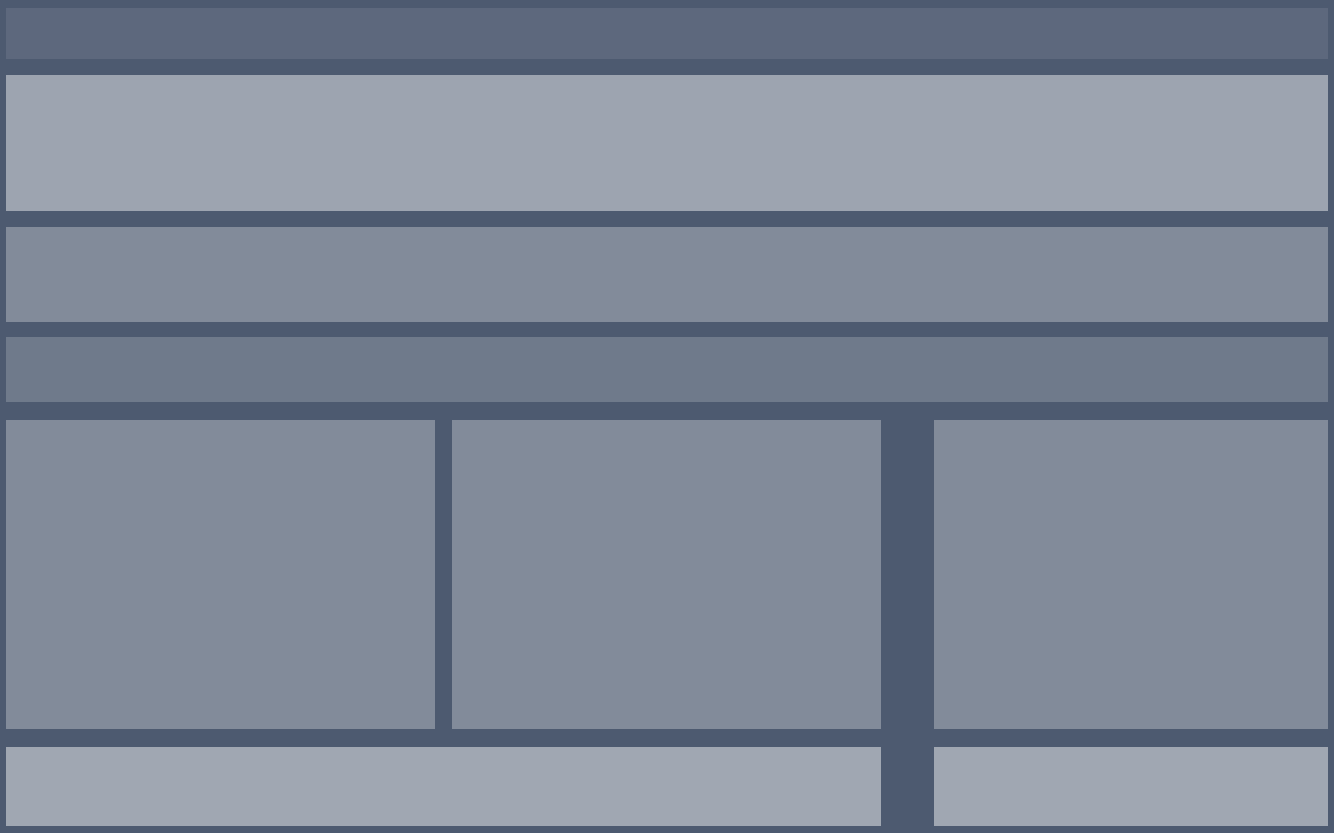
Enhancing Data Impact

A Critical Design Analysis of a Localized Policy Informatics Dashboard



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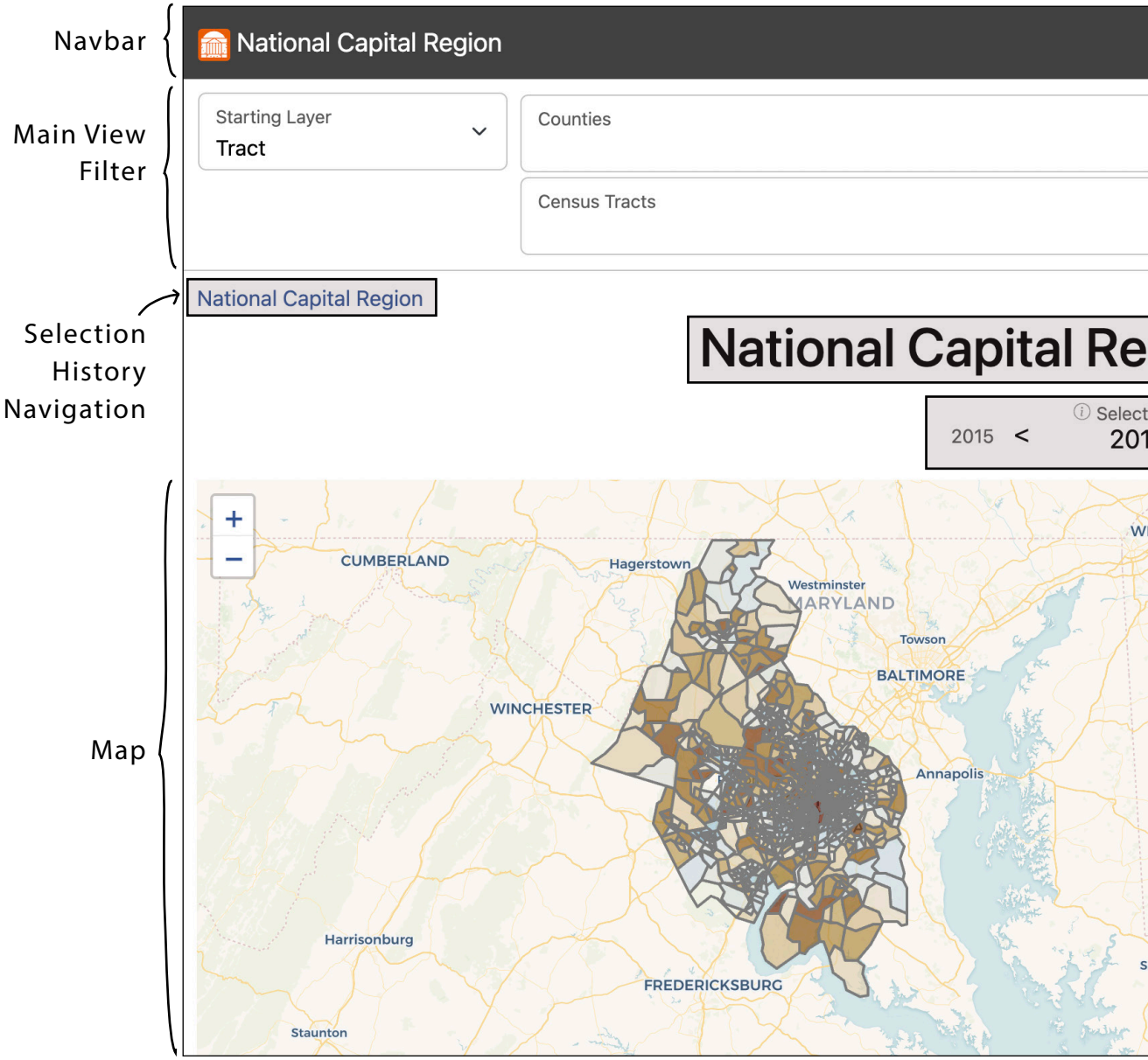
A special thanks to Alan Wang
for all his support, mentorship,
and constructive judgement.

Evaluating a National Capital Region dashboard by extending interaction design principles to information visualization.

In July 2023 I began working with the University of Virginia's Biocomplexity Institute at their Social and Decision Analytics Division. During this time, I, along with most of the division, have worked on the Social Impact Data Commons project where we are providing curated, open-source data at sub-county geographic levels. As a product of this project, we host a dashboard displaying data on the National Capital Region. The data we are providing is powerful and has the potential to inform policy that can affect real change, especially at the local level. However, there are issues with the design of the current dashboard such that the capabilities of the data are not matched in the scope of the dashboard. Using a heuristic method that combines Don Norman's design principles with tested dashboard usability criteria, I show that our current dashboard lacks discoverability and understanding. Without these characteristics, our dashboard is difficult to employ. Throughout this book, I point to specific areas hindering the efficacy of our dashboard and provide suggestions for overcoming these issues.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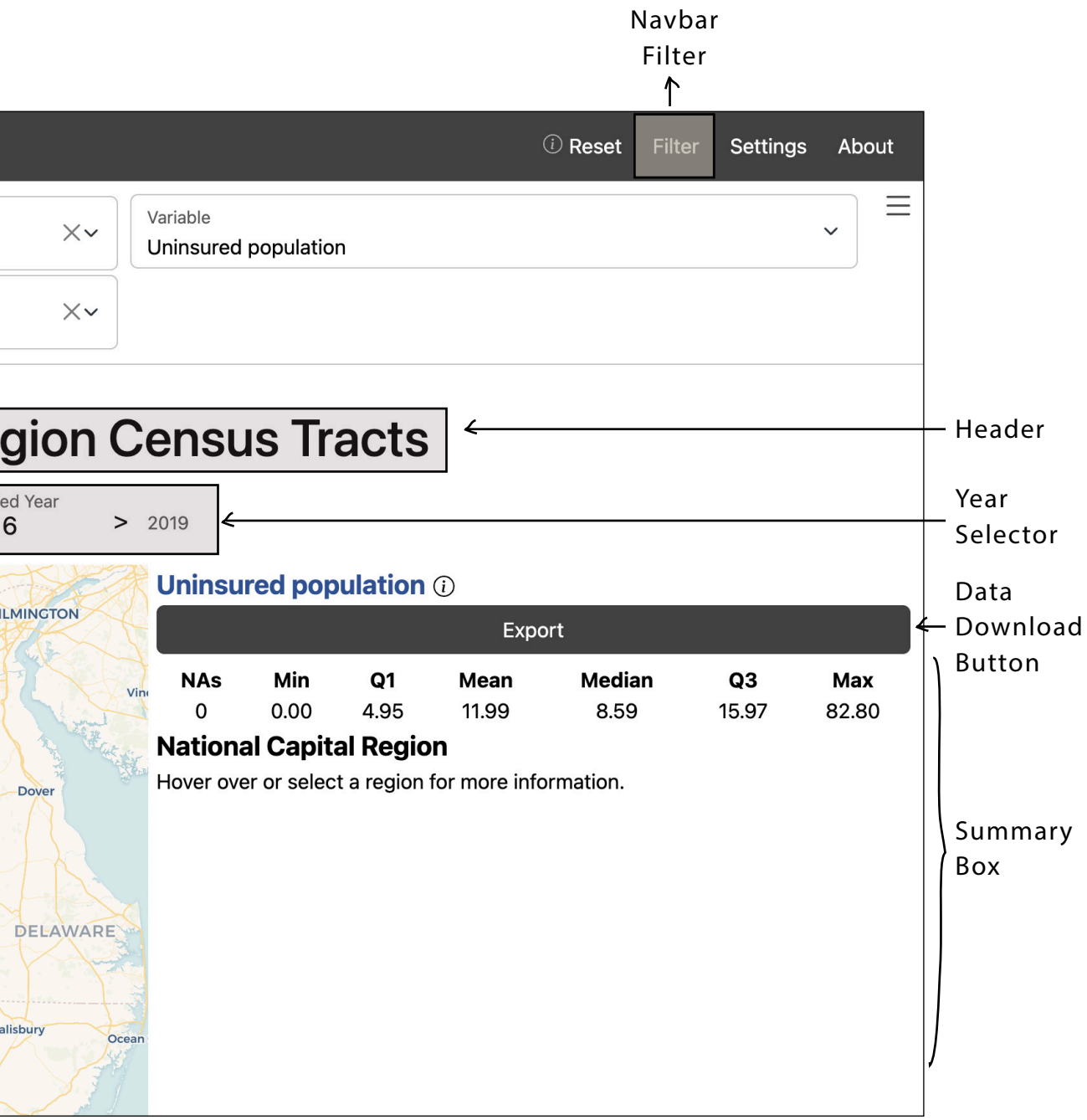
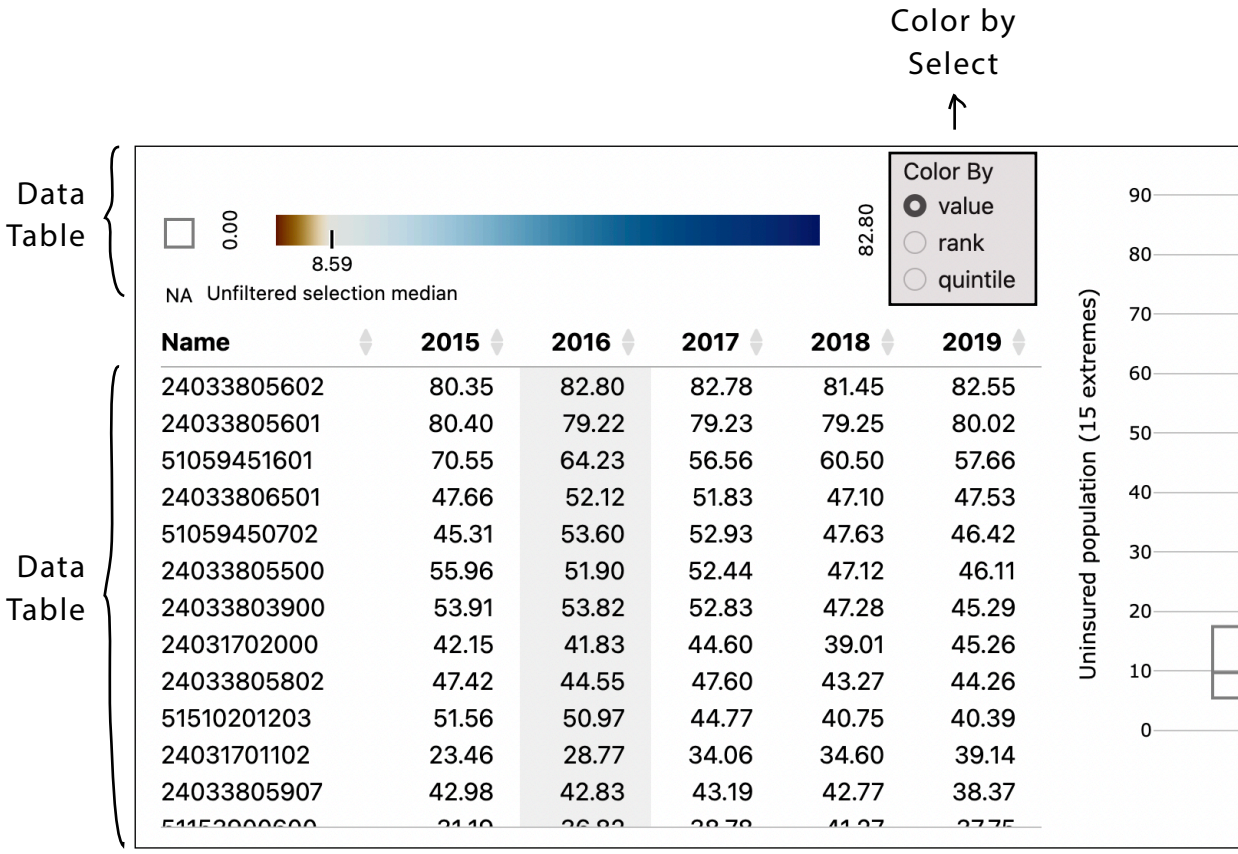


