Playable Data: Characterizing the Design Space of Game-y Infographics

Nicholas Diakopoulos, Funda Kivran-Swaine, Mor Naaman
School of Communication and Information
Rutgers University
{diakop, funda, mor}@rutgers.edu

ABSTRACT
This work explores the intersection between infographics and games by examining how to embed meaningful visual analytic interactions into game mechanics that in turn impact user behavior around a data-driven graphic. In contrast to other methods of narrative visualization, games provide an alternate method for structuring a story, not bound by a linear arrangement but still providing structure via rules, goals, and mechanics of play. We designed two different versions of a game-y infographic, Salubrious Nation, and compared them to a non-game-y version in an online experiment. We assessed the relative merits of the game-y approach of presentation in terms of exploration of the visualization, insights and learning, and enjoyment of the experience. Based on our results, we discuss some of the benefits and drawbacks of our designs. More generally, we identify challenges and opportunities for further exploration of this new design space.

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Infographics, Visual Analytics, Games, Interaction Science

ACM Classification Keywords
H5.m. Information Interfaces and Presentation: Misc.

General Terms
Design, Experimentation, Human Factors

INTRODUCTION
In recent years there has been growing international interest in openly publishing government and other civic datasets online. The U.S. federal government's data.gov initiative has expanded since its launch in 2009 to include over 3,120 datasets ranging from national education and public health, to environmental and transportation data. Other state, local, and international bodies are rapidly moving toward transparency and civic data publishing.

In response, new outlets seeking to make sense of this growing stream of data for the public have sprung up, such as the Guardian's Datablog in the U.K. [5]. Such journalistic channels often combine interactive infographics and textual stories to explain and contextualize datasets. In this work, we consider an alternative to traditional methods of creating interactive infographics from such datasets, and explore the design space of game-like or "game-y" infographics. Such an approach would allow data from published sources to be rapidly repurposed into playable experiences that are not only engaging, but also allow for visual analysis and personal insight from the data.

We designed, built, and evaluated three different versions of an interactive data-driven infographic, Salubrious Nation, with the intent of examining the benefits and drawbacks of the game-y mode of information presentation compared to a more traditional approach. To setup the design space of game-y infographics we first draw conceptual connections between visual analytic tasks and game mechanics. We then assess the various versions of Salubrious Nation with respect to measures that are important in both information visualization and game design including how exploration of the data was affected, whether insight generation was enabled, and to what degree the experiences were engaging and enjoyable. Our study contributes insights about interaction science and the design of goal-oriented game-like visual analytic experiences, including benefits and tradeoffs of the specific designs we implemented, and of the medium in general.

RELATED WORK
Here we provide an overview of other efforts toward telling stories with data including narrative infographics, simulation, and games that incorporate raw data.

Storytelling with Information Visualization
The notion of telling a story through information graphics and visualization has been explored in various capacities in the research literature [16, 19, 21, 33] and is increasingly used in media contexts such as journalism, to build visual narratives around data. Based on a sample of 58 exemplars, Segel and Heer [33] characterized and produced a typology of different genres of narrative visualization. A pertinent design dimension of narrative visualization is the degree of ordering and interactivity - from linear and author-directed, to more free-form and user directed [16, 33].

Perhaps the most interaction-limited form of infographic storytelling is theatrical performance using graphics, which we call *histrionic visualization*. For instance, John King has used the "Magic Wall" [6], a large touch-screen display, on CNN to depict voting results during elections by walking viewers through different visuals and scenarios with the data. Another well-known example of this is Al Gore's narrated traversal of information graphics in the movie "An Inconvenient Truth". The Economist routinely produces narrated animations of some of their information graphics called videographics [4].

At the other end of the interactivity spectrum are undirected information visualizations that allow the user to freely explore the data space according to whatever is of most interest to them. A criticism of such undirected visualizations has been that they result in a *gulf of goal formation,* where users may flounder under the complexity of finding a suitable data subset to explore or choosing among available interface options [25]. In reality, most visualizations lie somewhere between the extremes of narrative storytelling and undirected exploration [33]. Landmarks or other authored waypoints provide structure, but the user is transitioned in such a way as to allow for in-between free exploration [16, 19]. In contrast, this work explores how to use game design (i.e. rules and mechanics of play) as an alternative method of structuring a narrative.

Simulation and Data-Driven Gaming

While related to interactive storytelling, games are also a cousin to simulations–procedural representations of aspects of reality [29]. Simulations (of which some are *not* games) have been used for some time to help people interactively learn and explore phenomena being modeled [11]. Models for simulations can be data-driven, however, particularly in game simulations, simplified and abstracted models tend to be preferred. Some simulated models are physical (e.g. based on known mathematical or physical relationships), while others are subjective and editorial in nature (e.g. editorial newsgames).

In contrast to games built on top of complex models or simulations, another class of games that has emerged over the past few years is more directly data-driven. Raw data, usually in the form of media such as images, videos, or text are used as inputs to the game and form objects, which the player manipulates in the course of the game. Oftentimes the goals of these games are to annotate media [17] whereas one goal of our current work is to make data-driven games analytical and insight producing experiences.

