Exploring Design Opportunities for Visually Congruent Proxemics in Information Visualization: A Design Space

N. Chulpongsatorn[1], J. Yu[1], and S. Knudsen[1,2]

[1]University of Calgary, Alberta, Canada
[2]University of Copenhagen, Denmark

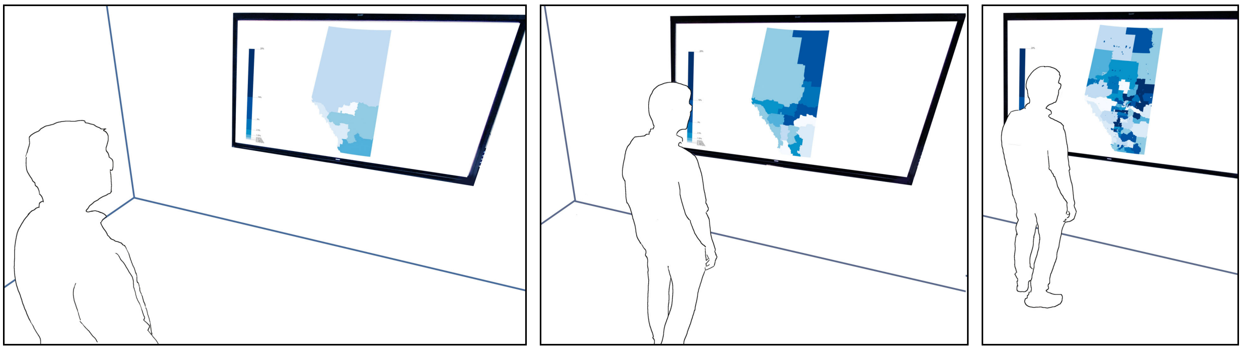


Figure 1: *Exploring distance for varying level of detail to a choropleth map prototype showing census data obtained from Stats Canada on visible minorities in Alberta. Here, far, middle and near to the choropleth are shown from left to right.*

Abstract

We explore design opportunities for varying visual complexity of information visualizations based on distance. Through considering visual congruency and proxemics interaction, we describe a design space that considers potential transitions between visualizations in relation to distance. Our design space is based on exploring prototyping and design possibilities. It describes three properties (boundedness, connectedness, and cardinality) and five design patterns (subdivision, particalization, peculiarization, multiplication, and nesting) that might be considered in design. We describe our design ideas and prototypes, as well as reflect on their usefulness. Finally, we discuss limitations and implications of our work.

1. Introduction

We explore varying the level of visual complexity between different visualizations based on proxemics. Proxemics has been suggested to support visualizations on large displays for individuals [JSKH13] and collaborators [DHKQ14, BAEI16, LKD19]. This context and modes of work offer exciting new opportunities for lowering the barrier of entry [LIRC12], increasing engagement [VB04], and may support more collaborative work [KH19].

Previous work has shown great promise for using proxemics interaction, and more specifically distance, to adjust the level of visual complexity and with it, the level of detail shown in visualizations. For example, Jakobsen et al. [JSKH13] defined a design space of categories of proxemics interaction and information visualization tasks. They described three designs, one of which varied the level of aggregation in a choropleth map. However, previous work has only described single solutions and have not emphasised exploring design possibilities. Thus, we lack a more thorough exploration of this design space and the possibilities offered from it. Such a design space might shed light on potential alternatives, be the first step towards creating design guidelines, and would allow for comparing and contrasting different possibilities.

We explore possibilities for adjusting level of detail based on distance. Building on top of previous work, we introduce *visually congruent proxemics*—transitioning from one visualization to another using proxemics where the transition is visually fluid.

We contribute a design space for visually congruent proxemics in visualization. Our design space describes three properties (*bounded*, *connected*, and *cardinality*) and five design patterns (*subdivide*, *particalize*, *peculiarize*, *multiply*, and *nest*). We developed the design space based on our experiences implementing two prototypes as well as from our discussions (for example, about potential design alternatives) during this process.

