan LLP. (n.d.). Trending: ADA Website Accessibility Lawsuits - Law360. Retrieved March 23, 2017, from <https://www.law360.com/articles/871491/trending-ada-website-accessibility-lawsuits>
17. U.S. Census Bureau, Demographic Internet Staff. (2013, March 14). Data. Retrieved March 23, 2017, from <http://www.census.gov/people/disabilityemptab/data/>
18. Sina Bahram, Multimodal eyes-free exploration of maps: TIKISI for maps (2013), ACM SIGACCESS Accessibility and Computing, Retrieved March 23, 2017, from <http://dl.acm.org/citation.cfm?id=2505402>
19. Blindness in America. (n.d.). Retrieved March 23, 2017, from <https://actionfund.org/blindness-america>
20. O. (n.d.). Web de la ONCE. Retrieved March 23, 2017, from <http://www.once.es/new/otras-webs/english/Briefhistory>
21. Blind massages of Southeast Asia. (2013, August 31). Retrieved March 23, 2017, from <http://www.worldette.com/ignite-your-travel->

life/travel/2011/blind-massages-south-east-asia/

22. (n.d.). Retrieved March 23, 2017, from <http://www.nib.org/>
23. Disabilities, Opportunities, Internetworking, and Technology. (2017, March 06). Retrieved March 23, 2017, from <http://www.washington.edu/doit/>
24. PA.Gov. (n.d.). Retrieved March 23, 2017, from <http://www.dli.pa.gov/Individuals/Disability-Services/bbvs/Pages/default.aspx>
25. The Holman Prize for Blind Ambition. (n.d.). Retrieved March 23, 2017, from <http://lighthouse-sf.org/>
26. Visual Disabilities Low Vision. (n.d.). Retrieved March 23, 2017, from <http://webaim.org/articles/visual/lowvision>
27. Mankoff, J. (2016). Accessibility in HCI. Lecture. Social Model of Disability. (n.d.). Retrieved 2017, from https://en.wikipedia.org/wiki/Social_model_of_disability
28. Universal Design. (n.d.). Retrieved 2017, from https://en.wikipedia.org/wiki/Universal_design
29. VoiceOver. (n.d.). Retrieved 2017, from www.apple.com/accessibility/mac/vision/

30. Gleason, C. (2017). SME Interview [in person interview].
31. Witt, J. (2017). SME Interview [Skype interview].
32. Branham, S. M. (2015). The Invisible Work of Accessibility: How Blind Employees Manage Accessibility in Mixed-Ability Workplaces. *As sets* '15, 163-171. Retrieved 2017.
33. French, S. (1992). Simulation Exercises in Disability Awareness Training: a Critique. *Disability, Handicap and Society*, 7(3), 257-267. Retrieved 2017.
34. Flower, A. (2007). Meta-Analysis of Disability Simulation Research. *Remedial and Special Education*, 28(2), 72-79. Retrieved 2017.
35. Kiger, G. (1992). Disability Simulations: logical, methodological and ethical issues. *Disability, Handicap, and Society*, 7(1), 71-80. Retrieved 2017.
36. Dunphy, P. (2013). Gaining Support through Empathy and Awareness Exercises. Lecture presented at CSUN in California, Northridge.
37. Heat map. (2017, February 15). Retrieved March 22, 2017, from https://en.wikipedia.org/wiki/Heat_map

38. StockMapper. (n.d.). Retrieved March 22, 2017, from <http://www.stockmapper.com/?sort=chg>
39. Robbins, N. (2012, January 09). A Histogram is NOT a Bar Chart. Retrieved March 22, 2017, from <https://www.forbes.com/sites/naomirobbins/2012/01/04/a-histogram-is-not-a-bar-chart/#42f812206d77>
40. Histogram. (2017, March 16). Retrieved March 23, 2017, from <https://en.wikipedia.org/wiki/Histogram#/media/File:Tips-histogram1.png>
41. Bar Charts | Charts | Google Developers. (n.d.). Retrieved March 23, 2017, from <https://developers.google.com/chart/interactive/docs/gallery/barchart>
42. Sparkline. (2017, February 15). Retrieved March 23, 2017, from <https://en.wikipedia.org/wiki/Sparkline>
43. Introduction to Candlesticks. (2014, June 09). Retrieved March 23, 2017, from http://stockcharts.com/school/doku.php?id=chart_school%3Achart_analysis%3Aintroduction_to_candlesticks
44. Rose C. Antonio, Quarterly Financial Report, Company Statistics Division, US Census Bureau. (2009, January 08). US Census Bureau's Quarterly Financial Report Main Page. Retrieved March 23, 2017, from <https://www.census.gov/econ/qfr/>

