

Guiding Novice Web Workers in Making Image Descriptions Using Templates

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This paper compares two methods of employing novice web workers to author descriptions of STEM images to make them accessible to individuals with visual and print-reading disabilities. The goal is to identify methods of creating image descriptions that are inexpensive, effective, and follow established accessibility guidelines. The first method explicitly presented the guidelines to the worker, and then the worker constructed the image description in an empty text box and table. The second method queried the worker for image information and then used responses to construct a template-based description according to NCAM guidelines. The descriptions generated through queried image description were more likely to include information on the image category, title, caption, and units. They were also more similar to one another, based on Jaccard distances of q-grams, indicating that their word usage and structure were more standardized. Lastly, the workers preferred describing images using queried image description and found the task easier. Therefore, explicit instruction on image-description guidelines is not sufficient to produce quality image descriptions. Instead, it is better to use novice web workers to provide information about images, and then generate descriptions from responses using templates.

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1. INTRODUCTION

There is a growing trend of integrating human workers into accessibility tools [Sato et al. 2010; Takagi et al. 2013]. This approach, referred to as human-powered access technology [Bigham et al. 2011], uses humans, alone or together with computer sys-

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tems, to create accessible materials. An example of such a system is VisWiz, a smart-phone application that enables blind and low-vision users to submit photos from their phone, and receive a near real-time textual description of the photo from a sighted web worker [Bigham et al. 2010a; Bigham et al. 2010b]. Another example is the Tactile Graphics Assistant (TGA), which transcribes some parts of a visual image into a tactile graphic using machine vision algorithms, which is then evaluated and revised by a tactile graphics expert [Jayant et al. 2007; Ladner et al. 2005]. In general, these technologies facilitate the production of accessible materials by non-expert workers, who are more available and lower-cost than accessibility specialists [Lasecki et al. 2012]. This paper examines how to best use non-expert workers, in particular web workers, to improve the accessibility of images for individuals with visual disabilities (i.e., those who are blind or have low vision).

Making images accessible to individuals with visual impairments requires the construction of either a tactile graphic or textual image description. Ideally, both of these options are made available to people with visual impairments to satisfy differing needs and preferences. The current report focuses on the creation of textual image descriptions (alt-texts), which can be accessed using a text-to-speech program or braille display. Image descriptions often contain both prose text descriptions and tabular data. These text-based descriptions are also of benefit to students with other print-reading disabilities (e.g., dyslexia) who may use auditory methods for reading textbooks.

Human workers provide a means to generate image descriptions, while machine-vision approaches remain an unsolved, and ongoing area of advanced research [Tagagi et al. 2013]. Until computer algorithms can offer a complete solution, untrained workers can provide descriptions for images such as those in textbooks and on the internet [Dardailler 1997]. Using non-expert web workers for image description will significantly expand the available work force and reduce costs [Bigham et al. 2011]. However, it is unclear how these workers should be prompted to describe images to ensure that these descriptions are of high quality and follow established guidelines.

This research focuses on images that appear in the context of science, technology, engineering, and mathematics (STEM), such as charts and graphs. Image accessibility in STEM is particularly important, because STEM topics often rely heavily on images to convey information that is not presented in accompanying text [Jayant et al. 2007; Ladner et al. 2005]. Guidelines for describing STEM images, with specific examples, are provided by the National Center for Accessible Media (NCAM) on their website [Gould et al. 2008].

Non-expert image describers are unlikely to be familiar with the NCAM description guidelines. In the past, most image descriptions have been provided by braille transcribers and teachers of the visually impaired who have had an opportunity to intensively study the NCAM image-description guidelines. However, extensive training of web workers is inapt because of their inherent transience [Bigham et al. 2011], making real-time guidance more appropriate.

