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Voices from Industry

Creating Accessible Infographics: Describing Scientific Data in Ways Everyone Can Understand

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ABSTRACT

The COVID-19 pandemic has thrust scientific literature into the global spotlight this year, as information about the virus, how to keep safe, and how to get vaccinated has been continually updated at a rapid pace. Much of this information is being conveyed through infographics. This has resulted in an abundance of easy-to-grasp information for sighted people with no learning disabilities, but this positive impact has not been extended to people with visual or learning disabilities. In effect, these infographics often serve to further marginalize individuals with disabilities. Consistent methods for writing descriptions of images should be developed and implemented by first looking at how information moves from working memory to long-term memory, and then examining how cognitive fatigue can inhibit understanding of complex images and scientific information vital to individuals with disabilities. Considering how best to describe scientific images with concise alternative text and in plain language will have clear and immediate benefits for the health and well-being of those with print-related disabilities.

Keywords: infographics, image descriptions, alt text, alternative text, BLV (blind and low vision), dyslexia, ADHD, learning disabilities, cognitive disabilities, cognitive load, image processing, learning from images, scientific diagrams, public health, coronavirus pandemic, COVID-19

CREATING ACCESSIBLE INFOGRAPHICS: DESCRIBING SCIENTIFIC DATA IN WAYS EVERYONE CAN UNDERSTAND

As the COVID-19 pandemic has taken hold in a world dominated by image-focused information sharing, many organizations have released infographics in an attempt to help the public understand the risks and impacts of the virus. This has resulted in an abundance of easy to grasp information for sighted people with no learning disabilities. However, this positive impact has not been extended to people with visual or learning disabilities. These infographics exclude people who cannot see or navigate the infographic, as well as people who need screen-reading capabilities or plain language to understand printed text. Because an infographic with an accessible description can be a source of helpful information for all who come across it, people and organizations wanting to disseminate important information should use infographics along with image descriptions that are designed to be accessible to the greatest number of people. This article will explain how we developed an evidence-based approach to writing image descriptions that are accessible, using studies from the fields of cognitive science and instructional design as well as feedback from screen reader users.

PERSONAL STATEMENTS

K. James Monroe

In my work writing educational alternative text for images in textbooks, I would often get overwhelmed while implementing our quality-control step, because our habit for a long time was to describe every single element of an image in exhaustive detail. We strove to never leave anything out, so that sighted students did not get more information than students who were blind or had low vision; this seemed like the most equitable and appropriate solution. However, if reading it over in the editing process was overwhelming for a sighted person, how much more exhausting would it be for someone without the visual context?

I began to search for studies that gathered feedback from blind and low-vision people about what sort of image descriptions were helpful, but there were almost none out there—only one in 2008 (Gould et al.), and another in 2020 (Stangl et al.). These two studies provided important information, but both were based on a fairly small sample size and yielded only qualitative data. A further limitation is that they were about highly specific sorts of images—the former discussed science, technology, engineering, and math images, while the latter discussed web browsing images, focusing on e-commerce and social media.

Because of this research gap, I decided to approach the problem from a new angle: How do people learn from images? I began with studies that explored the educational value of images, which led to related studies on cognitive load, the concept and study of how much information can actually be absorbed.

Ultimately, if you can understand how learning from images works, and you understand how learning in general works, you can create a description that more accurately duplicates the learning impact of viewing an image. And contrary to what may be assumed, this does not mean including every detail of an image, or necessarily explaining the visual aspects of the image.

Valerie Morrison

In making content accessible for individuals with disabilities, describing images often becomes the most time-consuming part of the process, and it yields the most disagreements about what to include. Managing a team of passionate writers and disability advocates, I've often found myself diplomatically negotiating a conflict about how to approach a particular project, and often it is the STEM projects with complex math equations and scientific diagrams that pose the most challenging questions. Although many companies and programs promise automated image description in the near future, the technology is not there yet, and a human must be part of the equation to translate the visual imagery into words for full understanding. And so we will continue to engage in these vigorous debates, in an effort to arrive at the most accessible solution when it comes to alternative text description.

Working in E-Text, we often encounter the pressures of transforming material quickly into digital formats for students taking courses. We want to be confident that their course materials are accurate and complete so that they can pass their classes and excel on their tests. But over this past year, these pressures have seemed trivial compared to the immense need for precision and speed in remediating material in collaboration with the Centers for Disease Control to educate people about public health and vaccine information during the COVID-19 pandemic. We have learned a great deal from our collaboration, and reexamined our own process of image description, striving for that perfect and elusive balance between comprehensive and effective.

TARGET AUDIENCE AND RELEVANCE

This paper should be of interest to educators of any grade level, accessibility specialists who describe images for educational purposes, media managers for organizations that distribute public health information, and anyone who wishes to share information in an accessible way. We will explain how to write image descriptions in such a way that they provide important information without being too cognitively overwhelming to be useful.

