Display Guidelines for Numerical Information

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EXECUTIVE SUMMARY

The goal of this report is to summarize the current state of the literature on number comprehension and to provide recommendations for applying these data to display design. We integrate results from empirical studies into a guide for display designers who have to present numerical information to users. We first provide a brief introduction to numerical information displays followed by a description of the factors that influence numerical information comprehension: number type, task requirements, interaction of number type by task requirements, and person characteristics. Each of these factors and their relevance to display design is discussed in detail. This research provides the basis for the display guidelines we have developed.

The guidelines for designing a numerical information display are organized by critical factors as follows:

- **Number type**
  - Natural numbers are the easiest type of numbers for people to understand.
  - Ratio concepts, such as fractions (e.g., 1/6), frequencies (e.g., 3 out of 1000), percentages (e.g., 74%) and decimals (e.g., 35.8) are more difficult for people to understand.
  - Number type should be kept consistent; requiring people to translate between number formats (e.g., between percentage and fraction) will decrease comprehension.
  - Numbers should be meaningful to the users: When scaling numerical information, higher numbers should mean “better,” whereas lower numbers should indicate “worse.”
- **Task requirements**
  - The display should provide numerical information that is readily available.
  - The user should not have to manipulate or integrate information.
  - Cognitive demands increase as the problem complexity increases (e.g., comparing values is easier than executing multi-step mathematical operations).

- **Interaction between number type and task requirements**
    - The numbers should match the task requirements. For example, if the task requires an answer as a decimal, then the numbers presented should be decimals.
    - Do not present numerical data that must be manipulated between formats (e.g., frequency to percentage).
    - Present fractions and frequencies with same denominators.
    - Using low cognitive demand number types such as natural numbers for a low cognitive demanding task such as magnitude comparison should yield good performance.
    - Conversely, using difficult to process number types such as percentages for a difficult problem type, will likely yield poor performance.
- **Presentation format**
    - Task requirements should guide the presentation format.
    - Optimal displays reduce cognitive demands by providing relevant information quickly and easily to the user.
    - Prose texts (e.g., for instruction manual design):
        - Make the text easy to read (e.g., elementary grade level of reading).
        - Use expository texts to convey numerical information.
    - Document texts (tables):
        - Minimize visual clutter.
        - Use meaningful titles and headers to organize the numbers.
        - Relevant numbers should be readily available to complete tasks.
        - Do not include irrelevant numbers.
        - Mathematical operations should be reduced or eliminated.
    - Graphs:
        - Refer to the technical report, “Visual Graph Display Guidelines,” HFA-TR-0803 (Fausset, Rogers, & Fisk, 2008).

- **Person characteristics**
    - Leverage existing knowledge.
    - Recognize that some users may experience math anxiety: May have to reduce or eliminate numbers from the display.
    - Reduce working memory demands.

- **General human factors principles**
    - Understand the physical, perceptual, and cognitive abilities of the target user group.
    - Test the users' ability to comprehend the numerical information throughout the design process, not just with the final product.
    - Conduct user testing with representative users, tasks, and contexts.
    - Consider training and instructional needs for the target population throughout the design process.

INTRODUCTION

There are many occasions that call for the presentation of numerical information. For example, farm equipment operators applying pesticide to crops must understand and monitor many different aspects of the system, and numerical information can provide an objective measure of the state of the system. The John Deere GreenStar 2 Rate Controller display shows an operator many different types of numerical information such as target and actual pesticide application rates, coverage per hour, tractor speed, nozzle pressure, and pesticide tank volume (see Figure 1).

