WHAT AM I MISSING?

IMAGE.JPG

IMAGINE

You have to make an **investment decision** based on an untitled **image you can't see**.

UNDERSTANDING FINANCIAL DATA NONVISUALLY

IMAGE.JPG

USEFUL TERMS TO KNOW

USEFUL TERMS TO KNOW

ACB: American Council of the Blind. Nationwide organization with the goal of helping people with visual impairments achieve independence and equality.

AFB: American Foundation for the Blind. Major non-profit organization for people with vision loss. Provides people with vision loss and their families with support for independent living.

AT: Assistive Technology. Tools used to maintain, improve, or increase the capabilities of people with disabilities. Frequently AT is used to expand the capabilities of people without disabilities (see Universal Design).

BVRS: Blind & Vision Rehabilitation Services of Pittsburgh. A local Pittsburgh division of the ACB.

CI: Contextual Inquiry. A user-centered research and interview method. Part of Contextual Design.

NFB: National Federation of the Blind. Major non-profit organization for people with vision loss. Focus on raising the expectations of people who are blind.

Numeronym: A number-based word in which the first and last letters of the word are used. The intermediary letters are counted and replaced with the number of characters. One common example in the accessibility community is #a11y ("ccessibilit" = 11 characters).

OVR: Office of Vocational Rehabilitation. Governmental organization that provides support for people with disabilities to maintain or obtain employment.

PWVI: People or Person With Visual Impairments. Because "blind," encompasses a wide range of visual abilities, we use this term throughout the book to include legally blind people with varying levels of vision.

Screen Reader: Screen reader software generates synthesized speech based on text and other content in a digital interface. Many visually impaired users interact with applications on mobile and desktop devices through screen reader audio.

SME: Subject Matter Expert

Universal Design: Designs that create accessible environments and tools for both people with and without disabilities.

EXECUTIVE SUMMARY

Visual cues in charts are essential in financial decision-making. The sudden plummet of a stock price, the steady rise of an index fund, the outlier within a sector: these are all visual triggers that sighted finance experts regularly use to identify investment opportunities. This report explores ways in which inaccessible data visualizations disadvantage people with severe visual impairments from entering or remaining in the finance industry. We also explore the ways that people with visual impairments successfully wrangle data with existing assistive technologies.

We identify the existing finance workflows of people with blindness and compare them to workflows of sighted finance experts. From our findings, we identify several opportunity areas to provide better context, navigation, and confidence, and control to people accessing financial data across the sighted spectrum.

TABLE OF CONTENTS

PROBLEM SPACE

Even people with full vision need access to data nonvisually, for example while multi-tasking or in conversation. Our team thinks about the role of universal design to create a tool for use by visually impaired and fully sighted populations alike. Finally, we consider the steps we can take as sighted designers to understand the needs of PWVI.

Designing for Inclusion

We approached this project aspiring to the ideals of universal design, in particular through the lens of the social model of disability. The social model of disability posits that a person is only disabled by lack of appropriate tools in their social environment.[1] We believe that PWVI are only disadvantaged in finance by the current state of tools for assessing financial data.

We also aspire to the ideals of universal design[2]: that something designed for people with disabilities may help the larger population as well. For example, though curb cuts on sidewalks were originally designed for people with disabilities using wheelchairs, they've been adopted for other uses, like rolling shopping carts, strollers, and suitcases.

74% **of working aged people with visual impairments are unemployed.[3]**

33% **of people acquire some form of vision-impairing disease by 65.[5]**

3.8% **of the world's population is legally blind.[4]**

0.3% **of STEM degrees are earned by people with visual impairments.[6]**

Understanding as sighted designers

As a team of five sighted designers, we began by asking ourselves what we could do to learn about the existing abilities and challenges of people with visual impairments. Research has shown a profound disconnect between the perceived and actual abilities of people with visual impairments, finding that sighted workers misjudged the majority of issues that their visually impaired coworkers encounter in the workplace.[7]

Through interviews with a range of accessibility academics, occupational therapists, and users with visual impairments, we pieced together an understanding of the professional context of visually impaired users. At the same time, we interviewed sighted finance experts to understand the role of visualizations play in the investment decisions they make.

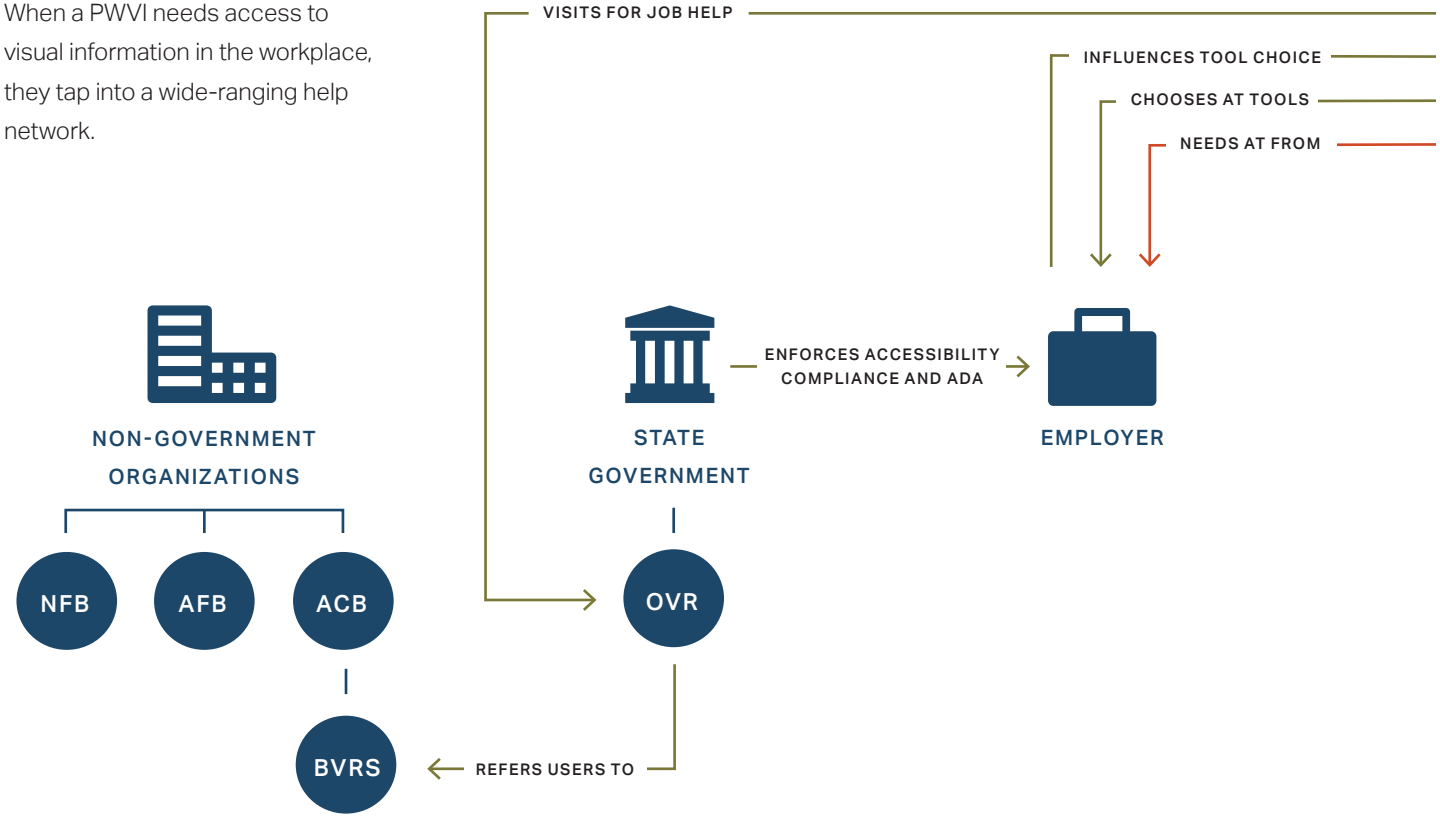
"Bank of America ATM Drive Thru" (CC BY 2.0) by Rusty Clark ~ 100K Photos