It is a legal requirement to provide alternative text as part of making documents fully accessible, yet there are no legal guidelines describing how to do so. Section 508 of the Rehabilitation Act (1998) does not directly mention image descriptions or even document accessibility; it simply requires "an alternative means of access that allows the individual to use the information and data" to be provided for people with disabilities. Lawsuits on inaccessibility are judged on whether one particular individual was discriminated against by inaccessible services or documents. Thus, rather than following the letter of the law, attention to the spirit of the law is required: We must make sure everyone has access.

Learning from Images

To answer the question "how do people learn from images?" we can turn to studies on instructional design and cognition. In these fields, it is generally accepted that the use of images can create improved learning outcomes (Anglin & Vaez, 2004). The positive impact of including images in an educational text is well-established enough to have been named: the Multimedia Principle (Fletcher & Tobias, 2005). However, these improved learning outcomes are only for specific scenarios; there are elements that must be present, and elements that should not be present, in order for images to be helpful to understanding.

Connection with Cognitive Load

The reason that images are only sometimes helpful is that they have the ability to increase or decrease cognitive load (Anglin & Vaez, 2004; Butcher, 2006; De Koning et al., 2009; Eitel et al., 2013; Folker et al., 2005; Mautone & Mayer, 2001). Cognitive load is the level of thinking effort needed for learning. It is made up of three pieces: the complexity and difficulty inherent to the knowledge (intrinsic load), how many distractors there are (extraneous load), and how much effort it takes for the particular person to process and integrate the information (working memory load). Images can either function as distractors, creating extraneous load, or as an additional mental pathway, decreasing the load on working memory (Carney & Levin, 2002).

Working memory is the amount of short-term memory available to process information. Greer et al. summarized cognitive research on working memory (2013) as allowing for approximately 7 elements at any one time, but only 2 to 4 elements when combining or processing concepts together. The amount of working memory a person has can also be decreased by some learning and cognitive disabilities such as ADHD and reading disabilities (Ghelani et al., 2004).

The Impact of Cognitive Load on Image Processing

For a sighted person without a print-related disability, the combination of words and images allows for the simultaneous use of verbal and visuospatial mental pathways (Artino, 2008), which puts less overall strain on working memory. This works best when the person is able to view the image and then read the verbal information (Eitel et al., 2013). This means that a non-disabled person has to put forth less effort to understand when images are included than when they are not.

However, for a blind or low-vision (BLV) person, it is the opposite: they have to put forth more effort. When a person has to mentally construct the image from a description, or has to parse the image piece by piece and then mentally reassemble it, there is an entire additional mental process that creates increased cognitive load. Since cognitive load of learning from images is inherently greater for BLV learners, we have to reduce strain on working memory as much as possible if we aim to provide equivalent access to information.

People with dyslexia also experience greater cognitive load when processing images than non-disabled people do. An eye-tracking study by Holmqvist Olander et al. showed that people with dyslexia do not spend as much time looking at images, do not look at as many parts of the image, slow down reading text when an image is present, and have decreased scores when images are presented along with text

(2017). This suggests that people with dyslexia experience greater strain on their working memory when images are present, and have more difficulty processing images. However, when measured as images separate from text, children with dyslexia may actually process images more effectively than children who do not have dyslexia (Fan et al., 2014; Hedenius et al., 2013). This may mean that when images are not competing with text, they may be a more efficient way for people with dyslexia to learn. Listening to image descriptions along with text may allow them to have access to the information in a way that is more effective for them to absorb.

Reducing Strain on Working Memory

In order to reduce strain on working memory, we must increase the qualities that ease strain, and decrease the qualities that cause strain. The qualities that ease mental strain are as follows: important information is emphasized, with trends and implications described; content is succinct, with a small number of concepts at a time; and content is well organized. Qualities that cause mental strain include: unnecessary naming tasks, redundancy, describing unimportant aspects, or adding context from outside the image.

Important Information Emphasized, Including Trends and Implications

It is important to cue the listener to important elements because otherwise, “searching for related elements and trying to relate them may impose a high cognitive load” (de Koning et al., 2009). These important elements can include relationships between parts or objects, the purpose of the image in context, and any trends or implications that stand out visually. If images include attention-getting elements like highlighted areas or bolded text, those elements are signals of importance (Mautone & Mayer, 2001) and the objects they point out should be described.

Stangl et al. interviewed 28 people who were blind or had low vision (2020) and noted that the first thing they wanted to know about an image was why it was present: What was the purpose? How was it related to text that was provided with the image? They expressed that the same image would need different descriptions depending on the context. For example, the same image might be described as a group of people standing in a field, or a group of people smiling and waving, or a group of people in long white robes, depending on which aspect is relevant. The purpose of the image is an essential piece of information to be emphasized, and the context must be considered to determine the image’s ultimate purpose.

