Eurographics Conference on Visualization (EuroVis) 2017
J. Heer, T. Ropinski and J. van Wijk
(Guest Editors)

Volume 36 (2017), Number 3

Internal and External Visual Cue Preferences for Visualizations in Presentations

H. Kong[1], Z. Liu[2], and K. Karahalios[2]

[1]University of Illinois Urbana Champaign, U.S.
[2]Adobe Research, U.S.

Abstract

Presenters, such as analysts briefing to an executive committee, often use visualizations to convey information. In these cases, providing clear visual guidance is important to communicate key concepts without confusion. This paper explores visual cues that guide attention to a particular area of a visualization. We developed a visual cue taxonomy distinguishing internal from external cues, designed a web tool based on the taxonomy, and conducted a user study with 24 participants to understand user preferences in choosing visual cues. Participants perceived internal cues (e.g., transparency, brightness, and magnification) as the most useful visual cues and often combined them with other internal or external cues to emphasize areas of focus for their audience. Interviews also revealed that the choice of visual cues depends on not only the chart type, but also the presentation setting, the audience, and the function cues are serving. Considering the complexity of choosing visual cues, we provide design implications for improving the organization, consistency, and integration of visual cues within existing workflows.

Categories and Subject Descriptors (according to ACM CCS): H.5.m [Information Interfaces and Presentation]: Miscellaneous—

1. Introduction

Presenters convey an idea to the audience to influence their perception or behaviors [Mad15]. For effective communication, all presenters, whether teachers explaining a visualization, business analysts reporting results, or students presenting class projects, purposefully plan key messages and the rhetoric used to deliver the messages. Incorporating visualizations such as graphs and diagrams can help presenters convey information in an appealing and efficient manner [Mad15]. However, if the visualization involves too much detail or complexity without clear attention guidance, the presentation can result in confusion [Col04].

This double-edged influence of visualization in presentations became apparent to us during our initial meeting with a group of analysts who regularly present results to their managers and directors to inform decision making. In fact, the analysts themselves mentioned the conflict between their desire to tell the comprehensive story backed by data and the multiple interrelated charts and graphs in the resulting slides (see Figure 1). They specified situations where preserving the relevant context on the same slide was essential. For example, a briefing of product usage results across four quarters in a year would benefit from presenting all the relevant information on a single slide for comparison. In these instances, presenters can use visual cues (e.g., dimming the background, magnifying the focus area) to guide the audience's attention to a particular section of the visualization rather than leaving the audience to search for the relevant information. Visual cues have been studied across various domains such as cognitive psychology, cartography, education, and visualization [EY97, dKTRP09, LH10, Rob11]. However, works on presenters' preference and use of specific visual cues have been limited. This led us to our first research question:

RQ1. What visual cue techniques can presenters use to guide the audience's attention in a presentation?

To answer the first question, we compiled a list of visual cue techniques through an extensive literature review. Our taxonomy

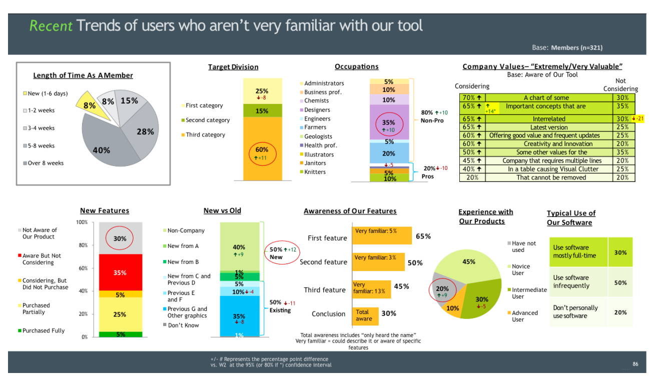


Figure 1: A remake of a complex slide in analysts' slide deck. The titles and labels were modified for anonymity.

introduces the division of external cues (that augment the original content by additional components such as arrows) and internal cues (that modify the characteristic of the original content) in the time-invariant category. The resulting taxonomy led us to our next research question.

RQ2. What are presenters' usage patterns and preferences when offered a set of internal and external visual cue techniques?

More specifically, our goal was to study a) the perceived advantages and disadvantages of each visual cue from our set and b) the distribution and arrangements of visual cues that were used in the slides. To answer our second research question, we implemented a Web tool that supports diverse visual cue techniques. We developed a new visual cue Web tool, VisualQ, because existing presentation tools do not currently support the use of internal cues. VisualQ facilitates previewing, manipulating, and combining internal and external visual cues. The study results show that participants felt internal visual cues to be most useful, and often combined them with other cues to emphasize areas of focus. The interviews also revealed that participants were currently choosing visual cues out of convenience and unawareness of other possible cues rather than the perceived usefulness. Considering the discrepancy between their current visual cue usage and their visual cue preference and usage during the study, we suggest how presentation tools can support the exploration and application of visual cues. Our research focuses on presenters' preference of cues in line with other works on preference [HHLB*12, OGH05] and sets groundwork for future studies on effectiveness – where several measures must be explored such as memorability, interpretability, and aesthetics.

2. Related Work

In this section, we define visual cues and review prior work on visual cues from different domains spanning from education, to psychology, to narrative visualization. Prior work in this domain has investigated visual cues by forming taxonomies [dKTRP09, LH10] studying the effectiveness of a single cue [THM*08], or comparing the effects of multiple cue types [GR10]. The prevalence of the presentation of results in various settings (e.g., academic conferences and business meetings) led us to focus on visual cues for presentation. Moreover, Lee et al. called for further exploration of presentation visual cues in "More than Telling a Story" by stating that "[m]ore research on supporting advanced features such as emphasizing different components via annotation, highlighting, and zooming during a live presentation is a promising avenue for research" [LRIC15].

2.1. Definition and functions of visual cues

Meyer initially defined cueing as "the addition of a non-content aspect of prose, which gives emphasis to certain aspects of the semantic content or points out aspects of the structure of the content" [Mey75]. Building on this definition of cueing, we define "visual cue" as an additional or modified visual elements that is used to guide the audience's attention to a certain visual region. Thus, we broaden the term from the addition of non-content to include the manipulation of existing visual components. Based on Mayer's theory of multimedia learning, de Koning et al. developed a framework to classify three functions for cueing: selection to guide attention, organization to emphasize structure, and integration to explicate relations between elements [dKTRP09]. We extract examples of each visual cue function from our study results and elaborate on each function in the discussion section.