In the commercial realm, there are also games that draw on media data. For instance, Audio Surf [1] builds on the popular dynamic of music pattern games like Rock Band by allowing players to input their own music tracks. Some commercial newsgames also use data such as NewsBreaker, a twist on the classic game Breakout that incorporates RSS news headlines into the game [7]. Another game that more deeply integrates news information into the game is Scoop [9], which constructs a crossword puzzle based on real news headlines. While these designs may generally help to increase *awareness* of news information, we go beyond text or audio to incorporate the *visual analysis of raw numeric data* as central game activities.

GAME DESIGN AND INFOGRAPHICS

The concept of game-y infographics introduced here builds on fundamental elements of game design and their intersection with visual analytics and interaction science, as we describe next. We should note here that while many games do contain infographics *within* them, such as for navigation or feedback on game stats or goals, here we consider the graphic as the dominant frame and game elements as subservient to the graphic. We should also note that we are interested in the design of more *casual* games requiring a time investment of only a few minutes.

Game-y Fundamentals

Salen and Zimmerman define a *game* as "*a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome*" (pg. 80 [29]). Puzzles are considered a subset of games that have a correct answer or outcome. Goals and rules are core constituents of what defines formal game systems [20]. Games also often include elements that support the conflict in the game such as scoring, competition, advancement or other reward mechanisms, and winning. The goals and structures in games serve to guide attention and motivate players' actions. Goals could include, for example, solving a puzzle, overcoming a competitor, exploring, collecting, constructing, or destructing. The design space is substantial when considering the sheer permutations of plausible systems of goals and rules that can be constructed.

In game design parlance, the salient interactivity present in a game is referred to as the *game mechanic*. According again to Salen and Zimmerman, the core game mechanic "*is the essential play activity players perform again and again in a game*" (pg. 316 [29]). For instance, in a trivia game, the core mechanic is answering questions, in a side-scroller the mechanic is to maneuver a character, and in a real-time strategy game it is to manage resources. The core mechanic can also be a compound activity composed of many actions such as simultaneous moving, aiming, and firing, as in 3D shooter games. Game mechanics can be altered by changing the existence, direction, symmetry, or semantics of relationships between objects in the game system.

Visual Analytics and Interaction Science

Visual analytics is the study of how visual interfaces amplify analytical reasoning, including both deriving insights from data, as well as producing and communicating judgments based on that analysis [34]. Research in visual analytics has examined an array of analytic activity both at the level of interactions, and representations [12, 31, 36, 38] and at the level of user intents [37]. For instance, Amar et al [12] developed a typology of low-level visual analytic tasks including *retrieve value, filter, compute derived value, find extremum, sort, range, characterize distribution, find anomalies, cluster,* and *correlate.* Applications of visual analytics are broad and span intelligence analysis [28], journalism [18], and bioinformatics [30] among others. This work extends visual analytics within the domain of journalism and data storytelling via games.

The field of *interaction science* has recently emerged as a distinct area of inquiry within visual analytics. It is defined in [27] as "*the study of methods by which humans create knowledge through the manipulation of an interface.*" The authors posit that "*the more ways a user can 'hold' their data (by changing their form or exploring them from different angles and via different transformations), the more insight will accumulate*" [27]. This developing theory suggests that the goals designed into games, reified through a game mechanic, itself composed of interactions, might provide the impetus for the exploration of a visualization parameter space. If we consider game mechanics as bundles of interactions, the concept of game-y infographics then is to creatively integrate visual analytic tasks [12] and interaction intents [37] into that bundle of interactions such that they are inexorably intertwined with accomplishing the goals of the game (See Figure 1).

This conception of game mechanics together with visual analytics gives rise to a number of questions including (1) Whether the structured and directed activity of a game motivates and engages more exploration of a visualization parameter space and of the data [22], (2) Whether visual analytic tasks embedded in game mechanics can lead to insights about the underlying data, and finally (3) Whether such a merging of analysis and gaming can be an enjoyable and fun experience. These questions are addressed in our evaluation using a combination of metrics drawn from visual analytics [15, 32] and user experience [26].

SALUBRIOUS NATION

To explore the space of game-y infographics and assess their benefits and limitations we designed and built three different versions of an infographic called Salubrious Nation (available online [8]). Two versions had game mechanics and the third did not. Next we discuss the data used as well as the visual, interaction, and game design of the different versions.

Dataset

As a theme for the infographics we chose national public health data as we thought this would be a compelling topic for a U.S. audience. We assembled a dataset from various online sources such as County Health Rankings [3] and the Department of Health and Human Services' Community Health Status Indicators [2]. The dataset consisted of eight health indicators geographically coded by county, including numerical values for *adult smoking rate, binge drinking rate, teen birth rate, fast food restaurants per capita, soda consumed per capita, diabetes rate, obesity rate, and heart attack death rate*. We incorporated other county-encoded demographic data acquired from the U.S. Census Bureau [10], such as population, poverty rate, life expectancy, and proportion of people over age 65.

Design

For each of our implemented versions we now describe the visual and interaction design as well as the game mechanics and visual analytic tasks supported. We primarily

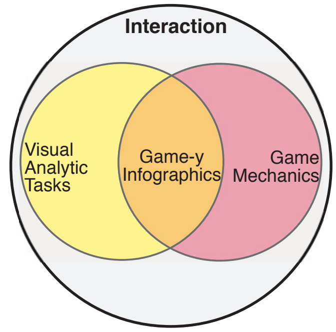

Figure 1. A conceptual diagram showing the relationship of game-y infographics, visual analytics, and game mechanics.

approached our designs via analogy by choosing mechanics popular in other casual games, such as guessing or color matching, and incorporating visual analytic tasks into these mechanics. In the design process we enumerated game interactions and their motivations (i.e. game goals) as well as how visual tasks [12] related to those interactions, taking into account visual and behavioral properties of game objects that could further enable visual analytics. We should note that these designs underwent substantive iterative revision based on feedback we obtained from play and usability testing performed using Mechanical Turk [23].

