An Exploration of the Effectiveness of Infographics in Contrast to Text Documents for Visualizing Census Data: What Works?

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Abstract. The U.S. Census Bureau conducted a usability research study using 3 published Census infographics on different topics containing statistics produced from Census survey data. The study used a mixed-factorial design with repeated measures, comparing user performance (accuracy of information recall and accuracy of searching for information) and satisfaction after using either the 3 infographics, or 3 text documents containing the same information. 55 participants were randomly assigned to either the Infographics condition or the Documents condition, accordingly. Results revealed significant advantage in accuracy for participants with any amount of college education, and a significant interaction between the stimulus type (infographics compared to documents) and the condition (searching versus recall) with infographics being related to increased performance in the searching task and not the recall tasks. However, there were no significant memory-related advantages for infographics above documents, and no interaction between education and stimulus type.

Keywords: Usability · Infographics · Memory

1 Introduction

Infographics represent an emerging medium of information visualization and statistical communication. In an era of rapidly increasing availability of information, infographics can attenuate the effects of information inundation by presenting information in a way that is quickly and easily digestible, as well as engaging and attractive. Some studies show that the human visual system can process and assign meaning to imagery in less than a second, which can be much faster than reading through a text explanation [1, 2]. Other research suggests that for online content, people read less than 28 % of the words presented to them [3]. Thus, increasing imagery and using words sparingly, as in an infographic, seem like obvious choices.

At the Census Bureau, infographics are created with the intent to convey data about a topic or concept in a way that is appealing and easily interpreted by a wide, public audience, especially those who may not have a formal background in statistics, or high level of education. Dowse, R. & Ehlers, M. (2005) found that medicine labels containing text and visual representations were interpretable by 95 % of subjects as

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opposed to labels with text alone for which the interpretability rate was much lower (70 % of subjects) [4].

There is a lack of published research pertaining to the effectiveness of infographics as an information visualization medium for complex statistics, and infographics can vary wildly in terms of composition, imagery, length, density, technical terms, use of traditional graphs, and content.

Currently, while Census data is available to the public, accessing these statistics requires querying complex data tables. If statistics on more than one aspect of a particular topic are desired, this can require multiple queries. This can be difficult and time-consuming for a member of the general public, who may have no knowledge of the structure of Census data. Census infographics allow for some comparison of multiple statistics on a particular topic to be presented without the need for querying or understanding the structure of Census data. Unlike data tables, infographics also allow visualization of the data (e.g. graphs) and imagery that may be engaging and related to the topic (iconic imagery). However, no research has yet been done to assess whether these presentations are effective and understandable for members of the general public.

The objective of the present research is to begin examining what makes an infographic effective at communicating statistical data and appealing to readers by measuring memorability, searchability, time required to read the infographic, understandability of language, use of imagery and graphs, user satisfaction data, and eye-tracking analyses. Results will be used to inform the development of future Census infographics and further research in the area of information visualization for a public audience.

2 Methods

A usability research study was conducted using 3 published infographics from the U.S. Census Bureau on different topics containing statistics produced from Census survey data. The study use a 2 × 3 × 3 mixed factorial design, comparing user performance and satisfaction after using either the 3 infographics, or 3 text documents containing the same information.

Between-subjects variables are "Condition" (2 levels, Infographics and Text Documents) and "Education" (3 levels, Highschool, Some College, Bachelor's Degree).

Within-subjects (Repeated Measures) variables are "Stimulus" and "Response Condition." Stimulus has three levels: Memorial Day, Home Improvements, Child Care. Response Condition has three levels: Free-Recall, Multiple-Choice, Search.

Dependent Variables: Accuracy scores for each combination of the Within-Subjects factors (e.g. "Memorial Day Free-Recall Score" is one dependent variable). Accuracy was measured on a scale of 0 to 10 and was determined based on a pre-established rubric. Ranges of acceptable values for Free-Recall responses were established prior to the study, and partial credit was awarded in multi-part questions.

2.1 Participants

A total of 55 participants were randomly assigned to either the Infographics condition or the Documents condition, accordingly. Participants were recruited from a pool of volunteers maintained by the Human Factors and Usability Group at the U.S. Census Bureau. Participants were recruited based on the following criteria:

- Participant is 18 years of age or older.
- Participant has completed at least 3 years of high school.
- Participant has completed no more than a Bachelor's degree.
- Participant speaks English.