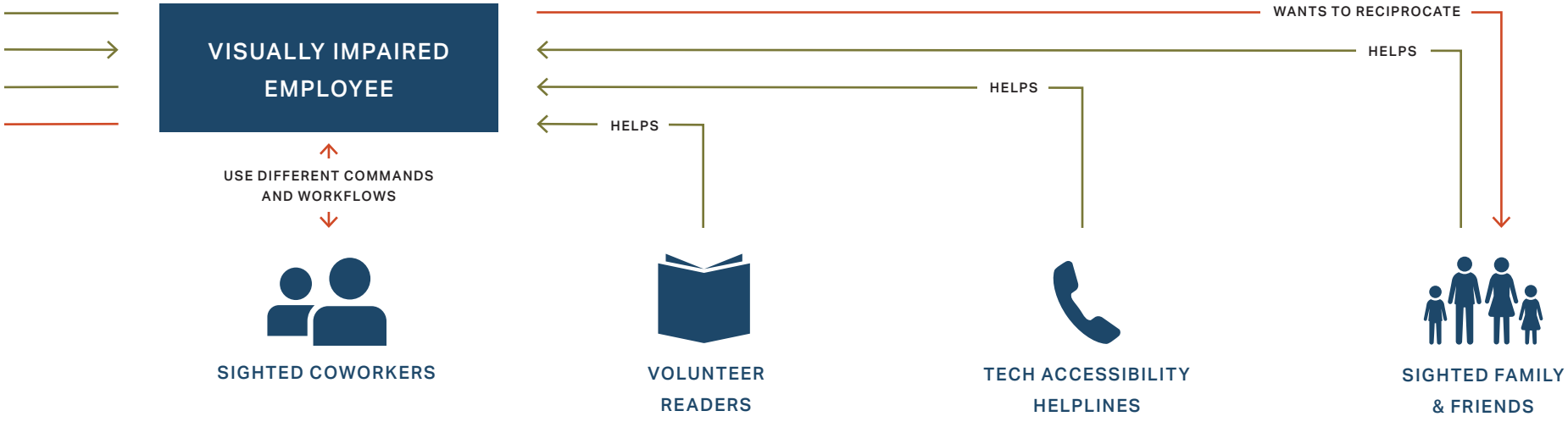
DOMAIN

Where do workers with visual impairments turn for help? How does it feel for a highly-educated employee to lose their sight in the workplace? What choices do they face? In addition, we assessed the financial problem space by considering the visual cues that finance experts use, and how the equivalent data is currently accessible to PWVI.

HELP NETWORK

When a PWVI needs access to visual information in the workplace, they tap into a wide-ranging help network.





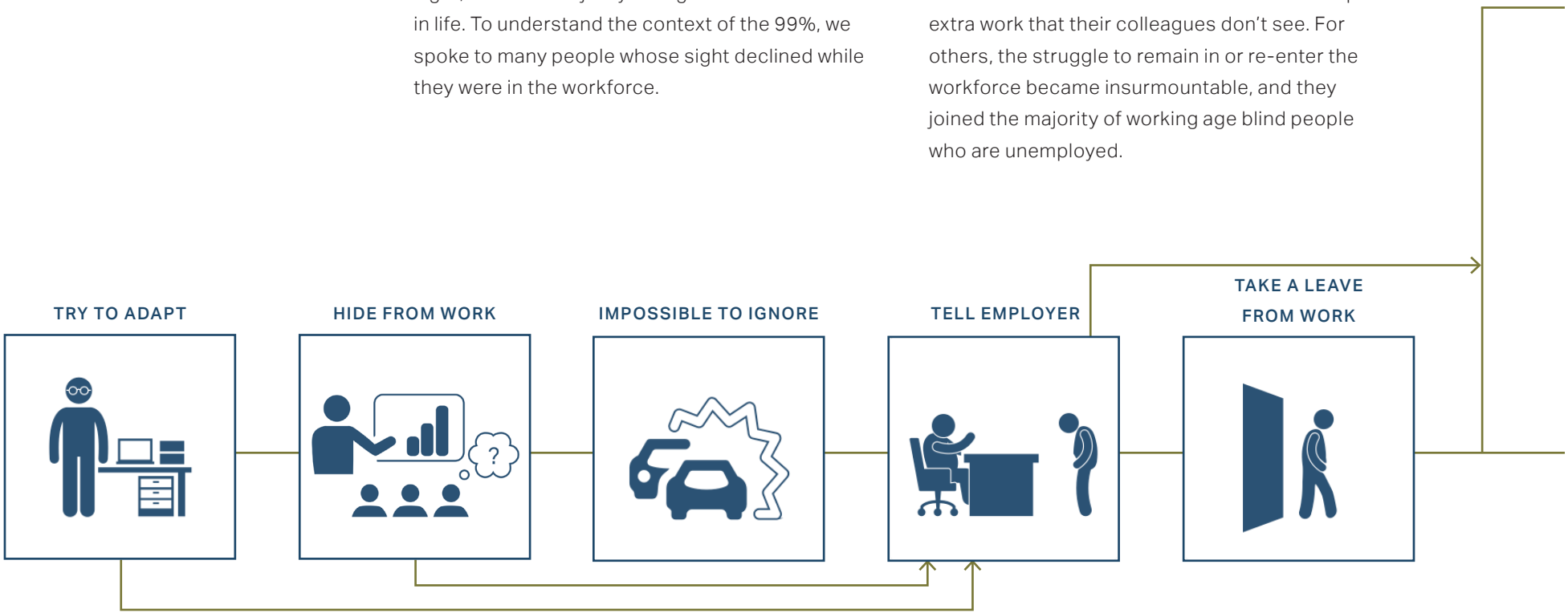
For PWVI, asking for help in the workplace often means risking that coworkers will view them as less competent. In addition, sighted coworkers may not always provide the right help as they navigate technologies differently. As a result, many PWVI only turn to help from coworkers as a last resort.