Dashboard view - upper half.
Adapted from [1]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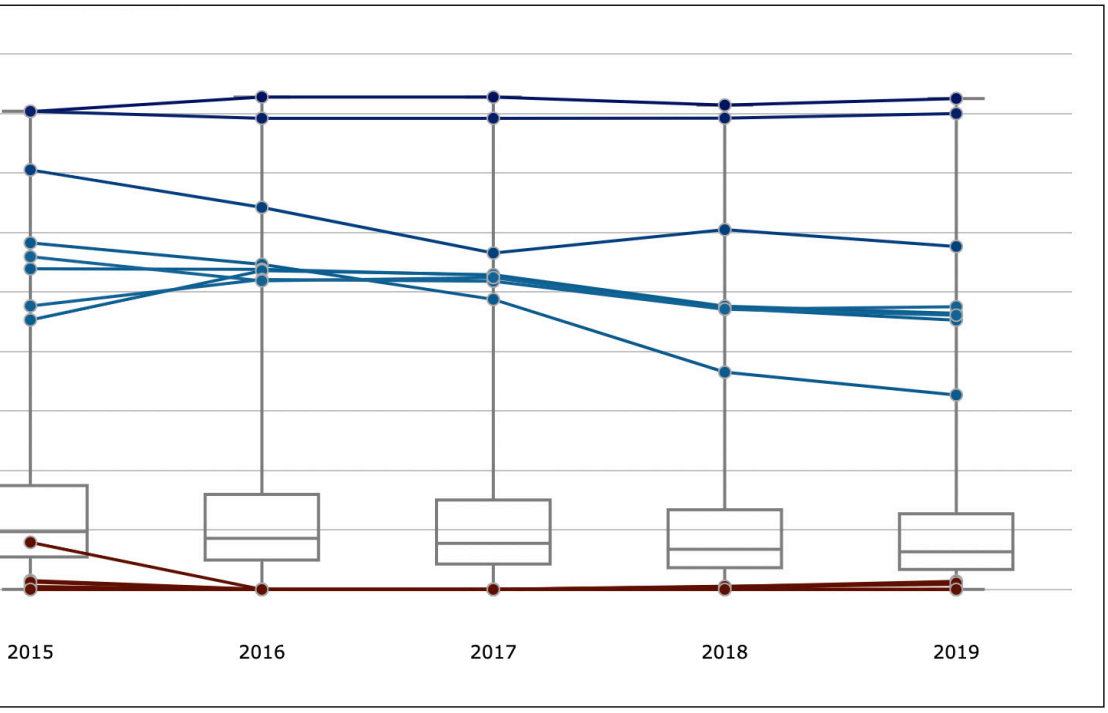
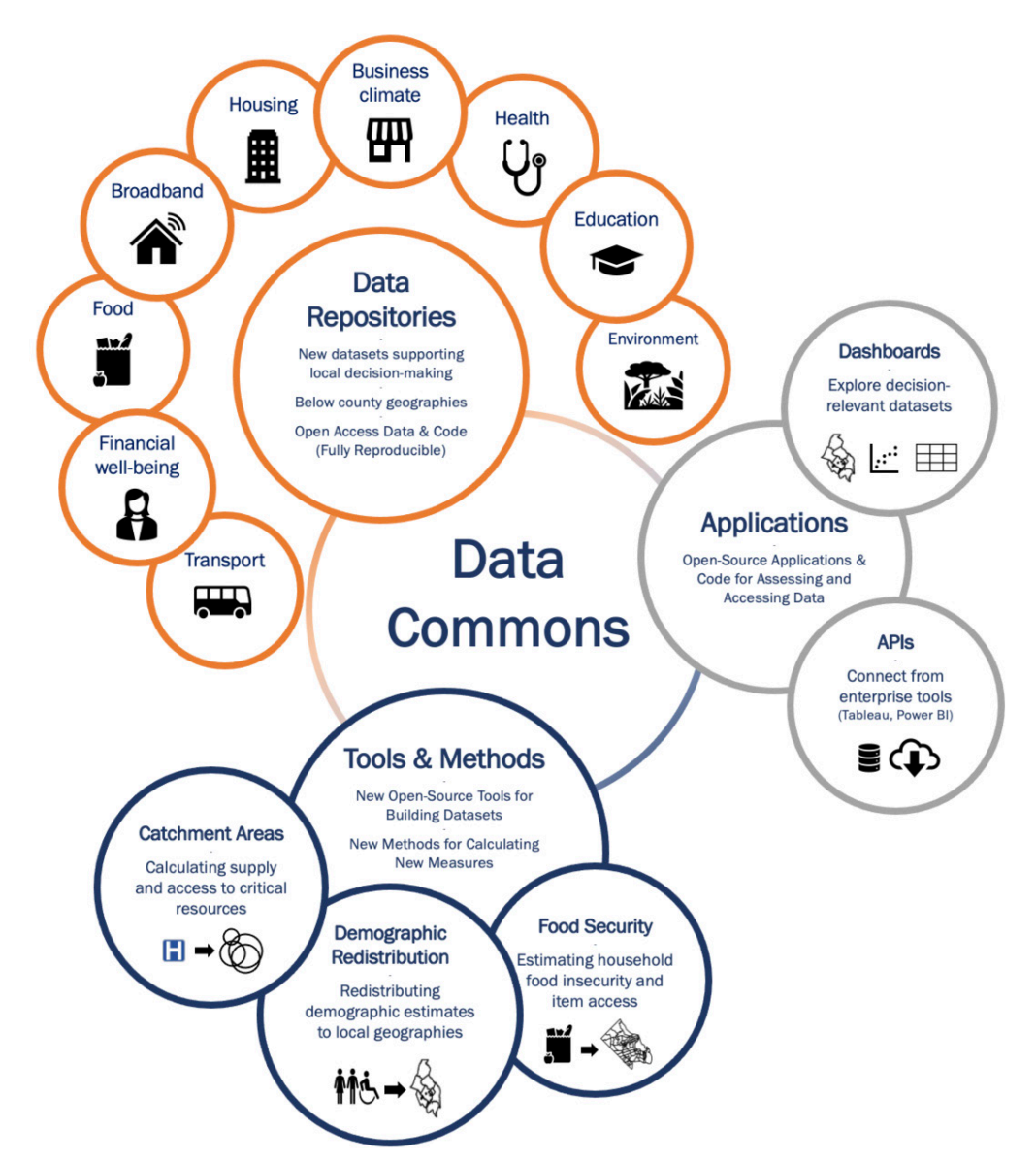


Dashboard view - lower half.
Adapted from [1]

Contents

Background



(Above) "The Social Impact Data Commons framework developed by the University of Virginia Biocomplexity Institute, Social and Decision Analytics Division." Taken from our current data commons landing page. This gives an overview of the factors that culminate to form the Data Commons. The National Capital Region dashboard is just one of these factors. Adapted from [1]

Fig. 1. From our current landing page. Descriptions of the purpose of the Social Impact Data Commons. Adapted from [1]

Background on the Data Commons

The social impact data commons hosts data on 224 measures categorized under ten topics: (1) broadband, (2) education, (3) employment/workforce development, (4) health, (5) behavioral health, substance use disorder, and recovery, (6) nutrition and food security, (7) demographics, (8) financial well-being, (9) housing, and (10) business climate.

[1, Fig. 1] is taken directly from our landing page and outlines the division-defined specifications on the dashboard. From this, I gather that the dashboard should be conducive to exploration. Our dashboard should not just allow users to gain new knowledge, but it should encourage them to. Further, this knowledge should be more than just surface-level facts. Users should be supported in gaining a deeper understanding of the system they are analyzing. Additionally, while the data should draw people in, it should not tell a story on its face but rather allow users to derive their own stories based on facts.

To understand more specifically the goals and requirements for the dashboard, we first need to understand our users and their needs. In looking at our target audience, I keep largely in mind the principles of human-computer interaction (HCI) and universal design. Over the past few decades, HCI has emerged to study what its namesake implies: the interactions of humans with computer technology. Liu et al. point out that research in HCI classifies users differently (e.g. target and filter groups; primary and secondary users with side-users and co-users) but consistently places "users' individual differences and their tasks" as the top factors in influencing usability [2]. Likewise, universal design greatly considers user characteristics,

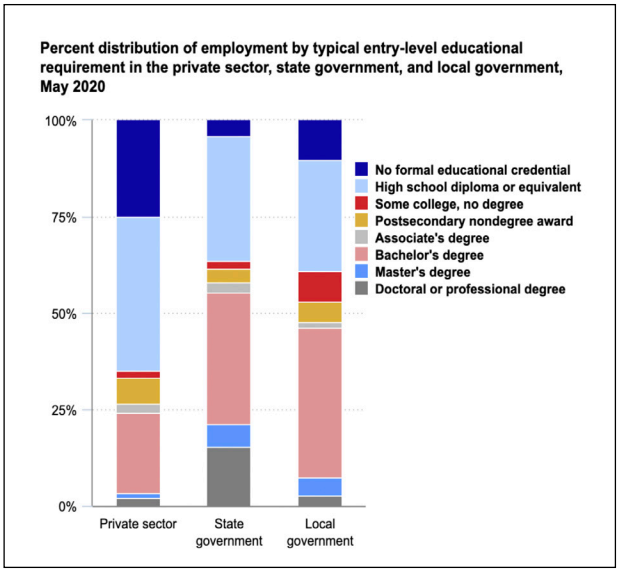


Fig. 2. The distribution of educational requirements for jobs in the private sector, state government, and local government. At the time of the data, state government jobs required the most education with local government jobs a close second. Both state and local government jobs required at least a college degree around 50% of the time and at least a high school diploma around 90% of the time. However, these requirements are changing, as I will explain below. Adapted from [3]

viewing usability and accessibility in tandem. Not every tool can be fit to everyone, but products and services should be "accessible and usable for the largest possible audience without the need for adaptation or specialized design" [4]. The seven principles of universal design are equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and use [4]. To apply these concepts it is necessary to next think about the characteristics of our audience.

Background on the Audience

Expertise

Broadly, this tool is geared toward local-level decision-makers in the public policy sphere. In other words, these users are expected to be knowledgeable about the areas and constituents they serve. A minimum understanding of basic local and census geographic levels (block groups, census tracts, etc.) is assumed. However, there is no guarantee our users have any technological expertise or high-level visualization literacy. To ensure accessibility to the largest audience, it is important to reduce the complexity of the dashboard where possible. I will continue to come back to this idea, especially when I look at affordances and signifiers under discoverability.

I additionally briefly consider the education of our users [3, Fig. 2]. However, I argue that in our case domain expertise is more indicative of capability than educational attainment.

This is under the assumption that there is already a certain skill requirement to attain a decision-making position. Indeed, Maryland and Virginia have both dropped degree requirements for many state jobs, favoring skills and experience over education and indicating that barriers to these jobs are skill-based [5], [6].

Culture

The majority of our users will be American and, thus, our dashboard should follow Eastern conventions. In dashboard design, culture has the most influence over the layout of the dashboard. Because Americans read left to right and top-down, we instinctively "read" dashboards in a similar manner [4]. Audience perception will play a large role when I talk about mapping as part of both discoverability and understanding.

Age and Gender

Fig. 3 reflects estimates of the demographic makeup of local governments at three different

		Sex	Sample Size	Estimated Total	Mean Age (weighted)	Median Age (weighted)	Max Age
United States	All local government employees	Male	57,367	5,653,451	46.0	45.5	95
		Female	95,510	9,017,111	46.6	46.5	95
	Local chief executives and legislators	Male	579	44,498	58.0	57.5	94
		Female	309	23,596	58.8	58.5	90
DC/MD/VA	All local government employees	Male	2,657	262,714	46.3	45.5	94
		Female	4,825	458,191	46.8	46.5	94
	Local chief executives and legislators	Male	16	1,047	56.0	54.5	79
		Female	8	441	59.0	65.5	79
National Capital Region	All local government employees	Male	571	57,353	45.0	43.5	80
		Female	990	94,528	45.4	43.5	94
	Local chief executives and legislators	Male	7	387	56.6	58.5	79
		Female	2	31	59.5	69.0	74

Fig. 3. Estimates of the makeup of local government. Estimates are calculated using data from [7] and filtered based on industry (local government). To get local chief executives and legislators, this data was additionally filtered based on occupation (chief executives and legislators).

geographical levels. While our audience likely resides in the National Capital Region (NCR), I look at overall trends in all three areas in order to reduce the level of uncertainty that comes with small sample sizes. Here are my general observations:

- In all areas, employee ages seem to be fairly normally distributed with centers falling mostly between mid 40's to late 50's
- The maximum age recorded for most categories was in the 90's. Local chief executives and legislators in the NCR and the NCR states had a slightly lower maximum age (still within the same generation)
- Local chief executives and legislators in all three areas had higher mean and median ages than the encompassing populations of all local government employees (generally, centered around the high 50s compared to mid-40s)
- In all three areas, the estimated total number of female employees in local government is about double that of male employees. This pattern is reversed when looking at these numbers solely for chief executives and legislators in local government

We must account for both male and female users of our dashboard. Differences in gender tend to account for certain differences in interaction styles. In particular, it has been found that "males tend to be more abstract learners, more intuitive and undirected, while females are more anxious about results, more analytical and organized" [2]. Additionally, females exhibit higher "computer anxiety", meaning they may be more resistant to learning unfamiliar technologies [2]. This, again, points to the need for greater clarity and reduced complexity in the design of our dashboard. Different learning styles point to the need for a certain level of user freedom and control. These considerations will be important when I talk about affordances and signifiers under both discoverability and understanding.

Differences in age can account for many of the difficulties users experience interacting with technology. While it is true that age factors into technical skill and interaction style, prior discussion of the other user characteristics have already addressed how deficits and differences in these things affect dashboard design. Instead, I focus on the idea that technological difficulties with age extend beyond technical skills and into

physical capabilities. For example, after the age of 40, most people experience some form of presbyopia – "the gradual loss of your eyes' ability to focus on nearby objects" [8]. Based on the average age reflected in Fig. 3, this is a condition that likely affects many of our users, especially those at the farther end of the age range. Therefore, the readability of our dashboard must be taken into account.

The General Services Administration recommend general guidelines for website readability: at least a font size of 16px for body text, 45-75 characters per line (ignoring captions, marginal text, and forms), a clear typeface with a large and consistent x-height, and clear headings [9]. Additionally, the most recent Web Content Accessibility Guidelines recommends at least a contrast ratio of 4.5:1 for general text and at least a contrast ratio of 3:1 for large-scale text [10]. Contrast ratio is calculated as (L1 + 0.05) / (L2 + 0.05), where L1 is the luminance of the lighter color and L2 is the luminance of the darker color [10].

Our current dashboard meets the general readability guidelines for characters per line, headings, and x-height. It also meets contrast ratio guidelines with the smallest contrast having a ratio of about 5:1. Most of the text on our dashboard is 16px, but some text is 13px, which does not meet the guidelines.

Audience Tasks

Our dashboard should provide a picture of the current landscape of an area. Decision-makers need to be able to understand and analyze the data we provide in order to affectively allocate resources and inform growth. Some high-level questions they should be able to answer are:

- What is the current state of [measure] in [region]?
- How has [measure] in [region] changed over time?
- How does [measure A] compare to [measure B] compare to … compare to [measure C] in [region]?
- How does [region A] compare to [region B] compare to … compare to [region C] for [measure]?

Background on the Literature

For the actual evaluation piece, I first ask myself two questions:

1. What makes a good design?
2. What makes a good dashboard?

The answers I found follow.

What makes a good design?

A pioneer in the field of interaction design, Don Norman points to discoverability and understanding as two critical components of a good design [11]. To put it in our context, one should be able to answer: how do I find the information (discoverability), and what does it mean (understanding)? Under this idea, Norman proposes seven principles that serve to inform good design:

1. Discoverability - The ability to find out what actions are possible and information about the system
    a. "It is possible to determine what actions are possible and the current state of the device" [11]
2. Feedback - How the results of an action are communicated
    a. "There is full and continuous information about the results of actions and current state. After an action, it is easy to determine the new state" [11]
3. Conceptual Model - An understanding of how the system works and what it all means
    a. "The design projects all information needed to create a good conceptual model of the system, leading to a good understanding and a feeling of control. Enhances both discoverability and evaluation of results" [11]
4. Affordances - The capabilities of a system
    a. "The proper affordances exist to make the desired actions possible" [11]
5. Signifiers - What signals that affordances exist
    a. "Effective use of signifiers ensures discoverability and that the feedback is well communicated and intelligible" [11]
6. Mappings - Relationships between parts of the system
    a. "The relationship between controls and their actions follows the principles of good mapping, enhanced as much as possible through spatial layout and temporal contiguity" [11]
7. Constraints - Limitations on capabilities
    a. "Providing physical, logical, semantic, and cultural constraints guides actions and eases interpretation" [11]

Each of these principles interplay with one another, feeding into the discoverability and understanding of a product. Par-

ticularly, feedback, affordances, signifiers, constraints, and mappings form a basis for discoverability and the conceptual model – supported by affordances, signifiers, constraints, and mappings – is what allows for "true understanding" [11]. Although Norman's principles were initially proposed for interaction design, I want to look at these ideas from a broader lens by extending them to the evaluation of data visualizations as well.

What makes a good dashboard?

Metrics for dashboard evaluation have long been developed for heuristic testing. I use the literature surrounding this topic to determine agreed upon standards that will allow me to more objectively evaluate our dashboard. Specifically, I bring together criteria from four sources that develop dashboard evaluation frameworks. [12], [13], and [14] used previous literature to create guidelines. [12] and [13] validated these sets through testing with domain experts where [14] used a set of inclusion and exclusion criteria to do so. [15] suggests criteria based on a strict definition of a dashboard: "a visual display of the most important information needed to achieve one or more objectives that has been consolidated on a single computer screen so that it can be monitored and understood at a glance." I use these four sources to derive a set of criteria for the evaluation of our dashboard.

An Overview of What's to Come

The rest of this book will focus on the chosen dashboard criteria as they relate to Norman's seven design principles and will look further at how these principles fit in our context. I group Norman's principles as they underlie discoverability and understanding. For each section, I look at affordances and signifiers in tandem because of how interconnected they are. Additionally, Norman frequently refers to the state of the system which I extend to mean not just the dashboard system but the contextual, real-world system as well.

For each criterion I cover, I give a general rating based on how well our current dashboard meets that criteria. The rating system is as follows:

- 0 - Not met
- 1 - Somewhat met but with some major issues
- 2 - Mostly met but with some minor issues
- 3 - Met

I include these ratings to give an overall picture of how our dashboard is performing. However, this is only meant as a shorthand to help quickly identify if the dashboard met a particular criteria. There are many more nuances in how I evaluate the dashboard that cannot be summed up in just one number.

While dashboards can be employed on both desktops and mobile devices, I focus my review on the desktop view of our dashboard. As a tool intended for work, I make the assumption that the majority of our users will be on desktops. One last general note: although it wasn't the purpose of this review, as I was going over our dashboard, I discovered several bugs in the system. I point out some of these throughout my evaluation. However, this is not a comprehensive list and the system should be generally reviewed for broken features and correctness. Ill-functioning features can cause much confusion and frustration for users.

Discoverability

How do I find the information?

"For designers, the visceral response is about immediate perception: the pleasantness of a mellow, harmonious sound or the jarring, irritating scratch of fingernails on a rough surface...It is all about attraction or replusion" [11]

I begin by looking at the discoverability of our dashboard. Before a user can begin to decipher meaning, they must find the information that would allow them to do so. In our context, I think about discoverability first in the broad sense: can the user find the possible actions? As a subset of this, I wonder: can the user find the actions necessary to find the right data?

At the end of this section, I will look at the overall discoverability of our dashboard with this criteria in mind:

1. Learnability - Users should be able to quickly familiarize themselves with the dashboard and "make good use of all its capabilities" [14]

However, first I break down this concept to look at each of the components that feed into it: affordances, signifiers, mappings, feedback, and constraints.

Affordances and Signifiers

Affordances are what is enabled by a product. Signifiers are the signs that indicate an affordance exists. In thinking about this under discoverability, I consider the different actions users can take with our dashboard and if signifiers make these possibilities clear. Additionally, I consider if users have sufficient and clear options for finding the data they need. After looking at the current state of affordances and signifiers in our dashboard, I will use the following set of criteria to evaluate:

1. Operability - Users should be able to "use and control [the] dashboard for performing their tasks." This represents if the proper affordances clearly exist for users to find needed information [14]
2. Orientation - Users should have support to direct themselves within the visualization (ex: control over level of detail or ability to undo actions) [12]
3. Flexibility and efficiency of use - Users should have "several options when it comes to finding content." This allows users to interact with the dashboard in ways that fit their needs [12]

The next few pages show the affordances and signifiers of our dashboard I feel fall under discoverability. For each, I go over the action enabled and what signifies that possibility (if anything). If I note any caveats with the current features, I also provide an example of how these problems are handled by other dashboards.