2.2. Visual cue categories and taxonomies

Liang and Huang organized a taxonomy of highlighting techniques in information visualization [LH10]. Although Liang and Huang's taxonomy for elements of highlighting was foundational for our own taxonomy of visual cues, we divided the categories differently based on visual cue literature and our preliminary slide deck collection. Segel and Heer analyzed the design space of data visualizations for storytelling and identified distinct genres, visual narrative tactics, and narrative structure tactics for narrative visualizations [SH10]. Their framework labels "highlighting" as a visual narrative tactic category containing six tactics: close-ups, feature distinction, character direction, motion, audio, and zooming. Kong and Agrawala's research on chart reading proposed additional visual cues to aid chart reading by distinguishing the focus points from the context or background. Examples include highlighting, redundant encoding, and annotating [KA12]. Because of the effectiveness of redundant encodings, we designed our visual cue Web tool to support the combination of varied visual cues. We discuss this in more detail in the design decision section.

2.3. Effectiveness of visual cues

De Koning et al. attributed the effects of visual cueing to their influence on perceptual and cognitive processes [dKTRP09]. Perceptual limitations allow people to focus only on a small portion of a visual display at once based on element characteristics such as visuospatial contrast (e.g., color) and dynamic contrast (e.g., abrupt movement) [SL08, Win93]. As visual cueing reduces visual search, "less visuospatial resources are required to control the execution of eye movements" [dKTRP09]. Unclaimed mental resources can then be used for other cognitive activities such as processing key information. Effectiveness studies on a *single* type of visual cue in education have yielded mixed results [LA11, THM*08]. De Koning et al.'s initial work found that cueing enhanced learning from complex animations [dKTRP07]. However, Moreno's study found that "improper use of cueing might be ineffective and even increase cognitive load on the learner" [dKTRP09, Mor07]. Works in other fields compared multiple visual cues [CCH*14, GR10] or studied combinations of visual cues [PO13, WPM16]. Pyysalo and Oksanen studied the effectiveness of cue combinations by comparing three highlighting conditions: size, size and shape, and size and color [PO13]. Participants completed the tasks more accurately in the cue combination conditions. Ware and Pioch studied the combination of two independent highlighting techniques on node-link diagrams through the use of circles, 3D rendering, motion, and blinking [WPM16]. Although they provided substantial evidence that combining static and motion visual cues can be effective, Robinson prompted for future work on "compounds of multiple static styles" [LRIC15], which we investigate in this work. Our work supported free exploration of different combinations where participants combined up to four different visual cue techniques for a single image. Although the participants perceived that the combined cues increased effectiveness, future work is still required to evaluate their actual effectiveness. The existing literature on visual cues has mainly explored pre-made visual cues that augment existing visuals. We extend the field by studying how presenters evaluate and choose visual cues, including internal cues that are not available in current presentation tools.

3. Preliminary Work

Our research started with a meeting with business analysts as stated in the introduction and involved five additional phases: the preliminary data collection, the taxonomy compilation, the design and implementation of a visual cue Web tool, a pilot study, and the final user study. We cover the two preparation phases of preliminary data collection and the pilot study in this section and discuss the remaining phases more thoroughly in their following corresponding sections.

3.1. Preliminary data collection

Our preliminary data collection of 13 slide decks, involved 261 slides from three analysts, two project managers, and six graduate students. We interviewed all of them regarding their current visual cueing practices using their slides as an artifact. Interviewees voiced that the use of visually complex slides without efficient attention guidance was a common problem across presentation environments from boardroom meetings, to lectures, to conferences. We analyzed the chart types and the visual cues in the slide decks to assess the current practices of our preliminary participants. We first calculated the frequency distribution of different types of visualizations in the slide decks, which contained a total of 138 visualizations. Bar charts appeared 49 times in total, making them the most common visualization in the slide decks. Stacked bar charts and a combination of bar and line charts tied as the second most common visualizations (N=33). A slide with visualizations contained 1.58 visualizations on average with a maximum of 9 visualizations (See Figure 1). Out of 89 visual cues in the slide decks, arrows composed 24% (N=21), shapes (e.g., rectangles, circles) composed 20% (N=18), font alterations composed 19% (N=17), and brackets composed 16% (N=14) of them. Other visual cues included tooltips, leaderlines, additional annotations, and color modifications. We used this information in combination with the taxonomy that follows to construct study materials for our user study and to design our visual cue Web tool.

3.2. Pilot study

We performed a pilot study with five participants to calibrate our stories and chart complexity for the final user study. In the pilot study, we presented users with two complex visualization images and a story script associated with each visualization. Presenting one visualization and the corresponding description at a time, we asked the participants to create a slide presentation by applying visual cues to highlight different sections of the visualization based on the story script. We learned through the pilot study that some visualizations were too complex – complex beyond the point of improvement. One pilot participant (PP5) displayed an emotional reaction in response to a visualization stating that "it makes [him] angry" to see such information overload in visualizations. Others also expressed desire to recreate one of the charts from scratch rather than simplifying it through visual cues. Thus, the disputed visualization was switched for a simpler graph of the same type in the final study.

4. Visual cue taxonomy for presentation (RQ1)

To answer our first research question, *"What visual cue techniques can presenters use to guide the audience's attention in a presentation?"*, we conducted an extensive literature review and compiled a list of the visual cue techniques used in different domains. We categorized the techniques largely based on Liang and Huang's taxonomy and de Koning et al.'s work [dKTRP09, LH10]. We first divided the cues into two broad categories: time-invariant cues and time-variant cues. Time-invariant visual cues are static and bring out the focus point within a single frame (e.g., a red arrow pointing to a value) while time-variant cues require multiple frames to bring audience's attention to the focus point (e.g., a blinking circle around the value).

4.1. Time-invariant cueing

We divided time-invariant cueing into external and internal cues based on whether the change involved addition of new components or a modification of existing components. The internal cues were largely derived from Trapp et al.'s work on highlighting in 3D virtual environments [TBPD11]. Boy et al. used a similar division for suggested interactivity in [BEDF16]

4.1.1. External cues

External cues append additional components (e.g., outlines, annotations, glyphs) to the existing image to emphasize the focus point. For example, outline cues highlight the focus area by adding a contour (See Figure 7a) or a glow (7i) around it. Annotations include textual additions such as a summary statistics, tooltips, and labels. External glyphs guide the audience's attention by specifying the focus point with a shape (rectangle in Figure 7d), bracket (7e), or arrow (7d). The prevalence of external glyphs in presentations emerged during our user study, and will be discussed further in the results section.

4.1.2. Internal cues

Internal cues modify the existing image by emphasizing the focus area or de-emphasizing the remainder of the image (i.e., the context). The term is compatible with Kosara et al.'s initial definition and Hauser's generalized definition of focus+context techniques [Hau05, KMH02]. Internal cue modifications may be contrast-based such as modifying the brightness (7f), transparency (7i), or depth of field (7g). Or they can be perspective-based such as fisheye and loupe (i.e., linear magnification of the focus point shown in Figure 7e) magnifications. Contrast-based cues may be applied on the focus (e.g., brightening the focus area) or the context (e.g.,

Figure 2: An example of a staged transition: one element of the visualization appears at a time

dimming the context). Color modification can occur on the associated text as well. Perspective-based cues emphasize the focus area by enlarging its screen "real estate" and reducing the context's. Leung and Apperley referred to these perspective-based cues as "distortion-oriented presentation techniques" and introduced two classes of magnification functions – non-continuous and continuous [LA94]. Non-continuous magnification functions include the use of bifocal display and the perspective wall, where two side panels show a distorted view of the out-of-focus region; continuous magnification functions include fisheye views and polyfocal displays.