As with anyone asking for help, PWVI don't want to place an unreasonable burden on their social network. When they do need help understanding inaccessible content, they try to return the favor.

VISION AND CHOICE

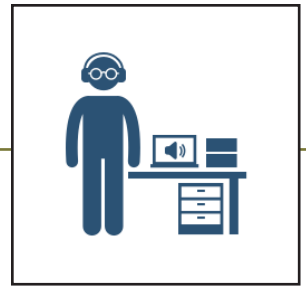
When people lose their sight in the workplace, they face a series of difficult choices. Only 1% of people living with blindness were born without sight,[8] with the majority losing their vision later in life. To understand the context of the 99%, we spoke to many people whose sight declined while they were in the workforce.

Those who remained employed describe the extraordinary lengths they go to avoid appearing incompetent to sighted coworkers, including hours of invisible work done each week to adapt: extra work that their colleagues don't see. For others, the struggle to remain in or re-enter the workforce became insurmountable, and they joined the majority of working age blind people who are unemployed.



As few as 26% of working age people who are blind in the United States are employed.[3] If there were better assistive technologies, would more people be in the workplace?

LEARN ASSISTIVE TECH SPONSORED BY WORK



EMPLOYED

Shift to a **more accommodating role** at company

Stay in the **same role**, now with the aid of assistive technology

Find a **new accommodating job**, for example at a call center

LEARN ASSISTIVE TECH INDEPENDENTLY

SEARCH FOR NEW JOB

LOSE HOPE

UNEMPLOYED

Live on **government disability assistance**

Take an **early retirement**

Focus on **family** or other goals

FOLLOWING THE INFORMATION SCENT

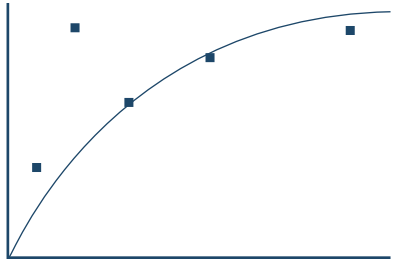
Sighted finance experts have told us time and time again: each investment decision is different and there are different pieces of information that trigger interest in a security or company. Many of these indicators immediately pop out in data visualizations. In particular, 6/6 finance experts we spoke to used simple line charts like stock price as a starting point, using visual changes as jumping off points to perform more complex analysis with raw data in tables. In contrast, at best, PWVI have access to data through tables, which they navigate value by value using a screen reader. At worst, if charts are included as images, a screen reader may just read off an ambiguous "image.jpg" without any title or description, or else skip over an image entirely.

That means that PWVI don't benefit from the visual cues that trigger a sighted user to dig deeper into a story, such as model outliers, dramatic peaks or valleys, comparisons of securities, and intersection points.

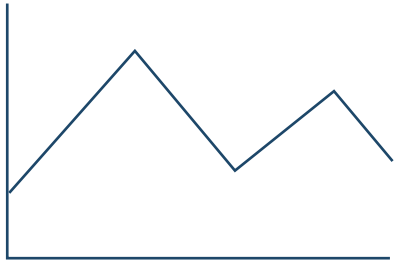
How quickly can you judge which information is most important?

Date	Open	High	Low	Close	Volume
Apr 18, 2017	141.27	141.90	140.61	140.96	14,807,472
Apr 17, 2017	139.76	141.55	139.75	141.42	11,519,663
Apr 13, 2017	139.62	140.58	139.33	139.39	10,965,614
Apr 12, 2017	139.72	140.40	139.44	139.58	11,612,456
Apr 11, 2017	140.80	141.03	138.81	139.92	16,638,087
Apr 10, 2017	141.00	141.43	140.63	141.04	9,039,366
Apr 7, 2017	141.20	141.55	140.24	140.78	11,818,341
Apr 6, 2017	142.11	142.22	140.91	141.17	15,103,426

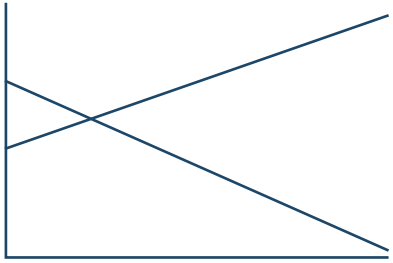
How quickly can you judge which information is most important?



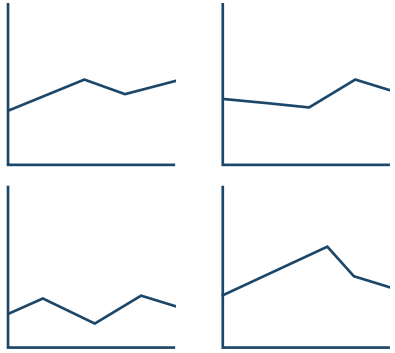
Model Outliers



Dramatic Peaks & Valleys



Intersection Points



Comparisons of Securities

GOALS AND QUESTIONS

Goals

In our domain analysis, we saw that "people with visual impairments in finance" encompasses people across the spectrums of sight and prior financial knowledge. We scoped our focus to the following goal:

> *We want to create a user interface to help **financially literate people who are blind** confidently investigate **market trends** to identify ideal entry/exit points for **investment decisions**.*

We scheduled interviews with 16 users: 10 people with blindness who accessed financial data on a regular basis. Five were blind from birth or early childhood, and five blind from degenerative vision loss which advanced later in life. We also spoke with six financial users: four who professionally invest and two who manage personal investments on a regular basis.

Questions

Before we could design a user interface, we had to fully understand both the accessibility and financial visualizations domains. Some of our guiding questions for our research process were:

1) How do people with visual impairments understand and use data?

2) What data and visualizations are most important to finance experts?

3) How do people across the sighted spectrum communicate with each other?