Sessions lasted one hour and participants were given a $40 dollar honorarium. Participant characteristics appear in Table 1 below.

Table 1. Participant Characteristics, $n = 55$

Total Participants	55
Gender	
Female	31
Male	24
Age (in years)	
Mean (SD)	42.5 (16.5)
Range	18 - 74
Education	
High school diploma or less	18
Some college	18
Bachelor's degree	19
Race	
White	13
Black	38
Hispanic	3
Asian	3
Other	1

2.2 Procedure

Participants were randomly assigned to either the infographics group ($n_i = 28$), or the text documents group ($n_t = 27$).

Three Census infographics and their corresponding text-documents were chosen based on length of the infographic, iconic value of imagery and density of information. Iconic value of imagery refers to the extent to which the imagery in the infographic was abstract (such as differently sized boxes representing varying statistical values) or iconic (imagery relates directly to the topic, e.g. drawings of people to represent quantities of people). The infographics chosen were of the following topics: Memorial Day (short length, low iconic value, high density), Home Improvements (short length,

high iconic value, low density), and Child Care (longer length, moderate iconic value, moderate density).

Each participant was verbally introduced to the purpose of the study, signed a consent form, and was calibrated for eye-tracking.

For the text condition, the publicly available blind-accessible document version of each infographic was used. The text-only documents contained the same data and text descriptions of the data as their corresponding infographics, but contained no imagery or visualizations. An example of a Census infographic section with its associated text-document section appears in Figs. 1 and 2, respectively.

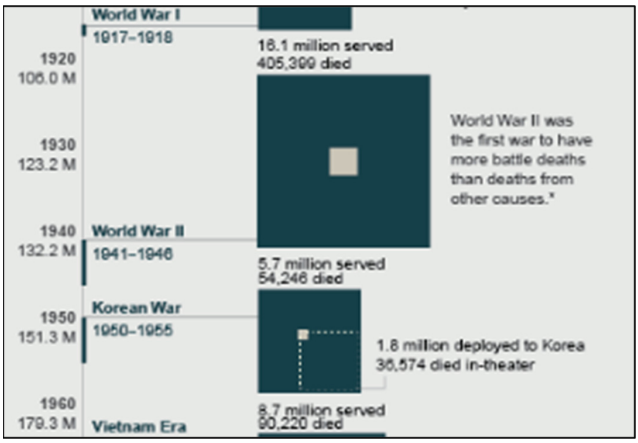

Fig. 1. Section from the Memorial Day infographic

Note: The last living World War I veteran, Frank Buckles, died in 2011 at 110 y

World War II

World War II began in December 1941 and ended in December 1946.

16.1 million people served worldwide during World War II and 405,399 died

1.8 million living veterans served during the World War II period

Median age is 87

Percent women 4.4%

Percent with a service-connected disability 13.6%

Note: World War II was the first war to have more battle deaths than deaths f disease, infections, or accidents.

Korean War

The Korean War began in July 1950 and ended in January 1955.

5.7 million people served worldwide during the Korean War and 54,246 died

Fig. 2. Section from the Memorial Day infographic blind-accessible text-document

To examine possible effects of infographics on the memorability of the information, each participant was presented with a stimulus (either in infographic or text form) and instructed to read it. Then they responded to 10 factual questions about the content of the stimulus, first in open-format response (Free Recall condition), then the same 10 questions in multiple-choice format (Multiple Choice condition). This was repeated for each of 3 stimuli.

To examine searchability, each stimulus was then presented again simultaneously with the same 10 questions from the prior two conditions, but the participant was instructed to search the stimuli for the correct answers (Search condition). Finally, each participant was asked debriefing questions related to their satisfaction with different aspects of the stimuli.

2.3 Hypotheses

It was predicted that infographics would be associated with higher accuracy scores for both memorability (as measured by Free-Recall and Multiple-Choice accuracy scores) and searchability (as measured by accuracy scores in the Search condition) as compared with the text documents. Because participants were allowed as much time as they needed to examine the stimuli, it was predicted that the length of time spent examining the stimuli would be associated with higher accuracy scores.