4.2. Time-variant cueing

Time-variant cues include dynamic zooming, the appearance and exit of specific visuals, and movement. Dynamic zooming animates zooming-in and out of the focus point across multiple frames. The rapid alternation between the growing and shrinking of the focus area creates a pulsing motion, which draws attention to it. With gradual zooming, the presenter can show additional focus point details that were previously not visible. Rapid alternation of appearance and exit gives a flickering effect. In Waldner et al.'s study on "Attractive Flicker," they indicate that "flicker is a strong visual attractor in the entire visual field, without distorting, suppressing, or adding any scene elements" [WLB*14]. The appearance and exit category also includes staged entrance where the presenter builds up the visualization one component at a time (see Figure 2). Lastly, the movement category includes changes in spatial position over time such as an arrow moving across the screen. Currently, many presentation tools, including PowerPoint, Keynote, and Google slides, support external cues and various dynamic cues. Similarly, Prezi facilitates visual guidance by leading the audience to the area of attention through motion, zoom, and spatial relationships. However, to our knowledge, none support internal cues directly. Motivated presenters sometimes try to achieve such effects by overlapping layers of images. This heightened our interest in our participants' perception and use of internal cues.

5. User Study (RQ2)

5.1. Participants

Participants were recruited through a company mailing list, a university mailing list, and flyers across the campus of a large university. To participate in the study, the subject must have made at least one slide presentation prior to our study. In total, 24 (13 females) people participated. The majority of the users were in the 25-34 year old age bin (46%), 24% in 18-24, 13% in 35-44, 8% in 45-54, and 8% in the 55-64 age range. Participants' self-reported professions included analyst, product manager, business consultant, university employee, and undergraduate and graduate student. Half of the participants (N=12) had made more than 50 slide presentations, 29% had made 20-49, 13% had made 10-19, and 8% had made 2-9 slide presentations. Over half (63%) of the participants were working on a presentation presently, and everyone indicated that they had incorporated visuals/graphics into their presentation before. The most commonly incorporated graphs were line graphs (79%), bar graphs (71%), and pie charts (63%). For the last question "If you have created images from data, what tools do you use to create images from data?", PowerPoint/Keynote (67%) and Excel (63%) were dominant over other tools including Photoshop (29%) and Tableau (21%).

5.2. Design of VisualQ

To assess use preference of internal and external cues, we designed and implemented a lightweight Web tool, VisualQ. To facilitate users to see all the available visual cues and compare their perceived effectiveness, VisualQ supports preview, manipulation, and combination of cues. Users can preview a cue in the sidebar and apply a cue by selecting the area they want to highlight and clicking on the preview image. Each cue has several parameters that can be manipulated such as color, stroke-width, radius, length, margin, transparency, and direction. When a user clicks on another cue, the previous cue is removed, and only the new cue is applied on the selection. This allows for easy toggling between the visual cues. When a user deselects the focus area, the currently selected cue is finalized. Users can save a selection for future use if they want to combine multiple visual cues on the same area. They can undo or redo all of their actions at any time.

We incorporated two categories of external visual cues and two categories of internal cues in VisualQ based on our taxonomy: *outline, annotations, contrast-based, and perspective-based*. We included *outline* and *annotation* cues due to their pervasiveness in presentations and familiarity as shown in the preliminary slide deck collection. *Contrast-based* cues were selected based on Trapp et al.'s taxonomy and de Koning et al's spotlight studies as well as their survey on visual cues in education [dKTRP09, dKTRP10, TBPD11]. For *perspective-based* cueing, we chose to implement the plain magnification and to exclude the fish-eye effect due to the distortion of contents it causes. Also, we chose the term "loupe" to describe this feature based on the Loupe feature in preview. Unlike the Magnifier or Zoom, Loupe does not facilitate navigation or selection but instead, highlights a portion of an image by permanently magnifying the area. *Outline* cues include contour and

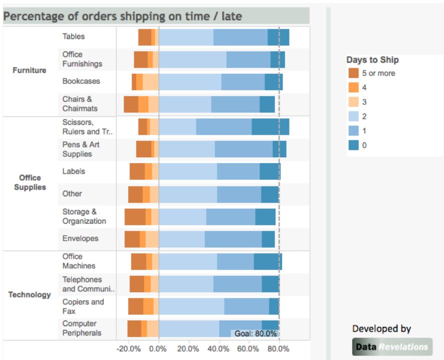


Figure 3: A divergent stacked bar chart of the superstore shipping timings.

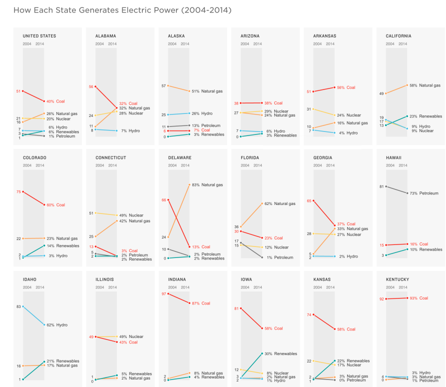


Figure 4: A small multiple visualization about the electric power generation in 2004 and 2014.

glow. *Annotations* include shape (rectangle and circle), bracket, and arrow. *Contrast-based* cues include brightness, desaturation, transparency, and depth of field.

5.3. User Study Design

After investigating the use of visual cues in natural settings through our preliminary interviews and slide deck collection, we conducted a study to observe how presenters chose cues given a specific visualization and story.

5.3.1. The visualizations

Informed by our pilot study, we selected two visualizations for the user study and composed a short description for each visualization. The first visualization shows superstore shipping times through a diverging stacked bar chart (See Figure 3). We chose a stacked bar chart visualization, the second most common visualization in our preliminary slide deck collection, over a plain bar chart since it is visually more complex, increasing the need for visual cues. More specifically, we chose a diverging stacked bar chart that displays products shipped on time (i.e., within two days) as positive values running right from zero, and products shipped late (i.e., in three or more days) as negative values running left from zero. Heiberger and Robbins recommend diverging stacked bar charts as "the primary graphical display technique for Likert and related scales" [HR14]. This suggests that diverging stacked bar charts could be used for narrative visualizations in various fields where Likert scales are common such as marketing research, psychometrics, and user experience design. The second visualization is a small multiple visualization about power generation in the U.S. (see Figure 4). A visualization concept introduced by Tufte, small multiples are efficient in representing rich, multi-dimensional data but are visually complex in nature since they contain multiple sections in one graph [VV13]. We found them useful in showing general trends and visual cues could be used to bring out details, matching Shneiderman's visual information mantra of Overview, Zoom and filter, and Details on demand [Shn96].