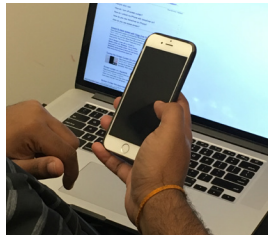
TIMELINE

QUESTION STORMING

We worked with our client to create a list of questions to set the project scope.

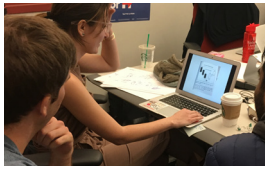
EMPATHY EXERCISE

After researching best practices in empathy exercises, we targeted our exercise to familiar finance tasks using a screen reader, creating a protocol designed to reduce prejudice and better understand the barriers that PWVI face.



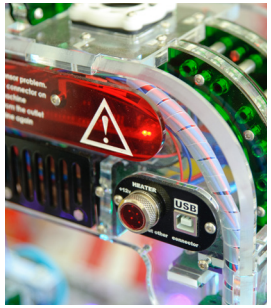
LITERATURE REVIEW

We read a large assortment of academic research papers on topics ranging from accessibility, vision loss, cognition, and data visualization.



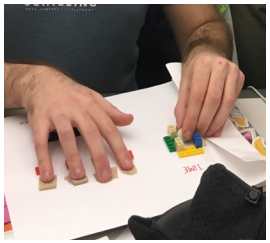
EMERGING TECH SURVEY

We did an emerging technology survey to make sure we were apprised of new technologies that could help our users, such as haptic and tactile interfaces and 3D sound and data sonification experiments.



EARLY PROTOTYPE

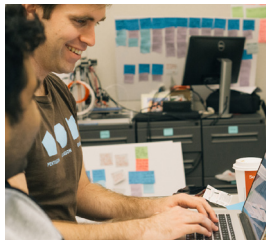
We created early prototypes to explore the forms of potential solutions. We experimented with tactile materials and audio cues, testing internally with blindfold simulation to identify directions for higher fidelity prototyping and user testing.



JANUARY — FEBRUARY — MARCH

EXPERT INTERVIEWS

We conducted interviews with accessibility and emerging technology researchers as well as industry accessibility and finance technologists in order to get a better understanding of our problem space.

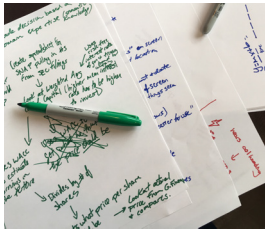


USER INTERVIEWS

We conducted six interviews with finance experts and 10 interviews with users who are legally blind, five from birth or childhood and five who lost their sight later in life.

INTERPRETATION SESSIONS

In order to synthesize findings from our user interviews, we interpreted our notes by modeling user workflows and identifying user breakdowns and attitudes.

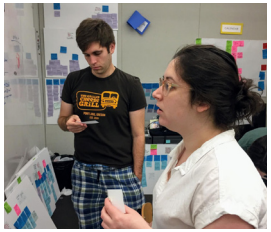


AFFINITY DIAGRAM

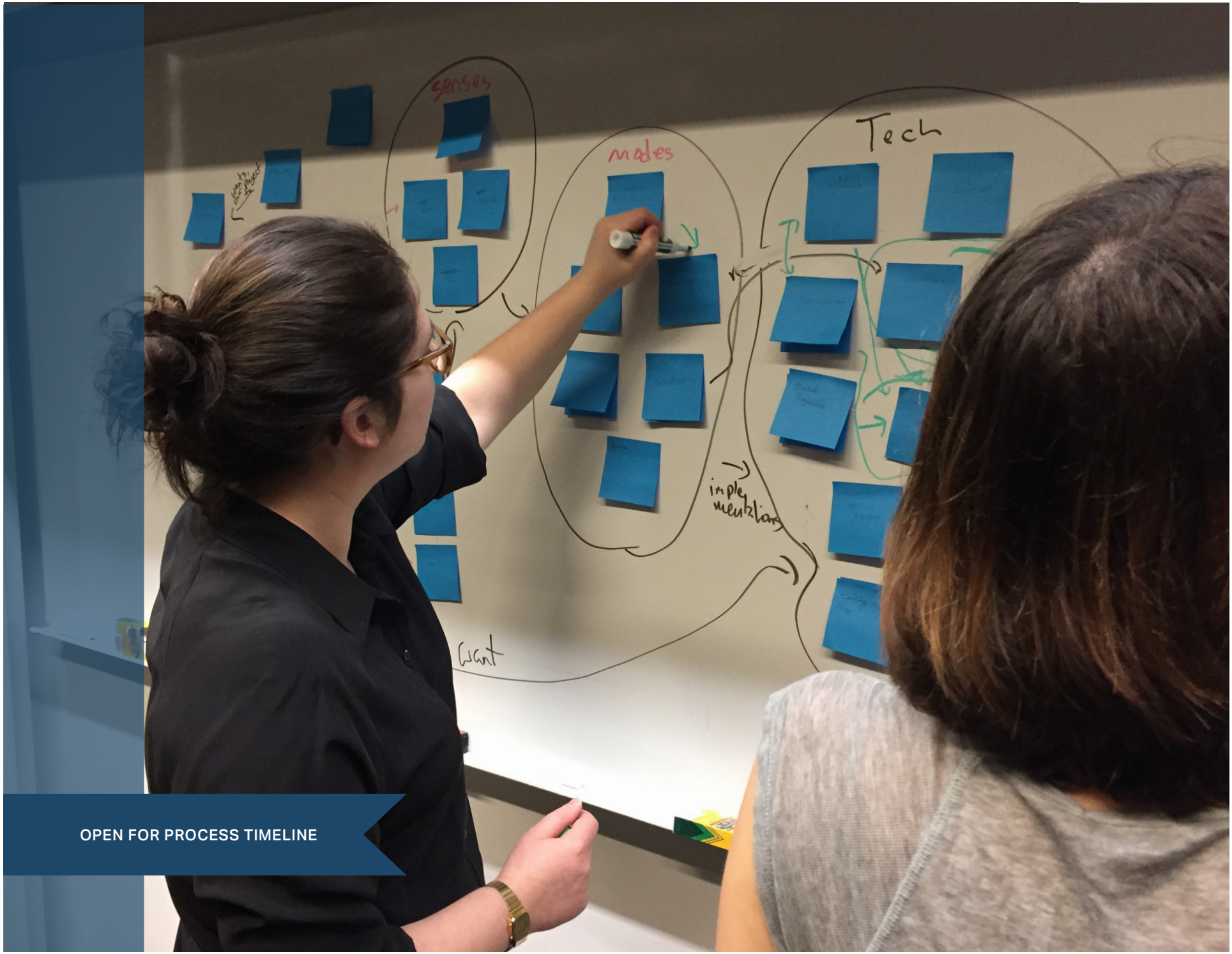
From over 600 notes created in our interpretation sessions, we clustered notes into layers of logical groupings developed from the bottom up. Notes were color-coded by the user type in order to see which clusters applied to both sighted finance experts and PWVI.