Salubrious Non-Gamey (SNG)

The non-game-y version of Salubrious Nation is shown in Figure 2a. It consists of a choropleth map as the dominant visual representation. The coloring of the map follows a spectral color sequence from yellow to red with the lighter more luminous yellow indicating "less" and the darker less luminous red indicating "more" [35]. A neutral gray is used to shade counties for which data is missing. These colors are explained in a key below the map. Above the map are instructions (instructions can also be obtained by hovering the mouse over the small question mark), a combo box for selecting the current parameter, and a slider. The slider is labeled with the minimum, maximum, and (population normalized) average for the current parameter.

As the slider is moved it displays the current value and the map is re-rendered such that the counties with a value below the slider value are shaded in yellow and yellow-orange, while the counties with a value above the slider value are shaded in orange-yellow and red. The shading transfer function is thus dynamic with the slider. Another option the user has for interacting with the map involves hovering over individual counties for details-on-demand. When the mouse is over a county the county boundary is emphasized and an overlay box pops up with the name of the county, the value of the currently selected parameter for that county, and other demographic information such as the population, poverty rate, life expectancy, and rate of people over age 65. A combo box is used to select the current parameter to visualize.

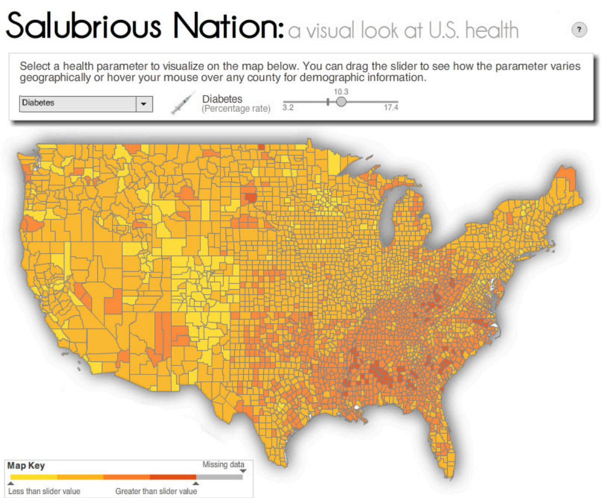

Figure 2a. Salubrious Non-Game-y - SNG

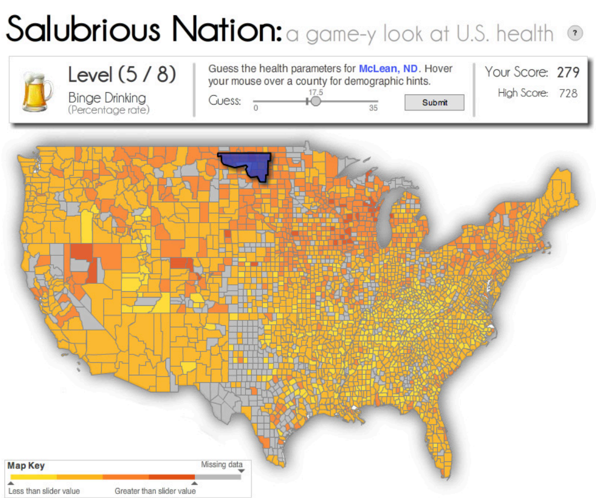

Figure 2b. Salubrious Guess - SG

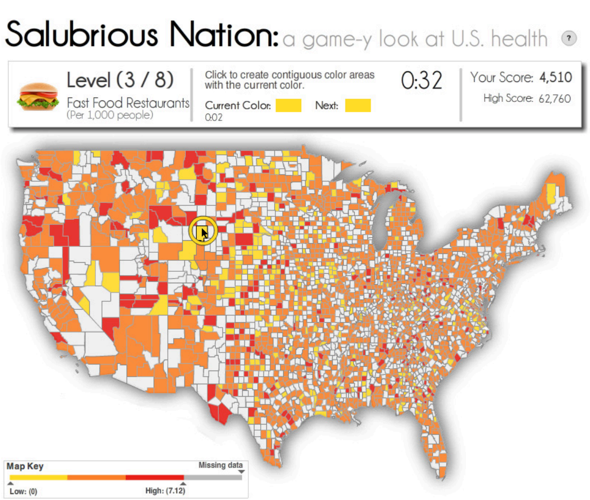

Figure 2c. Salubrious Eliminate - SE

Interaction is undirected but corresponds to analytic interaction intents and visual analytic tasks. Moving the slider enables interaction intents such as *encoding* and *connecting,* and facilitates tasks such as *characterizing* the parameter distribution geographically, seeing *anomalies* or *outliers*, and *clustering* values. The static representation of the slider also supports finding a *range* and *extremum* for the current parameter. Hovering over counties corresponds to the interaction intent of *elaboration* and supports *retrieving values* or looking for *correlations* between demographic statistics and the current parameter. Changing the parameter corresponds to a *filter* on the visible data and also supports *correlation* between parameters by flipping back and forth.