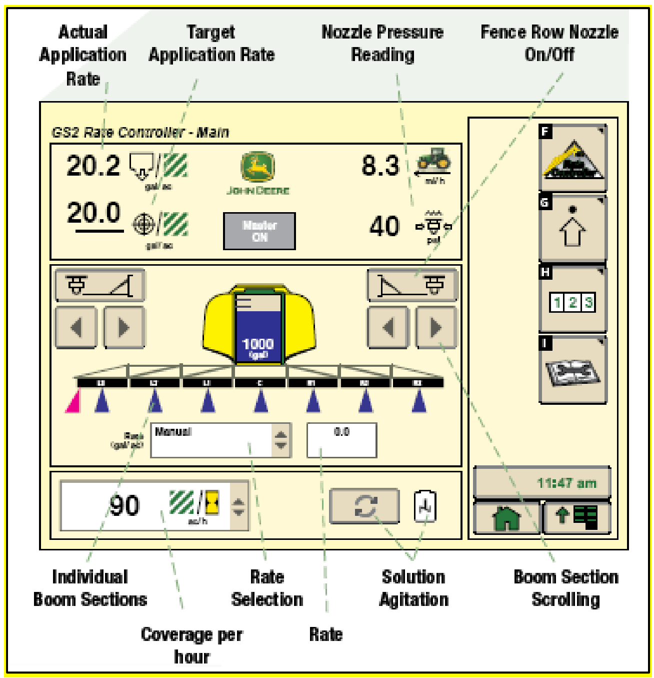

Figure 1. GreenStar 2 (GS2) Rate Controller screen shot taken from http://www.deere.com/en_US/ProductCatalog/FR/literature/2009/ams/dsaa40430_all_greenstar_products.pdf, p. 20.

The benefit of presenting numbers is that they provide objective and unbiased information, as in the example given above. However, a huge challenge facing display designers is that many people either do not understand numeric information or they do not attend to numeric information (Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2008; Lipkus & Peters, 2009; Paulos, 1988; Reyna & Brainerd, 2008; Reyna, Nelson, Han, & Dieckmann, 2009). The goal of this report is to provide recommendations and guiding principles for display design of numbers based on the extant literature. This report is organized by the following critical variables identified in displaying numerical information: number type, task requirements, presentation format, and person characteristics.

There are a few assumptions made in this report that must be recognized: The recommendations provided in this document are aimed at a population of users with the following characteristics:

1. Users are not visually impaired.
2. Users can recognize numbers.
3. Users can perform basic mathematical operations (addition, subtraction, multiplication, and division).

NUMBER TYPE

There are many types of numbers that can be used to convey quantitative information, such as Arabic numbers (e.g., 1, 2, 3, etc.), Roman numerals (e.g., I, II, III, etc.), or analogical representations (e.g., dots, length of bars in a bar chart, etc.). This report will focus on the display of Arabic numbers, and the following will describe how people process different types of Arabic numbers.

Natural numbers

When designing a display with numerical information, the characteristics of the number should be considered. That is, what type of number should be displayed? Past research has found that natural numbers (integers zero and higher) are the first quantities that people come to know and are the easiest for people to understand (Dehaene, 1997; Gallistel & Gelman, 2000; Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2008; Gigerenzer & Hoffrage, 1995). However, there may be situations in which displaying natural numbers just does not make sense: What if it is critical that the person reading the display understand a ratio or a percentage?

Ratios

If ratio concepts must be displayed, then real numbers have to be considered. Real numbers, which include fractions, decimals, natural frequencies, and percentages, are indeed more difficult for people to comprehend than natural numbers (Gallistel & Gelman, 2000; Gigerenzer & Hoffrage, 1995; Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2008). People must understand there are infinite numbers between two natural numbers which is a difficult concept to comprehend. In a series of four experiments, Bonato, Fabbri, Umilta, and Zorzi (2007) investigated how people understand fractions. They found that participants were biased toward processing only part of the fraction such that only the numerator or denominator was processed when comparing one fraction to a target fraction value. People did not process the real value of the fractions (i.e., holistic processing); instead, they processed each number of the fraction separately.

In another study that investigated how people processed fractions, participants focused on the numerator only (Yamagishi, 1997). For example, participants rated risk as higher (i.e., worse) when given a risk of 1,286/10,000 versus 24.14/100 even though the real values of these rates are 12.86% and 24.14%, respectively. These results suggest that people do not represent the real numerical value of a ratio. Instead, people rely on an initial impression of a number presented; specifically, how large or small the numerator is. This phenomenon has been termed denominator neglect (Reyna & Brainerd, 2008). With respect to comprehension of quantitative information, number format is a critical factor in comprehension and ultimately, the final behavior (e.g., decision-making or compliance).

What if a designer considers using a percentage instead of a fraction or natural frequency (e.g., 1 in 100)? In a study where participants were asked to rate the risk of a mental patient doing something harmful after release given either a percentage (10%) or a frequency (10 out of 100), the results suggested that not everyone understood these numbers to be objectively equivalent (Peters et al., 2006). Some people rated the risk as significantly higher when shown the frequency than the percentage suggesting that people do not represent the real numerical value or magnitude of a ratio. Therefore, if presenting a ratio is important, the designer must consider how the reader may process that ratio.