IDEATION AND VISIONING

We extracted insights from our affinity diagram and began ideating on possible solutions.



APRIL — MAY



OPEN FOR PROCESS TIMELINE

INSIGHTS

INSIGHT

1

People who help me are interfaces, too.

INSIGHT

3

I use charts as a communication tool.

INSIGHT

2

My AT can only provide one piece of information at a time.

INSIGHT

5

Changing tools is hard,
so it better be worth it.

INSIGHT

4

There is no normal.

INSIGHT

6

I use visuospatial metaphors
as mnemonics.

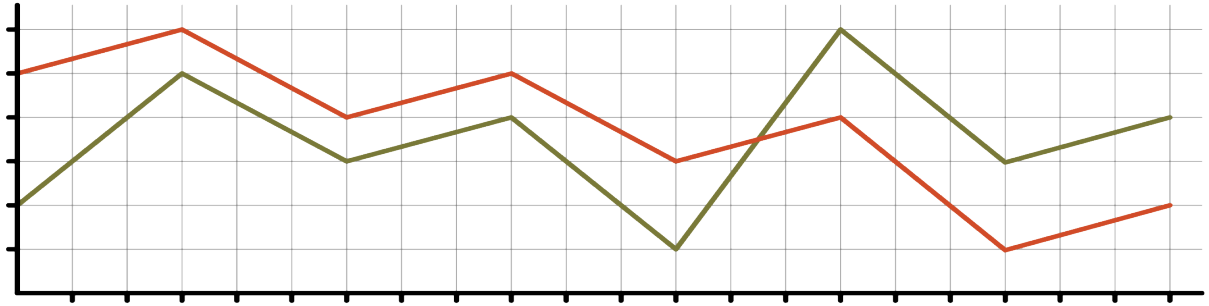
1 People who help me are interfaces, too.

The transfer of information by a sighted individual is subject to that person's interpretation and expertise.

People aren't always ideal interfaces: one PWVI mentioned a sighted friend who doesn't know how to read the X and Y axes on graphs.

When dealing with inaccessible interfaces, 7/10 PWVI noted they ask sighted people for help. The problem with seeking assistance is that PWVI need to understand exactly what the person helping them is capable of, as the information in question is subject to the interpretation of the sighted individual. Even if the sighted person has the knowledge to explain a problem, the PWVI can't always get help in the moment they need it.

Relatedly, PWVI and sighted coworkers necessarily have different workflows. Even if all parties are subject matter equals, different methods of accessing information create opportunities for misunderstandings. 2/10 PWVI mentioned the shortcuts they use to navigate an interface are frequently unknown to sighted counterparts, making it difficult to follow along.



4/10 PWVI told us they regularly call customer support of software companies to help complete or verify a transaction. Tapping into both the sight and subject-matter expertise of these employees minimizes the fear of missing out on crucial information. Many companies offer 24-hour accessibility hotlines.

2 My AT can only provide one piece of info at a time.

It's hard to view all parts of the puzzle at once because screen readers only provide one piece of information at a time.

"If information is linear, then sometimes you have to memorize which column [of a table] you're in. If there's a lot of data there, that can be very confusing."

Help desk analyst, blind from birth

Both sighted finance experts and PWVI remarked that they need simultaneous access to more information than they can remember. The 2/6 finance experts who spoke of this challenge overcome it using multiple screens at the same time, but this solution is not available to PWVI. Both finance experts and PWVI employ shortcuts to quickly navigate interfaces; many are hacks developed specifically to process relevant information more efficiently.

For example, 2/10 PWVI used the "T" shortcut to skip to data tables in finance interfaces. Additionally, all of our PWVI interviewees sped up their screen reader's output several times faster than normal speed in order to process more information while working.

4/10 PWVI and 2/6 finance experts cited the gist as integral to their understanding of charts. 5/10 PWVI told us that getting access to details quickly is important. 7/10 PWVI noted that they have to memorize information in order to complete tasks as efficiently as possible. PWVI felt that audio descriptions of the patterns of a chart are an efficient way to comprehend data, but this method breaks down when drilling into details, as a linear audio presentation of information quickly leads to cognitive overload.

One PWVI who is a retired Systems Analyst said he would not have been able to do his job without a braille display because braille allowed him to confirm and review details first heard through a screen reader, in particular numbers. Despite the multi-modal advantages of using braille in combination with a screen reader, fewer than 10% of Americans who are blind can read braille.[9]

3 I use charts as a communication tool.

Highlighting visual cues in charts is the easiest way to persuade colleagues and clients of investment decisions.

"Without charts, it would be hard to convince other collaborators about investment decisions."

Sighted analyst at a private investment fund

Through our interviews, we observed two distinct uses for charts in financial contexts: comprehension of data and communication of data. In the comprehension use case, as examined on pages 12 and 13, people use charts to get the gist of financial changes over time. PWVI don't benefit from the efficiencies of visual pop-out effects on charts to identify starting points for analysis. When it comes to analyzing data in tables, however, the combination of a keyboard and screen reader offers similar capabilities to traverse cells and write formulas to blind and sighted users alike.

We spoke with one PWVI who works as a Senior Channel Manager who was at a loss to think of an example of something he was unable to do analyzing data as a blind person, saying that tables are better than charts for his professional analyses of financial data.

The real data breakdown for many PWVI? Communication of data. 3/4 finance experts who invest professionally said they need to be able to share how they arrived at their investment decisions. One analyst at a private investment fund said she has to convince her clients, many of whom have poor understanding of basic finance concepts, that her investment decisions will outperform standard index funds. While eyes glaze over formulas and raw data, a strategically deployed pie chart or line chart in an email or presentation can make all the difference in helping her convince others that her decisions are sound.

In contrast, with current technology, PWVI are completely cut off when it comes to creating and validating the appearance of charts. This cuts them off socially as well, preventing from using charts editorially to communicate the reasoning behind their decisions to others at a glance.