2. Related work

Our work builds on important contributions from proxemics and visual congruency.

Movement in front of large displays is studied for a range of reasons. There is much work on people's movement in front of large display visualizations (e.g., the advantage of moving [BNB07] and the perceptual challenges in doing so [BI12]). However, little work focuses on using movement to interact with visualizations, such as Proxemics Interaction [GMB*11] might suggest. This is the focus in a paper by Jakobsen et al. [JSKH13], which explore a design space based on visualization tasks and dimensions of proxemics interaction. Their work considers interaction techniques that range from very explicit to very implicit. For example, moving closer to the display to select a data dimension (explicit) or to show less aggregated areas in a choropleth map (implicit). While they did not aim for this variation in their designs, their findings suggests the importance of considering these. Later work has shed more light on explicit and implicit proxemics interaction. Here, we focus on implicit interaction. Dostal et al. [DHKQ14] use distance to affect the level of detail, the type of visualization technique, and the zoom level. In agreement with Jakobsen et al. [JSKH13] as well as more recent work (e.g., [LKD19]), we focus on modifying level of detail based on distance in our design space. To more explicitly describe the visual changes, we describe level of detail as splitting one mark into multiple marks. Badam et al. [BAEI16] describe lenses for working collaboratively in front of large displays. While much of their work is about interacting with lenses, their work suggests that implicit interactions are best suited for subtle and easily revertible changes.

Isenberg et al. [IDW*13] also consider showing alternative visualizations based on distance and provide a great overview of combinations of local and global features. While their work is perhaps closest to our goals, they focus on a strong difference between the visualizations that are shown close to and far away from display. This goal seems almost opposite our intention of considering congruent visualizations. Particularly relevant to our work, they note that Pixel Bar Charts [KHDH02], FatFonts [NHC12], and NodeTrix [HFM07] point to interesting design possibilities in this direction.

Importantly, Heer and Robertson [HR07] introduces congruence as a design consideration. Their goal for incorporating animations with data graphics ".. is to visually interpolate the syntactic features such that semantic changes are most effectively communicated." Our properties and design patterns relate to their notion of "data schema changes" and scaling (see Section 3.2) to their "substrate transformation". We use congruency [HR07] in our design space. For proxemics interaction, the fluidity of transition and the clarity of intended semantics are integral to conveying correct interpretation of data visualization [EMJ*11]. We are inspired by this work to consider how we could provide meaningful visualization tools that shows different level of detail as appropriate for different distances.

3. Prototypes

In our work, we consider how different distances might be appropriate to show different visualizations or variations. A major deciding factor is the complexity of a visualization, or how much detail can be read from it. Some visualizations are inherently more complex than others. For example, an atomic visualization [PDFE18] is more complex than its bar chart counterpart. A single type of visualization may also vary in complexity depending on the level of aggregation. For instance, a choropleth map that visualizes mortality rate for each province in a country would be less complex than one that visualizes mortality rate for each city. In proxemics, moving closer to the screen might suggest a desire for more information, and therefore more complexity. In the following, we assume that people approach displays to gain more information.

We describe two prototypes that were partly influencing and influenced by our design space. As such, we used them as a tool in carving out the different design patterns and how they relate. For both, we split the space in front of a large display into three distinctive zones of interaction parallel to the display. Based on previous work that relates interaction zones and display size, we define these spaces as *implicit zone* (1.31m - 2.6m), *subtle zone* (0.87m - 1.3m), and *personal zone* (0m - 0.86m) [PB18]. We display different visualizations according to the zone. These visualizations are visually congruent in both our prototypes, and allow the transition to be smooth and coherent when stepping from one zone to another. We create the prototypes for an 86 inch SMART display. To track peoples' position in front of the display, we use an OptiTrack motion capture system based on active marker tracking that are integrated into a 10 by 10 cm active puck and is worn from a lanyard.