Fig. 4. Page header from our dashboard. This gives the user a sense of what data is shown and signifies the current state of the system. Adapted from [1]

Fig. 5. Year filter from our dashboard. This allows users to select the year of the data displayed in the map and summary box. The left-right and up-down arrows signify the ability to change the year incrementally, which can be done on click. The years on the left and right are the minimum and maximum year available and can be clicked to select that year. Although understandable, this is inconsistent with the controls used for our other selectors and with similar tools I found on other dashboards, which may make it difficult for certain users to recognize the affordance. If there is little assumption of our audience's technical skill, we should aim to use familiar tools where possible, rather than rely on users being able to figure out new technologies. See [16, 17, and 18, Fig. 6] for alternate examples. Adapted from [1]

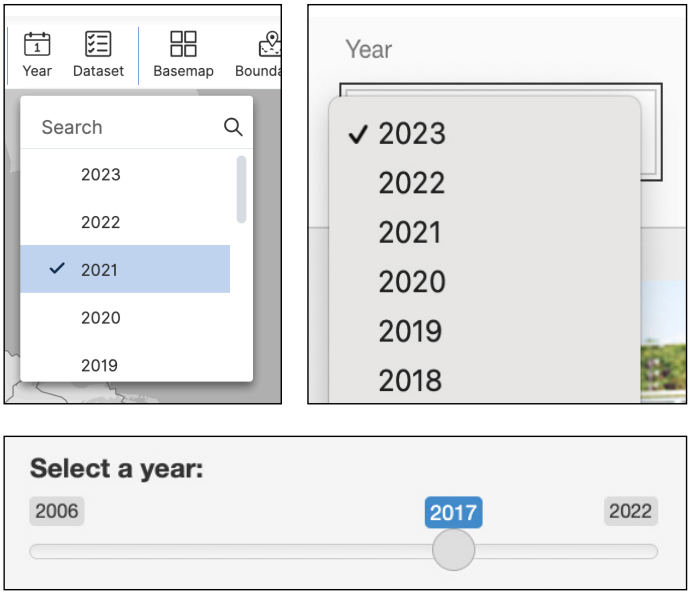


Fig. 6. Year selectors from outside dashboards. The dropdown selectors (top) match the mechanisms we use for our other filter selection tools. The sliding selector (bottom) mimics a timeline, which is recognizable as a way of displaying chronological data. This follows western cultural conventions where we view time as left to right. Either of these kinds of selectors may be more understandable for users either because of consistency with other tools on our dashboard or consistency with cultural norms. Adapted from [16], [17], and [18]

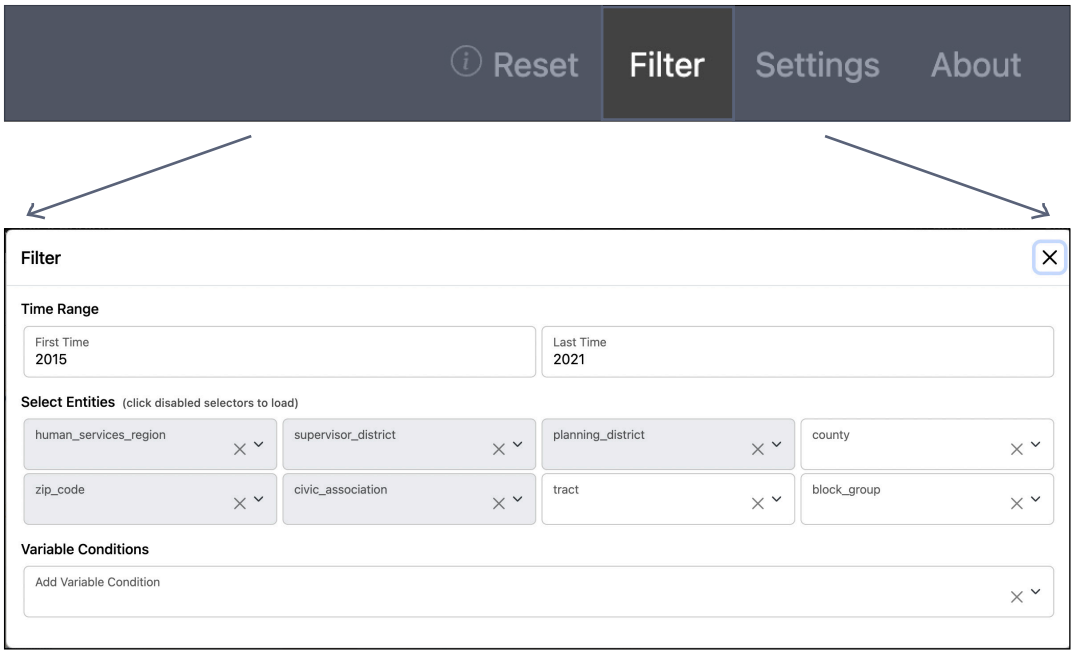


Fig. 7. Filter options from our dashboard. On click, the filter button in the navbar (top) pops up a filter box (bottom). This enables the user to filter data by years, regions, and variable conditions. The label along with highlighting and mouse icon change on hover, signify that something is there and that the "Filter" can be clicked. Boxes, labels, dropdown arrows, and mouse icon changes on hover signify the different filtering capabilities. Adapted from [1]

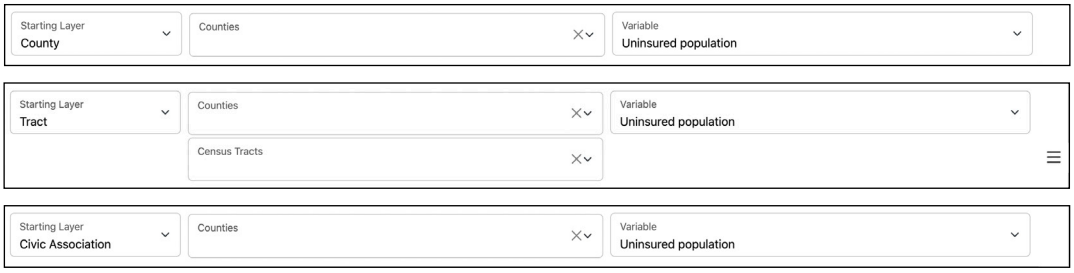


Fig. 8. Filter options from our dashboard with different starting layers. Users are able to define starting layer (controls the top map geography level), county, and variable shown. When tract or block group is selected as the starting layer, users are able to specify a census tract as well. Boxes, labels, and dropdown arrows signify ability to choose options. The ability to choose a census tract when tract is a starting layer (middle) is potentially a false signifier that this affordance exists here for other sub-county geographies. In fact, for all other geographies you can only choose a county (top and bottom), with the exception of block groups where you can specify a tract. County and tract are the only starting layers which match the geography selector. As pointed out by the previous figure, the affordance to select other sub-county geographies does actually exist, but in a separate area of the dashboard. If the signifiers imply that this possibility exists here rather than there, this limits discoverability. Adapted from [1]

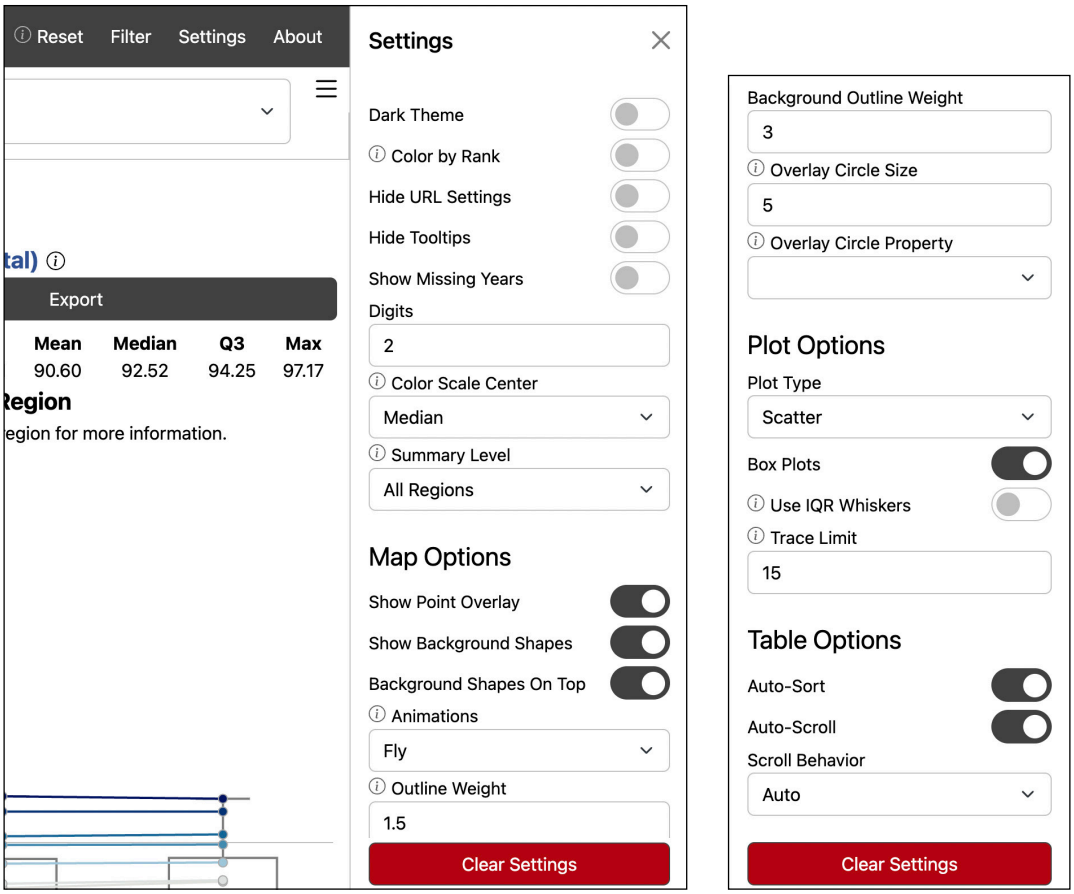


Fig. 9. Settings bar from our dashboard. When the settings button in the navbar is clicked, a box with settings options slides out from the right side of the dashboard. Labels, dropdown arrows, and toggles signify different customizability options. Users are able to customize certain aspects of the view of the dashboard along with map, plot, and table specifications. The red "Clear Settings" button provides a clear signifier that users are able to reset their selected settings options. The figure on the right is the bottom half of the settings pane, which is scrollable. However, there is no clear signifier that the settings box can be scrolled. A scrollbar appears only after scrolling starts. See [16, Fig. 10] for an alternate example. Adapted from [1]

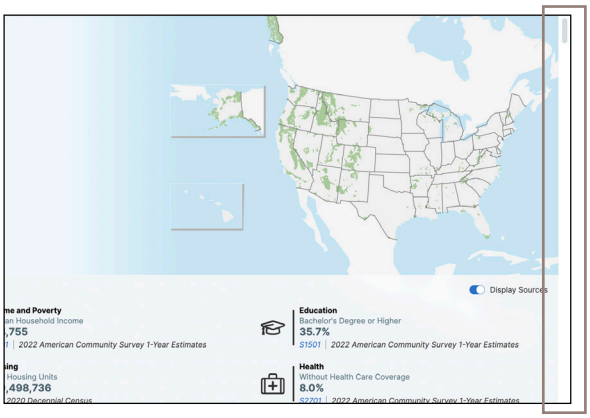


Fig. 10. From the United State's Census dashboard. A scrollbar on the right side of the page indicates that the page can be scrolled through. This scrollbar is visible at all times. Adapted from [16]

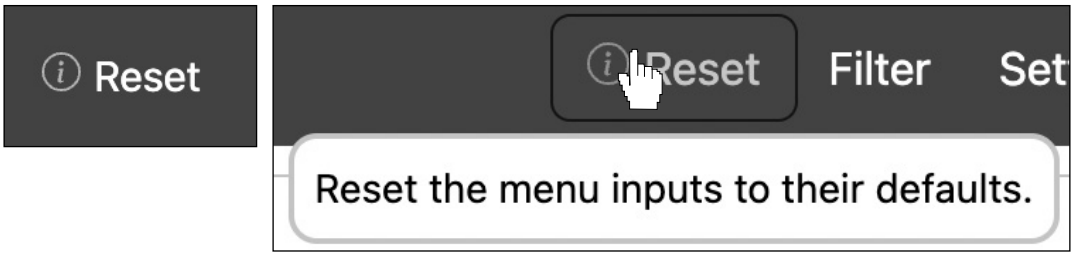


Fig. 11. Reset button located in the navbar of our dashboard. This resets the selected year, starting layer, region, and maximum year. This does not have effect on the minimum year or any variable conditions in place. The highlight when hovered over indicates that this can be clicked. It is not entirely clear what the "menu inputs" are, so it can be difficult to understand what this feature is used for. I do not provide immediate solutions for this as I will discuss this feature further later in this section under mapping. Adapted from [1]

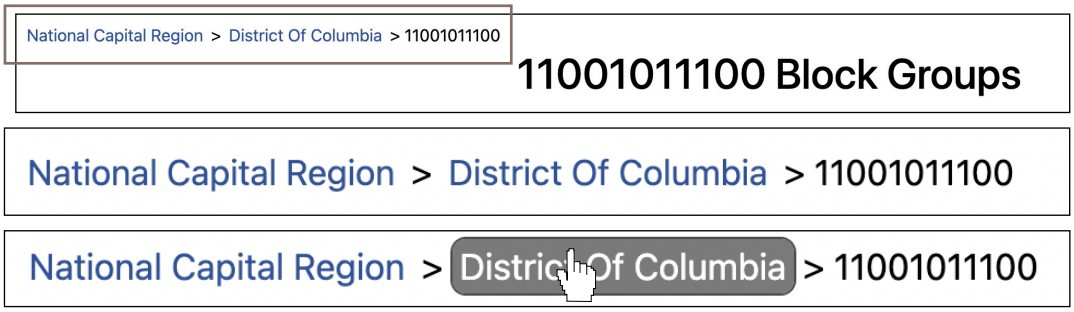


Fig. 12. Path history display from our dashboard. Users are able to essentially undo their actions by clicking on the layer they want to return to. This is signified by color and highlight on hover. The ability to navigate backwards through the dashboard is essential in the case of an error or simply continued use. Because of that, I consider this feature too easy to overlook. Due to its size and placement, this disappears from view if the dashboard is even scrolled just the slightest. Adapted from [1]

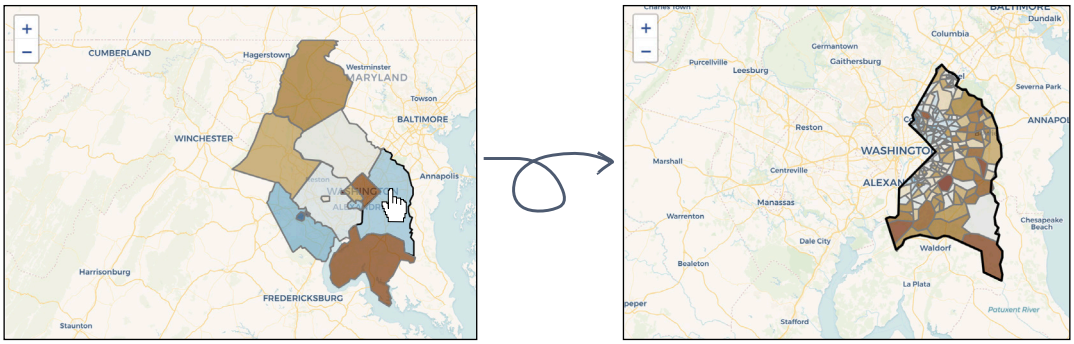


Fig. 13. The map from our dashboard before and after clicking on a region. When a region is clicked, the map "flies" to that area, allowing the user to see it in more detail. Users can zoom using the buttons in the upper left corner and pan by clicking and dragging. These capabilities are signified by highlights on hover, changes in the mouse icon, and the +- symbols. Although the map contains a functional toolset, it is inflexible relative to similar features on other dashboards. Interactive maps have become common tools online and users may have become used to working with them in certain ways. Many large mapping platforms including Apple Maps, Google Maps, Google Earth, and Waze all allow for zooming using touchpad motions (both scrollbar and two-finger pinch methods) when used on the desktop. A lack of features which people have become accustomed to may be confusing for some or just frustrating for others. Ensuring there are multiple ways to use certain controls allows users to work in ways that are most efficient for them. See [16, Fig. 14] for an alternate example.