In addition to the purpose or “why” of the image, trends and implications must be described. de Koning et al. (2009) explain that images are often included in educational materials to make implied relationships more concrete, especially cause and effect. If an arrow is included in an image, the implied meaning of that arrow is what should be described rather than the literal shape. In essence, there should be a focus on the meaning of a symbol, and not its appearance. Demir et al. (2012) describe how bar graphs and line graphs are designed with an intended meaning, and this meaning is predictable enough from the visual aspect alone that a computer can reliably replicate it. That meaning is extracted based on what is easiest to notice in the image. Hegarty (2011) points out that information given in a table is not identical to the same information given in a line graph, because a table requires mental computations for each

data point in order to understand the relationship between them. In contrast, a line graph exists to make the relationship between points easy to grasp; this means that in describing a line graph or other chart, it is the relationships or trends that should be described, rather than the point values. In practice, what this means is that it is necessary to analyze the image for its purpose, its meaning, and its implications before beginning to craft an effective description.

Succinct and Simple Content

An image description should be as succinct and as simple as possible. Gould et al. surveyed 54 BLV people about what they wanted in an image description, and the most common theme was brevity (2008); if it could be shorter, it should be. According to Smith et al., one important way to avoid overloading working memory is to present small amounts of information at a time, or a small number of new concepts at a time (2016). Mayer, Moreno, Boire, and Vagge (1999) examined the process of learning from animations, which mimics a non-sighted user's processing of static images in that a viewer has to hold previous scenes in working memory in order to understand the overall animation, as the viewer cannot see all scenes simultaneously. Mayer et al. point out that a larger amount of information in a single animation will reduce the learner's ability to hold all of the pieces in working memory at the same time, and thus the learner will be less able to integrate the information from the entire animation. Similarly, an image description should be as short as possible and leave out whatever is unnecessary so that a listener can absorb the maximum amount of information.

Organized Content

Organization is essential to a good image description, primarily because it helps provide a scaffold to integrate new information into existing knowledge. Robinson et al. (2003) explain that presenting an overarching view of information before presenting details allows a learner to create a scaffold or schema, which can then hold new pieces of information as they are presented. This can be imagined as a shelf for the working memory, so that rather than having to hold all new information in working memory and sort it out afterward, a learner can sort the new information onto the "shelf" as it is presented. This means it is important to begin with a summary sentence when writing long image descriptions, and to include sub-summaries with especially long image descriptions. Artino also emphasizes the importance of creating schemas, explaining that schemas "effectively augment working memory capacity" (2008), since these "shelves" of information count as one item within working memory.

In addition to organizing information by using summaries and sub-summaries, describing things by their relationship to each other helps to recall the relevant schema, which allows for the use of "shelves." These can be relationships of proximity, priority, structure, causality, sequence, or function. For example, rather than describing a circulatory system by listing the various names of parts, one would describe the flow of blood from the heart through the aorta to arteries, which lead to capillaries where oxygen is removed, which lead to veins, which lead to the lungs to trade carbon dioxide for oxygen, then lead back to the heart. This cue of describing a sequential, structural relationship between parts helps the listener know how to process the material (de Koning et al., 2009; Mayer & Moreno, 2003). In this example, instead of consisting of many separate objects, the circulatory system becomes one object.

Avoid Unnecessary Naming Tasks

Naming, or the recalling of a word associated with a concept, is a unique cognitive process that is impaired in people with dyslexia (Harrison & Stewart, 2019; Howland & Liederman, 2013) and other learning and cognitive disabilities such as ADHD (Rucklidge & Tannock, 2002). Because of this and because naming takes up part of the working memory process (Ghelani et al., 2004), naming tasks should be reduced as much as possible when describing images.

In practice, this means using the same name for an object or person throughout the description, as well as avoiding the use of acronyms or abbreviations unless they have become a word in and of themselves. It also means referring to things descriptively rather than by arbitrary designations—for example, using "the hungry group" and "the fed group" rather than "the left group" and "the right group." For someone who is processing an image mentally, it may be distracting to focus too much on directions or placement; focusing instead on the content or type of group could be more beneficial.

Avoid Redundancy

Redundancy forces a reader or listener to process the same information more than once, which creates extraneous cognitive load, reducing learning outcomes; this is known as the redundancy effect (Mayer & Moreno, 2003). This is especially taxing if the listener has a significant amount of knowledge already, and in studies this "expertise reversal effect" has shown to decrease learning when that is the case (Kalyuga et al., 1999).

In practice, this means integrating text overlays into the description, rather than repeating the text after describing what it labels. It also means not repeating information that is available in the caption or surrounding text. Another way to avoid redundancy is by describing objects or concepts by similarity first and difference second, rather than describing each one separately when there would be a lot of repetition. For example, instead of "a large tree, a medium tree, a small tree, a tall flower, a medium flower, and a short flower," you could instead describe "Three different sizes of tree and flower: tall, medium, and short."