3.1. Prototype 1: Choropleth map

The first prototype uses distance to display different levels of aggregation for a choropleth map of Alberta's black population (on average, different visible minorities have different healthcare needs—for example, African-Americans have a higher degree of high blood pressure than the average North American population). When the user is in the *implicit zone*, the choropleth is divided by the five different health zones, which represents the highest level of aggregation that we have chosen to represent in the prototype (Figure 1, left). Moving into the *subtle zone* splits the choropleth map into census divisions, which is shown as smaller regions (Figure 1, center). The final transition into the *personal zone* displays the aggregate dissemination areas, which shows the data in even higher spatial granularity (Figure 1, right).

Due to the nature of Alberta's longitudinal extent (see Figure 1), the map leaves a considerable amount of horizontal empty space. This limits the ability to incorporate interaction using lateral movement. During the ideation phase for this prototype, we explored designs that divide the map into health zones and lay them out horizontally, thus showing the map areas as *disconnected*. We imagined people who want more information on a particular zone could move in front of it. We also discussed how to sensibly reconcile this with consideration for congruency, since we had census divisions that crossed the *boundaries* of health zones. We discuss *connectedness* and *boundedness* in Section 4.

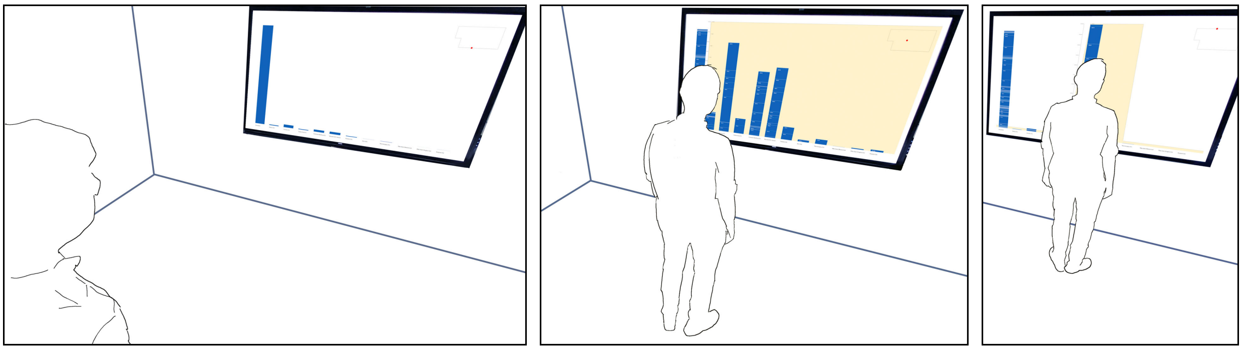


Figure 2: *Prototype 2: Dynamic Scaling. This prototype uses distance and position to re-scale elements. The implicit zone (left) provides a general overview of the data with a single scale. In the subtle zone (center), the zoom scale is introduced to help people compare the rest of the bars to the extreme value. In the personal zone (right), the zoom scale is only applied to the bar in front of the user.*

3.2. Prototype 2: Dynamic Scaling

The second prototype uses distance to show different bars in a bar chart at different scales. Each bar in the bar chart represents the number of admissions to different types of hospital care units in Alberta. The largest bar captures general hospital admissions. Other bars represent special care units, such as intensive care unit (ICU). Since there is a large discrepancy between the number of general admissions and admissions to special care units, there is a visual disparity between these elements in the representation.

We modify the domain of the scales depending on peoples' distance. In the *implicit zone*, the data is presented with a uniform scale (see Figure 2, left). We refer to this as the *base scale*. While the *base scale* is accurate in presenting the data, extreme values may cause legibility issues as evident from the figure. When moving into the *subtle zone*, we introduce a *zoom scale* to properly display the illegible data values (Figure 2, center). In the *personal zone*, a local *zoom scale* applies only to the visual elements directly in front of the user (i.e. in the users' focus). The other marks are now sized according to the *base scale*, pulling the other marks out of focus (Figure 2, right and Figure 3). The *zoom scale* is adjusted according to the maximum value in the focus area. Additionally, in the *subtle* and *personal zones*, we divide each bar into units across the Albertan hospitals. Each bar is thus changed from a bar in the in the *implicit zone* to a stacked bar in the other zones.