Also inconsistent with other map tools I found, when a region is selected, the surrounding areas on the map disappear. This adds an extra layer of difficulty for users who may want to change their selection. See [18, Fig. 15] and [16, Fig. 16] for alternate examples. Adapted from [1]

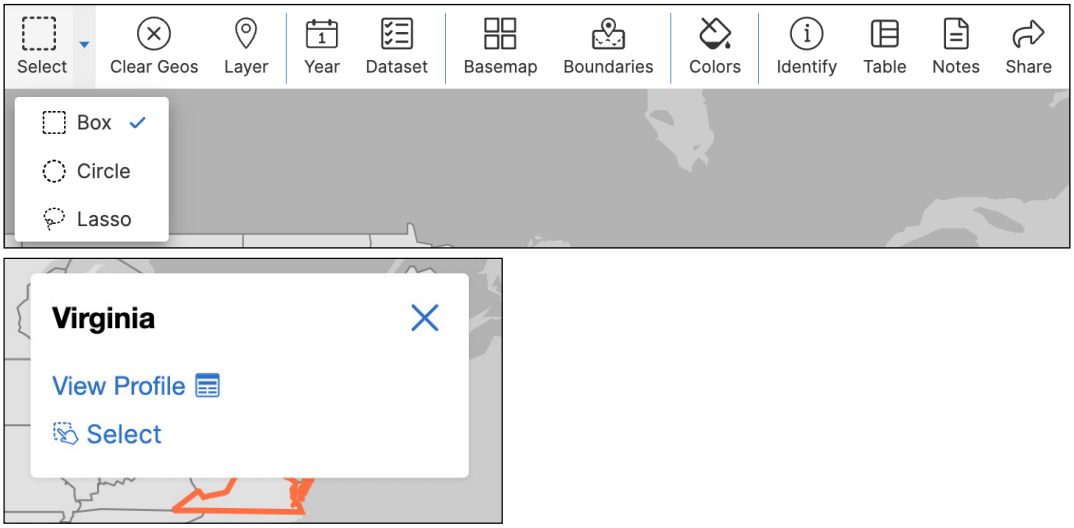


Fig. 14. Different controls available for interacting with the Census Bureau's map tool. In particular, there are multiple options for selecting regions on top of being able to click. Adapted from [16]

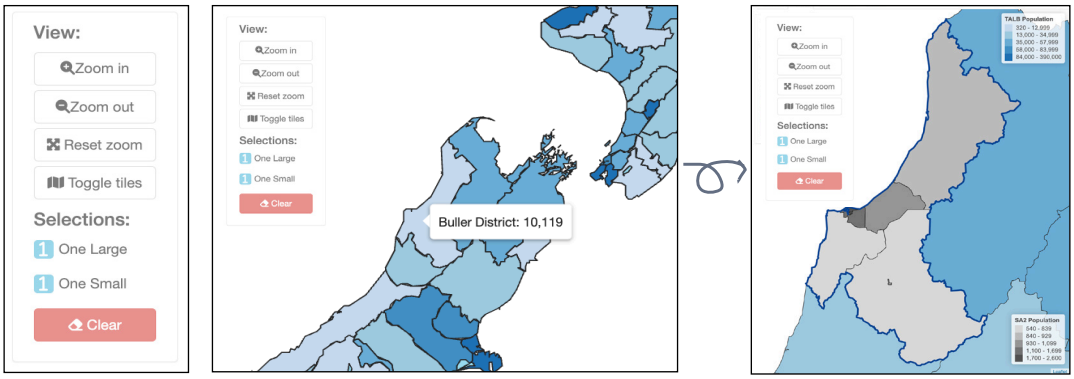


Fig. 15. Map feature from the New Zealand Aministrative Population Census dashboard. There are multiple ways to zoom on the map including touchpad motions. Similar to our map, their map includes a "fly to" feature on click. However, the outside regions remain visible and the region selected is shaded a different color to distinguish it. Adapted from [18]

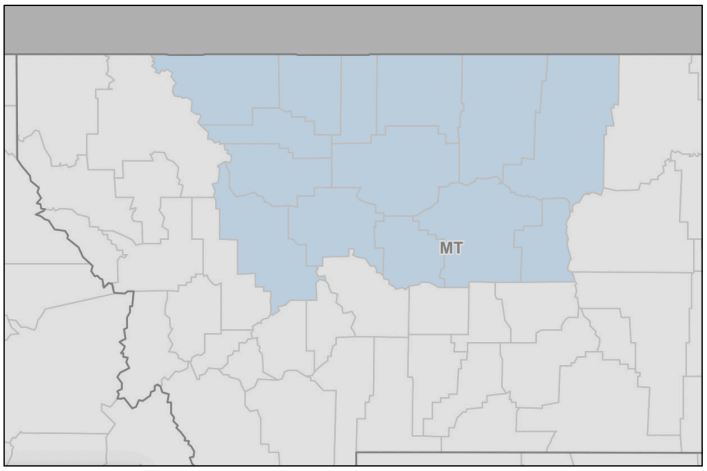


Fig. 16. From the Census Bureau's map tool. When areas are selected, the rest of the map remains visible but grayed-out. Adapted from [16]

Many affordances exist to aid in discovering data, but the discoverability of the affordances themselves is questionable. In addition, some of the affordances and signifiers we provide deviate from standards set by larger platforms and even other elements from our dashboard. This makes it harder for users to figure out how certain tools are meant to be used. I look more in detail about the implications of these considerations in the table that follows.

Criteria	Current Condition	Suggestions
Operability - Users should be able to "use and control [the] dashboard for performing their tasks." This represents whether the proper affordances clearly exist for users to find the information they need. [14]	Rating: 1 - somewhat met but some large issues While most of the necessary tools exist for users to control the dashboard, they are not neccessarily apparent. Unfamiliar conventions could make it difficult for users to determine what certain tools are meant to do or how to use them.	• Use a drop-down selector or timeline selector for the year selector tool. These may be more familiar to users. • Allow users to filter for all geographic levels in the main screen filter bar. • Add a scroll bar to the settings bar.
Orientation - Users should have support to direct themselves within the visualization (e.g. control over level of detail or ability to undo actions) [12]	Rating: 1 - somewhat met but some large issues There are capabilities for users to orient themselves, but not all of these capabilities are apparent or intuitive.	• Make features for navigating backwards through dashboard more apparent. The current feature should be visible regardless of scrolling. Larger font size can emphasize that this feature exists. • When an area is selected, gray out the surrounding regions rather than making them invisible.

Criteria	Current Condition	Suggestions
Flexibility and Efficiency of Use - "The system should offer users several options when it comes to finding content." This allows users to interact with the dashboard in ways that fit their needs [12]	Rating: 0 - not met Although there are features for which there are multiple similar controls, this is more of the same controls in multiple places rather than one control with flexible ways of using it. In fact, having the similar controls in multiple places adds more confusion than flexibility because it reduces the likelihood that users will find them all.	• Allow for touchpad zooming and alternate selection methods on the map tool.

Mapping

Mapping is an indication of a relationship between two elements. Proper mapping guides users in determining how things are used. When it is easy to see the relationship between controls and results, it is much easier to discover the various affordances of a dashboard, and, in turn, the necessary data. Under discoverability, I focus on how the mapping of our dashboard affects the user's ability to find controls for certain elements.

I follow one general guiding principle from Don Norman: "Controls should be close to the item being controlled" [11]. Because of this, I use one criteria to evaluate mapping for discoverability:

1. Spatial organization - Relates to the overall layout. Content/information should be easy to locate and follow a "logical organization" [12]

I focus largely on how the organization of the dashboard impacts the perceived "together-

ness" of certain elements. When I discuss mapping for understanding, I will look further at this criteria as it relates more to hierarchy and readability.

It is important to understand how people perceive objects as a whole to understand how people will perceive mappings. Gestalt theory posits that "the whole is other than the sum of the parts" [19]. In other words, we perceive systems as one entity before we perceive the elements that form that system. Gestaltism has become a vast school of psychology, of which the principles sit at the core of many good design theories. I choose to point out three that are particularly useful in understanding how our dashboard is interpreted:

1. Proximity - "Objects that are closer together are perceived as more related than objects that are further apart" [19]
2. Similarity - "Elements that are parallel to each other are seen as more related than elements not parallel to each other" [19]
3. Continuation - "Elements arranged on a line or curve are perceived as more related than elements not on the line or curve" [19]

From these principles, we can draw an explanation for why certain parts of our dashboard are perceived in certain ways. Nearly every element of our dashboard is placed in close proximity, making it difficult to pull out patterns at first glance. I would go as far as to say it creates a sense of disorder because of how tightly bunched together everything is. Taking a step back, I notice certain groups made by continuation. The dashboard is made up of three rows formed by lines, implied boundaries, and page breaks (represented by the different colored boxes in [1, Fig. 17]). Within each of these rows are columns seen due to the continuation of the vertical line and similarities in element widths (represented by the dashed borders in [1, Fig. 17]). Thus, in my first impression of our dashboard I was led to see this set of groups:

1. (Path History, [Title, Year Selector])
2. (Map & [Export button & Summary Box])
3. ([{Legend & Color By Selector} & Data Table] & Plot)

However, there doesn't seem to be much intention to these groups. In fact, they are counterintuitive. For example, it would make sense to group the map, supporting plot, color by

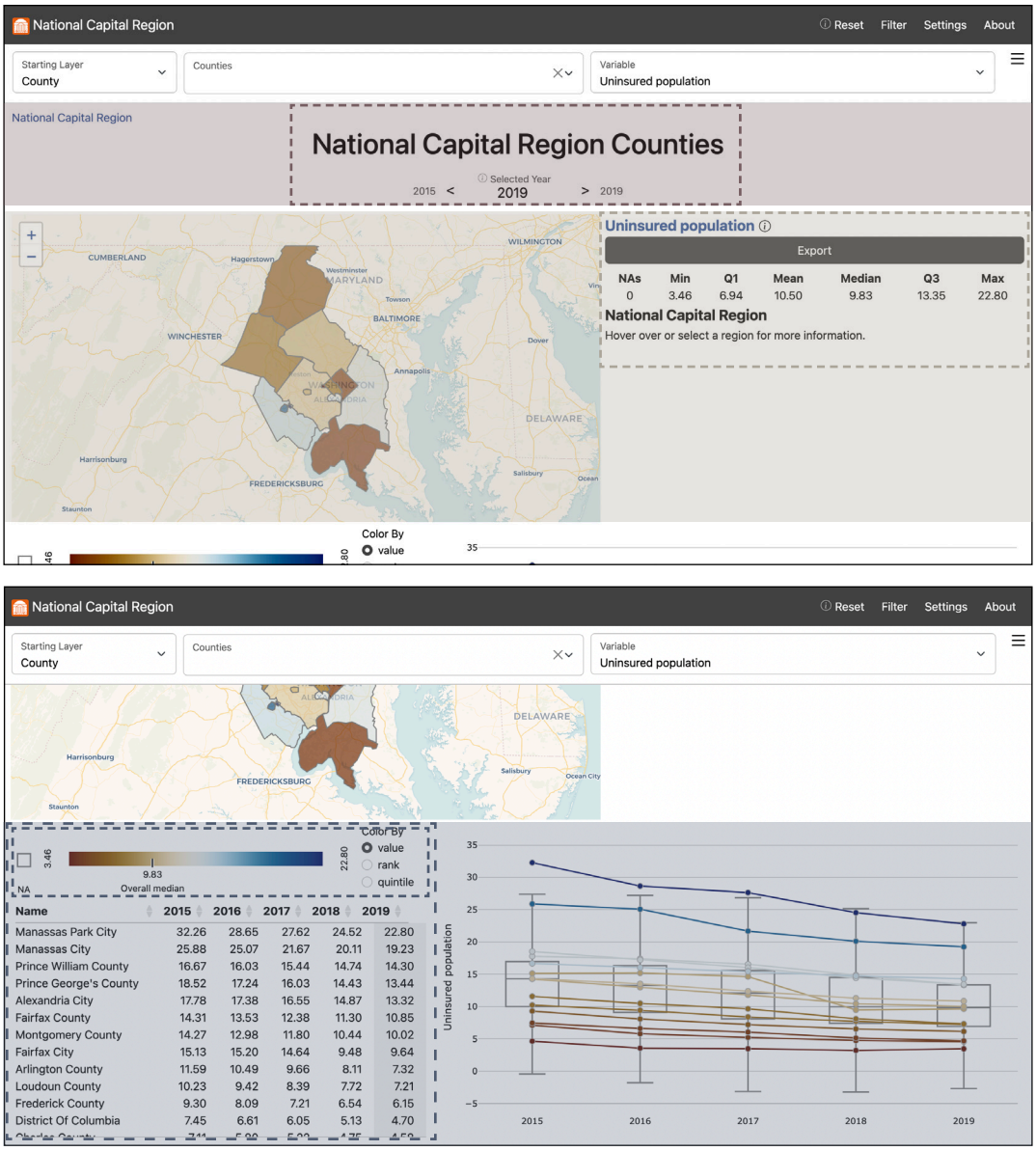


Fig. 17. Views of our dashboard. Top: Default, initial view. Bottom: Default view scrolled to bottom. Highlights and boxes are drawn on to emphasize implied groups. Adapted from [1]

selector, and legend together, but because of the inconsistent box sizes and overlapping, the color by selector and legend appear to fit closer with the data table – an unrelated element. Similarly, the export button appears to go with the rest of the summary box even though it exports the data from the data table. In these instances, it is made harder for users to determine how these features are meant to function and how they relate to each other.

Another group I see that is not implied by natural mapping is the different filter controls. Our dashboard places filter mechanisms in three locations: as a pop-up box in the navbar, at the top of the main view, and below the header. The controls in each of these places offer slightly different capabilities, but some interfere with the others. For example, the navbar filter allows for selecting multiple regions (to include counties) whereas the filter box in the main view allows for selecting exactly one county, meaning the two can be in conflict. If the user selects two counties from the navbar filter and selects one from the main view filter, it is unclear which should take precedence. The relationship between the two controls seems to depend entirely on the order of selection rather than logical progression. Even ignoring this issue, I question if the different filter controls should be scattered in the way they currently are. They all perform the same essential function (filtering data) and control the same elements. Making these controls disjoint decreases the likelihood that users can find tools that are necessary for them. Users may not even think to click the filter button in the navbar because the box at the top of the page is more apparent and seemingly serves the same purpose. If users are able to find these tools, the unclear mapping may still make it difficult for users to figure out how to use them.

The last thing I want to point out here is that the reset button should also be grouped with the filters. This is simply because the direct effect the reset button has is on the filters. By having this button separate from the filter selectors, it is unclear whether it is the filters in the main view, filters in the navbar, year filter, settings, or some combination of these features being reset.

In general, our dashboard creates counterintuitive groups that imply incorrect mappings and make it more difficult for users to find the data they are looking for. I consider what this means for our dashboard in the following table.

Criteria	Current Condition	Suggestions
Spatial Organization - Relates to the overall layout. Content/ information should be easy to locate and follows a "logical organization" [12] ** In this section, I only cover organization as it pertains to groups	Rating: 0 - not met Continuation, proximity, and similarity between elements of our dashboard causes perceived relationships between unrelated elements. This makes it difficult for users to figure out which elements are controlled by which controls and where the information they need is located.	• Group the legend, map, and plot together. • Group the export button with the data table. • Place all filtering controls in the same region. • Include the reset button with the filtering controls.

Feedback

Feedback is how the results of an action are communicated back to the user. This is key in ensuring audiences stay engaged and informed. With dashboards that have to load large amounts of data on request, it is important that users are aware that their actions are being processed. In addition, the new state of the system should be apparent once processed. Proper feedback of this sort confirms to the user that their action worked as expected.

I use this criteria to evaluate the feedback provided by our dashboard:

1. Visibility of system status - Users should be informed about what the current information being displayed is and what additional features exist [12]

In other words, the system should be constantly providing feedback to the user about its state. More than this, when an action is completed the feedback should align with the user's expected results or be sensible in some other way.

This manifests in our dashboard in several areas. Most of the feedback occurs when a user selects a filter option. This affects

the data loaded and is reflected by displays across the dashboard. The next few figures give more specific examples of feedback from our dashboard.

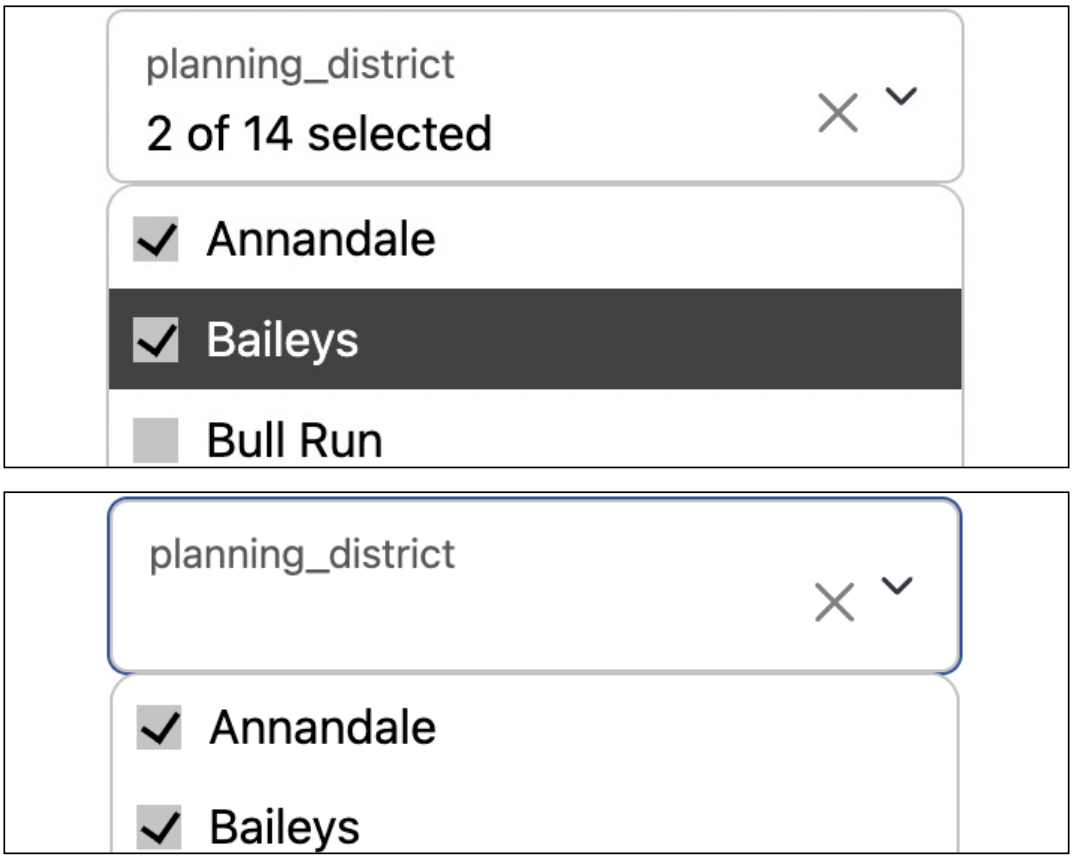


Fig. 18. Part of the pop-up filter box from our dashboard. When a user selects a region from one of the dropdown menus, that region is checked off, providing feedback to the user that the action was successful. Although an issue with the functionality rather than the design, I also note that when filters are reset, any regions previously selected keep their check marks (bottom). Adapted from [1]