45. Volume-by-Price. (2015, February 04). Retrieved March 23, 2017, from http://stockcharts.com/school/doku.php?id=chart_school%3Atechnical_indicators%3Avolume_by_price
46. Volatility Index (VIX). (2014, June 09). Retrieved March 23, 2017, from http://stockcharts.com/school/doku.php?id=chart_school%3Atechnical_indicators%3Avolatility_index
47. Trend Lines. (2014, December 15). Retrieved March 23, 2017, from http://stockcharts.com/school/doku.php?id=chart_school%3Achart_analysis%3Atrend_lines
48. Zalevsky, E. (2017). User interview. [In person interview].
49. Carmien, S. P., & Fischer, G. (2008). Design, Adoption, and Assessment of a Socio-Technical Environment Supporting Independence for Persons with Cognitive Disabilities. CHI.
50. Bliss, L. (2015, January 16). Maps That You Can Hear and Touch. Retrieved March 23, 2017, from <http://www.citylab.com/design/2015/01/making-better-maps-for-the-blind/384495/>
51. Morris, M. R. (n.d.). "With most of it being pictures now, I rarely use it": Understanding Twitter's Evolving Accessibility to Blind Us

ers[Scholarly project]. Retrieved from http://www-cs.stanford.edu/~merrie/papers/twitter_visual_chi2016.pdf

52. Smaller, Faster, Cheaper, Over: The Future of Computer Chips. John Markoff - https://www.nytimes.com/2015/09/27/technology/smaller-faster-cheaper-over-the-future-of-computer-chips.html?_r=0
53. Smart Jewelry and Accessories Ringly - <https://ringly.com/>
54. McGookin, D.K., and Brewster, S.A. (2006) MultiVis: improving access to visualisations for visually impaired people. In: Conference on Human Factors in Computing Systems, Montréal, Québec, Canada, 22-27 April 2006, pp. 267-270. ISBN 1595932984 (doi:10.1145/1125451.1125509)
55. VIVE™ | Discover Virtual Reality Beyond Imagination. <https://www.vive.com/us/>
56. Oculus Rift | Oculus. <https://www.oculus.com/rift/>
57. Gear VR. <http://www.samsung.com/global/galaxy/gear-vr/>
58. PlayStation VR. <https://www.playstation.com/en-us/explore/playstation-vr/>
59. Daydream. <https://vr.google.com/daydream/>

- 60. Google Cardboard. <https://vr.google.com/cardboard/>
- 61. Beyond Virtual Reality: HTC Vive VR Head set Helps A Legally Blind Man See Clearly For The First Time. Tech Times - <http://www.technimes.com/articles/180356/20161003/beyond-virtual-reality-htc-vive-vr-head-set-helps-a-legally-blind-man-see-clearly-for-the-first-time.htm>
- 62. Move Beyond the Eye Patch. <https://www.seevividly.com/>
- 63. Locatable camera. https://developer.microsoft.com/en-us/windows/holographic/locatable_camera
- 64. Cortana in more places. Microsoft - <https://www.microsoft.com/en-us/mobile/experiences/cortana/>
- 65. IrisVision - Low Vision Aids. <http://theirisvision.com/>
- 66. Tango. <https://get.google.com/tango/>
- 67. Perception Neuron by Noitom. <https://neuronmocap.com/>
- 68. Leap Motion. <https://www.leapmotion.com/>
- 69. Tanvas. <https://tanvas.co/developers/>

- 70. Senseg. <http://www.senseg.fi/index.php>
- 71. HAP2U - Touch & Feel what's on your screen. <http://www.hap2u.net/>
- 72. TouchSense SDK for Mobile Apps: Gaming. <https://www.immersion.com/products-services/software-development-kit-for-mobile-games/>
- 73. Vibration API. https://developer.mozilla.org/en-US/docs/Web/API/Vibration_API
- 74. Nintendo Switch™ - Official site – Nintendo gaming system. <http://www.nintendo.com/switch/>
- 75. A remarkable connection with technology. <https://www.ultrahaptics.com/>
- 76. LAMSAPTIC. <https://www.lamsaptic.com/>
- 77. Microsoft Surface Dial Changing the Game | Innovative PC Controllers. <https://www.microsoft.com/en-us/surface/accessories/surface-dial>
- 78. Dell's Canvas is like a Surface Studio without the PC. Jacob Kastrenakes - <http://www.theverge.com/2017/1/5/14128434/dells-canvas-touchscreen-display-announced-ces-2017>
- 79. PowerMate USB. <https://griffintech.com/us/powermate>

80. X-keys XK-12 Jog & Shuttle USB Keypad. P.I. Engineering - <http://xkeys.com/xkeys/xk12JSH.php>
81. NAVIGATE. <http://wearablex.com/navigate/>
82. Watch. <http://www.apple.com/watch/>
83. Fan Jersey (X). <http://wearablex.com/fan-jersey/>
84. Sprout Pro by HP (ENERGY STAR). <http://store.hp.com/us/en/pdp/sprout-pro-by-hp-%28energy-star%29-p-h0gm0aa-aba--1>
85. Intel® RealSense™ Technology. <http://www.intel.com/content/www/us/en/architecture-and-technology/realsense-overview.html>
86. 3D scanning, augmented reality, and more for mobile devices. <https://structure.io/>
87. Auro-3D. <http://www.auro-3d.com/>
88. Amazon Echo. <https://www.amazon.com/Amazon-Echo-Bluetooth-Speaker-with-WiFi-Alexa/dp/B00X4WHP5E>
89. Made by Google. <https://madeby.google.com/home/>

team b7g 2017 is:

clare marie carroll

conrad bassett-bouchard

emily saltz

jayanth prathipati

nora tane