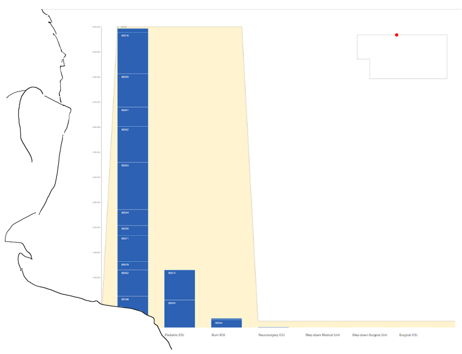


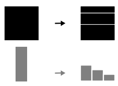
Figure 3: *Close up of Prototype 2 for a person in the personal zone. Here, the scale enlarges the bars directly in front of the user. The colored area connects the top of the zoom scale to the base scale.*

We use a shaded yellow background region to communicate the differences between the *base scale, zoom scale* and the local *base scale*. This region is shown in the *subtle* and *personal zones* and dynamically adjusts the height of its base according to the maximum value of the *zoom scale* to show the relationship between the two scales accurately as suggested in prior work on view relations [KC16]. Similarly, to communicate the scale changes, we use animation as suggested by Heer and Robertson [HR07].

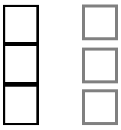
When starting to work on visualizing the data set, we were inspired by ideas of pixel- or particle-based techniques [KHDH02, PDFE18] to represent individual patients as particles. However, after working with the data, we realised that we would not be able to show each patient by an individual pixel or particle due to the volume of patients in our data set. Furthermore, implementing a layout algorithm for a particle-based visualization would add unnecessary complexity to our progress and exploration. However, this discussion was valuable in creating our design space.

4. Visually Congruent Proxemics

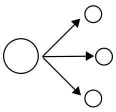
Based on our prototypes and exploration of design alternatives, we define a taxonomy of transition types that are applicable to proxemics. Doing so, we define congruent pairs as a tuple of visualizations that are congruent to one another. The transition between visualizations in each pair is built upon Heer's and Robertson's work on Animated transition [HR07]. There are two main syntactic elements that can be changed within a visualization: data mark and scale. Changes to data marks could include drilling down into a data point to explore elements that make up the whole by either *subdividing* or *multiplying* the data point. Alternatively, by finding congruent pairs, transitions to a different visualization altogether can be done via *nesting*. As for changes to a scale, it can be done in a way where the scale changes completely by changing the *domain* or by altering the *aggregation* level of the scale. We define three properties for congruent visualizations in proxemics.



(1) Boundedness: Data marks are bounded (■) if they are contained within the pre-transition data marks after the transition. Otherwise they are unbounded (▪).



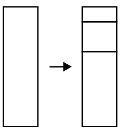
(2) Connectedness: Connectedness refers to the post-transition visualization. Data marks are connected (□) when they are adjacent or forms a cohesive shape. Otherwise, they are disconnected (▫).



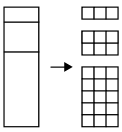
(3) Cardinality: Amount of post-transition data marks that corresponds to pre-transition data marks. This can be a $1 \rightarrow 1$ mapping (e.g., a point to a point), $1 \rightarrow m$ mapping (e.g., a bar to stacked bar), or $n \rightarrow m$ mapping (e.g., multiple regions to multiple cities).

4.1. Design patterns

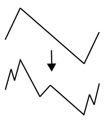
We identified five design patterns for congruent visualizations in proxemics. The design patterns are influenced by exploring the different combinations of the properties described above. The patterns visually breaks down data marks during transitions between zones. Our descriptions assume an increase in complexity after transition, as would typically be expected when moving towards a display.