Directionality of scaling data

In some situations, it may make sense to display several numbers that describe a variable on certain factors. This may be relevant to Deere & Company when designing product comparison materials based on customer ratings. Research has shown that higher values should indicate a “better” rating: Comprehension of data was improved when the data were scaled as higher numbers representing higher quality as opposed to lower numbers representing higher quality (Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007). These results suggest that it is more cognitively demanding to present rating data wherein a lower number represents a better score.

However, in some cases, lower numbers may be more desirable (“better”) than higher numbers, such as engine temperature or crops lost during harvest. Therefore, it is imperative that designers understand the target users and their domain knowledge. It is likely reasonable that an experienced farm equipment operator would understand that higher numbers in one instance (e.g., miles per gallon) is "better," whereas in another instance and perhaps maybe even on the same display, higher numbers may indicate "worse" (e.g., engine temperature). Display guidelines such as those offered by the proximity compatibility principle (Wickens & Carswell, 1995) suggest congruence of external and internal representations is essential for good displays.

Summary

In sum, use natural numbers whenever possible; these number types are the least cognitively demanding. Conversely, cognitive demands are high when ratio concepts are presented. Additionally, not all people represent objectively equivalent values as the same. Therefore, number type should be kept consistent; requiring people to translate between number formats (e.g., between percentage and fraction) will decrease comprehension. Figure 2 shows the increasing cognitive demands by number type.

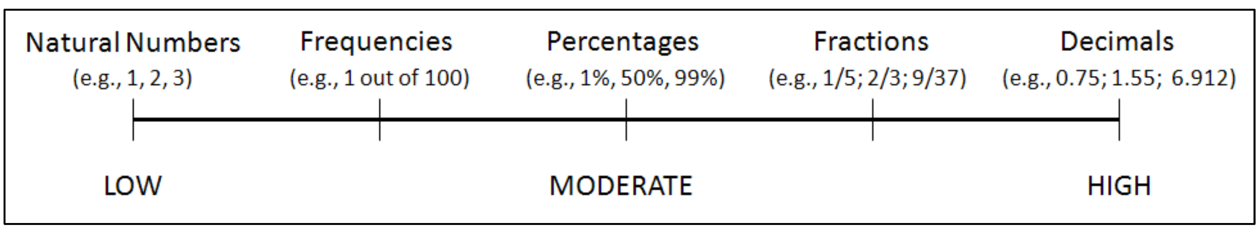

Figure 2. Cognitive demand spectrum of number type. Natural numbers are easier to process than ratio concepts that include natural frequencies, percentages, fractions, and decimals.

TASK REQUIREMENTS

When a designer considers a numeric display, the task requirements should be a high priority question. That is, a well-designed display provides information that is readily available to use for the task at hand (Wickens & Carswell, 1995). A display should not require the user to have to manipulate or integrate numerical information, as this is resource demanding, especially in a multiple-task environment such as operating equipment.

Identification

Some tasks may only require that the user identify a relevant number. As such, numeric information should be presented in such a way that prevents over-crowding or clutter in the display. Too many numbers to visually search through requires time and effort, and an optimal display design reduces such demands (Wickens & Carswell, 1995).

Comparing magnitudes

Other tasks may require the user to compare magnitudes of values. For example, referring back to the GreenStar 2 system in Figure 1, the operator must compare the target and actual pesticide application rates: Are the rates equal, or is the actual rate higher or lower than the target rate? The numerical cognition literature has identified factors that should be considered when comparing number values; these factors are referred to as the size and distance effects.

According to the size effect, comparing larger numbers is a more difficult process than comparing smaller numbers, as measured by an increase in response time (Dehaene, Bossini, & Giraux, 1993). For example, determining whether 572 is greater than 567 takes a longer time than determining if 6 is greater than 1. Additionally, the greater the distance (or difference) between numbers, the easier it is to compare values as measured by a decrease in response time: This is called the distance effect (Dehaene, Bossini, & Giraux). For example, it is easier to determine that 9 is greater than 1 than it is to determine that 9 is greater than 8. Thus, designers can predict users' performance based on these effects when evaluating display design.