This research compares two methods of providing non-expert workers guidance in creating image descriptions: Free-Response Image Description (FRID) and Queried Image Description (QID). In Free-Response Image Description (FRID) the worker is provided with the image to be described along with the relevant NCAM image-description guidelines. An open-ended text box and empty table are provided for the worker to enter descriptive prose and data respectively. This method is similar to that used by the open-source image-description tool POET [Benetech 2012]. In contrast, Queried Image Description (QID) presents the image without the NCAM guidelines. Instead, QID asks a series of questions specific to the image category, often with conditional sets of questions that may or may not be asked depending on responses to

earlier questions. Responses are then used to generate a text and table description that conforms to NCAM guidelines.

The conditional questions used in QID allow the system to adjust to different image content. For example, if the worker indicates that the image has a title, he/she is then asked to enter the text of the title. If the worker indicates that there is no title, then the question asking for the text of the title does not appear. Similarly, if the worker indicates that there are 5 wedges in a pie chart, he/she is then asked 5 sets of questions, one for each wedge.

QID generates image descriptions by slotting worker answers into a template: a set of pre-designed sentences and table with appropriate “blanks” to be filled by worker answers. Additionally, worker answers determine whether certain sentences are included or omitted from the template’s text description, and determine the number of rows and columns in the table description.

By removing the onus of reading and understanding the NCAM guidelines, we hope that fewer description mistakes will be made in QID compared to FRID. Specifically, the worker does not need to consider what image details to describe and what to omit, whether to put information in text or a table, and what order and with what language to present information. Thereby, resulting QID image descriptions may be more complete, use text and tables correctly, and use standardized language and content ordering. The description task may also be faster and/or easier with QID, which could increase the willingness of web workers to describe images [Takagi et al. 2013]. Templates have been used to generate image descriptions for a limited number of image categories before, e.g., simple bar charts by [Demir et al. 2010] and line graphs and bar charts by [Ferres et al. 2013]. However, the quality of template-based descriptions has not been compared to that from other image description methods.

STEM images fall into a number of image categories, such as bar charts, line graphs, and pie charts [Jayant et al. 2007], which require the development of distinct questions and templates. One contribution of the current research is the development of questions and templates for six image categories, which can be used as is, or can be used to inform the development of questions and templates for additional image categories. The second, more significant contribution is a user study that demonstrates that our QID task results in better image descriptions than a comparable FRID task.

2. METHODS

2.1. Images & Templates

Six images, each from a different image category, were selected from the NCAM website on “Guidelines for Describing STEM Images” [Gould et al. 2008]. These included the examples of horizontal and vertical bar charts, line graph, venn diagram, scatter plot, and pie chart. For these images, we created questions and templates based on the NCAM guidelines. The templates included both text and table descriptions. All images and templates are shown in the Appendix.

2.2. Participants

Twenty-two participants (web workers) completed the study remotely using their personal computers. Their average age was 34.81 years ($SD = 13.06$ years) and six were male. The participants were recruited through email lists for individuals willing to participate in any research or only image-description research. The study procedures were approved and provided exempt status from obtaining informed consent by the Smith-Kettlewell Eye Research Institute’s Institutional Review Board.

The study began with the participants answering questions about their characteristics. The majority of participants (59%) reported having no experience describing

images (for someone with a visual impairment) before this study. The other participants reported having described images in a casual context (14%), at a non-expert level for books (18%), or at an expert-level for books (9%). Most participants were non-teachers (45%), and a smaller number had taught informally as a volunteer or in the community (14%), as a classroom teacher (27%), as a special-education or paraprofessional teacher (9%), or as a teacher of students with visual impairments (5%). The participants mostly had background in STEM as non-educators (36%) or had no background in STEM (32%). The rest of the participants were interested and knowledgeable about STEM with no formal background (23%), or taught STEM in a K-12 (5%) or post-secondary (9%) setting. Lastly, twenty of the twenty-two participants were native English speakers (90%), and the other two were living and working in the United States, and reported being competent (5%) or fluent (5%) in English.

2.3. Procedure

Participants provided responses online through a free open-source survey tool called LimeSurvey [LimeSurvey Project Team / Carsten Schmitz 2012], which provides conditional scripting support. An email was sent to each participant with a list of tasks for them to complete. The email instructed the participants that, while it was okay to take breaks between the tasks, once a task had been started the participant should not take a break until that task had been completed and closed, allowing an accurate estimate of task completion time.