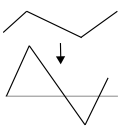
Subdividing: Marks are separated into smaller partitions that form the whole, allowing visual elements to retain its form. This design pattern is bounded (■), connected(□), and can exhibit all three variations of cardinality. For example, transitioning from a bar to a stacked bar, the shape of the bar is maintained after transition.



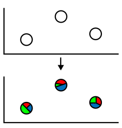
Particalization: Marks are separated into groups of small units that are partitioned by white space. This design pattern is bounded (■), disconnected (▫), and can exhibit all three variations of cardinality. For example, transitioning from a stacked bar chart to a unit visualization of the stacked bar (as in Park et al. [PDFE18]), the original stacked bar is dissolved into its constituent particles.



Peculiarization: Marks are given more detail by segregating a scale. This design pattern is unbounded (▪), connected (□), and exhibits $1 \rightarrow 1$ cardinality. For example, consider a line chart with a temporal horizontal axis. With this design pattern, the temporal axis might transition from showing quarterly to monthly intervals. This will introduce more data points, increasing its complexity while retaining its connectedness.



Multiply: Marks are separated into multiple marks. This design is unbounded (▪), disconnected (▫), and exhibits $1 \rightarrow m$ cardinality. For instance, imagine a line chart that shows the average of all the data points. Moving closer will transition from that line into multiple lines, where each of the new marks represent the average from aggregated groups of data points that formed the original line. The main difference between *particalization* and *multiply* is that the first is often bounded and the latter often unbounded.



Nesting: Marks are transformed into glyphs. This design pattern can have any combination of boundedness (■ ▪) and connectedness(□ ▫), and may also exhibit any three variations of cardinality. For example, using bounded and connected nesting, a scatterplot might reveal more details by showing a pie chart in each data mark. In contrast to subdividing, nesting uses a different representation post-transition.

5. Discussion

In establishing our design space of visually congruent proxemics for information visualization, we aimed to cover subtle, gradual changes. We deliberately excluded possibilities that cause more abrupt changes such as changes to the size of visualizations and completely changing the visualization technique. In our exploration, we created a network of congruency between visualization types. While serving as a nice point of discussion and helping us gain a deeper understanding of the design space, a simpler model of congruent visualization pairs were more actionable for our work.

We focused on varying visual complexity based on distance. We think this is a good match. However, proxemics interaction describes four other dimensions. We wonder if visual complexity is interesting to consider for other proxemics dimensions and if other dimensions of visualization design lend itself well to dimensions of proxemics? While prior work [JSKH13] give suggestions, we think the space is far bigger than they and we have yet considered. Our prototypes explored techniques that are relevant to consider in relation to our design space. Most notably, in Prototype 2, we used scaling to allow for working with extreme value differences. This technique supports some of the issues one might encounter in designing visually congruent proxemics for visualization but does not fit well in the presented design space. We think techniques like this might be worth exploring in future work. We also consider whether concepts from multiple views might be fruitfully applied or compared to our design space. For example, while Javed and Elmqvist [JE12] describe five design patterns for multiple views, only nesting is relevant to our work. While some research has already suggested such connections (e.g., [LKD19]), we think there are more possibilities. This is clearly beyond the scope of this paper, but we think drawing a stronger connection between proxemics and multiple views is important future work. Finally, we recognize the need for evaluating the ideas presented in this paper. While this is beyond the scope of this paper, we see this as interesting future work and note that our design space might be usefully applied in designing such studies.

6. Conclusion

We explored visually congruent proxemics for information visualization based on prototyping and discussing design alternatives. We focused our exploration on varying levels of detail based on distance. Doing so, we presented a design space for visually congruent proxemics, that provides three properties and five design patterns for visual congruency. Finally, our discussion sheds light on important considerations and interesting opportunities for future work. From our work, we show the vast landscape of unexplored opportunities in proxemics interactions for information visualization.

7. Acknowledgments

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