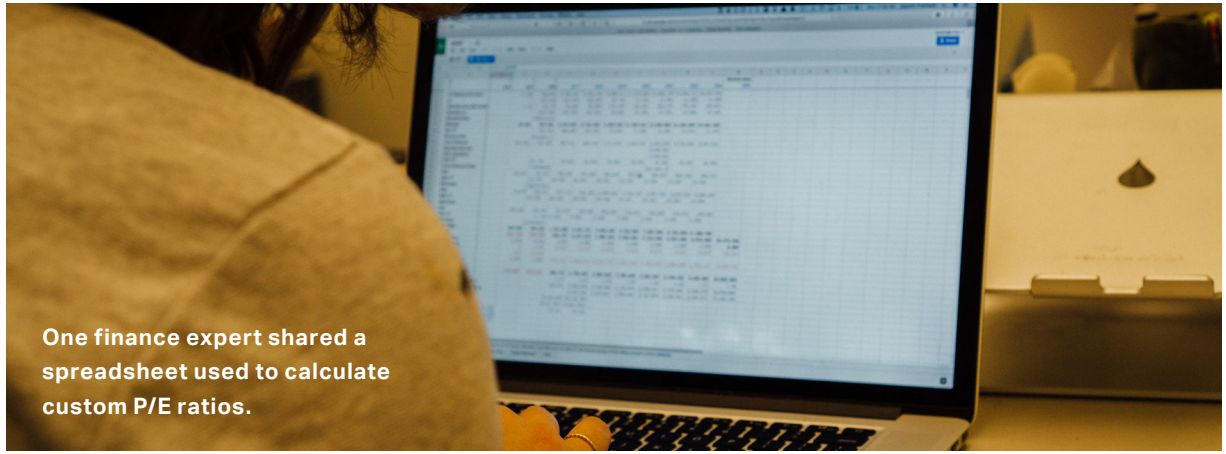
Charts are especially pervasive in slideshow presentations. One PWVI who works as a Senior Channel Manager uses an assistant to help him both understand and create charts for presentations. If he is concerned he missed something, his assistant will print out slides and describe the charts to him one by one. On the rare occasion that he needs to verify the data in another person's presentation, he contacts the presenter for the raw data to analyze in a table.

4 There is no normal.

Both PWVI and finance experts depend on their idiosyncratic workflows to get things done.

One thing that surprised us in interviews was the sheer range of techniques for accessing data amongst PWVI and finance users: one workflow does not fit all. Amongst finance users, one user user took pride in doing things "the hard way" and creating his own calculations. Another creates her own hodgepodge models based on financial data from different sources, using spreadsheets to make sense of the data rather than relying on models provided by the Bloomberg Terminal out of the box. More than one finance user, while describing the proliferation of spreadsheets and formulas essential to their processes, leaned in and mentioned as an aside that "they do things a little bit differently." In the context of investment, where information inequality is paramount, a user's customized workflow may be the key to their competitive advantage.

Similarly, PWVI find creative ways to customize their tools to their needs, for example by making custom markers for keyboard positions.



One finance expert shared a spreadsheet used to calculate custom P/E ratios.

Many PWVI find creative hacks to make their technology more accessible. For example, one of our interviewees customizes his bluetooth keyboard with tactile stickers to find his place. This trend can be seen more broadly: a 2012 WebAIM survey of over 1,700 screen reader users, over 90% of respondents reported customizing their screen reader settings, with over a quarter of respondents describing their screen reader settings as "very customized."[10]

5 Changing tools is hard, so it better be worth it.

A product must offer a meaningful improvement to justify altering a hard-earned workflow.

One PWVI who works as a help desk analyst never had a problem when her employer distributed paystubs in person, but ran into trouble when they implemented a digital portal which included visual security prompts. To get help, she was forced to share sensitive information with a sighted coworker.

For employed PWVI, their workflows already contain many examples of invisible work, or extra work done to make things accessible so that they can collaborate with sighted coworkers. Once a visually impaired user learns the structure and commands of an assistive technology, switching to another tool is no trivial undertaking. Changing tools or even updating software can cause huge changes in workflows for PWVI, hindering their ability to complete tasks they used to be able to complete easily through another method. 3/10 PWVI we spoke to mentioned reluctance to move to new companies because they may have to change tools.

This reluctance is heightened when it comes to financial information, where the stakes are high if a user makes a mistake: imagine losing thousands of dollars for accidentally clicking on touchscreen button that lacked an accessible label.

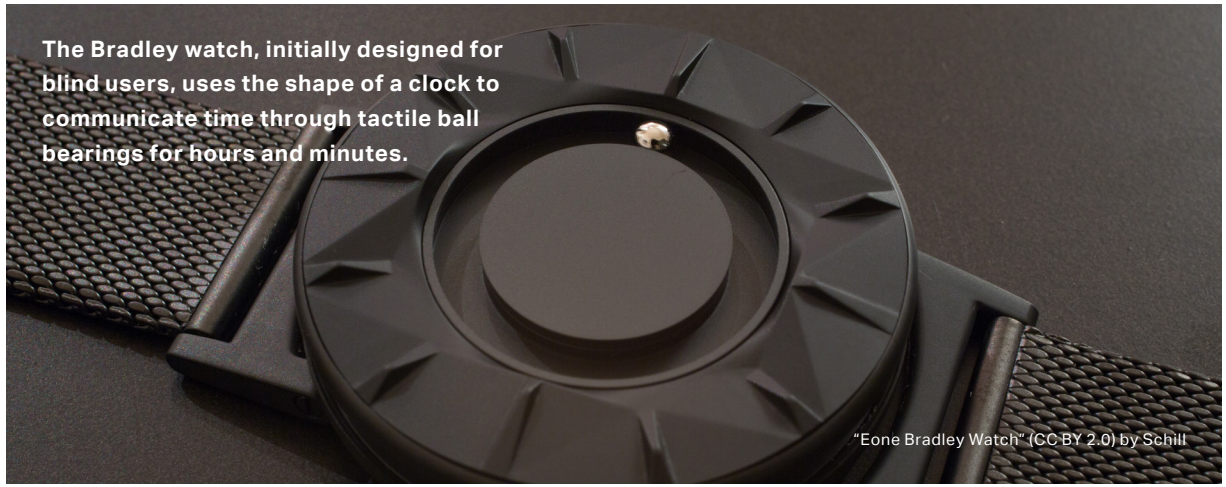
Using a new tool may be worth it to some PWVI, but not to others. One PWVI described his experience of trying to use an online payment system to collect dues as the treasurer for a technology group for visually impaired users. As treasurer, online banking offers him the meaningful new capability to count and calculate dues over his computer without the assistance of a sighted helper to read paper bills. In contrast, his group members have resisted switching over to the online payment system. Sending paper checks was not a major inconvenience for them, and the online system requires the high-friction process of learning a new interface and makes them vulnerable to potential error: the trade-off isn't worth it to them.