The first task each participant completed was a survey on the participant's demographic information (results described above). The last task was an exit survey. The intervening tasks, two through seven, were the image-description tasks. Participants were informed that they were to create descriptions to make images accessible to an individual who is blind.

Each participant described all six images in random order. Of the six images, three were randomly selected to be described using FRID, and three using QID. Across all participants, each image was described an equal number of times with FRID and QID.

2.3.1. Free-Response Image Description (FRID). During free-response image description, the participant was presented with the image to be described and the NCAM guidelines for describing that category of image. The participant was given an empty text box and an empty table to create their description. The empty table was sized 7 columns by 17 rows, to accommodate the specific images used in this study. Future implementations could allow the web worker to add/remove columns and rows to construct a custom-sized table.

2.3.2. Queried Image Description (QID). Queried image description presented the image, and then asked a series of questions about the image. A text description and table were then auto-generated from participant answers to create descriptions according to the NCAM guidelines. This was accomplished using the templates shown in the Appendix. The participant was given an opportunity to review and edit the template-generated text and table as the last part of the task.

2.3.3. Exit Survey. After completing all image descriptions, the participants were asked whether they preferred FRID, QID, or had no preference. They were also asked to rate the difficulty of describing images using FRID and QID methods on a 1-4 scale, 1 being easy and 4 being difficult.

2.4. Analysis

2.4.1. Descriptions. Participants' descriptions were exported into a spreadsheet program from LimeSurvey. These were output into a text file, one for each description,

that contained the participant's description text and table. Each description (text and table) was then evaluated with several metrics. Average metrics for FRID and QID descriptions were compared using paired t-tests, a pair for each image. All statistical analyses were done in R [R Core Team 2013].

Evaluation metrics included the amount of overall time it took to complete an image description, as well as separate metrics for the descriptions' text and table parts. Text descriptions were evaluated for having been included or omitted; word count; inclusion of the image category, title, caption, units, and data trend, when applicable; similarity to other text descriptions (explained in the next section); presence of syntactic errors (spelling, punctuation, or capitalization); and presence of content errors (unit, number, or label). Table descriptions were evaluated for completeness (non-completed tables resulted from QID when the participant did not answer all of the question prompts), as well as for the presence of syntactic and content errors.

2.4.2. Text Description Similarity. To evaluate the consistency of text descriptions we selected q-grams [Ukkonen 1992] for comparing the similarity of two text passages from a number of available options, see [Boytsov 2011] for review. We compared every pair of text descriptions generated for an image using a particular method, e.g., every possible pairing of the 11 FRID text descriptions for the bar chart. These were averaged to create an average similarity for each image's FRID and QID descriptions, which were compared using a paired t-test, a pair for each image.

Using q-grams, each description was stripped of white space and decomposed into overlapping sections of q sequential characters or words (grams). In comparing two descriptions, the grams from the first description were compared to those of a second using the Jaccard similarity distance [Chaudhuri et al. 2003]. The Jaccard similarity distance was equal to one minus the ratio of shared q-grams to the total q-grams across both descriptions (one minus the Jaccard coefficient). The closer the Jaccard distance was to zero, the more similar the descriptions, and the closer to one, the less similar. We computed the Jaccard distance for several values of q, 1-6, using q sequential characters and, separately, q sequential words. We present results where the text was cleaned, stripped of punctuation and capitalization, and the symbols were removed or changed to words (= to equal, & to and, and % to percent). However, comparing cleaned versus original descriptions did not appreciably change the results or significance levels.

2.4.3. Exit Survey. Difficulty ratings, which were on a 1-4 scale, were compared using a paired Mann-Whitney U test, due to the fact that rankings were ordinal (ordered, 1 through 4), but unlikely to be interval (have equal spacing between 1 and 2, 2 and 3, and 3 and 4).