Avoid Describing Unimportant Aspects or Adding Context from Outside the Image

Most images have relevant and irrelevant elements to them, but describing the irrelevant elements will hinder learning by putting additional strain on working memory (Fenesi et al., 2015). Butcher (2006) demonstrates that this includes unimportant details; students had better learning outcomes from a simplified diagram than a detailed diagram. Duesbery et al. found that when the same graph was more decorative, such as a 3-dimensional chart instead of a 2-dimensional chart, participants had a more difficult time understanding them when working memory was under more strain (2011). Unimportant details can be distracting and lead someone to pay attention to the wrong elements of a description (Cromley et al., 2013). People with low working memory capacity, such as people with dyslexia or ADHD, are especially affected by this, as they are less able to block out recalling irrelevant information (Kane & Engle, 2000). Blind and low-vision users affirmed the need for avoiding distracting details, particularly in elaborate diagrams (Gould et al., 2008). What this means in practice is similar to explaining the important elements: Begin with the question "Why is this here?" and then describe the most relevant aspects of the image.

OUTCOMES AND BENEFITS

The Need for Image Description

In this past year, the pandemic has shone a spotlight on scientific literature and the need for accessible graphics, data, and diagrams, as new information about the virus kept changing. Rapid developments in science and technology were being delivered each day on the news, online, and in print publications. In many of these broadcasts and posts, the language was at an extremely high reading level, and accompanying data was inadequately described. Due to the fact that people with disabilities were disproportionately affected by the COVID-19 pandemic, it is imperative that public health information be made accessible with effective description of visual elements. If individuals with disabilities have access to important health mandates and vaccine information, then they can choose to follow the guidance and recommendations and improve health outcomes. What has been proven time and again is that improving the accessibility of graphics and tables benefits all readers, not just those with disabilities.

At CIDI, our accessibility work has broadened our conception of who needs accessible documents. It is not just students who are blind or have low vision who are placing orders for accessible textbooks; increasingly, we see the majority of our orders being placed by sighted individuals. Students who have other print-related disabilities such as dyslexia, dysgraphia, or dyscalculia are using assistive technology to help them process information. Students with ADHD, auditory learners, and students with cognitive impairments also may prefer accessible text to print as it helps them to focus on content, and thus there is an increasing demand for accessible digital formats that satisfy users with many different needs. It is an important clarification to make that when we consider image description and cognitive load for those using assistive technology, it is often being utilized by sighted individuals.

Public health organizations who implement effective image descriptions will be best equipped to raise awareness and successfully spread accurate information. Often, even when well-intentioned people try to focus on making their materials accessible, they make the assumption that visuals will make complex subjects more understandable, and this is not always the case. In matters of public health, all important information should be presented primarily through text, and if visuals are included that also present information, they should be described. If an infographic or diagram contains additional information not represented in the text, it should be accompanied by an image description that encapsulates the information succinctly for both the sighted and non-sighted user equally. Using image descriptions is an egalitarian way to make sure that visual content will be understood by all.

Image description is often considered to be primarily a task that is performed in post-production of a document or website, something that is done to fill in the gaps for individuals who are blind or low-vision only. But with an increasing amount of reading and knowledge-gathering being done online on personal devices such as laptops and phones, often images do not load properly if at all, or content can be spatially distorted due to browser incompatibility or slow loading times. Adding alternative text in the early days of the web allowed users to preview the content of an image before using valuable and limited bandwidth downloading images. The same is true today, in that adding alternative text to images functions as a descriptor for all users, not just those with disabilities. Image description for images that have STEM

content often must function on two levels; it must be the sole method of conveying information for some, plus it must attempt in some way to simplify or interpret the data or information.

How to Approach Image Description

An excellent image description or alternative text description will encapsulate the image and move the listener or reader towards further understanding or comprehension. It is often not effective to just present all the visual information, as this often results in auditory noise or cognitive overload. The most effective image description will provide an overview of the image and then begin to organize that information in helpful ways that will be easy to comprehend and retain. Describing complex images should begin with an overview sentence that summarizes the visual content and provides a framework for the listener. Additional sentences can then be added after this first all-important sentence, to provide additional details or clarification. The importance of that first sentence cannot be stressed enough, as it gives the listener a way in to what is unseen. Starting with details and then eventually landing on the main point will only fatigue the listener, who may already have lost the thread of what was being described. By starting with the most important aspect and moving to detail, that overview sentence at the beginning will capture the listener's attention and establish a scaffolding or outline that can then be filled in with greater detail.