Computations

Despite the best efforts of designers to reduce the need for operators to perform mathematical operations with numbers displayed, there may be occasions in which the user is required to do so. An interpretation of the literature suggests that the least cognitively demanding operations are one-step addition, subtraction, multiplication, or division tasks.

The problem size effect must be considered when tasks require persons to make exact calculations or computations: Larger numbers increase response times and error rates (LeFevre, Sadesky, & Bisanz, 1996). However, this effect does not occur when direct retrieval of an answer can be used, such as in very common problems (e.g., 100+100). Additionally, the complexity of the problem must be considered; the least cognitively demanding problems are those that can be directly retrieved (DeStefano & LeFevre, 2005). Often these are small numbers, well-practiced, or may be meaningful to the person.

As the number of digits and processing steps increase, the more complicated and effortful the problem becomes. For example, when "carrying" of digits is required in addition, more cognitive demands are imposed on working memory (Ashcraft & Kirk, 2001; DeStefano & LeFevre, 2005). This is an important factor to consider when designing displays in multiple task environments where working memory demands may already be high.

Multiple-step operations of the same operation can be considered more cognitively demanding than single-step operations, and multiple-step operations of different operations can be considered even more demanding. In both of these types of tasks, answers from previous operations must be held in mind to continue to the next step, resulting in a high working memory load.

The literature has suggested that when people must constantly readjust calculations based upon fluctuating variables, such as humidity, soil temperature, or rainfall in the case of a farm equipment operator, the task becomes very difficult and demanding (Cavanaugh et al., 2008; Estrada, Martin-Hryniewicz, Peek, Collins, & Byrd, 2004). In this type of situation, the problem is always changing, and therefore the internal representation of the problem is changing. What was done last week, yesterday, or this morning, is likely different than what must be done this evening. It is likely that when there is little common structure to the task and people cannot draw on past experience, performance will suffer (Dixon, 2005).

People make errors when they are given tasks in which they must extract the relevant information and make the appropriate calculations (Osborn et al., 2007; Rothman, et al., 2006; Weiss et al., 2005). According to Kintsch and Greeno's (1985) model of word arithmetic problem solving, identification of the relevant information is driven by both top-down (i.e., goals and plans and prior knowledge) and bottom-up processing (i.e., the specific numbers and display format). Additionally, irrelevant information must be suppressed. Errors in performance may arise due to an interference effect of seeing many numbers suggesting a working memory issue or a selective attention deficit. Alternatively, it could be that the actual mathematical operation was not executed correctly. Designers should consider these errors when creating a numeric display to facilitate extraction of relevant information and to support computation.

Summary

The display should provide information that is readily available to use for the task at hand. Ideally, the user should not have to manipulate or integrate information as this is resource demanding, especially in a multiple-task environment such as operating equipment. Cognitive demands increase as the problem complexity increases. For example, executing multiple step operations is more demanding than comparing numerical values. To facilitate comprehension of quantitative information, the cognitive demands that are required for the task (i.e., operations) must be minimized. Figure 3 shows the increasing cognitive demands by task type.

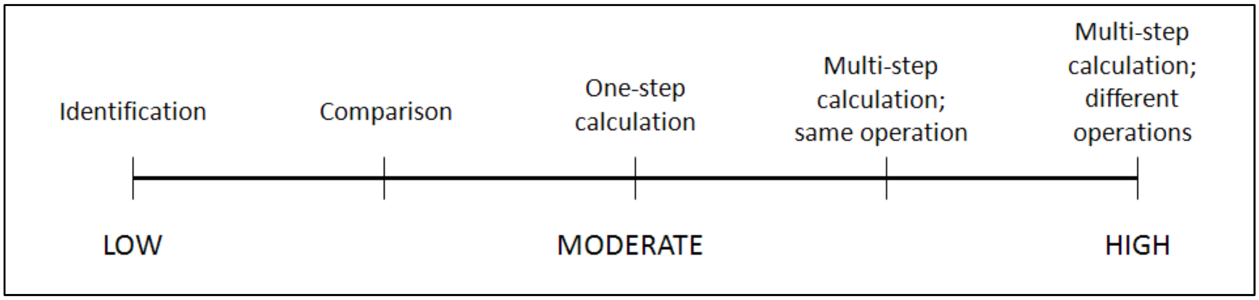

Figure 3. Cognitive demand spectrum of task requirements. Identifying and comparing numerical information is less demanding than executing multi-step operations.