Salubrious-Guess (SG)

The first game-y design that we developed, Salubrious Guess (SG), builds on the visual representation of SNG but adds a *guessing* game mechanic that includes goals, scoring, and competition. The overall goal of the game is to accurately guess the magnitude of a given health parameter for a randomly selected target county. The player may inform their prediction using their knowledge of the health parameter in conjunction with the given demographic statistics, or using information gleaned from how the map changes color in response to manipulating the slider. The more accurate the guess, the more points the player scores. The design structures attention such that each of the eight levels consists of one health parameter and one target county. In addition to earning points, players can compete for the high score and compare their score to others' at the end of the game.

The visual representation of SG is shown in Figure 2b. and is very similar to SNG including the map, key, and slider. One exception is that the target county for each level is increased in size and highlighted in blue. An animation at the beginning of each level draws attention to the target. There is additional feedback at the top of the graphic to show the user the current level, parameter, and scores.

There is a slider similar to that of SNG that is used by the player to enter their guess for the current parameter. A submit button next to the slider enters the guess and scores it, while providing visual feedback about the correct answer. The user interacts with the graphic via the slider, which works the same way as for SNG, via hovering to obtain demographic statistics for the given county, and by hitting the submit button. The visual analytic tasks supported by SG are very similar to that of SNG except that in SG, there is *no* capability to *filter* or *correlate* between variables by flipping back and forth. Clicking the submit button supports *retrieving a value* by revealing the true value for the health parameter. After submitting a guess, the user can continue to explore the map until deciding to advance to the next level. In this interim period the hover info box also shows the exact value for the parameter.

Salubrious Eliminate (SE)

The second game-y version of Salubrious Nation that we developed explores a different part of the design space. We recognized that color matching games such as Bejewled or Snood are tremendously popular online casual games. The game mechanic entails matching groups of colors in order to eliminate game units, such as blocks or balls. We adapt this game mechanic for data in Salubrious Eliminate (SE). To do this we partition counties into low, medium, or high values based on a Z-score; each level of the parameter corresponds to a game color. Sixty percent of the counties on the map are randomly selected and colored based on their value; the other counties are left blank. The goal of the game is then to color blank areas of the map with the current color so as to create contiguous color areas. When a contiguous color area is created it is eliminated from play and the player receives points based on the size of the area cleared (i.e. the number of counties in the contiguous area). To quicken the pace time-pressure is added by having the current color switch randomly every 10 seconds and by limiting the level to 50 seconds total. As in SG each level consists of one health parameter and the player can compete for the high score and compare their score to others at the end of the game.

The visual representation of SE is somewhat different than SNG or SG (See Figure 2c). We use only three shades of color on the map and the meaning of the colors is different; it is based on the partitioning of the parameters into low, medium, and high values. The map key is labeled with the low and high values for the parameter. Additional feedback at the top of the graphic shows the current color, the upcoming next color, scores, and the amount of time left in the level. Feedback on the current color is also given by showing a colored ring around the mouse cursor. The ring blinks when the current color changes in order to draw attention to the new color.

The user interacts with SE by clicking the current color onto blank counties on the map. Creating a contiguous area scores points and eliminates those counties from play by dropping their transparency; their coloring is still apparent however so that visual trends can still be detected. In comparison to SNG or SG, SE is more limited in the range of visual analytic tasks that it supports. Clicking a county enables interaction intents including *select* and *connect* and facilitates visual analytic tasks including *characterizing the distribution*, *clustering*, and geographic *correlation*. The map key supports the tasks of identifying the *range* and *extremum* of a parameter. After the level timer expires we enable another interaction: the user can hover over the map to *retrieve values* or look for *correlations* between demographic statistics and the current parameter.

USER STUDY

We conducted a between-subjects online user study in order to compare the relative merits of the different versions of Salubrious Nation. The experiment was designed to assess the three research questions articulated earlier, namely: (1) Whether the structured and directed activity of a game motivates and engages more exploration of a visualization's parameters and data; (2) Whether visual analytic tasks embedded in a game mechanic can lead to learning, insights, or hypotheses about the data; and (3) Whether game-y infographics can be an enjoyable experience.

Procedure

The evaluation of Salubrious Nation was conducted online rather than in a lab setting in order to enhance the ecological and external validity of the study. Deploying the study in this way came at the expense of closer control of the display environment and forced us to rely on post-task recollections of insights. In order to recruit participants we published calls for participation in local university mailing lists, as well as social media sites such as Twitter. Participants were entered into a drawing to win one of two $50 gift certificates. The participants were given a URL address, and were assigned randomly to one condition of the infographic upon consenting to the study. Users were free to interact with the graphic for as long as they wanted and were asked to fill out the questionnaire when they felt they were done using the graphic.

Data Collection

We collected data by logging user interactions with the interface and from a questionnaire. We adopted several measures developed for the assessment of visual analytics tools, such as exploration and insight generation [32]. The interaction log collected data such as the time spent with the graphic and the number of entities considered via clicks, hovers, and drags. The questionnaire collected basic demographic information, Likert scale ratings of subjective impressions of the experience such as enjoyability and learning, and what we expected to be covariates such as degree of interest in public health and experience with online graphics and casual games. The questionnaire also included open-ended questions, which asked about the enjoyability of the experience and about the observations and questions users had during their experience. These open-ended responses were analyzed using affinity diagramming and iterative coding to arrive at patterns and typologies of use; insights were further categorized using a fact typology from Chen et al. [15].