The greatest challenge in describing STEM images is figuring out where to start, and how to encapsulate everything in one sentence. Writing alternative text is more often about editing than writing. We find that it will often take two or three sentences of writing around the main point before you land on the essence of the image, and then deleting those first two sentences to streamline things and reduce cognitive overload for the listener. Editing techniques for revising your image description will improve the accessibility of your visuals, plus raise your own awareness of the art of image description. These editing techniques include:

- Using Clear and Concise Syntax
    - Edit for clarity
    - Simplify word choice
    - Spell out acronyms or symbols
- Organizing Information
    - Organize information in predictable ways
    - Work from general to specific to provide a framework
    - Group like items and describe images by their similarities first, differences second
    - Describe objects or parts in relation to each other: proximity, priority, causality, sequence, or function
    - Describe trends and highlighted or visually emphasized information
- Providing Information in Multiple Modalities
    - Provide information in different or additional ways
    - Add image descriptions as well as short alternative text when possible
    - Transform graphs into tables, and describe trends
    - Present flow charts as lists
- Reducing Redundancies
    - Avoid repeating what is in a caption or the surrounding text

- Edit your description if it becomes wordy
- Integrate symbols or labels into your description: describe the function of symbols, not the appearance of them.

In addition to reading with the above considerations in mind, it helps to have another person review your writing. We often establish a workflow that allows for multiple people to both write and edit alternative text descriptions, so that we catch mistakes and fill in essential details that may have been overlooked. Using tools like spellcheck in Microsoft Word also helps isolate spelling or grammar mistakes, allowing us to optimize how the assistive technology will pronounce each word for maximum clarity. If you don't have the luxury of a large team to assist you with image description, it often helps to use time to your advantage, writing your alternative text and then waiting a full day or more before going back for an editing pass. Once some time has elapsed, you are more likely to have some detachment from your own writing, to pinpoint omissions or confusing syntax. The ultimate goal is to describe things as simply as possible, and often simplicity and elegance in writing takes time and effort.

Collaboration with the Centers for Disease Control

In our work at CIDI providing accessible materials for those with disabilities, we are often fighting the clock, aiming to get textbooks remediated as quickly as possible for students taking a college course so they can keep up with their classmates. We also face the additional pressure of providing quality content, knowing that students may be tested on the material we remediate. Our mission and goal is giving everyone equal access to information, and so our efforts at describing difficult STEM material have always been focused on how to convey information with clarity and precision. The stakes were raised tremendously in our collaborative work with the Centers for Disease Control this past year, in that now we had the responsibility of making sure individuals not only accessed their course information effectively, but understood risks to their physical health. Suddenly, our concerns about whether or not to include details such as gender or ethnicity in our image description seemed theoretical and of little consequence in comparison with information about how and why to make an appointment for a vaccination.

We were truly fortunate in that the CDC cares deeply about accessibility, and their teams were dedicated to getting accessibility right, even if that did take more time and effort than initially planned. The CDC's materials also leaned heavily towards text and easy-to-digest lists of information, and any additional graphics were used either as decoration or reinforcement of the text, which is ideal in terms of accessibility. Illustrations of people following the CDC guidelines that were listed out in text needed scant description, and if they were excluded entirely by the assistive technology, the important content was still contained within the text. Flyers detailing how to quarantine, or how to socially isolate within a home where someone was infected, had simple illustrations echoing the main point of the text instructions. These images played the role of backing up the relevant points of the text and did not present new information that would be inaccessible to some users. When graphics simply illustrate the text, image description becomes far less imperative.

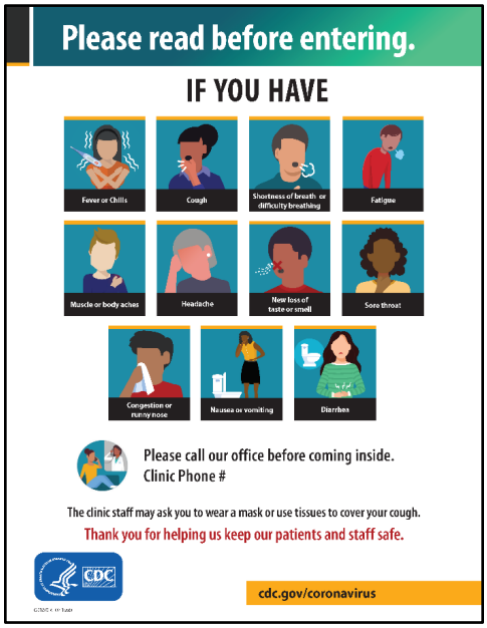
Examples of Infographics and Effective Alternative Text Descriptions

The two flyers featured below were created by the CDC, and are available for download in PDF format.

Similar versions were made with less emphasis on visuals or graphics, that were available for download in accessible Microsoft Word document format, and also for conversion to Braille. These PDF files were both highly accessible to a wide variety of users. All of the text on each flyer could be read aloud by the screen reading software, and all images were fully described by their captions. These two flyers are exemplary in that they use the graphics to reinforce the text content, and thus writing image description becomes incredibly simple; the captions do all of the heavy lifting, and have the added benefit of being available to sighted users as well.

As an exercise, we've written out example image descriptions for each flyer if they were to be shared as images instead of accessible PDF files. If we were to find these flyers shared on social media as a JPG file, we would recommend the following descriptions so that all of the important health content was conveyed adequately. One thing to pay particular attention to is how much of our descriptions focus on the text and not the graphics. This is an ideal way to share information about public health that has visual interest and color, with graphics that do not cause auditory fatigue or involve lengthy description and accessibility work.