A PWVI shows off his knfbReader app, a popular and game-changing app for visually impaired users. It uses the phone camera as an OCR scanner to read back text in a user's environment — an ability which was previously impossible or prohibitively expensive. He uses it to interpret text found in menus and signs around him.

6 I use visuospatial metaphors as mnemonics.

Visual and spatial reference points help bridge communication between sighted and blind colleagues.

2/5 PWVI we spoke to who went blind later in life referenced times when they used their prior knowledge of visual information, such as charts, layouts, and colors, to help them chunk and synthesize information. For example, a user said sighted colleagues describe complex pie charts to him through describing the placement of clock hands as a metaphor. At other times, sighted colleagues move his hands through space in the shape of a chart's curve. In these cases, visual and spatial metaphors are being used as mnemonics to offload information that would be harder to remember if linearly encountered as values in a table: the same reason sighted people benefit from visualizations. Research has shown that even people with congenital blindness show improved memory for a task when given instructions with descriptions of imagery.[11]



The Bradley watch, initially designed for blind users, uses the shape of a clock to communicate time through tactile ball bearings for hours and minutes.

One PWVI, blind from birth, uses her screen reader to understand the color priority tags that her coworkers assign to emails. She is able to adopt her coworkers' color coding system by using the color names to understand priority level.

NEXT STEPS

Our research of sighted finance experts and people with visual impairments points us in several distinct opportunity spaces. Based on our findings, we asked ourselves how we might improve the state of financial visualizations for people across the sighted spectrum.

Provide Context for Visualizations

PWVI make the most of any provided chart descriptions, titles, and tables to complete work independently, yet due to inaccessible images, they often don't even get access to labels (pg. 12, pg. 23). When labels fail, many depend on other people for help (insight 1). However, we've also seen that it can be hard for another person to match the PWVI's knowledge level and provide them with the context they need (insight 1).

These findings point us to a solution that provides better descriptions of charts for PWVI. A solution may feature conversational descriptions by implementing visual and spatial references (insight 6), such as the shape of a chart, to bridge communication with sighted coworkers.

Provide Control in Data Navigation

Our team also sees an opportunity to improve interface navigation of financial data for PWVI. Sighted finance experts benefit from being able to recognize triggering events across multiple screens. While access to table data through a screen reader allows PWVI to read raw data, it's tedious to navigate through a large table, and nearly impossible to retain a precise mental model of all changes in values—an issue made even harder when column and row headings start to fade from memory. We're interested in exploring how different navigation controls, for example through a controller or specialized queries, could enable PWVI to move more freely around financial datapoints. New controls could provide PWVI the same ability to "jump around" interfaces that sighted people gain visually (insight 2).

Having learned that the few PWVI who use braille displays in combination with a screen reader benefit from accessing information in multiple modes, we're inspired to prototype other multi-modal tools that empower users to process more information at once (insight 2).

Provide Confidence in Data Accuracy

We found that many PWVI lack confidence while working with financial data. This is understandable,

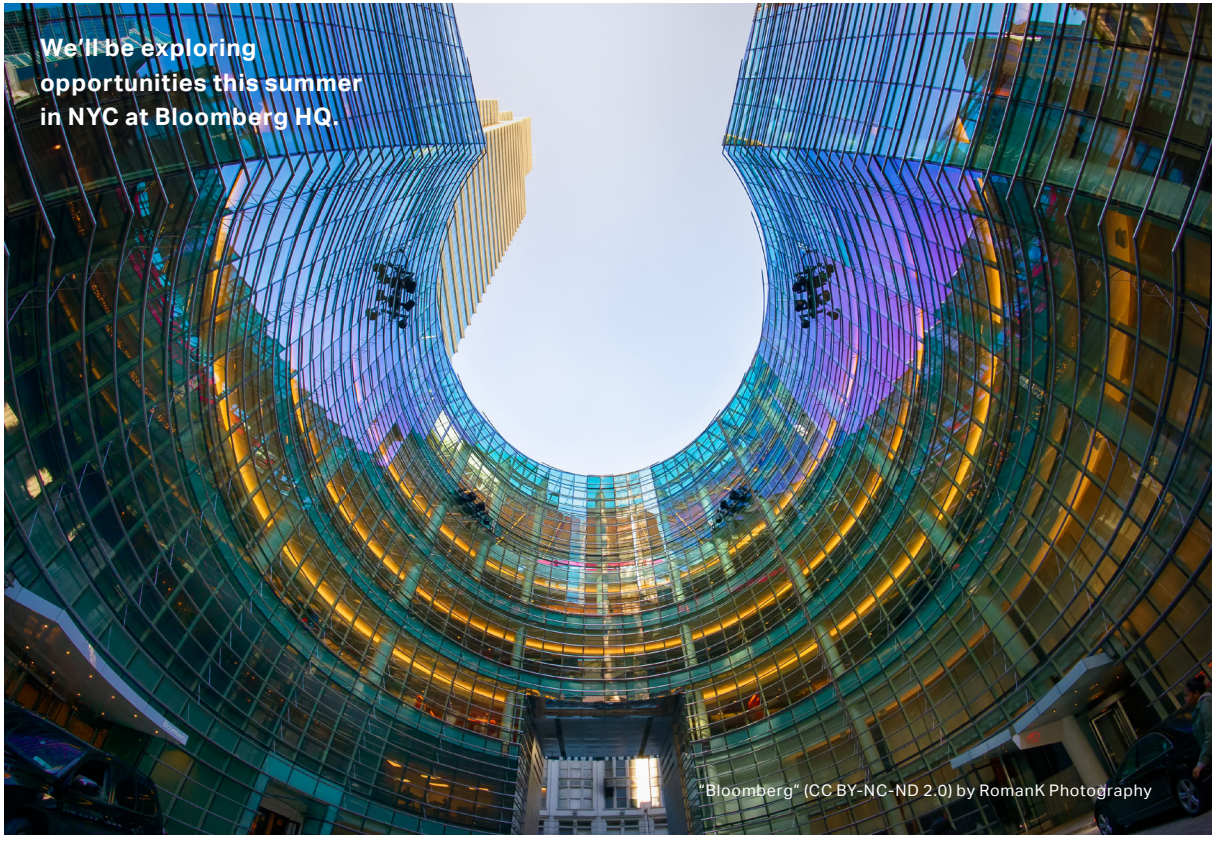
as validating information through a screen reader requires replaying row after row of data, and stakes are high for making a mistake (insight 2, insight 5). These findings indicate that PWVI could benefit from tools that ensure users that data is laid out correctly. Since sighted finance workers are equally prone to error (though able to more easily check their work), data validation is also an opportunity for universal design.