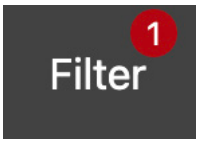


Fig. 19. The filter button in the navbar of our dashboard. When a filter is in place, a red marker appears next to the button with the number of filters currently enacted. Adapted from [1]

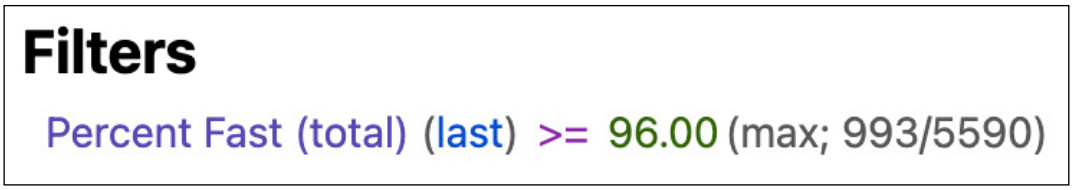


Fig. 20. Part of the summary box on our dashboard. When certain filters are in place, a list of filters is shown in the summary box. This lets users know their actions were successful and reminds them what filters are in place. Adapted from [1]

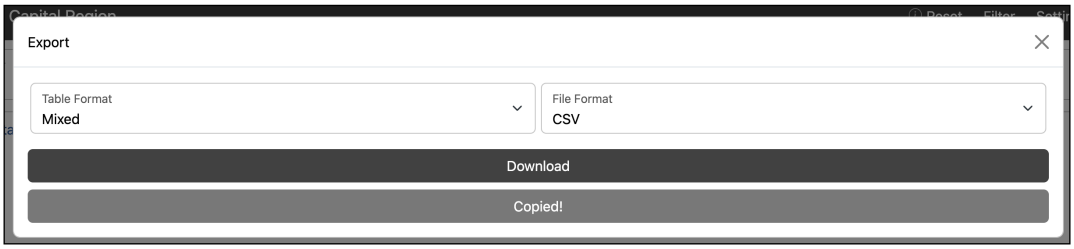


Fig. 21. The data download tool from our dashboard. When users download data or copy the API link, the button highlights and reflects the message "Downloaded!" or "Copied!". This lets the user know that their action was successful. Adapted from [1]

Fig. 22. Part of the filter bar from our dashboard. This provides feedback to the user that a county is selected. Adapted from [1]

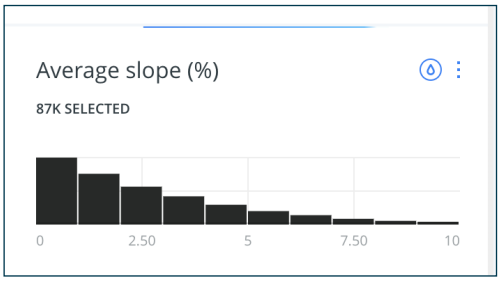


Fig. 23. A bar plot from a dashboard on cycling in Sydney. When data filters are changed, the blue bar at the top indicates loading by running across the screen. Adapted from [20]

I find no glaring issues with the feedback our dashboard provides. I also did not find any obvious areas where we were missing necessary feedback. Although I did point out a functionality error, the design itself was clear.

The one feature I feel could be included is something that indicates the dashboard is working on a request (e.g. [20, Fig. 23]). When I have used the dashboard I have never had issues with slow data load, which is why not having this feature didn't stand out to me. However, it is something that would be missed if these issues were ever encountered.

The table below gives my final thoughts on the feedback of our dashboard based on the criteria named earlier.

Criteria	**Current Condition**	**Suggestions**
Visibility of System Status - Users should be informed about what the current information being displayed is and what additional features exist [12]	Rating: 3 - met The necessary feedback is provided to reflect the state of the system.	• Include loading signals as an intermediary between actions and results

Constraints

Constraints limit the actions users are able to take. If implemented correctly, constraints make it much easier for a user to realize what they are supposed to do. Though there is not one set path our users are intended to take, it should be clear for users what the steps are to get to their desired result. What I note here are issues that tie directly into the learnability of our dashboard (my overarching criteria for discoverability).

The current filter options allow users to select a starting layer, region, and variable in any order they want. However, there are various combinations or layers, regions, and variables that we do not have data on. Still, these are allowable filter combinations that result in empty visualizations ([1, Fig. 25]). This makes it difficult for users to discover what is truly available to them and can lead to frustration if something that appears available is not. It should be clear if data does not exist for a given region-variable combination and users should not be able to select data that does not exist. I suggest we constrain users to select in one direction in one of two ways:

1. Choose region or variable as the primary selection. Have users select the primary selection first and then the other filter.

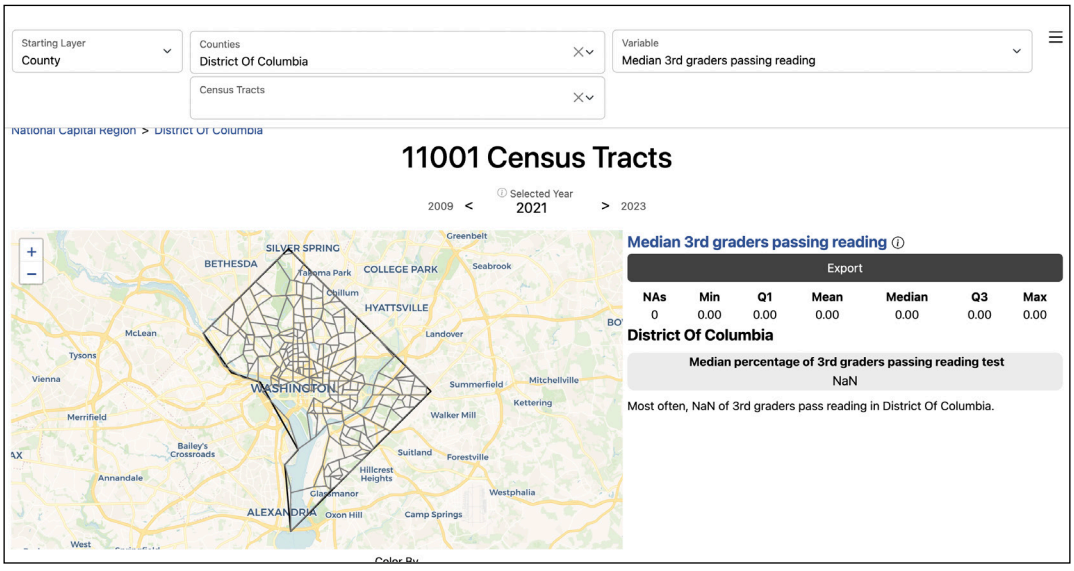


Fig. 25. From our dashboard. An example view when the filters result in an empty dataset. Adapted from [1]

2. Have users select which topic to use as their primary filter (region or variable). Then have users select the primary selection and, finally, the remaining filter.

Depending on the results of the initial selection, variables or regions without data should not be possible to select. [21, Fig. 24] gives an example of what this can look like.

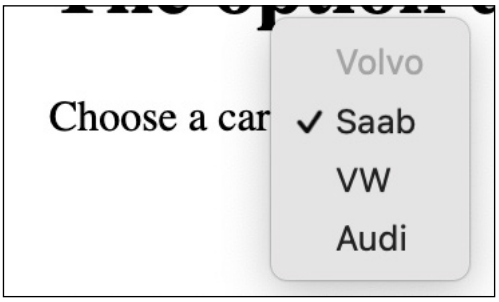


Fig. 24. An example of a selector tool with a disabled option. Adapted from [21]

Putting the Pieces Together

Of the five criteria considered under discoverability, our dashboard only fully met one. In thinking about each of the components, it has become clear that the dashboard is lacking discoverability. This means that it is difficult for users to find the controls and information our dashboard has to offer. Earlier, I mentioned the criteria of learnability. If the dashboard is not discoverable, then inherently it cannot be easily learnable. I choose not to include a table for this criterion because it is a culmination of the factors I have already addressed.

For truly good design, the affordances, signifiers, mappings, feedback, and constraints must all work together to enhance the discoverability of the dashboard. Without this, we fail to engage users enough for them to benefit from the service we are providing. Without discoverability first, we cannot have understanding.

Understanding

What does it all mean?

Figure taken from Don Norman's The Design of Everyday Things. "The designer's conceptual model is the designer's conception of the look, feel, and operation of a product. The system image is what can be derived from the physical structure that has been built (including documentation). The user's mental model is developed through interaction with the product and the system image. Designers expect the user's model to be identical to their own, but because they cannot communicate directly with the user, the burden of communication is with the system image." [11]

I turn now to look at the understandability of our dashboard. While understanding is not one of Norman's principles itself, it is directly derived from the conceptual model. I first explain how this works, and then look at the current performance of our dashboard under this principle. A user's conceptual model is built through affordances, signifiers, mappings, and constraints, and so, I evaluate components of our dashboard as they fall under these categories.

Conceptual Model

Put simply, a conceptual model is a view of how something works. Anyone who interacts with a system has a conceptual model of that system and this model varies from person to person. Conceptual models do not need to truly and fully represent how something is working, but they should give the users information on how to interact with the product [11]. Norman gives the example of folder icons on a computer screen. Though a highly simplified view, these folders give users an idea of what they are meant for. The conceptual model aids users in understanding what they can do with a device, the effects of their actions, and how to react when something goes wrong [11].

Users infer a conceptual model based on their view of the structure of a system. Thus, the presentation of a product – affordances, signifiers, mappings, and constraints – is a necessary aspect for overall understanding. As Norman states, "Good conceptual models are the key to understandable, enjoyable products: good communication is the key to good conceptual models" [11].

For evaluating the conceptual model and the understanding of our dashboard as a whole, I use this criteria:

1. Improvement of situational awareness - The dashboard should provide users a view of "what is going on and what might happen next" [14]

I will come back to this idea at the end of this section, but first, I look at each of the components that comprise the conceptual model and understanding of our dashboard. I will use these considerations to ultimately determine if the criterion above is met.

Affordances and Signifiers

In our context, affordances and signifiers under the conceptual model relate more to the un-

derstanding users gain of the data rather than the dashboard. I think of this as: what information are users able to gain? In other words, the affordance is the knowledge gain and the signifiers are how that information is presented.

As I go over the affordances and signifiers of our dashboard, I keep in mind two criteria:

1. The dashboard enables the user to monitor and understand the displayed information at a glance - The full potential of the dashboard is met not just in the information displayed but the understanding the user gains. While a dashboard may contain a complete view of the data, this is moot if the information is not communicated understandably [15]
2. Usefulness/suitability for tasks - The dashboard should be useful to the target user and meet their task requirements [14], [13]

The following figures display affordances and signifiers that influence understanding. The majority of these are pulled from our dashboard for evaluation, while a few are pulled from outside dashboards as inspiration.

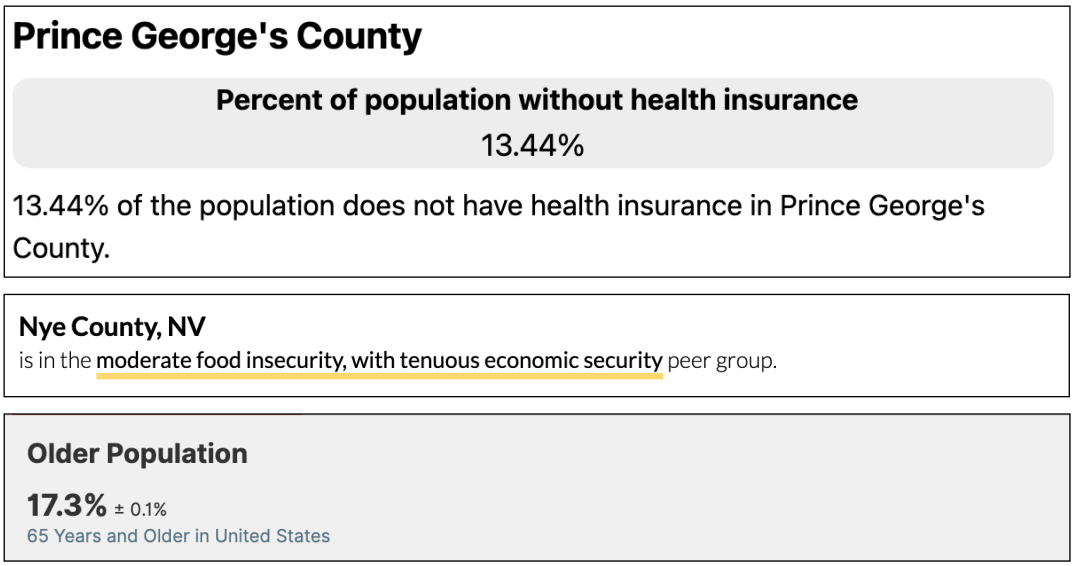


Fig. 26. Different ways of summarizing data. From top to bottom: the National Capital Region dashboard, the Urban Institute's food insecurity dashboard, and the Census Bureau's area profiles dashboard. As noted for the previous figure, the display of summary data in a "human readable" format makes it easier and more efficient for users to gain a "big picture" view of the data. Adapted from [1], [22], and [16]

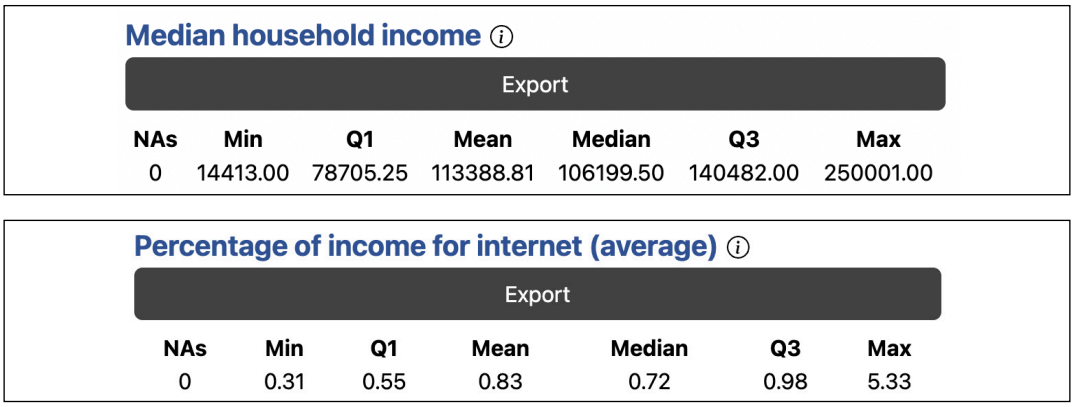


Fig. 27. Two views from the National Capital Region dashboard. Summarizing data enhances how quickly a user is able to gain an understanding of the data and gives an initial view of the state of the system. However, missing commas between digits means that the numbers are not necessarily displayed in the most reader friendly format. This makes it such that measures with data over four figures are slower to read (top). Adapted from [1]

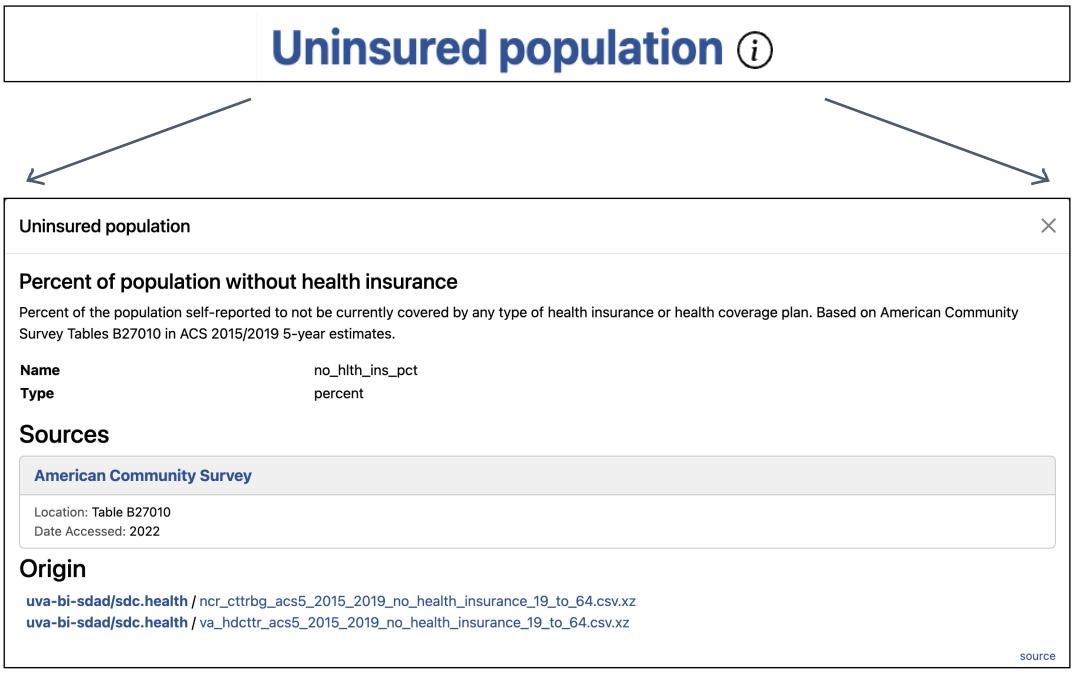
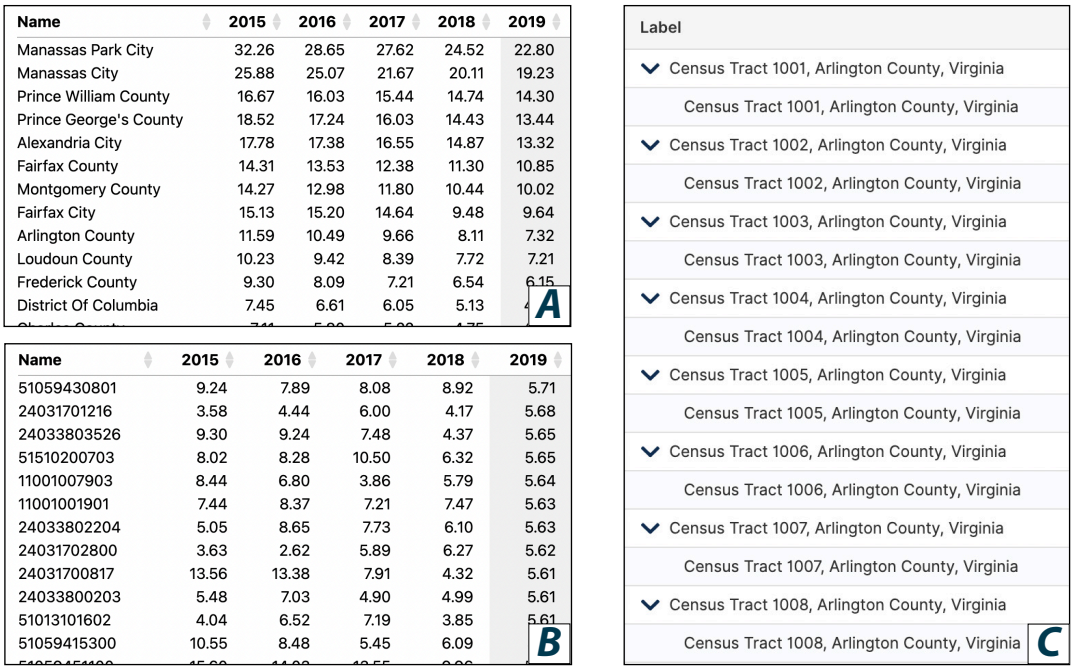