Preference ratings, which indicated whether participants preferred FRID, QID, or had no preference, were evaluated by a Thurstonian model. This model estimated the underlying distributions of preference for QID and FRID methods and then tested whether the difference in means scaled by standard deviation, d' , was significantly different from zero [Bojesen Christensen et al. 2012]. A significant difference would indicate that FRID or QID was preferred over the other. This analysis was done in R using the sensR package [Bojesen Christensen et al. 2012].

3. RESULTS

The mean results for QID and FRID descriptions (standard errors in parentheses) and associated statistical tests are shown in table I.

Table I. Results

Metric	Description Method		Test Statistic	p-Value
	Free-Response (FRID)	Queried (QID)		
Text & Table				
Time to Describe (sec)	738.26 (155.21)	613.19 (111.05)	t(5) = 1.20	0.282
Any Text Description (%)	96.97 (3.03)	100.00 (0.00)	t(5) = -1.00	0.363
Completed Table (%)	60.00 (10.98)	89.09 (3.40)	t(4) = -2.14	0.099
Text Description				
Word Count (count)	63.09 (9.28)	82.17 (20.23)	t(5) = -1.19	0.289
Syntactic Error (%)	37.04 (7.49)	48.48 (13.42)	t(5) = -0.78	0.469
Content Error (%)	11.28 (4.62)	12.12 (5.59)	t(5) = -0.22	0.835
Data/Trend Summary (%)	61.28 (11.42)	75.76 (16.87)	t(5) = -1.05	0.343
Image Type (%)	72.05 (6.49)	100.00 (0.00)	t(5) = -4.31	0.008**
Title (%)	34.55 (15.05)	83.64 (16.36)	t(4) = -2.90	0.044*
Caption (%)	18.18 (5.25)	93.94 (3.03)	t(2) = -9.45	0.011*
Units (%)	36.20 (6.59)	100.00 (0.00)	t(5) = -9.67	<0.001***
Text Description Similarity				
<i>Jaccard Distance (q = number of characters)</i>				
q = 1	0.17 (0.03)	0.06 (0.02)	t(5) = 2.47	0.056
q = 2	0.50 (0.04)	0.20 (0.06)	t(5) = 3.60	0.016*
q = 3	0.70 (0.03)	0.33 (0.09)	t(5) = 3.75	0.013*
q = 4	0.79 (0.02)	0.39 (0.10)	t(5) = 3.87	0.012*
q = 5	0.83 (0.02)	0.42 (0.11)	t(5) = 3.89	0.012*
q = 6	0.86 (0.02)	0.44 (0.11)	t(5) = 3.87	0.012*
<i>Jaccard Distance (q = number of words)</i>				
q = 1	0.73 (0.03)	0.35 (0.09)	t(5) = 4.04	0.010*
q = 2	0.91 (0.01)	0.48 (0.11)	t(5) = 3.88	0.012*
q = 3	0.96 (0.01)	0.53 (0.12)	t(5) = 3.56	0.016*
q = 4	0.98 (0.01)	0.57 (0.12)	t(5) = 3.36	0.020*
q = 5	0.99 (0.00)	0.60 (0.12)	t(5) = 3.10	0.027*
q = 6	0.99 (0.00)	0.63 (0.12)	t(5) = 2.87	0.035*
Table Description				
Syntactic Error (%)	12.66 (3.58)	8.44 (3.81)	t(4) = 1.64	0.177
Content Error (%)	14.52 (6.65)	10.22 (5.48)	t(4) = 0.64	0.554
Participant Feedback				
Difficulty (1-4)	2.95 (0.18)	1.95 (0.14)	U = 174	0.001**
Preference (count)	3 (3 no pref)	16	d' = 1.20 (0.40)	0.002**

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4. DISCUSSION

This research compared the quality of image descriptions created through a free-response method (FRID) to those created using a querying approach (QID). FRID provided the web worker with relevant description guidelines and prompted for an image description in an empty text box and table. QID created image descriptions by querying the worker about image properties, and then constructing a description from the worker's answers using a template, without explicitly informing the worker about description guidelines. Our results indicate that the QID image descriptions were at least equal to, and in many ways superior to, FRID image descriptions.