Because Census infographics report statistical data, it was predicted that higher education level would be positively associated with overall accuracy scores. However, because of the presence of visualizations and imagery, it was predicted that infographics would be associated with higher accuracy scores for those with less education than the text documents, and that this effect would not be present for those with higher education level.

2.4 Apparatus

Tobii × 120 Monitor
Internet Explorer 10

3 Results

3.1 Time Spent on Stimuli

Contrary to predictions, time spent on stimuli was not found to be significantly correlated with accuracy scores ($r = .04$, $p = .52$).

3.2 Accuracy

A 2 × 3 × 3 mixed ANOVA was performed to test the main effects and interactions of Condition, Education, Response Condition, and Stimulus on the accuracy scores for the recall question sets.

Mauchly's Test of Sphericity was not significant for the within-subject factor "Stimulus," but was significant for the within-subjects factor "Response Condition" ($X^2(2) = 21.10$, $p < .001$), and for the interaction between Stimulus and Response condition ($X^2(9) = 29.03$, $p = .001$). Therefore, the Greenhouse-Geisser correction was used to interpret significance for F values related to these factors ($\varepsilon = .73$, $\varepsilon = .77$, respectively).

ANOVA results revealed a main effect of Stimulus (topic) ($F(2, 96) = 38.23$, $p < .001$). Furthermore these differences were significant, as indicated by repeated contrasts ($F(1,48) = 37.53$, $p < .001$, $F(1,48) = 9.65$, $p = .003$). Regardless of experimental group, Response Condition or Education, accuracy scores for Child Care stimuli were the highest ($M = 6.25$), followed by Home Improvements ($M = 5.61$), followed by Memorial Day ($M = 4.50$). In general, the Child Care topic appeared to be the easiest to interpret, despite it being the longest infographic/document (about 3 times as long as the other two). Therefore, it was inferred that length of the infographic is not necessarily a negative factor in the composition of an infographic.

There was a main effect for Response Condition ($F(1.47, 70.50) = 215.73$, $p < .001$) as expected. This main effect indicates the overall difference in scores across groups and education level, with Search having the highest average score ($M = 7.24$), followed by Multiple-Choice ($M = 5.37$), followed by Free-Recall ($M = 3.75$). Contrasts show that the differences between these means was significant ($F(1,48) = 200.22$, $p < .001$, $F(1,48) = 82.63$, $p < .001$). Overall, Free-Recall was the most difficult condition, Multiple-Choice (a form of cued recall) was easier, and finding the answers by searching the stimulus was easiest, as expected.

There was also a main effect for the between-subjects factor of Education ($F(2,48) = 10.36$, $p < .001$), with education level of Bachelor's degree being highest ($M = 6.10$), followed by Some College ($M = 5.92$), followed by High school or less ($M = 4.34$). The Bonferroni post hoc test revealed that the difference in average scores was significant between Bachelor's and High school ($p < .001$), and between Some College and High school or less ($p = .001$), but it was not significant between Bachelor's degree and Some College. This overall effect shows the influence of even some college-level education on the interpretation of the stimuli, because the difference exists regardless of which stimulus was being viewed, which response condition was employed, or which type of stimulus (infographic or text document) was being viewed. Although this effect does not imply causality (i.e. college-level education cause these participants to perform better), it may be indicative of the difficulty level of the material being presented.

However, there was no significant interaction, as predicted, between Education and Condition. The information being presented in infographic form did not offer a distinct advantage to those of a lower education level in comparison to text documents. This could be due to the material being difficult enough to understand that imagery could not benefit the less-educated participants, or perhaps the imagery and visualizations that were chosen were not particularly effective.

There was a significant interaction between the between-subjects factor "Condition" (Infographics or Documents groups) and the repeated-measures factor Response Condition (Free-Recall, Multiple-Choice, Search) ($F(2,96) = 4.76$, $p = 0.02$). Contrasts show that the interaction was significant between the Multiple-Choice and Search

response conditions ($F(1,48) = 6.153$, $p = .017$). This interaction shows that Census infographics did not aid in accuracy for either of the memory conditions, but that they did improve accuracy for finding information compared to the text documents, regardless of the stimulus topic or the participant education level. The effect, although significant, represented an advantage of around 10 %, or 1 out of 10.