Interaction of Number Type by Task Requirements

Interactions between the characteristics of the data (number type) and the task requirements were alluded to in the previous section. For example, comparing ratios expressed with the same denominator (e.g., comparing 5% to 10% or 5/100 to 10/100) is easier than when 5% must be compared to 5 out of 100. Presenting fractions with the same denominator accounts for the denominator neglect effect (Reyna & Brainerd, 2008); however, care must still be taken because users may not fully understand the value or magnitude of the fraction if they are only comparing numerator values. Designers should consider this drawback when creating displays.

When the number type matches the task, performance improves (Schwartz, Woloshin, Black, & Welch, 1997). This result aligns with Vessey's (1991) cognitive fit theory, which states that a match (or mismatch) between the task and the representation influences performance. Designers should consider the match between the task and the data when designing displays.

These results further illustrate that representational fluency, or the ability to recognize various numerical formats of objectively equivalent numbers as equal (Ancker & Kaufman, 2007), is difficult for people. More specifically, if the numbers or quantitative information people are given does not match the task at hand, it is unlikely that people will manipulate the numbers to perform the task. Alternatively, it could be that people incorrectly manipulate quantitative information. The key message here is that quantitative information should be presented such that no manipulations of numbers are required to complete the task.

Summary

To summarize, do not present people with numerical data that must be manipulated between formats (e.g., frequency to percentage) or give them numerical data that has mismatched denominators. To facilitate comprehension of quantitative information, the data characteristics must match task demands. For example, using low cognitive demand data characteristics such as natural numbers for a low cognitive demanding task such as magnitude comparison should yield good performance. Conversely, using difficult to process number types such as percentages for a difficult problem type will likely yield poor performance. Presenting number types (natural numbers) for an easy task (magnitude comparison) will be cognitively less demanding than presenting easy number types for difficult operations (multi-step; multi-operations), which will be less demanding than presenting difficult number types (ratios) for difficult multiple-step operations.

PRESENTATION FORMAT

The presentation of quantitative information can facilitate (or disrupt) comprehension. This variable necessarily interacts with both number type and the requirements of the task. Prose, document, and graphical presentation formats will be reviewed with respect to their potential influence on comprehension of quantitative information.

Prose texts

Relevant to Deere & Company instruction manual designers is the role of prose text in comprehension of numerical information. For example, the purpose of the manual may be to provide a description of the uses of the GreenStar 2 display. One critical aspect of the design process is making the manual easy to read: The easier the reading level (i.e., low grade level as assessed by Flesch-Kincaid reading level test), the higher users' performance (Sheridan, Pignone, & Lewis, 2003). Furthermore, the type of text can influence how numerical information is understood.

In a study that compared comprehension using three types of texts, expository (informational text, like a health brochure); narrative (e.g., a newspaper article); and procedural (e.g., a step by step instructional manual), Harris, Rogers, and Qualls (1998) found that people processed expository texts more accurately than narrative and procedural texts. This result suggests that to facilitate comprehension of quantitative information, expository texts should be used.

Document texts

Another type of presentation type that may be relevant to instruction manual design or display design is document texts (also called non-continuous texts or tables). For example, a user may have a need to see many numbers organized in a table. The requirements of the task should guide the decision on how best to organize and present the numerical information.

Visual clutter is a concern when using tables to display many numbers, so designers must take care to organize the table in a way the user can identify relevant pieces of information. General engineering psychology design principles suggest using headers and titles that are meaningful to the target users to support performance. When irrelevant numbers with respect to the task are included, performance suffers (Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007). In some situations, it may be optimal to present numbers in a table if the table can eliminate computations or mathematical operations, thereby reducing cognitive demands (Huizinga et al., 2008).