FRID and QID descriptions took equally long to create, each taking, on average, 10-12 minutes per image. Some descriptions contained only text or only a table, and others had tables that were incomplete, but this was not more or less common in FRID or QID descriptions. The number of words in the text descriptions, when present, were

also similar for FRID and QID descriptions. Lastly, descriptions created with FRID and QID were equally likely to include syntactic and/or content errors in both text descriptions and tables.

Descriptions created with FRID and QID did differ in the content they contained. Descriptions created with FRID were more likely to omit the image category, title, caption, and units. These are serious omissions, especially considering that these details are those immediately asked about by visually impaired users exploring a STEM image [Ferres et al. 2013]. Given that descriptions created with FRID were likely to omit information, it's surprising that the lengths of text descriptions created with FRID and QID were similar. This may be explained by the similar inclusion of data/trends in FRID and QID text descriptions, which may have compensated, in word count, for omitted information. However, an image description that contains information on data/trends, without indicating the image category, title, caption, or units, as was more often the case with FRID descriptions, has questionable utility.

The QID descriptions were also more similar to one another than were FRID descriptions. Description similarity was assessed using the Jaccard distance for different size q -grams of characters and words. Words and word fragments (clusters of adjacent characters, lengths 2 through 6) and sentences and sentence fragments (clusters of adjacent words, lengths 1 through 6) were more frequently shared between pairs of QID descriptions than FRID descriptions. For example, an average of 37% of 6-word segments were shared between pairs of QID descriptions. In contrast, only 1% of 6-word segments were shared between pairs of FRID descriptions. Therefore, image descriptions created using QID were more standardized in word use and content ordering. Previous research has shown that it is easier to understand and use image descriptions that have consistent language and present information in a systematic and predictable format [Ferres et al. 2013].

Finally, web workers preferred describing images using the QID method, and found the task easier than when describing with the FRID method. These are important factors that may encourage productivity by web workers producing image descriptions [Takagi et al. 2013].

Beyond issues of description quality, the QID method provides several additional benefits in a web-worker scenario. One benefit is that it makes accuracy checking by comparing responses from redundant web workers easier. Comparing one- or few-word answers about image properties is easier than comparing multi-sentence descriptions and a table. Previous work has shown that such redundancy is a viable approach to ensure accuracy from web workers [Von Ahn and Dabbish 2004], and this is a less costly method than using vetted or expert workers to check accuracy [Bigham et al. 2011].

Image-description data, for book and/or website images, can be indexed and stored on a remote server, as proposed by [Dardailler 1997]. This enables many people to access the image descriptions and reuse the work of image describers [Takagi et al. 2013]. The QID method enables image information to be stored, not as a finished description, but in labeled parts. Thereby, users could tailor the description to their needs through the design of custom templates. For example, a user may prefer a template that provides a brief overview of the image, color information to be omitted, or a table of data only. Given that blind and sighted individuals may navigate the information in image descriptions differently [Ferres et al. 2013], preferences in image description styles may depend on extent of vision loss and time since onset. Alternatively, image data could be used to render tactile graphics or audio/tactile graphics where appropriate.

Putting aside alternative uses of our system, there are several ways in which the current image descriptions could be improved. Text processing could be applied to remove spelling and grammatical errors, or at least make these errors more apparent to

the worker. Also, visual information may be added to some of our templates. For example, information was not collected on the colors or visual patterns of the bars in bar charts. This may be important information, e.g., for a student when the teacher asks “what trends do you see in the red bars?”

It is important to note that our present research only offers metrics related to the production of image descriptions with FRID and QID. This work does not investigate any metrics related to the differential usability of descriptions created with FRID and QID. We did not have users with visual impairments assess the usefulness or usability of image descriptions. Future research is needed to understand what properties of image descriptions promote comprehension and usability by individuals with visual impairments in different contexts, and whether these properties are more easily obtained using FRID or QID methods.