3.3 Eyetracking and Satisfaction

Eyetracking and item-by-item analysis of the recall questions for each stimulus, together with participant commentary during debriefing led to the identification of dimensions of each infographic that were both facilitative for finding information and detrimental to this task. Major areas of adjustment included size of font, spacing, use of plain language, and use of iconic imagery. Infographics with adequate spacing, font size, simple language, and iconic imagery were favored by participants and facilitated higher accuracy in recall and search task items, and those lacking in these dimensions were more difficult for participants to interpret. These results are not reported here.

4 Limitations

This study was partially exploratory in nature, and thus is subject to several limitations, including limitations in design and scope.

4.1 Scope

Perhaps the most obvious limitation of this study is that although we would like to address the potential benefits of infographics per se, we restricted our investigation to infographics published by the Census Bureau. Such infographics must necessarily conform to particular guidelines and are not representative of infographics in general, such as others that may be produced by other sources or concerning non-statistical topics.

4.2 Design

Participants in this study were asked the same set of 10 "factual" questions three separate times, and participants saw each stimulus twice. The second viewing of the stimulus, along with prior knowledge of the questions that would be asked could have influenced the accuracy scores for the "Search" condition. However it should be noted that despite having the stimuli present simultaneously with the recall questions in the "Search" condition (like an open-book test), few participants were able to achieve a full 10/10 score (8 for Memorial Day, 6 for Home Improvements, 12 for Child Care, out of 55 participants).

Another design limitation arose from usability. We intended to address regarding how long participants would spend on the infographics if given no specific direction.

Because we chose to allow participants to spend as much time as they needed to view the infographics and documents, this aspect of the study was not specifically controlled (i.e. we did not enforce a time limit). However, because education level may affect the amount of time needed to read the stimuli, and because we wanted to see possible differences in the behavior and performance of participants of different education levels, time was not enforced. In the end, the length of time spent reading the stimuli was not related to any of the measured factors, including education level, and is likely attributable to individual differences.

Text documents and infographics were not compared within subjects, so it cannot be assessed whether an infographic would be more effective than a text document at an individual level. Learning styles, reading ability, and spatial ability could all play a role in the interpretation of infographics and text documents.

Finally, the choice to use the blind-accessible documents as a control condition for the infographics was not truly representative of the differences that may be encountered when a person tries to extract statistics from Census data tables and compare them. A more true-to-experience control condition might have been to present participants with the data tables and require them to compare the data on their own. Providing the data in the form of blind-accessible text documents allowed us to examine the effect of the presence of imagery/visualizations, but this may have given the text condition an advantage over real-life data consumption processes.

5 Discussion

The present study did not provide overwhelming evidence that infographics in and of themselves increase memory for statistical information, but the results may suggest that they make information easier to locate when compared to finding the same information in text documents. This may be due to the imagery being used as a form of landmark or cue. While the results on accuracy scores may not be compelling on their own, other usability data was gathered which led to recommendations to the teams responsible for producing infographics. Thus, the present study combined of experimental and qualitative data to provide recommendations for the design of future Census infographics. We list only a few instances of these recommendations.

Some imagery which is very abstract was found to be difficult to interpret and actually become distracting and confusing to participants. The Memorial Day infographic was related to less accuracy for the infographics group than for the text-documents group, which was opposite of the data trend for the other two infographics. The Memorial Day infographic used abstract imagery (i.e. differently-sized boxes representing proportions of soldiers who served versus soldiers who died in each war (Fig. 3)) whereas the Child Care and Home Improvements infographics used iconic imagery and traditional graphs (e.g. a drawing of a house containing the data for each room (Fig. 4); bar graphs (Fig. 5), respectively). This accuracy data was supported by participants' verbal feedback that the "boxes" from the Memorial Day infographic were not understandable (only 3 of the 28 participants in the infographics group could identify the meaning of the boxes), so a recommendation to use more iconic imagery to represent data in future infographics was made.