Fig. 28. Features from the National Capital Region dashboard. Top: button showing the name of the current variable in view. Bottom: a pop-up window with measure info on the current variable. When the button is clicked, the measure info window pops up at the top of the screen. The blue text is a common indicator that text is clickable. Ensuring that variables are well-defined to the audience is incredibly important for accurate analysis. Adapted from [1]



Name	2015	2016	2017	2018	2019
Manassas Park City	32.26	28.65	27.62	24.52	22.80
Manassas City	25.88	25.07	21.67	20.11	19.23
Prince William County	16.67	16.03	15.44	14.74	14.30
Prince George's County	18.52	17.24	16.03	14.43	13.44
Alexandria City	17.78	17.38	16.55	14.87	13.32
Fairfax County	14.31	13.53	12.38	11.30	10.85
Montgomery County	14.27	12.98	11.80	10.44	10.02
Fairfax City	15.13	15.20	14.64	9.48	9.64
Arlington County	11.59	10.49	9.66	8.11	7.32
Loudoun County	10.23	9.42	8.39	7.72	7.21
Frederick County	9.30	8.09	7.21	6.54	6.15
District Of Columbia	7.45	6.61	6.05	5.13	4

A

Name	2015	2016	2017	2018	2019
51059430801	9.24	7.89	8.08	8.92	5.71
24031701216	3.58	4.44	6.00	4.17	5.68
24033803526	9.30	9.24	7.48	4.37	5.65
51510200703	8.02	8.28	10.50	6.32	5.65
11001007903	8.44	6.80	3.86	5.79	5.64
11001001901	7.44	8.37	7.21	7.47	5.63
24033802204	5.05	8.65	7.73	6.10	5.63
24031702800	3.63	2.62	5.89	6.27	5.62
24031700817	13.56	13.38	7.91	4.32	5.61
24033800203	5.48	7.03	4.90	4.99	5.61
51013101602	4.04	6.52	7.19	3.85	5.61
51059415300	10.55	8.48	5.45	6.09	

B

Label

- Census Tract 1001, Arlington County, Virginia
  - Census Tract 1001, Arlington County, Virginia
- Census Tract 1002, Arlington County, Virginia
  - Census Tract 1002, Arlington County, Virginia
- Census Tract 1003, Arlington County, Virginia
  - Census Tract 1003, Arlington County, Virginia
- Census Tract 1004, Arlington County, Virginia
  - Census Tract 1004, Arlington County, Virginia
- Census Tract 1005, Arlington County, Virginia
  - Census Tract 1005, Arlington County, Virginia
- Census Tract 1006, Arlington County, Virginia
  - Census Tract 1006, Arlington County, Virginia
- Census Tract 1007, Arlington County, Virginia
  - Census Tract 1007, Arlington County, Virginia
- Census Tract 1008, Arlington County, Virginia
  - Census Tract 1008, Arlington County, Virginia

C

Fig. 30. Parts of data tables from the National Capital Region dashboard (A, B) and the US Census's dashboard (C). The tables allow users to see the numbers themselves to get a more precise view of the data. The problem, however, lies when looking at sub-county geographic levels. In particular, the non-county geographies we display on our dashboard use FIPs code identifiers. B shows what this looks like when using census tracts as the base layer. While it is likely that policy makers know the FIPs code for the county of their constituents and possible that they know some of the tracts within their jurisdiction, the mental load required to decipher the table is heightened with this formatting. C shows an alternate way of displaying these, which makes it much easier to pull out information. Another way of thinking about it: If I am looking for something in Arlington County, it would take me one step to locate it in C. On the other hand, it would take me two steps to locate it in B since I am first required to convert 'Arlington County' to '51059'. Adapted from [1] and [16]

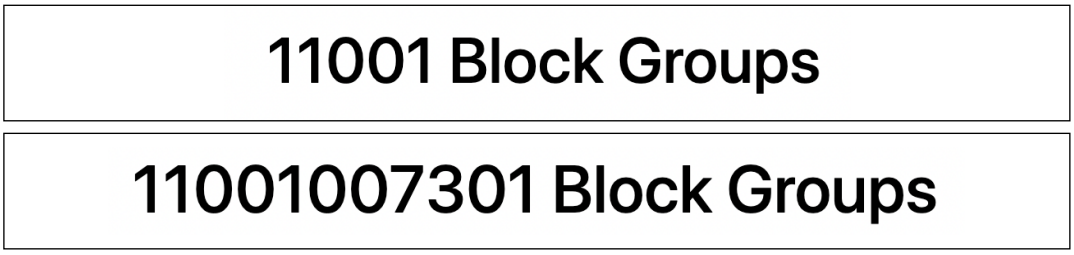


Fig. 31. Headers from different views of the National Capital Region Dashboard. This faces the same issue as the table, where FIPs code identifications are used rather than familiar names. This is especially important in this case since the header should be a clear indicator of the data being showcased. Adapted from [1]

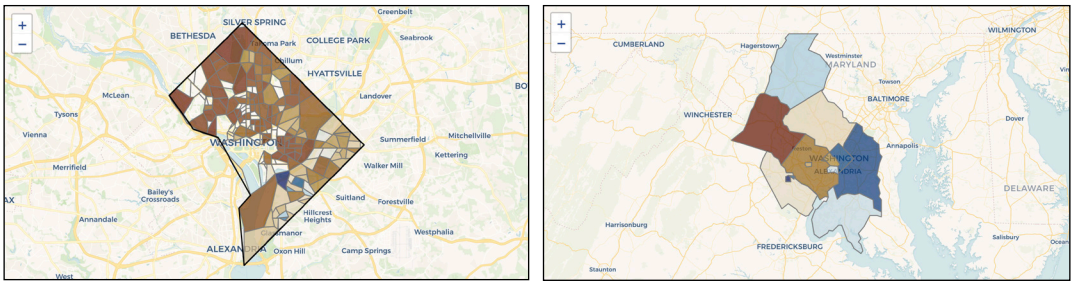


Fig. 32. Different choropleth maps accessed from the National Capital Region dashboard. These provide a view of the current state of a region for a given measure. Particularly useful is the level of granularity we are able to provide, giving insight into patterns within a county. Adapted from [1]

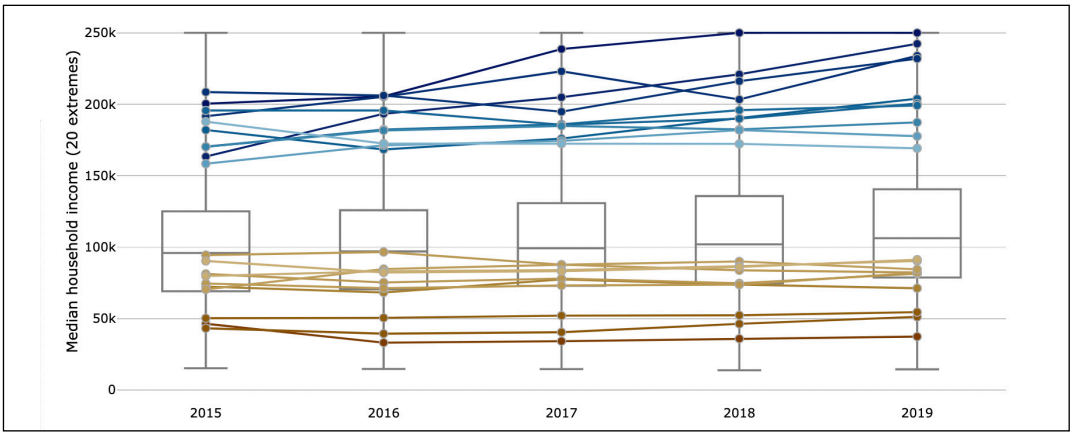


Fig. 33. Taken from the National Capital Region Dashboard. Median household income in Arlington County, VA over time. Each dot/line represents a census tract. Adapted from [1]

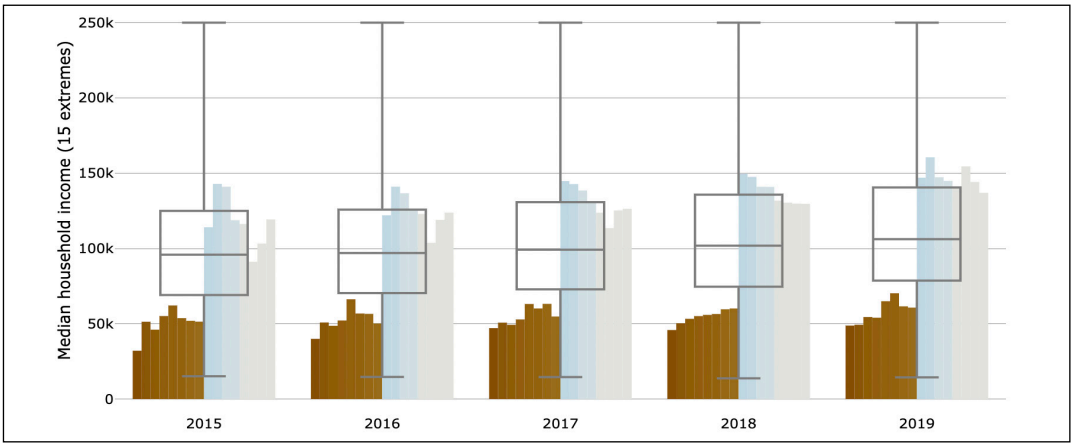


Fig. 34. Taken from the National Capital Region Dashboard. Median household income in Arlington County, VA over time. Each bar represents a census tract. This graph replaces the scatter plot ([1, Fig. 33]) in the dashboard view. The control to switch between the two graphs is at the bottom in the settings menu. Adapted from [1]

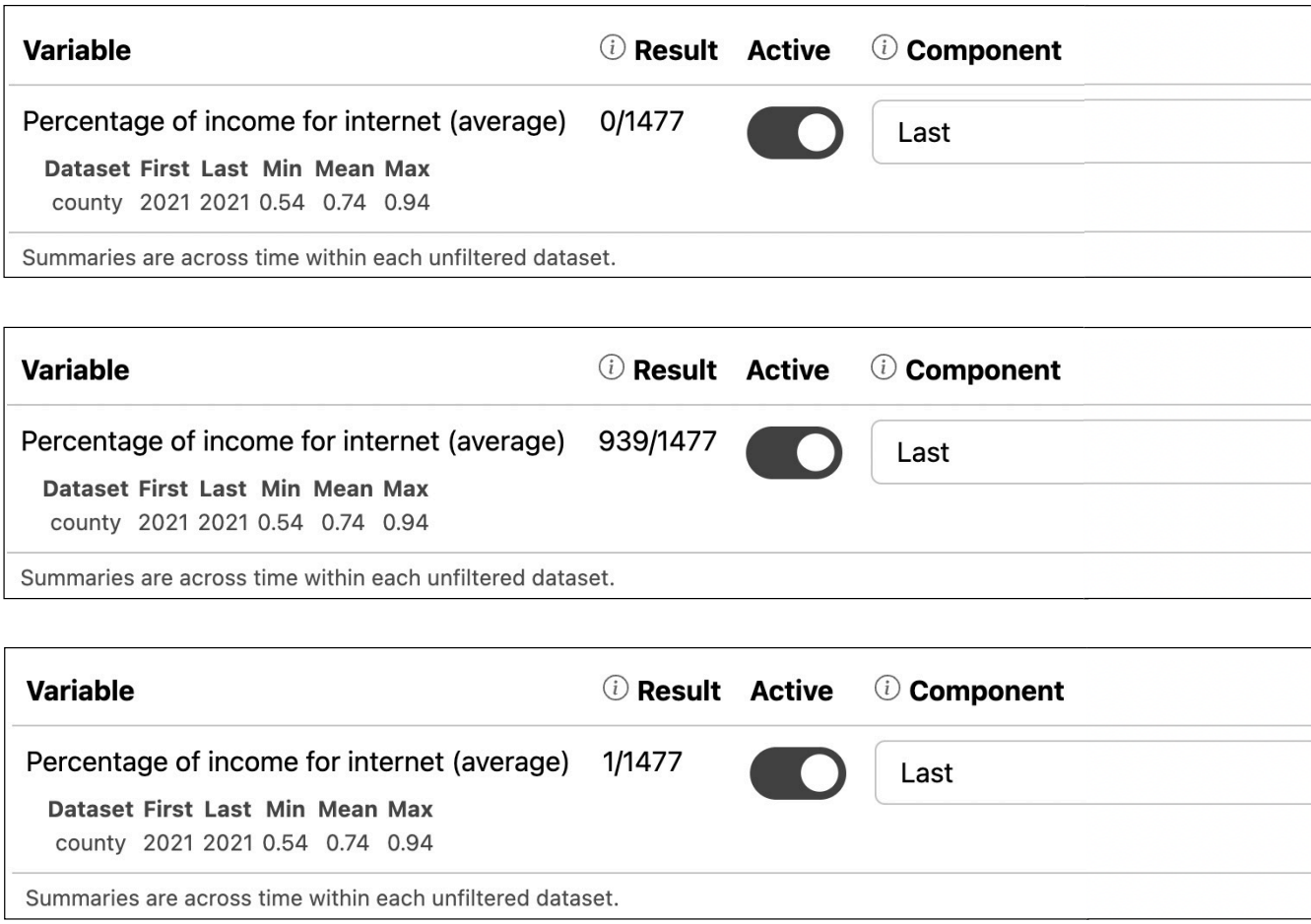
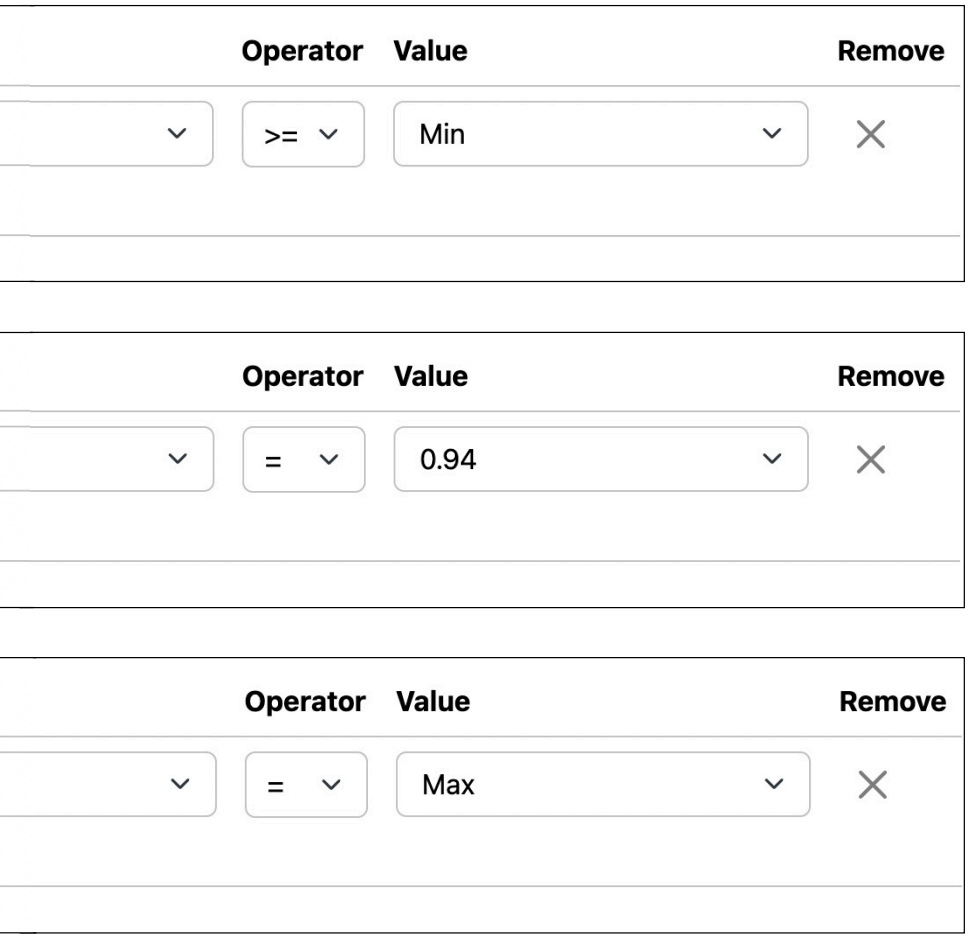


Fig 29. More detailed view of the variable condition selector tool from our dashboard (proportions adjusted for clarity). This tool is a part of the filter pop-up box discussed on page 19 and allows users to filter data on a given variable based on value. Once a variable is selected, there are labels, toggles, and dropdown menus displaying what can be customized. Hovering over "Result" and "Component" causes an informational tooltip to display. The variable condition feature can be very useful for users to draw specific analyses from the data, but there are several issues which impact its understandability. For one, component represents a year to filter the data based on, which is not signified by the name or selection options (first, last, selected). The only clue given is the word "time" in the description. Perhaps a larger issue, though, is that it is difficult to even comprehend how these function. These filters actually work on whatever data is currently displayed on the dashboard. For example, if the current display is percent uninsured population for tracts in 2019, then the variable condition represents the intersection of that dataset with the given condition. However, when this selection option is open, the current display is not visible and there is nothing that signifies what data this is working on. This makes the result of this feature unclear. To prove my point anecdotally, it was only after much scrutiny that I understood what component meant and much testing of the tool that I realized this feature was, in fact, being applied to the dashboard regardless of what variable was currently in view. Adapted from [1]


Operator
Value
Remove
>=
Min
Operator
Value
Remove
=
0.94
Operator
Value
Remove
=
Max

Earlier, I outlined a set of user needs that our dashboard should be able to meet. I wonder, which of these questions does our dashboard address? If these questions are used to paint a picture of a given area, then the answers together build a useful conceptual model of the National Capital Region (the real-world system represented by our dashboard).