Graphs

The third type of presentation format that will be discussed in this report is the graph. Graphs of various types may support comprehension of quantitative information by providing analog pictorial representations of numeric values from which patterns and relationships between the values can be recognized and evaluated (Kosslyn, 1989). Therefore, depending upon the requirements of the task, display designers may consider using graphs to convey numerical information. For example, referring back to Figure 1, the GreenStar 2 displays both the actual and target pesticide application rates for the user to compare. However, when the target rate is 20.0 gallons/acre and the actual rate is 20.2 gallons/acre—what does this mean? Is the difference of 0.2 a significant practical difference such that the operator should make adjustments? Or, is 0.2 a very small practical difference such that all systems are performing within an acceptable range?

Depending on the practical meaning of the numbers in this specific context, perhaps an external support such as a bar graph could support operator understanding. That is, if the 0.2 difference is practically significant and action should be taken, then two bars representing target and actual application rates can be used and the scaling can be designed such that there is a visibly large difference between the rates. Alternatively, if 0.2 is a practically small difference then the bars can be scaled such that there is a very small visible difference between the bars. See Figures 5 and 6.

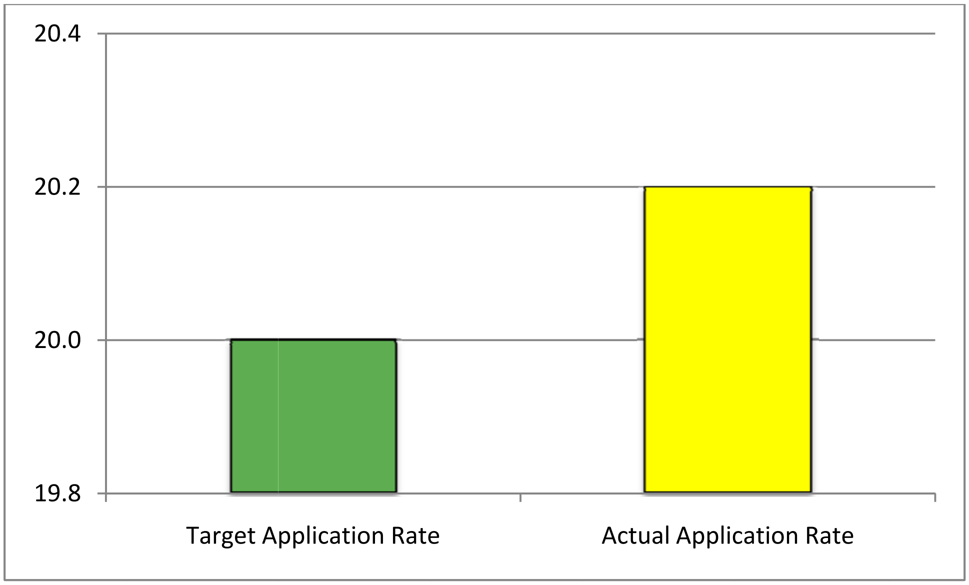

Figure 5. Graph illustrating a visually large difference between target and actual application rates.

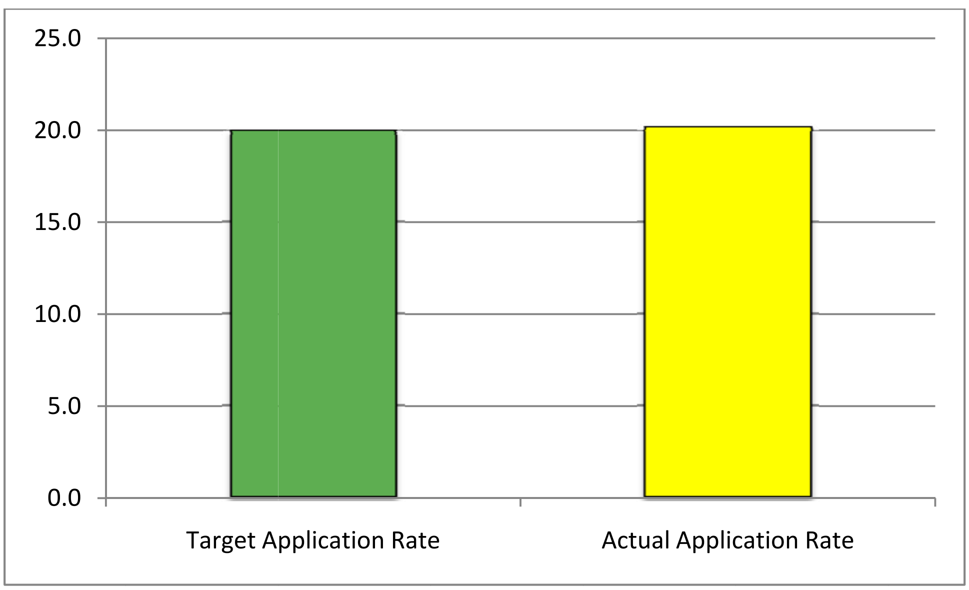

Figure 6. Graph illustrating a visually small difference between target and actual application rates.