5.3.2. The task descriptions

We iterated on several methods in our pilot study control for the variability in storytelling across different participants. We settled on a method that presented the same script along with an associated visualization to each participant. To design our script, we started with the stories from the National Public Radio article and the Data Revelation blog post where the visualizations originally appeared [9,32], and refined the task units to address the spectrum of cueing practices. Each task description contained four task units, and we targeted to uniformly distribute probable cues; every cue in our tool was a probable cue for at least six of the eight smaller tasks. The superstore shipping task description opened with the fact that majority of the orders were on time, but some were late. To explore various components of the visualization, the description contained a sentence that focused on one category (e.g., chairs represented as a row) and another that focused on one shipping time (e.g., items shipped in two days represented as light blue sections across all rows). Overall, it covered five products across three categories. For the power generation visual task, the description started with the line, "The government has proposed new standards to lower emissions from coal-fueled powerplants." Then, we described the national trend of decline of coal and increase in natural gas. We also specified three states (i.e., Delaware, Alabama and Georgia) that followed this trend.

5.3.3. User study protocol

We began the study by obtaining the users' consent and asking them to fill out a brief demographic and presentation experience questionnaire online. After the participants completed the survey, we showed them VisualQ and introduced the ten visual cue techniques with four examples per cue. We showcased each visual cue through a five-minute introductory video, in which we used VisualQ to highlight a portion of an infographic. Then, the participants experimented with visual cues on the infographic that was presented in the video by pointing to the cues and instructing the researcher in how to use them. One researcher acted as a proxy to apply all the changes in the tool for consistency. We elected to have the researcher interact with the tool on the behalf of the participants so that participants focused on their design goals rather than with

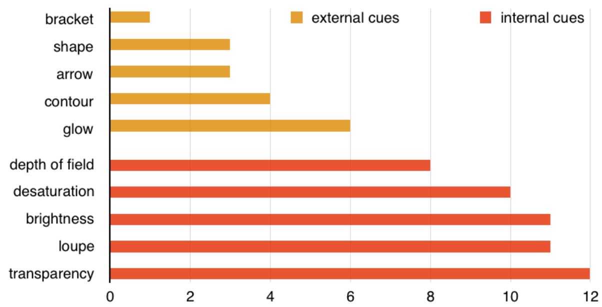


Figure 5: Responses to the interview question "Which cue did you find most useful?" Some participants chose multiple cues.

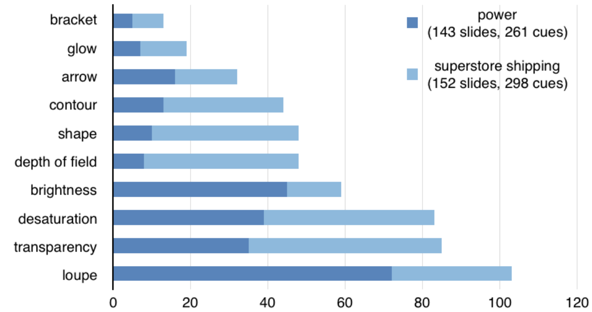


Figure 6: The frequency distribution of cues in the slides by task.

learning a new interface. Our research questions targeted visual cues preference over user interfaces. We discovered in the pilot that proxy made it easier for the participants to focus on the visual cues. After the exploration phase, participants were given a visualization with a story script and were prompted to think aloud and to imagine that they were preparing a slide presentation based on these materials that their manager had provided. After they were done with the first visualization, we repeated the process with the second visualization. Half of the participants started with the stacked bar chart; the other half started with the small multiple. We concluded with a post-study semi-structured interview with five questions on their preference and thoughts on visual cues and the resulting slides. The duration of the studies averaged one hour. All of the sessions were audio-recorded and transcribed, and the participants received a $10 gift card upon completion of the session.

6. Results

Overall, participants enjoyed exploring different visual cues and were satisfied with the resulting presentation slides. In response to the first interview question, participants chose transparency (N=12) followed by brightness and loupe (N=11), then desaturation (N=10) as the most useful cues. The preference of internal cues over external cues can be clearly seen in Figure 5. The actual usage of the visual cues in the slides is shown in Figure 6. Some participants used visual cues in unexpected ways. For example, participants used loupe to reorganize the elements in the visualization by scaling the selection by 1 and moving it to a new location, or to crop an image by magnifying the selection and filling the unselected area with white. One participant used contour to thicken lines in an existing visual. We excluded these instances of participants' alternative usage of visual cues in our cue count but discuss the creative implications in our discussion.The overall distribution of visual cues in the 295 slides created by the participants generally matched their perception of usefulness. Pearson's chi-square tests showed significantly smaller proportion of the slides contained at least one external cue (N=121) compared to slides with at least one internal cue (N=218) ($\chi^2 = 27.18$, $p < 0.001$). Next, we studied the relationship between participant demographics and the use of external and internal cues. We performed a linear mixed effects analysis with gender, age, and prior presentation experience as fixed effects, and participants and the task type (shipping and power generation) as random intercepts. P-values were derived from likelihood ratio test of the full model against the null model. None of the demographic factors were statically significant. Using a similar model, we examined the influence of the task type on the use of internal and external cues. Although internal cues were used more frequently for both tasks, we found that participants were significantly more likely to use an external cue for the shipping task than for the power generation task ($\chi^2(1) = 4.96$, $p = 0.02$). More precisely, Figure 6 shows that participants used shape and contour more frequently for the shipping task. This may be due to the visual cues' secondary function of organizing information, which will be discussed further in Section 7.2. No difference was found for the internal cues. Below, we list the participants' perception of each visual cue in more detail.

6.1. Perception of Internal cues

The ability to keep the colors relatively intact distinguished transparency from other contrast-based cues. P8 said, *"when I still want the users to see the color difference, then transparency is the best."* On the other hand, P24 indicated, *"I didn't like transparency because the colors were still visible and it was just less distracting to me to just only have that thing in color."* Despite the mixed reaction to the subtle color change, most participants reacted positively and rated it as most useful cue in our set and used it frequently in their slides (Figure 6). On the other hand, the use of brightness was considerably low compared to its stated usefulness during the post-study interview, especially for the superstore shipping task. Its advantages are similar to those of transparency, but P21 pointed out that *"if there is already a lot of light color, then [...] nothing much changes with transparency. But with brightness, you can definitely tell the difference."* Loupe was most frequently used in the user study output slides and tied as the second most preferred cue from our list. Half (N=71) of the slides for the power generation task contained loupe. *"You could read the specific part better, and you could also tell because it was bigger, that that was what needs to be focused on"* (P20). Participants also combined loupe with a contrast-based cue to distinguish the magnified portion from the background, or to draw a contour around the magnified section to create a pop-out effect as shown in Figure 7d. P5 "loved" desaturation for the power generation task because *"seeing the coal went down is interesting but it doesn't tell you what took its place, and that's a relevant part of the discussion. [...] You want to maintain* *the integrity of the chart, but you don't want the other pieces of the element to be the main focal point."* However, applying desaturation changed the saturation and not the value so *"the darkness still competes with [the area of focus]"* (P24). One participant (P21) also warned that desaturation would not be as effective if the visualization mainly involved pastel colors or grayscale colors.