In conclusion, the current work demonstrates that the QID method produced better image descriptions from novice web workers than the FRID method. Image descriptions created with QID had less omitted information, were more similar to one another, and were preferred by and easier to create for describers. Therefore, our research suggests that web workers tasked with producing image descriptions, and possibly other accessible materials, cannot be expected to successfully follow accessibility guidelines, even with explicit instruction. Instead, it is better to use web workers to extract image, or other inaccessible, information, and then use this information to construct accessible materials according to established guidelines.

APPENDIX

Horizontal Bar Chart

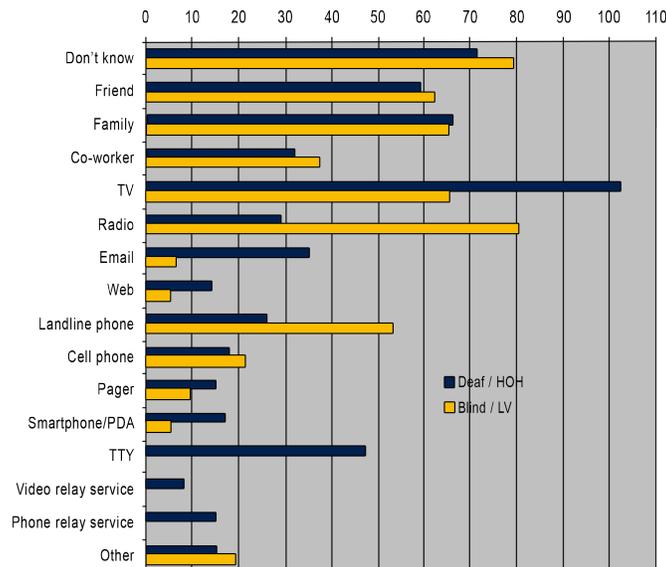


Fig. 1. Horizontal bar chart image.

Horizontal Bar Chart Text Description Template.

This is a horizontal bar chart, titled title, measuring x-axis units
 for number y-axis label bars / clusters of bars.
 A caption reads: “ caption .” The data range from x-axis min to
x-axis max in increments of x-axis increments x-axis units.
 Description if data trends.

Horizontal Bar Chart Table Description Template

	number of columns equal to number of sub-bars per cluster	
	<i>Sub-Bar 1 Label</i>	<i>Sub-Bar 2 Label</i>
<i>Bar / Cluster 1 Label</i>	<i>x-value</i>	<i>x-value</i>
⋮	⋮	⋮
<i>Bar / Cluster 16 Label</i>	<i>x-value</i>	<i>x-value</i>

number of rows
equal to number of
bars or bar clusters

Line Graph

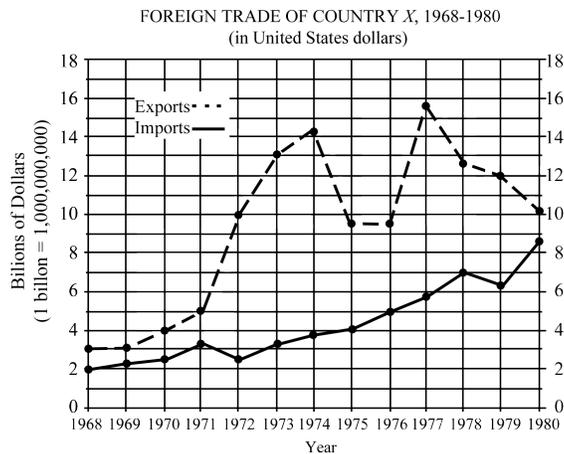


Fig. 2. Line graph chart image.

Pie Chart Text Description Template

This is a pie chart, titled title. A caption reads: “caption.” The chart has number wedges, labeled in units and percentages. The data are summarized in the following table.

if titled
if captioned

if units
if both
if percentages

Pie Chart Table Description Template. A table is only presented if there are 10 or less data points.

	Color / Pattern	<i>units</i>	Percentage
Wedge 1 Label	<i>color / pattern</i>	<i>value</i>	<i>value</i>
⋮	⋮	⋮	⋮
Wedge 5 Label	<i>color / pattern</i>	<i>value</i>	<i>value</i>

if labeled in units
if labeled in percentages

number of rows equal to number of wedges

Scatter Plot

The graph below shows the relationship between annual rainfall and plant tissue growth rates in an ecosystem.