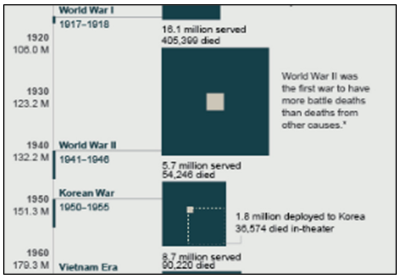

Fig. 3. Abstract "Boxes" from Memorial Day infographic

Fig. 4. Iconic "House Drawing" from Home Improvements infographic

Fig. 5. Traditional bar graphs in Home Improvement infographic

Wording was found through debriefing questions to be an aspect of the infographics that could have been hindering performance and influencing the effectiveness of the imagery. Jargon words and complex sentence structure made some graphs difficult for participants to interpret. Despite the participants saying that they liked the imagery and layout of the data in the infographics, they pointed out areas in which the wording hindered their understanding of the graphs. Two small graphs had titles with wording that confused participants.

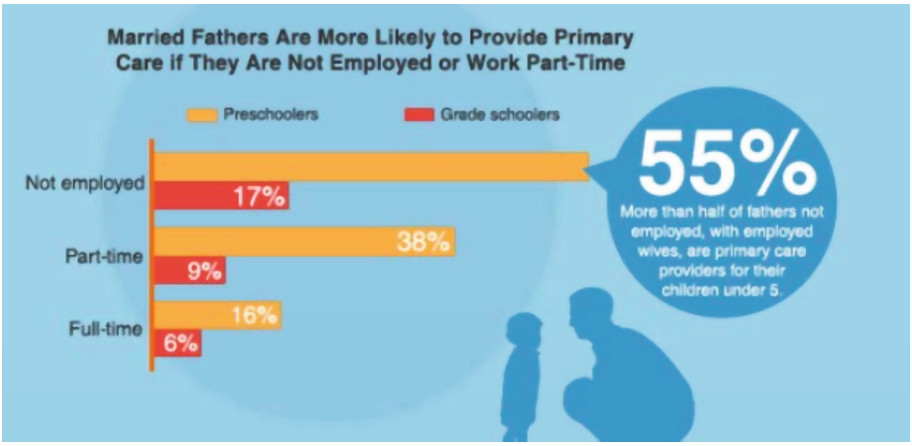

Fig. 6. Fathers section of the Child Care infographic, with difficult wording

For example, the title of one graph in the Child Care infographic and the text in the blue bubble next to the graph were confusing to participants due to the language/structure (Fig. 6). Participants had trouble interpreting these statements and answering the recall questionnaire question even when they had the infographic in front of them (and could therefore look directly at the data). The wording, however, made the data difficult to interpret for some participants. The repeated use of "employed" and "not employed" as modifiers for the parents within the same sentence made the sentences difficult to read. In the case of infographics, clarity in wording may be just as important as the imagery chosen to represent the data.

Interestingly, although Census infographics were created with the intention to convey statistical data to an audience with no statistical background, and to a broad range of education levels, results showed that those with a high school education or less responded much less accurately than those with any amount of college education. Furthermore, the infographics did not improve performance for the less educated participants to a greater extent than the college-educated participants (as compared to the text documents). To be consumable by a wider audience than just the college-educated, infographics may benefit from user testing research and reorganization. Accompanying the data with imagery may improve their appeal, but information clarity via reduction of jargon and simplification of wording may improve the understandability of the data.

Possible future studies could include investigations of infographics from sources and topics external to the Census Bureau, comparison of performance of infographics versus text-documents within subjects to explore individuals factors, comparison of infographics to text accompanied by varying levels of iconic imagery and traditional graphs, to address some of the topics that were not investigated in the present study.

References

1. Thorpe, S., Fize, D., Marlot, C.: Speed of processing in the human visual system. Nature **381** (6582), 520–522 (1996)
2. Holcomb, P., Grainger, J.: On the time course of visual word recognition: an event-related potential investigation using masked repetition priming. J. Cogn. Neurosci. **18**(10), 1631–1643 (2006)
3. Nielsen, J.: How Little Do Users Read? (2008) http://www.nngroup.com/articles/how-little-do-users-read/
4. Dowse, R., Ehlers, M.: Medicine labels incorporating pictograms: do they influence understanding and adherence? Patient Educ. Couns. **58**(1), 63–70 (2005)