Depth of field was the least preferred of the internal cues. Some people expressed a strong dislike as they found the fuzziness disorienting or distracting while others liked the pop-out effect. *"It's kind of doing the same thing as these [contrast-based] ones, but I feel like it's just doing it in a way that's distracting. If something is in grayscale, I can still read it equally well. If you made it fuzzy, I am sitting here like 'Am I going blind? Can I read those words?' and I will get distracted and I might even focus more on the stuff that is out of focus than stuff that's in focus"* (P10).

6.2. Perception of External cues

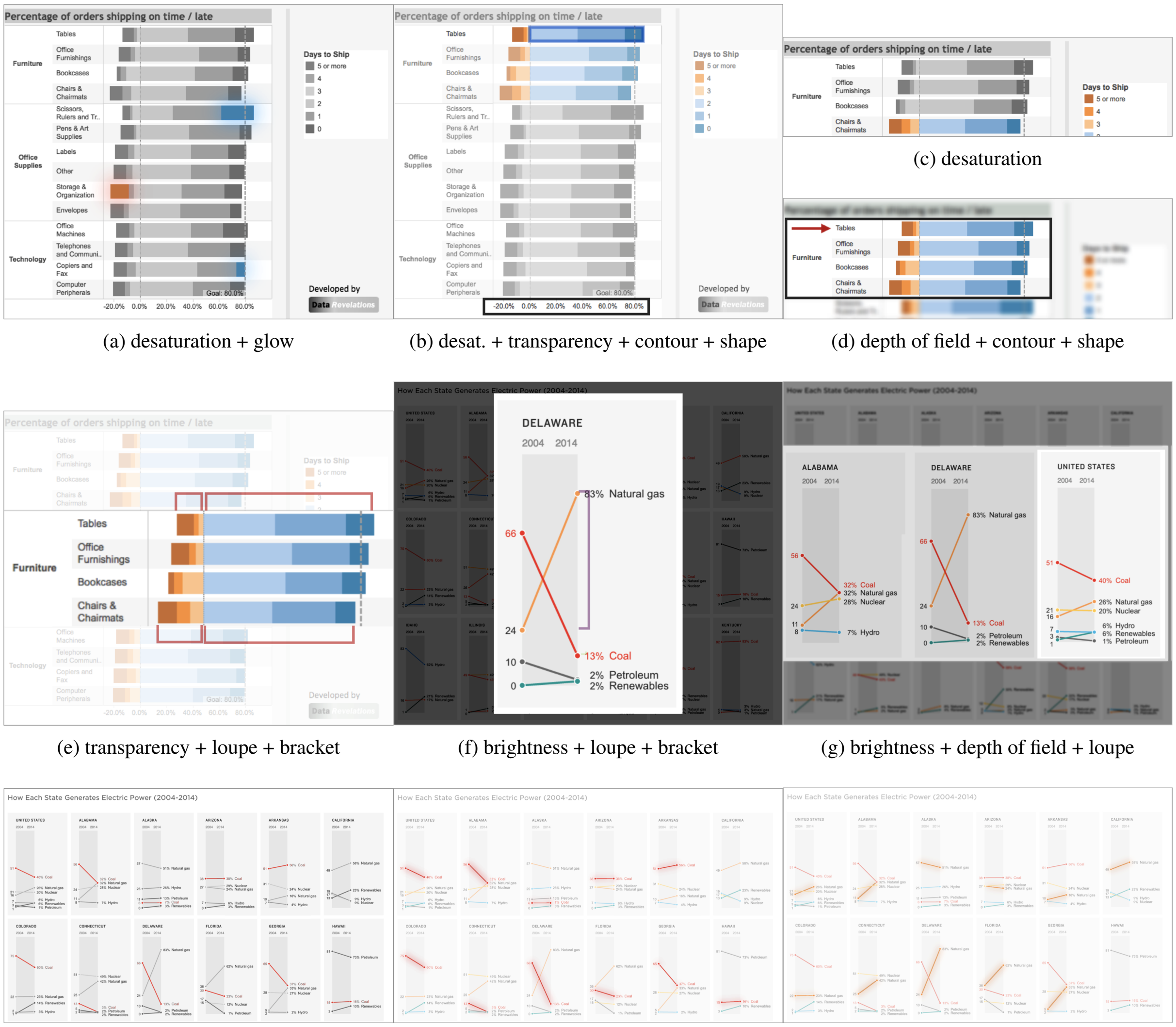
Although more participants rated glow as the most useful cue compared to the other external cues, and claimed that it "looks really nice" (P14), few of them actually used glow in their presentations. During the interviews, three participants commented that it did not seem very effective or "really harsh enough" (P22). Participants found contour, shape, and arrow cues useful for emphasizing a small region such as one bar in the stacked bar graph (see Figure 7d-f). One participant used arrows to indicate the direction of the power generation trends. PP5 described his struggle with arrows as such, *"I have a real problem with arrows. I kind of feel like I need them at times, but aesthetically, it's just awful."* Only one participant found brackets useful, and four participants expressed their dislike of brackets finding them "silly" (P5) and "distracting" (P15). As for the use of brackets in the presentations, some participants used them as a frame by placing a bracket on either side of the focus area or to mark the increase or decrease of a power source as shown in Figure 7f. Out of 261 slides that had at least one cue, the mean number of cues per slide was 2.04 (s.d.=0.85, max=4). Of all the cues, desaturation was most likely to be used alone (N=31). The most frequent combinations were "transparency+contour" (N=20), "brightness+loupe" (N=18), and "brightness+loupe+arrow" (N=11). The most common strategy was the combination of external and internal cues (N=111); 69 slides had combinations of two internal cues and two slides exhibited two external cues. Several participants expressed great interest in the tool and asked for a follow up when the tool was released for public use. Some mentioned that the cues would not only be useful for visualizations, but also for text (P6) and photographs (PP4, P10 and P17). In the post-study questionnaire, users rated that they would consider using the tool in the future for their presentations as 4.3 on a scale of 1 (would not consider) to 5 (would consider). After rating it a 5, P17 asked, *"I am [giving a presentation] in January on public health and some of these [cues] will be really helpful [...] Will this tool be public soon?"* Reasons for not wanting to use the tool included that the users could derive a similar effect with their current presentation software, although it took longer, and the cost of learning to use new software. Users expressed satisfaction with the resulting slides rating the result for the power generation task a 4.32 out of 1 to 5 (very satisfied) and the results for shipping task as 4.24. Participants (N=9) added that they took off points for the initial visualization or the lack of time rather than the tool itself. *"I would rate [superstore shipping] a 4, because I want to spend more time on it. [...] I don't like [stacked bar] charts in general, so I would use a different type of image to illustrate. I'd rate [power generation] as 3"* (P8). Although the tool offered 2-5 parameters for external visual cues (e.g., color, direction, stroke-width), some participants wanted more control over the external visual cues such as shape opacity or bracket direction. On the other hand, two participants felt overwhelmed by the number of available choices. They requested automatic suggestions of appropriate visual cues and parameters based on the given chart type and the presentation venue. Half of the suggestions for the tool (N=9) related to animations such as blinking and zooming-in. Other requests included features to change font size, family, or color.