	Is the answer apparent?	**Comments**
What is the current state of [measure] in [region]?	Yes	The combination of visualizations and descriptive data on the site allow for this question to be answered without too much confusion. The choropleth map especially showcases this information ([1, Fig. 32]). That said, there are certain caveats to this because of the layout, which I will go over later in this section.
How does [measure A] compare to [measure B] compare to ... compare to [measure C] in [region]?	No	Our measures are inextricably intertwined in some way or another, but we show them individually without a way to view them side by side. If confined to only one screen, it is difficult to glean any information about the relationship between different measures without memorization. The one feature which may allow some of this comparison is the variable condition filter [1, Fig. 29], but the caveats of this tool have been well-discussed.
How does [region A] compare to [region B] compare to ... compare to [region C] for [measure]?	Somewhat	The map allows for comparison across regions at the same level. However, there is no ability to compare subsets to the whole.

	Is the answer apparent?	Comments
How has [measure] in [region] changed over time?	Somewhat	While the information exists to make this question answerable, the presentation is not widely understandable. The plot in the bottom right corner of our dashboard ([1, Fig. 7] and [1, Fig. 8]) shows time series data for a given measure across different geographies. However, it is difficult to understand what data is being shown in this plot. This stems from a disconnect between the data in the map and the data in the plot. The map only shows one year and plot shows the whole range of years, but the change from one dataset to another was not explicit. Having to decipher the meaning of the plot and then having to hold this meaning in ones head forces more complexity onto the user. This issue can be remedied simply by adding a title (i.e., "X Measure over Time") and an x-axis label (i.e., "Year") to clearly signify what is being shown. Additionally, while scatter plots and bar charts are typically considered a basic visualization, the underlaid box and whisker plots adds to the amount of knowledge requisite for understanding. Our assumption was that our users would only necessarily have a base-level of visualization literacy. Thus, this graph is not suitable to our general audience. ** There is a toggle in the settings to turn on and off the box and whisker plots -- a setting I didn't discover

Given that the dashboard does not make the answers to all necessary questions apparent, the proper affordances and signifiers for understanding do not exist. Certain areas provide meaningful and useful information that is well communicated. However, others lack clarity making the data difficult to interpret and adding to the mental load placed on the user.

The following table gives my suggestions for improving these aspects of the dashboard based on the considerations laid out above and with the two criteria listed earlier.

Criteria	**Current Condition**	**Suggestions**
Enables the User to Monitor and Understand the Displayed Information at a Glance - The full potential of the dashboard is met not just in the information displayed but the understanding the user gains. While a dashboard may contain a complete view of the data, this is moot if the information is not communicated in an understandable way [15]	Rating: 2 - mostly met but some small issues The summary table and choropleth map both provide this capability. However, there are some issues with the way information is displayed which make deciphering the information slower.	• Add a title and x-axis label to the time series plot. • Add commas to large digits displayed in the summary table. • Where possible, replace the 5 digit FIPs code with the county and state name.

Criteria	Current Condition	Suggestions
Usefulness/Suitability for tasks - The dashboard should be useful to the target user and meet their task requirements [14], [13]	Rating: 1 - somewhat met but some large issues Although the dashboard contains the information to answer most of the tasks laid out, the ways in which it is currently being communicated is not suitable for a large audience.	• Remove the box and whisker plots in the initial view of the time series plot. Make customization for turning these underlays off and on more apparent (i.e. show with the plot the controls go with). • Add descriptor showing how the current region compares to its larger, surrounding region (ex: Arlington County, VA compared to VA). This can be placed as part of the summary box. • Add variable comparison capabilities. Because this serves a distinct purpose from what we currently display, it would be reasonable to have a tool for this on a separate page.

Mapping

Where in discovery I focused on mapping aiding in finding controls for certain elements, here I think about the mapping between the controls, actions, and results. Based on the mapping, it should be clear to the user the interrelatedness of different elements of the dashboard. This pertains to both the mapping of dashboard elements to other dashboard elements and the mapping of dashboard elements to elements of the real world.

I consider three criteria for this evaluation:

1. Recognition rather than recall - The necessary information to gain an understanding should be apparent on the dashboard without users needing to "remember information from one part of the dialogue to another" [12]
2. Match between system and real world - The system should be intuitive based on the user's background. It should follow "real-world conventions" such as what is viewed as a logical order [12]
3. Fit on a single screen - The initial view of a dashboard should allow the user to quickly gain an "initial situational awareness" [15]
4. Spatial organization - Relates to the overall layout. Content/information should be easy to locate and follow a "logical organization" [12]

You may note the reference to a "logical order" or "logical organization" within these criteria. I determine this based on how a user would "read" our dashboard and the hierarchical structure of elements. Using sizing and positioning, dashboards can dictate where users' focus is drawn and in what order elements are seen. As noted earlier, because of Western cultural norms, we tend to be initially drawn to objects in the top-left corner of our screen. This concept along with things like size, contrast, and spacing work to create a visual hierarchy, assigning implied importance to different features.

[22, Fig. 36] and [1, Fig. 37] depict the layouts of a food insecurity dashboard from the Urban Institute and our current National Capital Region dashboard. The Urban Institute dashboard contains stacked elements, creating a top-down hierarchy. Margins around certain features create natural groups (i.e., title and description, legend and map, and summary and supporting plots). These groups are ordered from least to most detailed, imploring the user to "dig deeper" as they scroll

through the dashboard.

On the other hand, the National Capital Region dashboard has no clear focal point or consistent hierarchy. Fig. 35 displays two hierarchy diagrams, where each row represents one level of hierarchy. On the left, I give my view of a "logical" ordering of our dashboard's elements. On the right, I give my interpretation of our dashboard's structure based on the current layout. I group these largely based on functionality (data controls vs. data results) and rank the results based on their level of detail. Comparing the two diagrams side by side gives a picture of the randomness of much of the current structure. Especially where the data is displayed, elements of different hierarchies are well-mixed and no clear alternate patterns emerge. If the diagram on the right is the intended conceptual model, then it is clear from the diagram on the left that this is lost in the layout.

Another important note is that the map and scatter plot do not both fit on one screen [1, Fig. 37]. This becomes an issue because the two figures are linked such that hovering over one highlights corresponding data in the other. The linkage between the two figures implies something to be found by com-

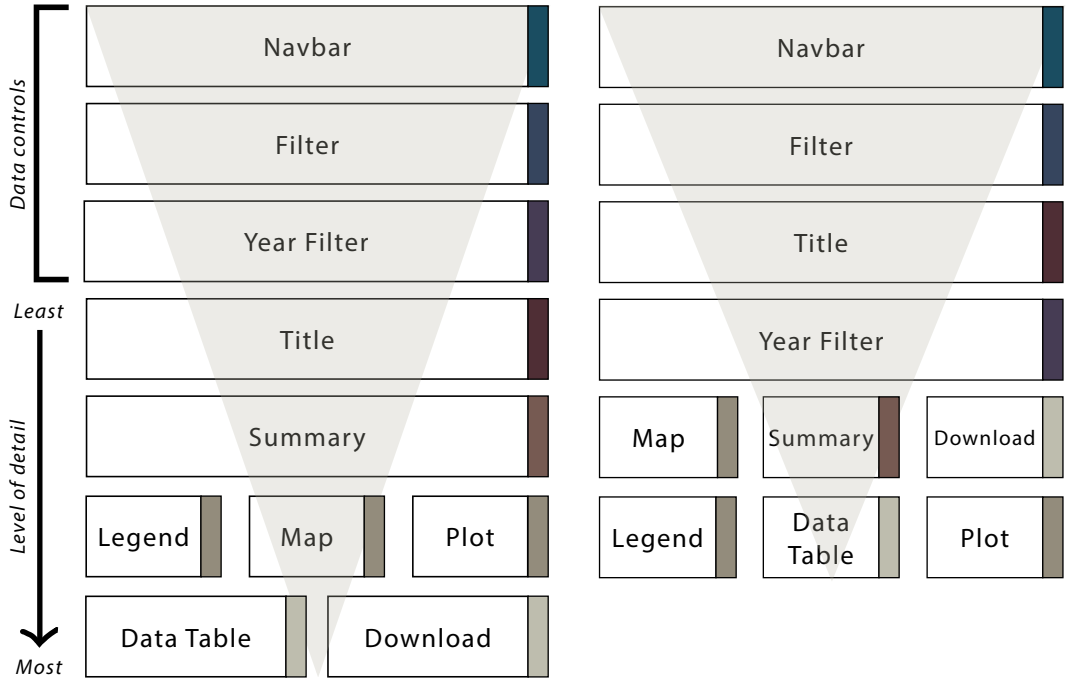


Fig. 35. Diagrams representing hierarchical structures. Left: the hierarchy suggested by the layout of the National Capital Region dashboard. Right: my view of a "logical" order/hierachy of our dashboard's elements.

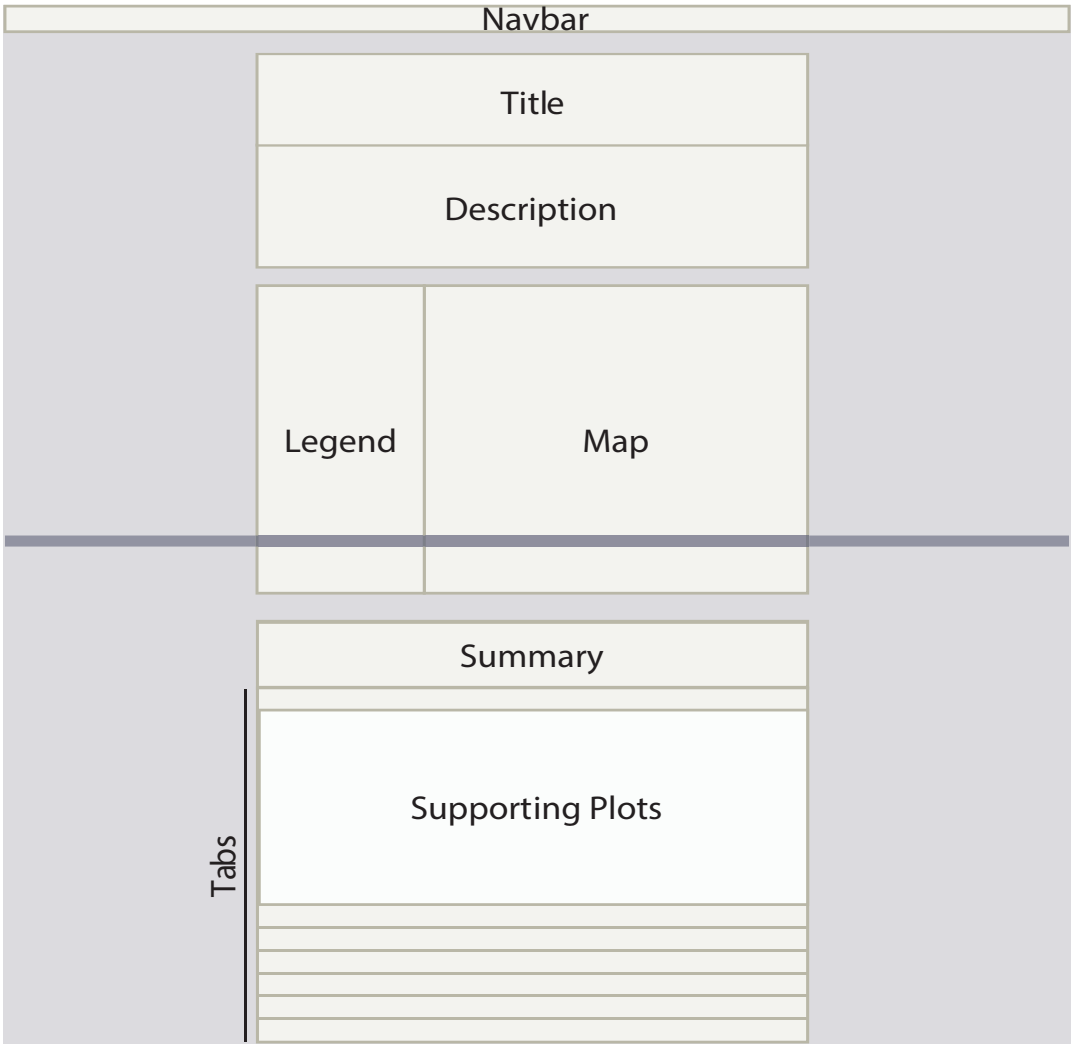


Fig. 36. The desktop layout of a food insecurity dashboard from the Urban Institute. The dark gray line delineates a screen break. Adapted from [22]

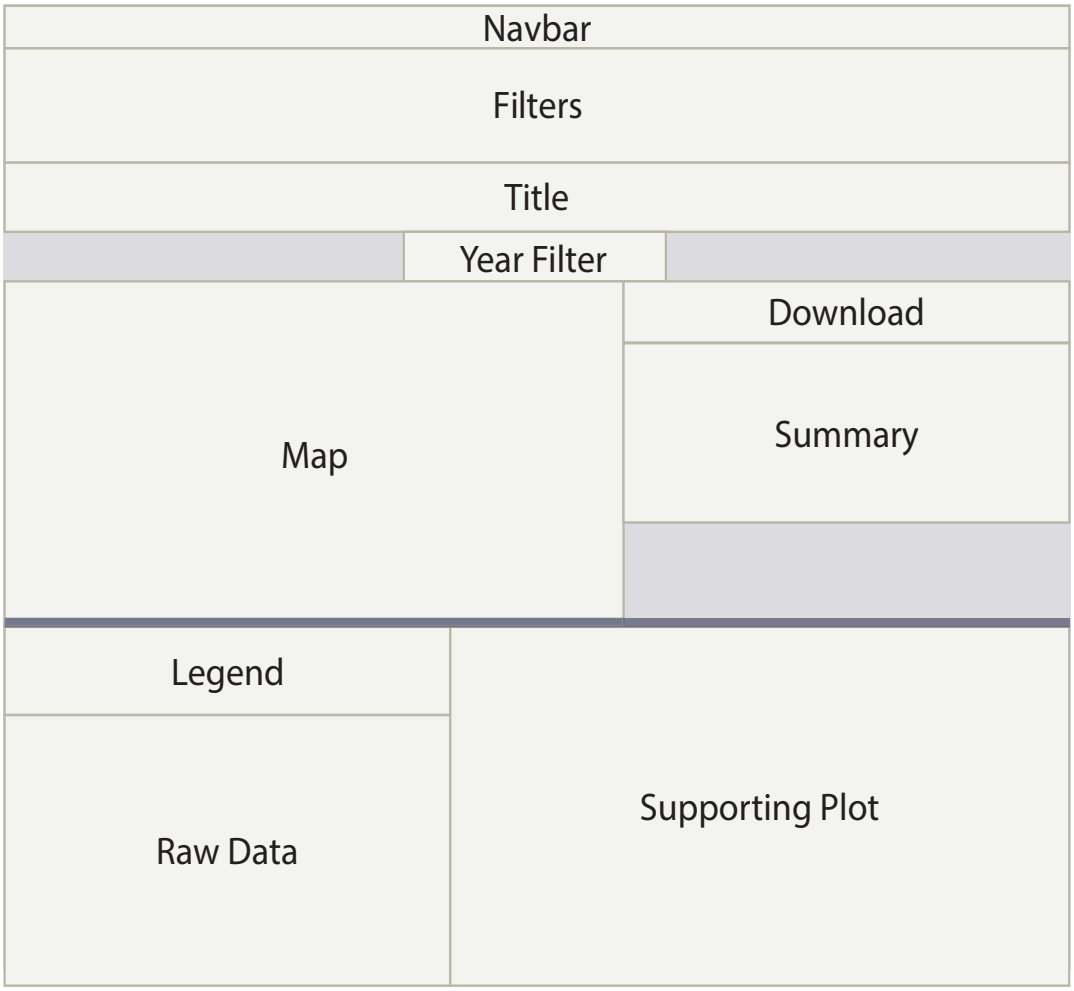


Fig. 37. The desktop layout of our current National Capital Region dashboard. The dark gray line delineates a screen break. Adapted from [1]

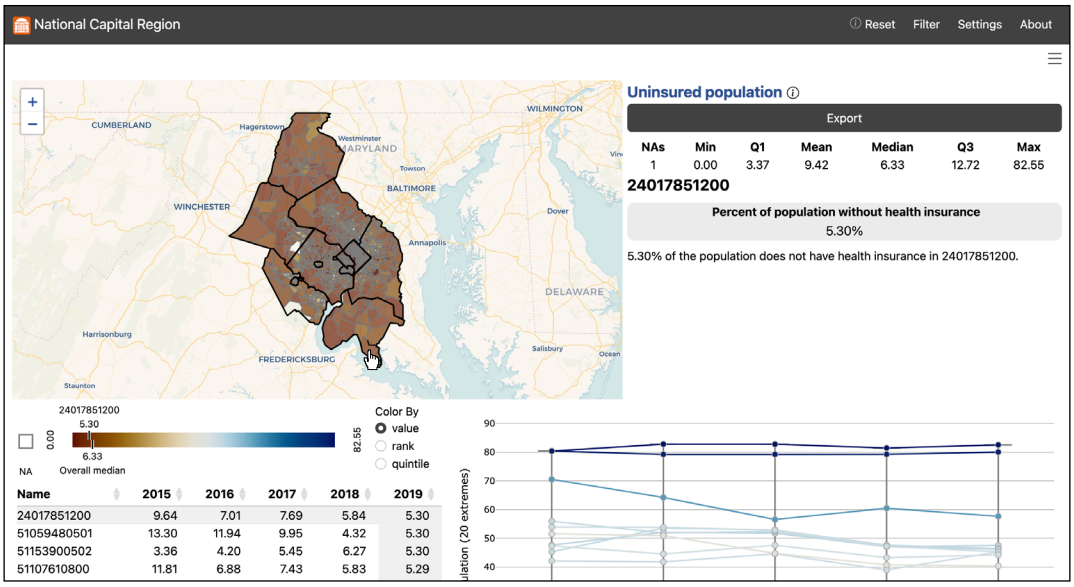


Fig. 38. Desktop view of the national capital region dashboard with the filter collapsed. The current view shows the mouse hovering over one of the tracts and how this affects the other features on the screen. However, you cannot see the how the line plot is affected since the map and plot do not fit in one screen. Adapted from [1]

paring them. If you are unable to see both at once, this interaction adds confusion to the user's conceptual model.