Figure 1: Please Read Before Entering



Example alternative text description if this were to be shared as an infographic:

A flyer about coronavirus safety in a shared building. At the top in large text: Please read before entering. There are eleven illustrations of people who should call before coming inside the office: people with fever or chills, a cough, shortness of breath or difficulty breathing, fatigue, muscle or body aches, headache, new loss of taste or smell, sore throat, congestion or runny nose, nausea or vomiting, or diarrhea. The clinic staff may ask you to wear a mask or use tissues to cover your cough. Thank you for helping us to keep our patients and staff safe. Website: cdc.gov/coronavirus

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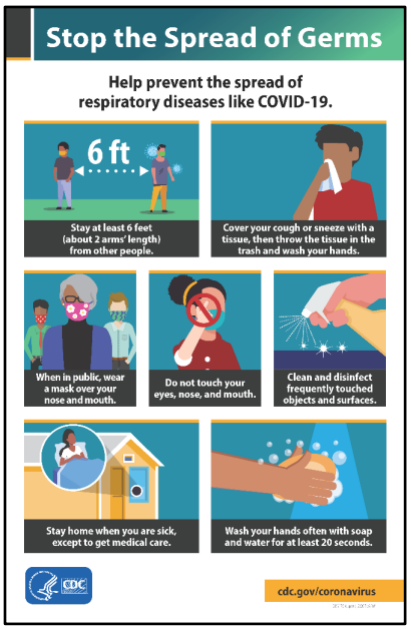
Figure 2: Stop the Spread of Germs



Example alternative text description if this were to be shared as an infographic:

A flyer about coronavirus safety titled, Stop the spread of germs: Help prevent the spread of respiratory diseases like COVID-19. Seven tips are illustrated with simple drawings. 1. Stay at least 6 feet (about two arms' length) away from other people. 2. Cover your cough or sneeze with a tissue, then throw the tissue in the trash and wash your hands. 3. When in public, wear a mask over your nose and mouth. 4. Do not touch your eyes, nose, and mouth. 5. Clean and disinfect frequently touched objects and surfaces. 6. Stay home when you are sick, except to get medical care. 7. Wash your hands often with soap and water for at least 20 seconds. Website: cdc.gov/coronavirus

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Why the Descriptions of Scientific Data Benefits All Users

Graphs of data require a figure caption or descriptive alternative text to be understood by most individuals, not only those with disabilities. The pandemic has turned many of us into researchers this year, as we scour the internet for data on our states, our counties, and the infection rates in areas where our loved ones reside. The websites providing this data often feature complicated graphs showing spikes in infection rates with no text to explain the visual graphs, making these visual elements functionally invisible for those relying on screen-reading technology. These charts are also difficult for the lay person to interpret; a figure caption would help guide people towards an interpretation of the data.

Similarly, table captions that are placed before a table that describes the trends of the data would help all users in understanding the numbers or information contained within that table. Providing information or important content in multiple modalities is a highly effective strategy when looking at STEM content. For instance, writing a detailed figure caption to describe the data trends of a graph, and then reinforcing

that with the visual image, plus adding brief alternative text description to the figure to reinforce that information in different words, means that there are three different modalities of education occurring. The trick would then be to ensure that the figure caption and alt text description are not too redundant or repetitive, so as not to bog down the working memory of the person accessing both modes of information.

Tables are often overlooked in terms of accessibility, as the text can be highlighted and is therefore considered accessible or available to assistive technology. However, those using assistive technology such as JAWS or NVDA know well the difficulty in navigating tables and understanding where you are within the table as the data is read aloud. Any attempt at framing the contents of the table beforehand would be helpful for users knowing how to interpret and perceive the onslaught of data cells being read aloud. A large table with many rows and columns could become a labyrinth for someone using the keyboard to navigate, and writing alternative text for that table to describe the table's structure will give users an overview of the table's layout and overall content. Structural alt text would consist of counting how many rows and columns the table contains, and then listing each column header in order. This simple step allows non-sighted users the ability to hear the contents of the table in one quick overview, and decide whether or not they want to enter into table mode and process all that data. Again, as with figure captions, table captions that precede the table can benefit all users, and guide individuals towards an interpretation of the data.

Especially in the realm of public health, any attempts to encapsulate complicated data and guide individuals towards a greater understanding will have immediate benefits. Making complex material more accessible with effective alt text or captions helps with the understanding and retention of information that could be life-changing or even lifesaving. Providing this extra layer of accessible description and interpretation will also bolster the trust and confidence that the provider has with the public. If data seems too abstruse to decipher, people will lose interest and become frustrated, eventually looking elsewhere for practical information they can understand and apply to their lives. For public health officials looking to make an impact on the disability community, making sure that images are described fully without causing auditory fatigue is of primary importance. Not only will it help with information retention, but it will help retain users, keeping them engaged and coming back for more information, which has been a core feature of this pandemic—the constantly-evolving information and need to keep the public informed, aware, and responsive to new ideas.