7. Discussion

The results indicate that internal cues were preferred and used more frequently compared to external cues. And, participants often combined cues to maximize the focus effect rather than using a single cue. We discuss these results in more detail and cover the factors considered in cue selection and the role of consistency in participants' storytelling sequences in this section.

7.1. Internal and external cues

As shown by Figures 5 and 6, participants noticeably preferred internal cues to external cues and used them more often in their slides. Some participants held the view that external cues added visual clutter rather than simplified the image. P10 strongly expressed her dislike for external cues, *"I think [using external cues] is crazy for the following reason. I can convey that emphasis of highlighting out that set of elements just by deemphasizing the other elements. There is no reason for me to add more things on the page to convey the same amount of information."* Another reason for choosing internal cues was the dilution of extraneous information. *"I want to let the audience focus on the only piece of information I want to present. So I would use brightness or transparency because [...] I think that's the most effective for contrast or taking one piece of information out of the background"* (P16). Twelve of the participants' current visual cues only included external cues such as arrows and shapes. Four of them added that they used external cues such as arrows and shapes out of convenience or habit because they commonly appeared in books and presentations. *"A lot of times, I've just used arrows. [...] I guess it's what I am used to or conditioned to try. But when I saw [internal cues], [external cues] didn't seem to be very effective."* (P19). However, P16 still preferred external cues in certain circumstances such as specifying small portions of data or a specific bar in the chart. As shown in Figure 7, participants also used external cues in combination with internal cues. We discuss this overlay of cues further in the next section on the organizational role of visual cues. To note, even though participants perceived internal cues to be effective and aesthetically pleasing, future study is required to evaluate actual effectiveness of internal cues.



(a) desaturation + glow

(b) desat. + transparency + contour + shape

(d) depth of field + contour + shape

(e) transparency + loupe + bracket

(f) brightness + loupe + bracket

(g) brightness + depth of field + loupe

(h) desaturation

(i) transparency + glow

(j) transparency + glow

Figure 7: A selection of the slides made during the user study

7.2. Factors for cue selection

Many participants (N=17) mentioned that their choice of a visual cue or the cue intensity depended on the desired visibility level of the context after the cue had been applied. For example, increasing the cue intensity for depth of field (i.e., making the background blurrier) increases the contrast between the focus area and the background area by making the background less visible. The preferred level of visibility differed largely across participants based on the intended function of the visual cues and the presentation setting and audience. We discuss below how the function of visual cues and the presentation environment influence visual cue selection.

7.2.1. The function of visual cues

1. Guiding the audience's attention. This is the primary role of visual cues as indicated by the definition of a visual cue. Its influence on visual cue selection depends on whether this is the *sole* function of the visual cue. When a visual cue is used solely for directing attention, the cue intensity was increased since the participants saw the context as a distraction. For example, transparency was maximized to the point where the context almost became white.

2. Organizing information. Participants used redundancy of visual cues to create a hierarchy of importance. The redundancy often consisted of layering different types of visual cues (Figure 7a-f) or repeating the same cue on different selections (Figure 7g). When the same cue is repeated, the cue intensity is adjusted

to a weak or medium value to differentiate different levels as shown in Figure 7g. The rationale behind the multi-layering of cues was to help the audience construct a mental representation of the overall organization of information. For example, Figure 7d shows that Tables (pointed out by an arrow) is the best performing product out of the furniture department (brought out by depth of field and contour). This might also explain why participants used external cues more frequently in the shipping task compared to the power generation task; internal cues (e.g. desaturation) were often used to highlight a department while external cues (e.g. contour) were used to highlight a product in that department (refer to Figure 7b). In some cases, participants felt the context provided necessary background information and chose to minimize the cue intensity. When we asked P7 why he did not remove the unselected states, he answered, *"the reason is [...] when you have it hidden, but not highlighted, it's not going to distract the audience but you can still see the context of it."*

3. Relating elements in the visualization. The third function of a visual cue is to reveal the relationship between elements across the visualization. "It is common in expository text or complex illustrations that elements having a relation with respect to content or function may be difficult to find and link because they are widely separated across the content (Lowe 1989)" [dKTRP09]. Visual cues are also used for direct comparison of elements by highlighting one element in one slide and then highlighting another element in the next slide as shown in Figures 7i and 7j; the national downward trend of coal and the upward trend of natural gas in the power generation task were revealed in sequence to suggest the possible replacement of coal by natural gas. The shipping task also involved the comparison of elements across departments, which prompted participants to keep all the departments on the same slide. P10 elaborated that *"maybe it's good to shame poor performers and show them how much better they could be doing. I can imagine breaking it down into separate furniture, office supplies, technology sections, but then I maybe want the office supplies people to see how much better overall technology is doing.'*

7.2.2. Audience and settings

Participants (N=12) often referred to and asked about the potential audience of the presentation throughout the user study. Characteristics of the potential audience, such as visual capabilities, attention span, and preference of visualizations, were considered during the presentation preparation task. Although participants generally found desaturation aesthetically pleasing, they pointed out two limitations considering the potential audience due to its sole use of color. Three participants mentioned that desaturation would not help people with color-blindness at all. One participant (PP1) suggested layering the colored selection with a texture or pattern (e.g., hash lines or dots). P13 pointed to a second limitation of only using color for distinguishing elements; he often made black and white printouts for future reference. By using desaturation, the cueing effect would be lost when he wanted to review black and white printed versions of the material. P22 specified that the change between the slides must be obvious since subtle visual cues would go unnoticed by people with poor eyesight. He further noted that introducing new information through movement would be most noticeable.

At other times, the setting of the presentation was considered including the time of day and the lighting in the room. While explaining why contour might not be enough to draw people's attention, P21 added, *"Especially in the morning times, some people didn't get their coffee, probably didn't sleep well. You need some help."* She also mentioned that *"[brightness] is good when you have a presentation in a darker room because everything is already dark. You only see one thing that is bright."* Another participant remarked that he gives the same talk in different settings and further explained, *"I don't tend to rely on being able to have a laser pointer or being able to point to something. So if I am giving a presentation, and I know that box is around that particular text, then I know that that particular audience knows what I am talking about."* The need to reuse the same presentation under different settings requires careful selection of visual cues since the effectiveness of a cue could be affected by the room size and the screen size. The discussion of the audience and the setting revealed that there is no panacea for complex visualizations in presentations. The choice of cues depends not only on the chart type, but also on the presentation setting, the audience and the function it is serving.