The Urban Institute's food insecurity dashboard contains similar classes of elements to ours. Likewise, their map, summary box, and supporting plots (bar graphs) are all linked and in separate views. Yet, the implied hierarchy of elements allows their dashboard to avoid the confusion this same situation creates in ours. As in, each data piece is treated like the next piece to a story rather than one collective object.

However, unlike the Urban Institute, our map and supporting plot fall on the same hierarchical level. The Census Bureau's profile dashboard places their map and other plots side by side to fit in one window [16, Fig. 39]. This signifies an equal relationship between the two elements.

It is also possible that the two graphs should not be part of the same story at all since they represent different dimensions (geographic versus time series). Both the Census Bureau's data website and Statistics New Zealand's experimental administrative population census dashboard use tabs to separate different analytical tools or di-

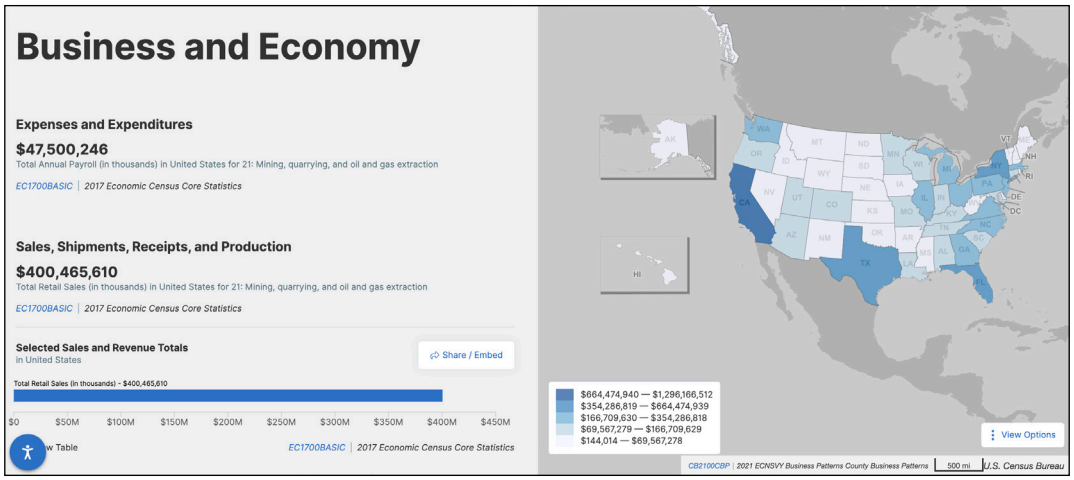


Fig. 39. Part of the Census Bureau's area profiles dashboard. The two boxes span the width of a desktop screen. Adapted from [16]

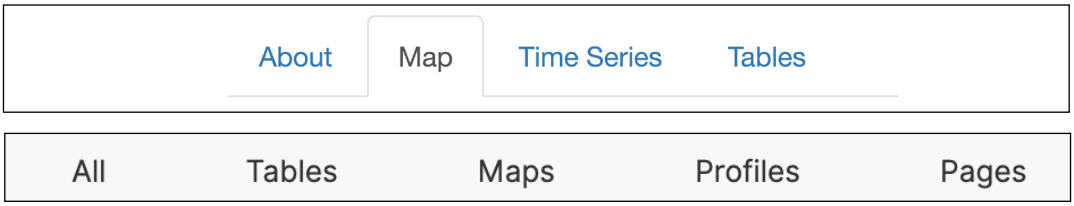


Fig. 40(a) and 40(b). Examples of tabs from Statistics New Zealand (top) and the United States Census Bureau (bottom). Adapted from [18] and [16]

mensions of data into different pages [18, Fig. 40(a)]-[16, Fig. 40(b)].

For my final thought here, I switch gears to talk about the choropleth map and how this maps data to the real-world system. Fig. 41 shows different ways of viewing our choropleth map. Providing a familiar visual model of the system makes it much simpler for users to draw connections between the data and the real world. The noted "color by" feature is useful for showing multiple perspectives for analysis. I do, however, question the difference between coloring by value versus rank since the distance between the colors of each county remains the same. Adding to this confusion, a "Color by Rank" toggle exists in the settings bar and it seems to more effectively implement this feature. However, when the settings color by rank feature is switched on, the map color by feature remains on whatever it setting it was last set to (not necessarily rank). Not only are these features in conflict, but when the settings bar is closed there is no indicator that color by rank is switched on or off, potentially causing the user to misinterpret the data being

shown.

Certain filter controls are in conflict as well. While the filter in the navbar allows the user to select regions under any geographic level, it only shows the level selected as the starting layer ([1, Fig. 42]). It was mentioned earlier the issues conflicting filter controls cause for discoverability. In this case, these conflicts also cause confusion in the user's conceptual model since the results likely do not align with expectations.

From these considerations, I posit that there is some good mapping between the data and the world, but this is overshadowed by issues with layout and organization. This is negatively impacting the readability of the dashboard and causing confusion rather than understanding. The next table outlines my evaluation of our dashboard based on the criteria stated earlier. I then give my suggestions for better meeting these criteria.

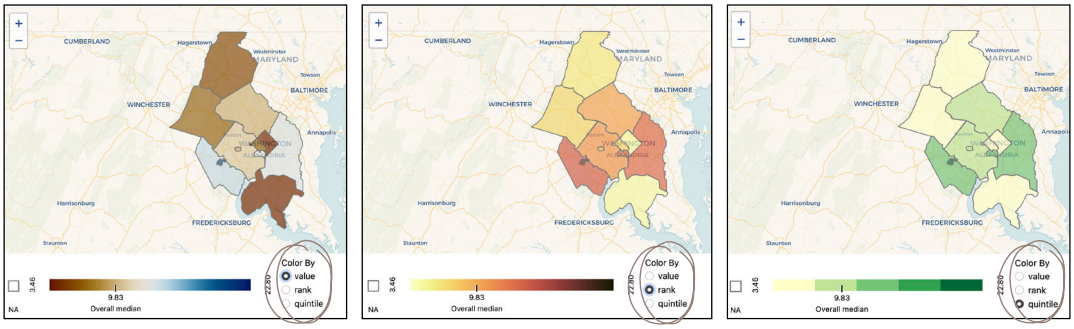


Fig. 41. Different views of the choropleth map on our dashboard. Left to right: colored by value, colored by rank, colored by quintile. Adapted from [1]

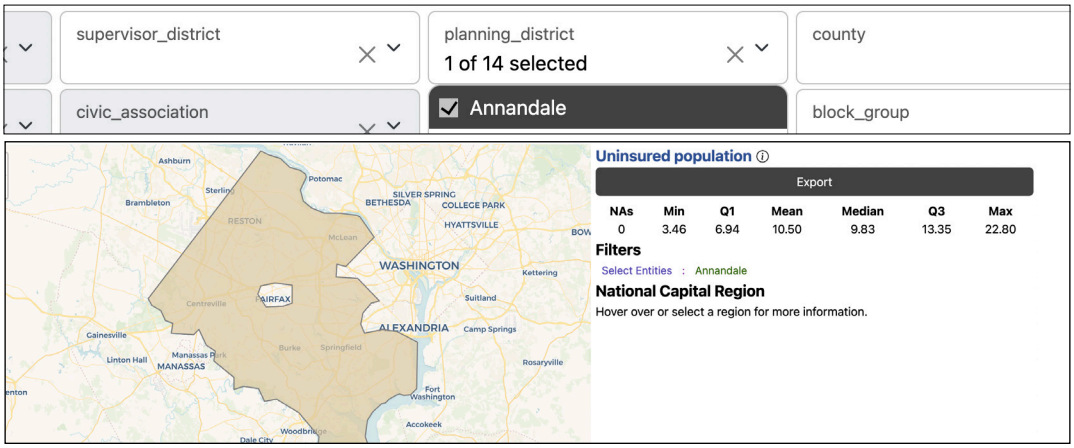


Fig. 42. From our dashboard. An example of what happens when a sub-county geography is selected with "county" as the starting layer. Users will likely expect Annandale to be highlighted much like what happens when a county is selected using the other filter box. However, only Fairfax is shown. Adapted from [1]

Criteria	Current Condition	Suggestions
Recognition Rather than Recall - The necessary information to gain an understanding should be apparent on the dashboard without users needing to "remember information from one part of the dialogue to another" [12]	Rating: 0 - not met Because related elements cannot all fit in one view, users are required to recall information from one element in order to understand how it relates to the other. Otherwise, this understanding is lost completely on them.	• Linked items (map, raw data table, and time series plot) should all be completely visible within the same window. The current map can be cut in half width-wise without losing any data.
Match Between System and Real World - The system should be intuitive based on the users background. It should follow "real-world conventions" such as what is viewed as a logical order [12]	Rating: 2 - mostly met but some small issues The dashboard somewhat follows western intuition. The readability is more hindered by grouping than unintuitive flow, but it is important to keep the "top-left to bottom-right" principle in mind if changes to layout are made. The choropleth map makes understanding the data more intuitive. Although, certain actions related to the map do not produce the expected results.	• Reduce dependencies between filter controls. Selecting a region in the navbar filter should have the same effect as selecting a region in the main view filter. • Ensure the color by feature under the map is producing clear and accurate results. Get rid of the color by toggle in the settings.

Criteria	Current Condition	Suggestions
Fit on a Single Screen - The initial view of a dashboard should allow the user to quickly gain an "initial situational awareness" [15]	Rating: 0 - not met If this tool is largely used for work, the assumption is that it will be most frequently viewed on a desktop screen. Even with the larger screen though, the NCR dashboard cannot be viewed on a single screen. This makes it more difficult for a user to quickly and accurately understand the conceptual model of both the dashboard and the NCR system.	• Ensure everything is on one screen for a standard desktop view.
Spatial Organization - Relates to the overall layout. Content/ information should be easy to locate and follows a "logical organization" [12]	Rating: 0 - not met Illogical hierarchy and groupings make it difficult to understand how different elements fit in with one another.	• Ensure the structure reflected by the layout matches a logical hierarchy of elements (refer back to Fig. 35). I suggest a "funnel" approach where the design flows from most general to most detailed.

Constraints

I have previously brought up many affordances that our dashboard makes possible. Yet, according to Don Norman, "Many products defy understanding simply because they have too many functions and controls" [11]. Proper constraints for enhancing understanding should consider what affordances are actually necessary. This falls under this criterion:

1. Remove the extraneous ink - The dashboard "should not contain information which is irrelevant or rarely needed" [12]

However, I do not feel comfortable determining what is and is not relevant to our audience. This kind of information should be determined through user testing and interviews. While I am able to guess what questions might be useful for our users to answer, it is much harder to guess what is not actually useful without having done that kind of work.

In the time I have spent using the dashboard, I have not noticed any capabilities that directly inhibit understanding. That is to say, the existence of the affordances themselves has not raised any red flags for me. The most important suggestion I can provide here, and perhaps at all, is that users must become a part of the discussion of our dashboard.

Putting the Pieces Together

The dashboard did not meet four out of six of the criteria considered under this section. Of the two I felt were mostly met, there were still caveats preventing the conditions from being completely true. If I consider improvement of situational awareness the overarching criteria for understanding, it cannot be met if the other criteria do not hold true. Even if our dashboard is providing users with sufficient information, not all of this information is presented in a way that is clear or understandable. I particularly want to note that certain aspects of our dashboard that I pointed out are still interpretable even if not clearly understandable. This becomes especially concerning because it increases the likelihood of users developing a false understanding of the data. Although I provided suggestions for the improvement of certain features, if it is felt that these suggestions cannot be met or would not fully rectify certain clarity issues, I would ultimately advise against including those features. If being used to sway decisions, it becomes far more dangerous to provide unclear information than no information at all.

Conclusion

"The development of a dashboard is a continuous process, since the organization — ideally — is always learning. It is important to constantly ask whether it is time to update the current business goals, assumptions, strategy, and measurement goals" [22]

The design of our dashboard is limiting its potential. If users are unable to discover much of our data and capabilities, then there are two possibilities. First, the dashboard is unable to meet the user's needs. Second, the dashboard contains extraneous or irrelevant information. Based on assumptions made about our users, I believe our dashboard falls short of meeting user needs. However, as I mentioned earlier, it is necessary to ask these questions of the people whom the tool is designed for. While I cannot say with certainty, it has been my impression that no user testing has been done. If only one piece of my advice is taken, I hope that it is this: include users (in particular, local-level decision makers) in the discussion of the dashboard. The best any one of us at the division can do is guess what users need. This leads me to mention the largest limitation of this evaluation: I am a student who has only begun to learn about design. I am not an expert in this area and I bring my own biases, background, and expertise, which likely do not align with that of our users. While I have done my best to evaluate our dashboard objectively, it is important to keep in mind that many aspects of design do not have one objective truth. Perception and preferences can differ based on a multitude of factors. This is part of why flexibility and control are important factors to include in dashboard design. It is also why universal design is so important.

Evaluation Summary

I focused on two core design characteristics as a basis for my evaluation: discoverability and understanding. I posit that our current dashboard is lacking in both of these characteristics. Without discoverability, users cannot gain true understanding simply because they cannot access the entirety of the information we provide. Yet, even if we ignore the issues with discoverability, it is clear that our dashboard lacks the requirements for providing understanding. In the table on page 61, I have compiled the criteria I used for each of Don Norman's design principles. I summarize my thoughts on how our dashboard did by providing a rating for each criterion. A reminder of the rating system I used:

- 0 - Not met
- 1 - Somewhat met but with some major issues
- 2 - Mostly met but with some minor issues
- 3 - Met

These are not meant to create

an evaluative score but rather make it easier to see where I feel our dashboard lies overall. Of the thirteen criteria, I evaluated six as not met and nine as either not met or somewhat met with major issues. While our dashboard contained good feedback, every other area fell short. I compile a list of the suggestions I made on pages 62 and 63. My hope through this evaluation is that the suggestions provided help rectify issues hindering the discoverability and understanding of our dashboard as well as allow us to meet the standards I have set forth.

The work that the division is producing can be key in informing change. Ensuring that this work reaches and makes an impression on the right audiences centers around how it is displayed.

Component	Criteria	Rating
Affordances and signifiers	Flexibility and efficiency of use	0
	Orientation	1
	Operability	1
	Usefulness/suitability for tasks	1
	Enables the user to monitor and understand the displayed information at a glance	2
Mapping	Spatial organization	0
	Fit on a single screen	0
	Recognition rather than recall	0
	Match between system and real world	2
Feedback	Visibility of system status	3
Discoverability	Learnability	0
Conceptual model	Improvement of situational awareness	0

0 - not met
1 - somewhat met but some large issues
2 - mostly met but some small issues
3 - met

Suggestions for Dashboard Improvement

Component	Suggestion
Layout	• Group the legend, map, and plot together. • Group the export button with the data table. • Place all filtering controls in the same region. • Include the reset button with the filtering controls. • Ensure everything is on one screen for a standard desktop view. This may be more attainable if specifications for elements are determined separately for desktop and mobile. • Ensure the structure reflected by the layout matches a logical hierarchy of elements (refer back to Fig. 35). I suggest a "funnel" approach where the design flows from most general to most detailed. • Linked items (map, data table, and time series plot) should all be completely visible within the same window. The current map can be cut in half widthwise without losing any data.
Filter Controls	• Use a more conventiona; format for the year selector. A drop-down selector or timeline selector may be more familiar to users. • Allow users to filter for all geographic levels in the main screen filter bar. • Reduce dependencies between filter controls. Selecting a region in the navbar filter should have the same effect as selecting a region in the main view filter.
Map	• When an area is selected, gray out the surrounding regions rather than making them invisible. • Allow for touchpad zooming and alternate selection methods on the map tool.

Component	Suggestion
Plot	• Remove the box and whisker plots in the initial view of the time series plot. Make customization for turning these underlays off and on more apparent (i.e. show with the plot the controls go with). • Add a title and x-axis label to the time series plot.
Summary Box	• Add descriptor showing how the current region compares to its larger, surrounding region (ex: Arlington County, VA compared to the National Capital Region). This can be placed as part of the summary box. • Add commas to large digits displayed in the summary table.
Other	• Add a scroll bar to the settings bar. • Add clearer features for navigating backwards through the dashboard. The current feature should be visible regardless of scrolling. • Include loading signals as an intermediary between actions and results. • Add variable comparison capabilities. Because this serves a distinct purpose from what we currently display, it would be reasonable to have a tool for this on a separate page. • Where possible, replaces the five digit FIPs code with the county and state name. • Ensure the color by feature under the map is producing clear and accurate results. Get rid of the color by toggle in the settings.

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