In our collaboration with the CDC, the accessible materials that were posted informing people about the pandemic and vaccine were downloaded hundreds of thousands of times, exceeding everyone's expectations, and people came back for more, wanting updates that they could download, print, and share. By crafting documents that included accessible graphics and easy-to-understand text, we were truly making an impact and providing a service that people found useful and instructive. Armed with this important public health information, individuals across all types of disability communities could make informed decisions about their own safety and well-being.

DISCUSSION/CONCLUSIONS

Combining our research on cognitive load and image processing with our practitioner knowledge remediating highly-complex STEM material, we have arrived at the above recommendations for making materials more accessible and easier to comprehend. By providing information in multiple modalities and supplementing alternative text descriptions with captions, complex scientific infographics, graphs, and diagrams can be understood more fully by individuals who may struggle to decipher complex data. Graphics that are used to reinforce the text will help and not hinder understanding, and will function as another modality or pathway to convey information.

Adjacent to the topic of image description, there are many opportunities for further research and studies concerning Plain Language and Minimized Text Complexity. These movements emphasize reducing the complexity of the reading level of text within a document, ensuring that those who read at middle-school or grade-school levels can understand the text fully. Reading levels in various disability communities are often far below national averages, and the need to focus on making the words themselves more accessible should not be overlooked. Karen Erickson and her team at the Center for Literacy and Disability Studies at University of North Carolina, Chapel Hill, have established a robust set of guidelines for reducing the complexity of a text document, and this work goes hand-in-hand with the need to describe images in ways that reduce cognitive load and allow someone to process information effectively.

Our work converting materials for students with print-related disabilities has given us tremendous insight into the wide range of needs when it comes to accessible file formats. Any discussion of accessible graphics should be grounded in practice, and our practice has shown us that some students prefer brief alt text, others want longer comprehensive alt text, and content providers such as publishers or public health officials should aim somewhere in the middle to satisfy the majority of people's needs. Often, the more complex the image, the more detailed the description needs to be, but by following the editing guidelines outlined above, your alt text description should achieve a balance between too little and too much information. In our work, we are always cognizant of the danger of oversimplifying images in our description, and again, it always helps to have another person to edit and fill in missing pieces in your image descriptions whenever possible, especially when that final content could affect someone's health, safety, or lifestyle choices.

DECLARATIONS

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REFERENCES

Anglin, G., & Vaez, H. (2004). Visual representations and learning: the role of static and animated graphics. In G.J. Anglin, H. Vaez, & K. L. Cunningham (Eds.), *Handbook of research on educational communications and technology* (2nd ed., pp. 865-916). Routledge. https://doi.org/10.4324/9781410609519

Artino, A. R., Jr. (2008). Cognitive load theory and the role of learner experience: an abbreviated review for educational practitioners. *Association for the Advancement of Computing in Education (AACE) Journal, 16*(4), 425–439. http://www.learntechlib.org/p/25229/

Butcher, K. (2006). Learning from text with diagrams: promoting mental model development and inference generation. *Journal of Educational Psychology, 98*(1), 182–197. https://doi.org/10.1037/0022-0663.98.1.182

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 14*(1), 5–26. https://doi.org/10.1023/A:1013176309260

Cromley, J. G., Perez, T. C., Fitzhugh, S. L., Newcombe, N. S., Wills, T. W., & Tanaka, J. C. (2013). Improving students' diagram comprehension with classroom instruction. *Journal of Experimental Education, 81*(4), 511–537. https://doi.org/10.1080/00220973.2012.745465

de Koning, B. B., Tabbers, H. K., Rikers, R. P., & Paas, F. (2009). Towards a framework for attention cueing in instructional animations: guidelines for research and design. *Educational Psychology Review, 21*(2), 113–140. https://doi.org/10.1007/s10648-009-9098-7

Demir, S., Carberry, S., & McCoy, K. F. (2012). Summarizing information graphics textually. *Computational Linguistics, 38*(3), 527–574. https://doi.org/10.1162/COLI_a_00091

Duesbery, L., Werblow, J., & Yovanoff, P. (2011). Graphical literacy moderates the interaction of decorative dimensionality and cognitive demand in computer-based graph comprehension. *Journal of Educational Computing Research, 45*(1), 75–93. https://doi.org/10.2190/EC.45.1.d

Eitel, A., Scheiter, K., Schüler, A., Nyström, M., & Holmqvist, K. (2013). How a picture facilitates the process of learning from text: evidence for scaffolding. *Learning & Instruction, 28,* 48–63. https://doi.org/10.1016/j.learninstruc.2013.05.002

Fan, Q., Anderson, A. W., Davis, N., & Cutting, L. E. (2014). Structural connectivity patterns associated with the putative visual word form area and children's reading ability. *Brain Research, 1586,* 118–129. https://doi.org/10.1016/j.brainres.2014.08.050