7.3. Sequences and storytelling

As Hullman et al. found in their work on sequence in narrative visualization, maintaining consistency was the main principle for arranging the sequences [HDA13]. For the power generation task, 14 participants cropped or magnified the U.S. graphic to show the national trend and followed it by other state level trends. Participants who chose to magnify instead of crop the visual reasoned that maintaining the context lowers the transformation cost [HDA13] by keeping the background consistent across slides. All participants covered the sources in the same order for both national and state level (i.e., U.S. coal→U.S. natural gas→state coal→state natural gas). This "perfect" parallelism maintains the consistency of the presentation, and also improves "sequence memorability for sequences" [HDA13]. For the state level trends, some people exclusively focused on the states where the decrease of coal and the increase of natural gas was the most dramatic, as indicated in the script, while others additionally chose to emphasize outlier states where the coal usage increased or remained static. Many participants (N=13) started their presentation with the original visualization to provide the overall big picture before proceeding onto the details through visual cues. This shows that visual cueing could help accomplish Overview, Zoom and filter, and Details on demand mantra for storytelling [Shn96]. Others voiced concerns about showing the original visualization as displaying such a visually complex slide would overwhelm the audience; instead, they chose to start from a simpler visualization.

7.4. When cueing is not the solution

Through the study, we found that there are situations where presenters intentionally refuse to use visual cues. We first encountered this in our pilot study. It revealed that visualizations could be overly complex, beyond the point of attempting to make sense of them with cues. PP5 indicated that he would rather redo the chart by estimating the number for each data point. Secondly, some participants indicated that they liked visual cues but that their preparation time for presentations was too short to consider visual cues. This leads to the last reason for not using cues; the culture of the presentation settings or communities makes visual cues unnecessary. At the end of his session, P12 cautiously mentioned that he might not use a visual cue at all, because *"in my presentation, I would rather point my fingers to the graph. People in my department don't care about aesthetic features of the graph."*

8. Design implications

In this section, we present two design implications based on the user study results: integrating visual cues into existing workflows to promote the use of more diverse and effective visual cues and providing ways to reorganize visual components for consistency.

8.1. Integrating visual cues into existing workflows

Some participants (N=4) reported that although they found visual cues very useful, they introduced too much additional work given the time they usually spend preparing for a presentation. Although one participant (P4) reported that she "loved copy and pasting into PowerPoint" compared to her current workflow that involved saving and importing images, others still found the toggling between VisualQ and Powerpoint troublesome. We suggest two methods for improving the integration of visual cues into existing workflows. The first method is supporting visual cues in existing slide presentation tools such as Powerpoint. This could take the form of a plugin or a built-in functionality within the tool. The second approach is a standalone product that supports various presentation file types. This requires image pre-processing and post-processing to extract and manipulate the visualizations and text from the slides. One participant (P16) also suggested adding shortcuts and making the cueing tool compatible with Tableau.

8.2. Organizing visual components

As mentioned previously, participants reappropriated loupe to use it as a cropping and translation tool to reorganize images based on their desired stories. The most common reorganization of visual components in the user study, which occurred in 14 slides, was the placement of two or three states visuals side by side in the power generation task (see Figure 7g). Participants also expressed interest in possibilities for other reorganizations; *"This task doesn't require that, but suppose I want to initially arrange by category, and then arrange them by the height of the data."* (P14). Specifically, participants suggested showing guiding lines, snapping the selection to the nearest guideline, and supporting the centering and alignment of objects. *"The reason I wouldn't rate it a 5 is because it's easy to use the tools but to actually put everything exactly where you want, so making sure everything is centered would take time"* (P20). Assisting with the organization of visual elements will additionally aid in maintaining consistency, as the element alignments will match across slides.

9. Limitations

One of the limitations of this study is the small size of our preliminary data collection. Since a small data sample might not accurately reflect all current practices of presenters, we primarily considered the preliminary analysis as a motivation of our work. Similarly, the small number of participants and task types in the user study limits the generalizability of this study.

10. Conclusion

We presented a study on visual cues – visual elements and modifications that are used to guide the audience's attention to a particular area of the visualization. Our work offers two contributions. First, we present a taxonomy of visual cues, where time-invariant cues are further divided into internal and external cues. Second, our user study reveals that people are currently choosing visual cues out of convenience or unawareness rather than the perceived effectiveness of the cues. While participants reported mainly using external cues as their current cues, their reported preference and usage in the example tasks showed that they considered internal cues more useful than external cues. We also discuss how the three functions of visual cues, the audience, and the setting of the presentation are considered in choosing visual cues. We conclude with two design implications for visual cue tools in the hope of further encouraging the exploration and usage of visual cues.

References

[BEDF16] Boy J., Eveillard L., Detienne F., Fekete J.-D.: Suggested interactivity: Seeking perceived affordances for information visualization. *IEEE transactions on visualization and computer graphics 22*, 1 (2016), 639–648. 3

[CCH*14] Carenini G., Conati C., Hoque E., Steichen B., Toker D., Enns J.: Highlighting interventions and user differences. *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14* (2014), 1835–1844. URL: http://www.scopus.com/inward/record.url?eid=2-s2.0-84900453515{&}partnerID=tZOtx3y1, doi:10.1145/2556288.2557141. 2

[Col04] Collins J.: Education techniques for lifelong learning: giving a PowerPoint presentation: the art of communicating effectively. *Radiographics : a review publication of the Radiological Society of North America, Inc 24*, 4 (jul 2004), 1185–92. URL: http://pubs.rsna.org/doi/10.1148/rg.244035179http://www.ncbi.nlm.nih.gov/pubmed/15256638, doi:10.1148/rg.244035179. 1

[dKTRP07] de Koning B. B., Tabbers H. K., Rikers R. M. J. P., Paas F.: Attention cueing as a means to enhance learning from an animation. *Applied Cognitive Psychology 21*, 6 (sep 2007), 731–746. URL: http://doi.wiley.com/10.1002/acp.1346, arXiv:NIHMS150003, doi:10.1002/acp.1346. 2

[dKTRP09] de Koning B. B., Tabbers H. K., Rikers R. M. J. P., Paas F.: Towards a Framework for Attention Cueing in Instructional Animations: Guidelines for Research and Design. *Educational Psychology Review 21*, 2 (2009), 113–140. doi:10.1007/s10648-009-9098-7. 1, 2, 3, 4, 9

[dKTRP10] de Koning B. B., Tabbers H. K., Rikers R. M. J. P., Paas F.: Attention guidance in learning from a complex animation: Seeing is understanding? *Learning and Instruction 20*, 2 (2010), 111–122. doi:10.1016/j.learninstruc.2009.02.010. 4