Provide Communication of Data

Insight 3 describes the current inability of PWVI to create visualizations for communicating their decisions to sighted colleagues. We see an opportunity for a solution that enables PWVI to create shareable data visualizations.

Going Forward

With these opportunities in mind, our team will spend the summer at Bloomberg in NYC prototyping and testing a range of solutions to enable blind users to confidently assess market trends in order to make investment decisions.



ABOUT B7G

The name b7g is a numeronym, or number-based word, for Bloomberg, our team's sponsor. From left to right, team b7g is:

Conrad Bassett-Bouchard | UX Designer

Conrad is the youngest North American Scrabble Champion. Prior to MHCI, he memorized the dictionary, co-managed a food truck and backpacked through 20 countries and 46 states. He has a degree in cognitive psychology from UC San Diego and enjoys solving problems that don't have an objectively correct answer.

Emily Saltz | UX Researcher

Emily Saltz studied Linguistics and Russian at UC Santa Cruz. Most recently, she was Content Strategist at Pop Up Archive. Her role encompassed UX Design, Data Analytics, and Project Management. She loves long reads and long podcast listens.

Nora Tane | Project Manager + UX Designer

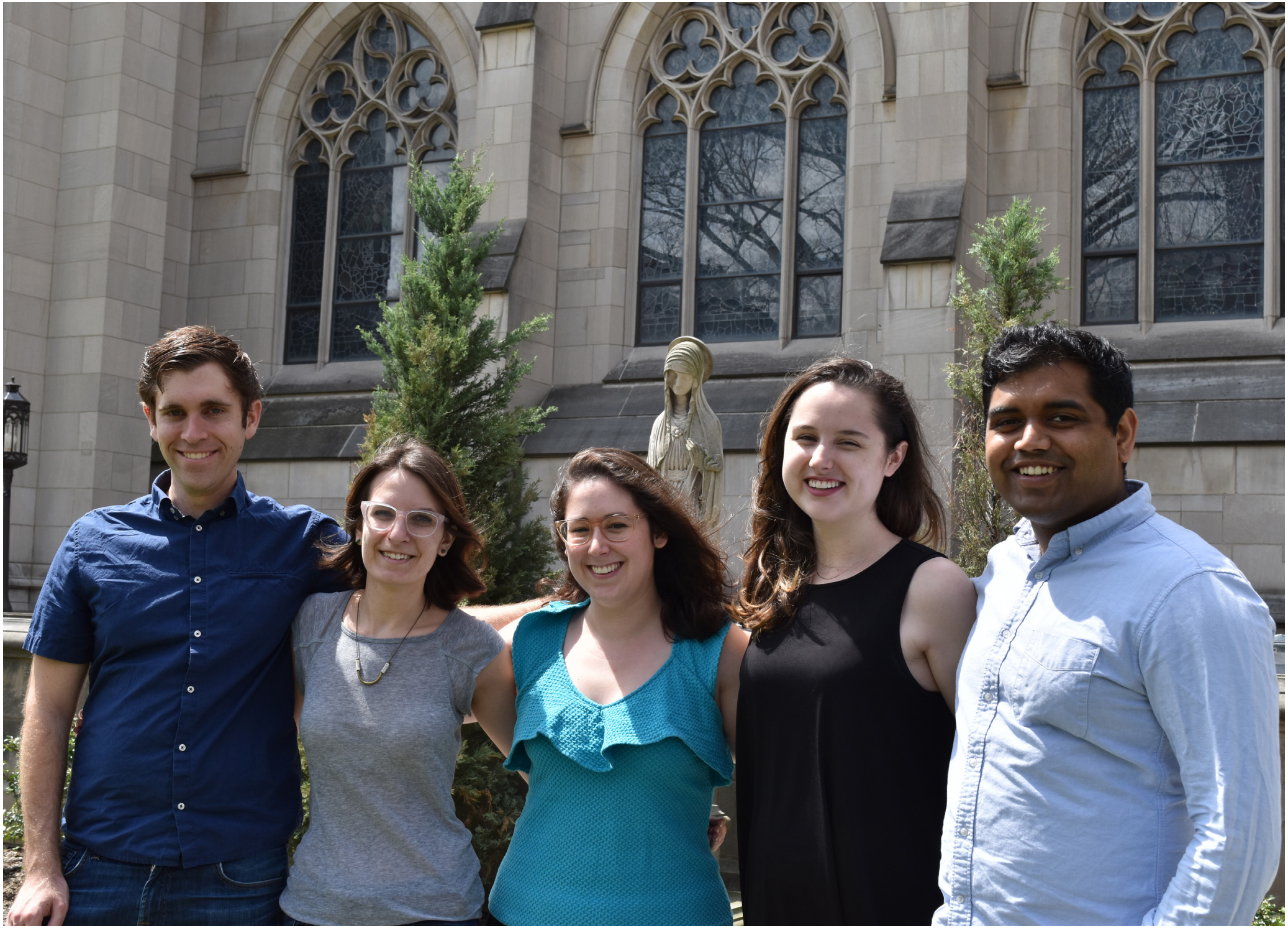
Nora is from NY and is happy to return to work with Bloomberg. She has worked at startups and studied psych and bio at Washington University in St. Louis (big science nerd). She loves reading, trying new food, and enjoying theater, art, and comedy.

Clare Marie Carroll | Tech + Prototyping

Clare is a creative technologist with a passion for creating interactive, immersive experiences using emerging technologies. Before coming to CMU, Clare worked at the NYU Media Research Lab, Body Labs, and the Samsung Accelerator.

Jayanth Prathipati | Product Manager

Jayanth is a Software Developer and UX Researcher. Prior to MHCI, he worked at the Notification Systems Lab at VT and developed software at Element 84. He has a degree in Computer Science and is interested in mobile health and behavior change.



CREDITS AND ADDITIONAL RESOURCES

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Finally, a shoutout to **Nicole Willis**, **Jenn McPherson**, and **Skip Shelly** at the CMU HCII for maintaining the MHCI capstone project as an unrivaled experience for so many budding user experience professionals.

Accompanying this book is a flash drive with the following materials:

Secondary Research Insights Report, Accessible Word version of Secondary Research Insights Report, Primary Research Insights Report, Accessible Word version of Primary Research Insights Report, Final Report, Scaled Up Final Report, Accessible Word version of Final Report, Presentation slides, Accessible Word version of Presentation slides, Project Plan, Hunt Statement, Research Plan, Images of Assumption Prototype, Client Communiques.

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