Participants

One hundred forty-seven participants were recruited and assigned randomly to one of the three conditions, SNG, SG, or SE. A limitation of deploying our study online was the need to carefully vet responses and activity to exclude those that were perfunctorily participating in order to be entered into the gift certificate drawing. We excluded three participants from SNG due to no substantial log activity (i.e. they just filled out the questionnaire without using the interface), two participants from SG because they didn't complete at least half the game levels, and seven participants from SE because they didn't complete at least half the game levels. For all of the eliminated participants we verified that their questionnaire responses were largely unsubstantive. Furthermore, seven participants were excluded from the study because they did not record their user identifier on their questionnaire (which allows us to link responses to log activity). This left us with one hundred twenty seven valid participants: SNG (N=47), SG (N=41), SE (N=39). Of these participants, 64% (N=82) were female and 36% (N=45) were male. The ages of the participants ranged between 19 and 57 (M=29, SD=7.17). There were no statistically significant differences between groups on any of the demographic, interest, or experience variables measured.

RESULTS

Our analysis surfaced some key factors alluding to the benefits and drawbacks of game-y visual analytics, including aspects of the exploration of the graphic, insights and learning, and enjoyability.

Exploration of the Data and Parameter Space

Jankun-Kelly et al [22] have argued that the core activity of the visualization exploration process is manipulating different configurable variables which impact the generation of a visualization (i.e. the visualization's parameterization). Visualization exploration can be assessed by measuring metrics such as the number of entities and other parameterizations considered [32].

One measure of the amount of the data space considered is the number of unique health parameters visualized (recall there were eight parameters in total). In both game versions each parameter corresponded to a level thus in order to finish the game each parameter was considered, whereas in SNG the user was allowed to freely decide which parameters to explore. This resulted in the average number of unique parameters considered being 8.0 in SG and 7.94 in SE (one person didn't finish all eight levels) versus 5.94 in SNG. A Z-test indicates that the mean for SNG is significantly less than that for SG or SE ($p < .001$). In both game-y conditions all or almost all of the parameters were considered by every participant whereas, when left to their own inclinations, participants in the non-game-y condition only considered about 74% of the parameters on average.

Another measure of the exploration of the parameters and demographics in the graphic is how much hover activity was performed by participants (recall hovering the mouse over a county shows a detail popup with demographic statistics such as population and poverty rate). We compared the average number of hover interactions logged per user across conditions: users of SNG had the most hovers (M=532), users of SG had the next greatest amount (M=401) and users of SE had the least number (M=196). As the number of hovers was not normally distributed we applied a log transform and ran an ANOVA with post-hoc Dunnett C tests for unequal variances. Differences between SNG and SE as well as between SG and SE were significant at $p < 0.05$ indicating that participants used the hover interaction less in SE than in either SNG or SG, but there was no significant difference between SNG and SG. This is consistent with hovering being central to the mechanic in SG but non-essential to the mechanic in SE.

Besides the absolute volume of hover activity we looked at the *distribution* of hovers by plotting the aggregate density of interaction over each county for each condition. This is depicted in Figure 3 with darker counties indicating more hover interactions. The figure exposes one of the difficulties in log analysis: *intentionality*. Two salient trends apparent on the maps are artifacts of interface layout. The high density of hovers in the north-western area for SNG is a result of a drop-down combo box placed just above the map there (See Figure 2a.). The high density of hovers over Minnesota in SNG and SG is also a result of a slider (See Figure 2b) being placed above the map at that location.

However, there are other trends that are not artifacts of interface layout. For instance, in SNG there is a high density of interaction around New York and New Jersey, where the majority of the recruiting for the study was done. Perhaps unsurprisingly, people were most interested in details from the area where they reside. In SG however we see this geographic bias has disappeared–the interaction is more uniformly spread across the country. In SE the geographic bias has returned but is oriented toward larger counties. If we consider the aggregate *click* density (the primary interaction in SE) in Figure 4 then this trend towards interacting with larger counties becomes even more clear. Compared to the small counties in the eastern U.S., western counties represent faster (i.e. larger) targets to acquire, thus this interaction pattern is consistent with players optimizing the click-based game mechanic.

Between SNG and SG we can also compare the average volume of interaction with the slider to see how often that parameterization of the graphic changed. The mean per person number of slider changes for SNG was 108 and for SG it was 208. We log transformed the variable to make it normal and found a significant difference between the conditions ($F(1,80) = 10.43$ $p < .01$). The specifics of this difference become more apparent when we graph the number of slider changes logged for each tick of the slider (See Figure 5). In particular we see a much larger spike for central values of the slider indicating that participants in SG

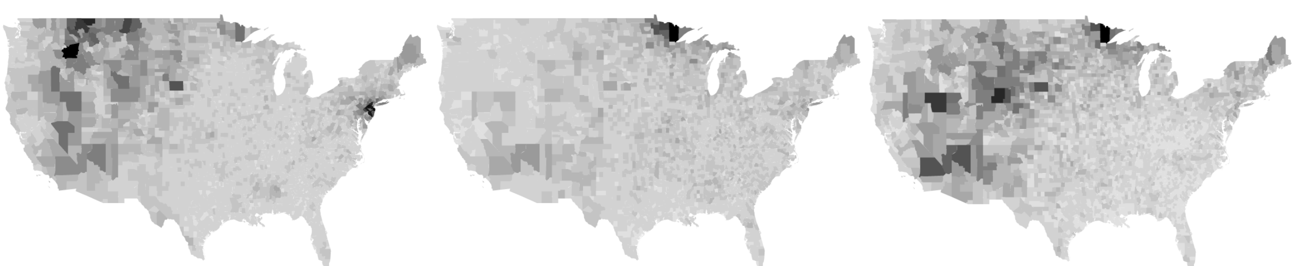

Figure 3. Normalized hover density for SNG (left), SG (middle) and SE (right).