[EY97] EGETH H. E., YANTIS S.: Visual attention: Control, representation, and time course. *Annual review of psychology 48*, 1 (1997), 269–297. 1

[GR10] GRIFFIN A. L., ROBINSON A. C.: Comparing color and leader line approaches for highlighting in geovisualization. *GIScience 2010 21*, 2005 (2010), 339–349. 2

[Hau05] HAUSER H.: Generalizing focus+ context visualization. *Scientific Visualization: The Visual Extraction of Knowledge from Data* (2005), 305–327. URL: http://www.springerlink.com/index/v2521525q6148447.pdf. 3

[HDA13] HULLMAN J., DIAKOPOULOS N., ADAR E.: Contextifier: Automatic Generation of Annotated Stock Visualizations. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13* (2013), 2707. URL: http://dl.acm.org/citation.cfm?doid=2470654.2481374, doi:10.1145/2470654.2481374. 9

[HHLB*12] HAILPERN J., HARRIS A., LA BOTZ R., BIRMAN B., KARAHALIOS K.: Designing visualizations to facilitate multisyllabic speech with children with autism and speech delays. In *Proceedings of the Designing Interactive Systems Conference* (2012), ACM, pp. 126–135. 2

[HR14] HEIBERGER R. M., ROBBINS N. B.: Design of diverging stacked bar charts for likert scales and other applications. *Journal of Statistical Software 57*, 5 (2014), 1–32. doi:10.18637/jss.v057.i05. 5

[KA12] KONG N., AGRAWALA M.: Graphical overlays: Using layered elements to aid chart reading. *IEEE Transactions on Visualization and Computer Graphics 18*, 12 (2012), 2631–2638. doi:10.1109/TVCG.2012.229. 2

[KMH02] KOSARA R., MIKSCH S., HAUSER H.: Focus+context taken literally. *Computer Graphics and Applications 22*, 1 (2002), 22–29. URL: http://ieeexplore.ieee.org/xpls/abs{_}all.jsp?arnumber=974515, doi:10.1109/38.974515. 3

[LA94] LEUNG Y. K., APPERLEY M. D.: A review and taxonomy of distortion-oriented presentation techniques. *ACM Transactions on Computer-Human Interaction (TOCHI) 1*, 2 (1994), 126–160. URL: http://dl.acm.org/citation.cfm?id=180173, doi:10.1145/2493102.2493112. 4

[LA11] LIN L., ATKINSON R. K.: Using animations and visual cueing to support learning of scientific concepts and processes. *Computers and Education 56*, 3 (2011), 650–658. doi:10.1016/j.compedu.2010.10.007. 2

[LH10] LIANG J., HUANG M. L.: Highlighting in information visualization: A survey. *Proceedings of the International Conference on Information Visualisation*, Fig 1 (2010), 79–85. doi:10.1109/IV.2010.21. 1, 2, 3

[LRIC15] LEE B., RICHE N. H., ISENBERG P., CARPENDALE S.: More Than Telling a Story: Transforming Data into Visually Shared Stories. *IEEE Computer Graphics and Applications 35*, 5 (2015), 84–90. doi:10.1109/MCG.2015.99. 2

[Mad15] MADSEN S.: How to Become a Deliberate Communicator in Your Projects, 2015. URL: http://www.esi-intl.co.uk/blogs/pmoperspectives/index.php/how-to-become-a-deliberate-communicator-in-your-projects/. 1

[Mey75] MEYER B. J.: *The organization of prose and its effects on memory*. Elsevier, New York, 1975. 2

[Mor07] MORENO R.: Optimising learning from animations by minimising cognitive load: Cognitive and affective consequences of signalling and segmentation methods. *Applied cognitive psychology 21*, 6 (2007), 765–781. 2

[OGH05] OLSON J. S., GRUDIN J., HORVITZ E.: A study of preferences for sharing and privacy. In *CHI'05 extended abstracts on Human factors in computing systems* (2005), ACM, pp. 1985–1988. 2

[PO13] PYYSALO U., OKSANEN J.: Outlier highlighting for spatio-temporal data visualization. *Cartography and Geographic Information Science 40*, 3, SI (2013), 165–171. doi:10.1080/15230406.2013.803706. 2

[Rob11] ROBINSON A. C.: Highlighting in Geovisualization. *Cartography and Geographic Information Science 38*, 4 (2011), 373–383. URL: http://www.tandfonline.com/doi/abs/10.1559/15230406384373, doi:10.1559/15230406384373. 1

[SH10] SEGEL E., HEER J.: Narrative visualization: Telling stories with data. In *IEEE Transactions on Visualization and Computer Graphics* (2010), vol. 16, pp. 1139–1148. doi:10.1109/TVCG.2010.179. 2

[Shn96] SHNEIDERMAN B.: The eyes have it: a task by data type taxonomy for information visualizations. *Proceedings 1996 IEEE Symposium on Visual Languages* (1996), 336–343. arXiv:arXiv:1011.1669v3, doi:10.1109/VL.1996.545307. 5, 9

[SL08] SCHNOTZ W., LOWE R. K.: A unified view of learning from animated and static graphics. In *Learning with animation. Research implications for design*. 2008, pp. 304–356. 2

[TBPD11] TRAPP M., BEESK C., PASEWALDT S., DÖLLNER J.: Interactive Rendering Techniques for Highlighting in 3D Geovirtual Environments. In *Advances in 3D Geo-Information Sciences*, Kolbe T. H., König G., Nagel C., (Eds.), Lecture Notes in Geoinformation and Cartography. Springer Berlin Heidelberg, Berlin, Heidelberg, 2011, pp. 197–210. URL: http://link.springer.com/10.1007/978-3-642-12670-3, doi:10.1007/978-3-642-12670-3. 3, 4

[THM*08] TVERSKY B., HEISER J., MACKENZIE R., LOZANO S., MORRISON J.: Enriching animations. In *Learning with animation: Research implications for design*. 2008, pp. 263–285. 2

[VV13] VAN DEN ELZEN S., VAN WIJK J. J.: Small multiples, large singles: A new approach for visual data exploration. *Computer Graphics Forum 32*, 3 PART2 (2013), 191–200. doi:10.1111/cgf.12106. 5

[Win93] WINN W.: A Constructivist Critique of the Assumptions of Instructional Design. *Designing Environments for Constructive Learning 105* (1993), 189–212. 2

[WLB*14] WALDNER M., LE MUZIC M., BERNHARD M., PURGATHOFER W., VIOLA I.: Attractive flicker-Guiding attention in dynamic narrative visualizations. *IEEE Transactions on Visualization and Computer Graphics 20*, 12 (2014), 2456–2465. doi:10.1109/TVCG.2014.2346352. 4

[WPM16] WARE C., PIOCH N. J., MAPPING O.: Multiple Independent Highlighting Techniques. 1–9. 2