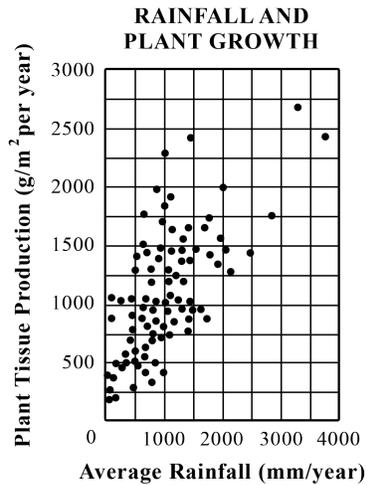
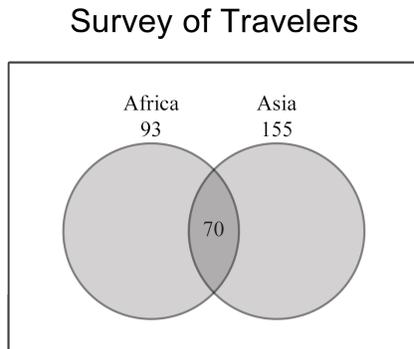


Fig. 4. Scatter plot image.

Venn Diagram



In a survey of 250 European travelers, 93 have traveled to Africa, 155 have traveled to Asia, and 70 have traveled to both of these continents, as illustrated in the *Venn diagram* above.

Fig. 5. Venn diagram image.

Venn Diagram Text Description Template.

This is a Venn diagram, titled title, showing number circles.

if titled

A caption reads: “ caption .” The circles are labeled circle 1 label, value

if captioned

equals value units, circle number, values equals value units

repeat to number of circles

. There is number area / areas of intersection that equal / equals

number units, between circles list .

repeat to number of intersections

Venn Diagram Table Description Template.

	Value (<i>units</i>)
<i>Circle 1 Label</i>	<i>value</i>
<i>Circle 2 Label</i>	<i>value</i>
<i>Intersection 1 Label</i>	<i>value</i>

number of rows equal to number of circles and intersections {

Vertical Bar Chart

FIGURE 1. First dose rotavirus vaccination coverage among children aged 3 months, * by quarter --- immunization information system (IIS) sentinel sites, United States, 2006--2007[†]

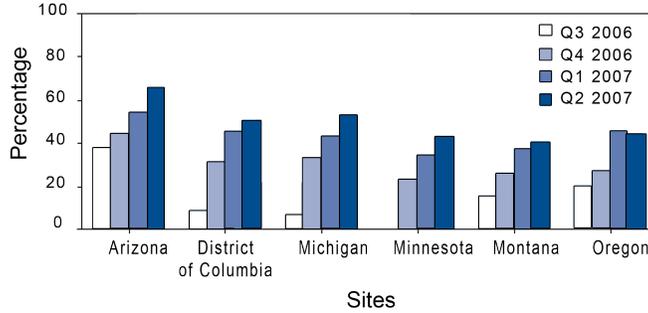


Fig. 6. Vertical bar chart image.

Vertical Bar Chart Text Description Template.

This is a vertical bar chart, titled title, measuring y-axis units for number x-axis label bars / clusters of bars.
if titled if y-axis has units
if x-axis labeled if x-axis not labeled

A caption reads: “caption.” The data range from y-axis min to y-axis max in increments of y-axis increments y-axis units.
if captioned if y-axis has units

Description if data trends.
if trends described

Vertical Bar Chart Table Description Template.

	number of columns equal to number of sub-bars per cluster	
	<i>Sub-Bar 1 Label</i>	<i>Sub-Bar 2 Label</i>
number of rows equal to number of bars or bar clusters {	<i>Bar / Cluster 1 Label</i>	<i>y-value</i>
	⋮	⋮
	<i>Bar / Cluster 4 Label</i>	<i>y-value</i>

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