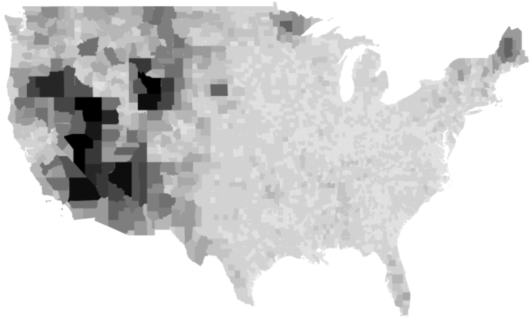

Figure 4. Normalized click map for SE

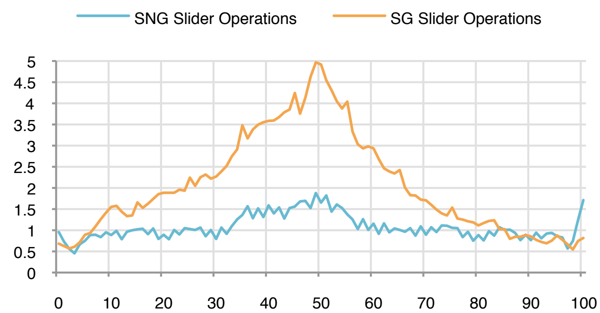

Figure 5. Average per person slider parameter exploration

moved the slider back and forth through the midpoint more often than in SNG. This interaction pattern coincides with the game mechanic: using the slider provides visual feedback with which to better inform a guess.

Insights and Learning

Having examined how the different designs of Salubrious Nation influence parameter and data exploration, we next turn to how this exploration enabled (or hindered) participants' ability to make sense of the data in terms of insights, questions, or hypotheses derived from their interaction. Here we are primarily interested in the potential of game-y infographics to engender new observations or insights and less interested in standard measures of learning such as recall, though we did also measure participants' self-reported perceptions of learning. We included two open-ended questions on the questionnaire to probe at insights, asking participants what observations, insights, or questions they had, based on their interaction with the graphic. For our analysis we adopt the definition of insight offered by Chen in [15] which corresponds to the observation of some fact (e.g. detecting an outlier) combined with an interpretation via some mental model. We manually coded the text responses using a typology of fact types [15] and present results characterizing the kinds of insights and observations reported in each condition.

SNG produced the most insights (M=1.87 per person) in comparison to the game-y versions, SG (M=0.95) and SE (M=0.54). Participants identified many different kinds of facts such as extremes, correlations and associations, geographic distributions and clusters, comparisons, and observations about the data itself such as units of measurement or missing data. Some observations were encoded as factual statements, while others were hypothetical or posed as questions, tacitly indicating some underlying observation. Responses showed that there was deductive reasoning (i.e. (dis-)confirming a tacit hypothesis) as well as ampliative abductive reasoning [14], involving the construction or promulgation of "new" hypotheses based both on the existing data as well as on some external knowledge that the participant brings to the tool. For instance, participants conjectured about the relationship of health parameters to external variables such as race, education, urbanity, and latitude with some going on to posit *causal* relationships to external variables such as literacy and education.

Users of SG generally had the same types of observations as users of SNG, albeit in lower numbers. In SG there were more questions from users about the *nature* (i.e. existence or strength) of the relationship between the given demographic statistics and the health parameters. One participant in SG wrote, "*Are the parameters displayed correlated to the health questions? Are they the best parameters to use?*". Users of SG also had more observations about associations between the demographics and the health parameters, rather than between different health parameters (SG M=0.32 per person; SNG M=0.13 per person) indicating increased attention to these relationships. In SG we begin to see people having insights not just about the data but also about the game, such as strategies for increasing points and winning: "*I tried to use the color information of the neighboring counties the most in deciding my answer values. By trying to equalize the number of counties above and below my answer, I tried to minimize my error.*"

In SE there were substantially less insights and observations about the data and more comments about how to optimize scoring in the game. For instance, one participant wrote, "*Depending on the category, regions with smaller districts tended to connect with each more than the larger regions. Hence, more points.*" Many participants, instead of reporting on observations about the data, griped about their inability to do so and complained that the game directed attention away from the data. Time pressure meant there wasn't enough time to take everything in: "*I was so focused on scoring points that I didn't notice much else about the graphic*"; "*It's hard to actually remember which areas are high or low for the stats because you concentrate hard on playing the game...*"; "*Being timed made it more of a challenge, and I ended up paying more attention to click the right colors than to being able to actually observe the map as a whole.*"

But while SE had substantially less insights about the data than SNG or SG there was an interesting relationship with interest level. We dichotomized interest level to high interest (>= 5 out of 7) and low interest (<= 4 out of 7). In SNG, high interest participants generated 64% of the insights and in SG they produce 67%. In SE the trend was reversed with 71% of insights coming from *low* interest participants. This difference is statistically significant (χ^2=9.789 $p < .01$) suggesting that although the absolute numbers were lower, SE enabled people less interested in public health to have proportionally more insights about the data.