Fenesi, B., Sana, F., Kim, J. A., & Shore, D. (2015). Reconceptualizing working memory in educational research. *Educational Psychology Review, 27*(2), 333–351. https://doi.org/10.1007/s10648-014-9286-y

Fletcher, J. D., & Tobias, S. (2005). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 117–134). Cambridge University Press. https://doi.org/10.1017/CBO9780511816819.008

Folker, S., Ritter, H., & Sichelschmidt, L. (2005). Processing and integrating multimodal material: the influence of color-coding. *Proceedings of the Annual Conference of the Cognitive Science Society, 27,* 690–695. https://escholarship.org/uc/item/5ch098t2

Ghelani, K., Sidhu, R., Jain, U., & Tannock, R. (2004). Reading comprehension and reading related abilities in adolescents with reading disabilities and attention-deficit/hyperactivity disorder. *Dyslexia, 10*(4), 364–384. https://doi.org/10.1002/dys.285

Gould, B., O'Connell, T., & Freed, G. (2008). *Effective practices for description of science content within digital talking books.* The WGBH National Center for Accessible Media. https://www.wgbh.org/foundation/effective-practices-for-description-of-science-content-within-digital-talking-books

Greer, D. L., Crutchfield, S. A., & Woods, K. L. (2013). Cognitive theory of multimedia learning, instructional design principles, and students with learning disabilities in computer-based and online learning environments. *Journal of Education, 193*(2), 41–51. https://doi.org/10.1177/002205741319300205

Harrison, A. G., & Stewart, M. (2019). Diagnostic implications of the double deficit model for young adolescents with dyslexia. *Dyslexia, 25*(4), 345–359. https://doi.org/10.1002/dys.1638

Hedenius, M., Ullman, M. T., Alm, P. A., Jennische, M., & Persson, J. (2013). Enhanced recognition memory after incidental encoding in children with developmental dyslexia. *PLoS ONE, 8*(5): e63998. https://doi.org/10.1371/journal.pone.0063998

Hegarty, M. (2011). The cognitive science of visual-spatial displays: implications for design. *Topics in Cognitive Science*, *3*(3), 446–474. https://doi.org/10.1111/j.1756-8765.2011.01150.x

Holmqvist Olander, M., Wennås Brante, E., & Nyström, M. (2017). The effect of illustration on improving text comprehension in dyslexic adults. *Dyslexia, 23*(1), 42–65. https://doi.org/10.1002/dys.1545

Howland, K. A., & Liederman, J. (2013). Beyond decoding: Adults with dyslexia have trouble forming unified lexical representations across pseudoword learning episodes. *Journal of Speech, Language, and Hearing Research (JSLHR), 56*(3), 1009–1022. https://doi.org/10.1044/1092-4388(2012/11-0252)

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology, 13*(4), 351–371. https://doi.org/10.1002/(SICI)1099-0720(199908)13:4%3C351::AID-ACP589%3E3.0.CO;2-6

Kane, M. J., & Engle, R. W. (2000). Working-memory capacity, proactive interference, and divided attention: limits on long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(2), 336–358. https://doi.org/10.1037/0278-7393.26.2.336

Mautone, P., & Mayer, R. (2001). Signaling as a cognitive guide in multimedia learning. *Journal of Educational Psychology, 93*(2), 377–389. https://doi.org/10.1037/0022-0663.93.2.377

Mayer, R., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of Educational Psychology, 91*(4), 638–643. https://doi.org/10.1037/0022-0663.91.4.638

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 43–52. https://doi.org/10.1207/S15326985EP3801_6

Rehabilitation Act of 1973, Section 508, as amended. 29 U.S.C §794d (1998). https://www.access-board.gov/law/ra.html#section-508-federal-electronic-and-information-technology

Robinson, D. H., Corliss, S. B., Bush, A. M., Bera, S. J., & Tomberlin, T. (2003). Optimal presentation of graphic organizers and text: a case for large bites? *Educational Technology Research and Development, 51*(4), 25–41. https://doi.org/10.1007/BF02504542

Rucklidge, J. J., & Tannock, R. (2002). Neuropsychological profiles of adolescents with ADHD: effects of reading difficulties and gender. *Journal of Child Psychology & Psychiatry*, *43*(8), 988–1003. https://doi.org/10.1111/1469-7610.00227

Smith, J. L. M., Sáez, L., & Doabler, C. T. (2016). Using explicit and systematic instruction to support working memory. *Teaching Exceptional Children,* *48*(6), 275–281. https://doi.org/10.1177/0040059916650633

Stangl, A., Morris, M. R., & Gurari, D. (2020). “Person, shoes, tree. Is the person naked?" What people with vision impairments want in image descriptions [Research article]. *CHI 2020 Conference on Human Factors in Computing Systems* (pp 1–13). Association for Computing Machinery. https://doi.org/10.1145/3313831.3376404