We also measured and compared participants' self-reported learning on a seven point Likert scale ("How much do you think you learned by using the information graphic?"). We ran an ANCOVA on participants' self-reported learning with their frequency of online graphics use as a covariate ($F(2,123) = 9.885$ $p < .001$). Post-hoc Bonferroni tests showed significant differences between SNG and SE ($p < .001$) and between SG and SE ($p < .05$) but not between SNG and SG (SNG M=4.68; SG M=4.07; SE M=2.74). These results reinforce what we gleaned from our analysis of insight responses: people also *felt* they learned more in SNG or SG than in SE but the difference between SNG and SG was not statistically significant.

In both SNG and SG participants commented that they would like to see more information and knowledge explicitly communicated such as known facts for target counties, links to external information or details, explanations for differences, or contextualization and explanations for outliers and extremes. This suggests that some users approached the graphics as they would other narrative infographics and were expecting the *messaging* of *known facts* typical of that genre [33] instead of being left to their own insight generation capabilities.

Enjoyment

The last major research question we sought to address in our evaluation of Salubrious Nation was how engaging and enjoyable the experience was. On the questionnaire we asked participants to evaluate how enjoyable and fun their experience was on a Likert scale and also solicited open-ended explanations to more fully understand the ratings.

Participants in both SNG and SG often reported that their ability to have analytic insights led them to enjoy those experiences. People enjoyed seeing spatial patterns and geographic trends across regions and figuring out aspects of the data such as extremes or comparisons. In SG and SE people mentioned the game-y aspects as enjoyable as well. For instance in SG some people enjoyed the challenge and cognitive effort of the puzzle aspect. No one mentioned score as a motivator in SG, however in SE score was mentioned several times in terms of beating the high score (challenge) or just trying to score as many points as possible: "*It was fun to get a large chunk of counties and gain a lot of points at once.*" Participants in SE thought aspects of the game mechanic like clearing a big area or visually searching for areas were enjoyable.

Limitations of the interface were often the impetus for frustrations or a less enjoyable experience. In particular participants in all conditions complained of the diminutive size of the counties in the eastern U.S. as well as a lack of landmarks (e.g. cities, state boundaries) and ability to zoom and pan the map, which would help with navigation. In SE frustrations had to do with difficulty understanding the rules and goals of the game. Some participants thought it was initially unclear or not well-explained how their actions connected with the underlying data. They also complained of the time pressure and how this conflicted with their ability to focus on the data. In SG there were some complaints about the *relevance* of the targets since they were randomly generated and were likely not geographically germane to individual users. Several participants in SG also did not appreciate the guessing nature of the game. They thought it was inappropriate (and stereotyping) to be using demographics such as poverty to predict health issues; it was simply too serious an issue to be playing a game about.

Self-reported enjoyability ratings (1 to 7) showed SNG to be the most enjoyable (M=5.23), SG to be next most enjoyable (M=4.63) and SE to be least enjoyable (M=3.71). An ANOVA showed significant differences among the conditions ($F(2, 124) = 9.084$, $p < .001$) and post hoc Bonferroni tests showed significant differences between SNG and SE ($p < .001$) and between SG and SE ($p < .05$) but not between SNG and SG. Enjoyability ratings interacted with co-variates such as health interest and use of online graphics differently across conditions. In SG enjoyment ratings were positively correlated with interest in public health ($r = .508$, $p < .01$) but this correlation did not hold in the other conditions.

We compared the group main effects of public health interest to enjoyment at three levels (low=2, medium=4, high=6) and found that at low interest levels there was no significant difference in enjoyment between the conditions, but that for medium or high levels of interest there was a significant difference in enjoyment between SNG and SE ($p < .05$). We similarly compared the group main effects of use of online graphics to enjoyment at three levels (low=2, medium=4, high=6) and found that at low levels there were significant differences between SNG and SE ($p < .01$) and SG and SE ($p < .05$), but for medium levels the difference between SG and SE disappears and for high levels all differences disappear. So although SNG was overall the most enjoyable among the three, for certain subsets of participants (i.e. people minimally interested in public health and more frequent users of online graphics) the enjoyability was not significantly different.

DISCUSSION

In this paper we have begun to explore the design space and potential of game-y infographics. Our results suggest that game-y designs have benefits in terms of increased exploration of the data space. At the same time, absolute measures of insight, learning, and enjoyability were higher in SNG with important caveats such as that the proportion of insights was greater for less interested users of SE, and that content interest or use of infographics impacted the enjoyability of the designs differently. We further discuss these results and their impact on design below.

Directing Attention

Our evaluation shows that traditional infographics such as SNG generally outperformed the game-y designs across metrics of number of insights generated, self-reported learning and curiosity evoked, as well as enjoyment of the experience (though differences were often insignificantly different, especially between SNG and SG). The main contribution of our study is in showing that the primary benefit of game-y infographic designs lies with their ability to *redistribute attention*. We see substantial evidence of this when comparing metrics such as the number of unique parameters explored, counties hovered over, and slider drags. For instance, in both SG and SE levels served as structured filters on the data, essentially directing attention to each health parameter one at a time – this led users of those conditions to be exposed to more health variables than in the SNG condition.

Game goals provide mechanisms to *emphasize objects and relationships* between objects in the game. In the case of SG the relationship between the demographic statistics and the health parameters saw more questions and insights due to the predictive power of those relationships in helping the player be successful in the game. Another example is that the random nature of the target counties in SG served to more evenly distribute hover attention around the nation by pulling users away from their natural inclination to only look at locally relevant counties. In SE, the visual representation of counties led users to interact more with larger counties since they made easier targets to acquire.

Seen from this vantage point, we have shown that *game-y infographics are a mechanism to bias attention and interaction via the goals and representations embedded in the game mechanic*. For instance, data sub-sets with known lower levels of intrinsic user interest might have a bias applied to them because they are editorially deemed to be of high importance. The downsides to redistributing attention are that it requires careful authorial thought on *how* and *where* attention should be directed, and in so doing it may focus attention on objects or relationships that overlook other subtleties of the data. Finally, the very nature of game mechanics draws attention away from data and to game elements such as score or time. In particular, we found time pressure should be avoided in order to give people the requisite time to consider data as part of the game.

Another general take-away from our evaluation is that users would appreciate more explicit messaging in the graphics to teach them known facts or pieces of knowledge about the data they are interacting with. This is perhaps unsurprising since such messaging is common in information graphics and educational games [33]. This could be accomplished with more authorial effort by pre-analyzing the dataset to add context or factoids. Another less labor intensive approach would be to integrate datasets with semantic web resources such as Freebase in order to automatically link to relevant and contextual information. At the same time, designers of such experiences should consider the tradeoffs of providing information and insights explicitly versus engendering users' production of their own ampliative abductions in connection with their interactions. While the more cut and dry experience may provide more measurable "learning", an approach to engender more divergent and creative questioning may have advantages that lie outside of traditional learning. While all games are in some sense about learning [24] data-based games have the added potential to create opportunities for personal insight.

Design Challenges and Opportunities

We presented two different game designs, one based on guessing and another based on color matching. The informed guessing mechanic was largely a success whereas the timed color matching mechanic was less effective overall. Future designs might incorporate different player interaction patterns (e.g. player vs. player), game resources (e.g. lives, currency, power-ups) and goals or mechanics (e.g. collecting, building) [20].

There is substantial room for the continued exploration of the game-y infographic design space by considering different data types and different non-map-based visual representations. Some game mechanics may be more general and adaptable to different types of data whereas others may be very specific. For instance, the nature of interacting to accomplish visual tasks with temporal, hierarchical, network, text, image, or geographic data will lead to different kinds of interactions [37] and thus game mechanics for these different data types. While this is a challenge to generalizability it is also a huge opportunity to explore a range of game mechanics that may work better or worse across data types and visual representations.

Another set of design challenges arises from the definition of games as complex systems involving objects and relationships [29]. Many games are heavily *authored* experiences involving meticulous attention to designing not only object relationships and actions that can be taken in a game, but also the *particular* constellation of objects that appear at any given stage or level. Careful authorship controls for balancing difficulty and challenge as well as enriching the *semantics* via the premise and back-story of the game. In comparison, potentially *raw data*, from which a game-y infographic can be generated, may be incomplete or inconsistent, and the structure and relationships in the data may be unknown to the game designer a priori. If the data were updated, refreshed, or otherwise dynamic it could alter such relationships, disrupt the balance or challenge, and diminish the playability of the game. The design difficulty is in abstracting the data so as to impute *meaningful* objects and relationships on an uncontrolled data source. And not only must these objects and relationships be meaningful in the context of the game, they must also be meaningful for visual analysis.

A puzzle-like design, as demonstrated in SG, seems to be a promising avenue that provides a meaningful experience and also minimizes authoring costs. With the exception of the thumbnail icons used to represent each health parameter a similarly geocoded numeric dataset could easily be substituted. On the other hand, future explorations of this design space might consider a more semantically laden game aesthetic with a premise and back-story. Bonuses or other game rewards that are meaningful in the context of the data could be given for analytic tasks accomplished (e.g. a golden syringe is awarded if the county with the highest rate of diabetes is found). More semantically imbued infographic presentations have recently been shown to be more enjoyed and to improve memorability [13]. Whereas our designs were visually framed as infographics, adding more dramatic elements may make them more playful and contribute to a stronger game aesthetic.

CONCLUSIONS

In this paper we have made strides in connecting the disparate disciplines of visual analytics and game design. We have shown that although attention deficits prevail in limiting the insights and learning potential of game-y designs, such designs can redistribute players' attentional resources in interesting ways. We have shown that game-y infographics are at least as enjoyable as a non-game version under some conditions. Most importantly we have demonstrated that the goals embedded in game-y infographics can successfully motivate interactions and cause users to explore and *bias* both the exploration of parameters and the nature of insights in interesting ways. The design space for Playable Data is immense, but represents an exciting opportunity to advance interaction science by studying how different mechanics, data types, and visual representations influence exploration. Future work should further expand the spectrum of artifacts between straight infographic and casual game to better understand how that framing impacts the experience. We hope others will join us in the investigation of this space.

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