Summary

To summarize, the task requirements should guide which presentation format to be used. Optimal displays reduce cognitive demands by providing relevant information quickly and easily to the user. Additionally, mathematical operations should be eliminated or at least reduced to a minimum. The following points are specific to each of the three types of presentation formats discussed: Prose texts, document texts, and graphs.

The literature has supported the following recommendations for displaying numbers in a prose text:

1. Make the text easy to read (e.g., elementary grade level of reading).
2. Use expository texts to convey numerical information.

When document texts (tables) are being considered to present numerical information to users, the following factors should be considered:

1. Minimize visual clutter.
2. Use meaningful titles and headers to organize the numbers.
3. Relevant numbers should be readily available to complete tasks.
4. Do not include irrelevant numbers.
5. Mathematical operations should be reduced or eliminated.

When considering using graphs to display numeric information, designers should ensure that the graph supports the task. For more details about designing graphs, refer to the technical report, “Visual Graph Display Guidelines,” HFA-TR-0803 (Fausset, Rogers, & Fisk, 2008).

PERSON CHARACTERISTICS

Characteristics of the individual must also be considered when designing displays of numerical information. Although the aforementioned factors are important to consider when designing display of numerical information, it is critical that designers understand who their target users are.

Domain Knowledge

Users' experience or domain knowledge will likely influence their performance using a numerical information display (Shah, Freedman, & Vekiri, 2005). If users have extensive experience with a system, they may be able to easily recognize what numerical information is important to understand under specific conditions. Referring back to Figure 1, an experienced user may understand at a glance that a difference between 20.0 gallons/acre target application rate and 20.2 gallons/acre actual applications rate does not require any adjustments or action. However, an inexperienced operator may struggle with understanding the meaning behind these numbers, thus reducing the cognitive resources available for other tasks. Therefore, a designer must consider users' experience when deciding what type of display to use.

Although the ideal situation is to eliminate the need for mathematical operations altogether, there may be occasions and display design trade-offs where this is not feasible. If this issue does arise, designers should try to design a display that requires computation that can be directly retrieved (DeStefano & LeFevre, 2005). By using small value numbers or meaningful numbers to the person or common computations such as "100 + 100," this goal can be accomplished (LeFevre, Sadesky, & Bisanz, 1996).

However, there may be instances when users' past experience and knowledge may be a disadvantage and result in poor performance (Brown & Park, 2002). For example, if a display shows numbers that a user is unfamiliar with or modified versions of numbers that an operator has used in the past, there may be negative carry-over effects (Gick & Holyoak, 1987). An example of a display re-design that did not leverage users' knowledge was the Microsoft Office 2007 Word menu structures. The titles and menus looked similar, but users had to re-learn how to execute what used to be familiar functions. This type of design results in negative carry-over effects along with user frustration with the possibility of discontinued use.

Math anxiety

The role of math anxiety must also be addressed. Task requirements, no matter how "simple" may be cognitively demanding for those who have high math anxiety. Additionally, those with higher math anxiety demonstrated lower working memory capacity (Ashcraft & Kirk, 2001). Thus, it is imperative to understand the target users with respect to their comfort with numerical information. If the majority of the users express math anxiety, then displaying numbers is likely not the ideal display. Instead, displays could use graphs or other visual analogue indicators that represent numerical information.

Working memory

Working memory is part of the memory system that is used for temporarily storing and manipulating information (Baddeley, 1986). Moreover, people have a limited working memory capacity, which is important to recognize when designing numerical information displays. Some people may be able to maximize working memory capacity, whereas others may have lower capacity, perhaps due to reduced cognitive resources (e.g., Craik & Salthouse, 2008) or math anxiety (Ashcraft & Kirk, 2001). Therefore, it is important to provide as much external support to users as possible to reduce demands on working memory (Morrow & Rogers, 2008). For example, if a user must perform several mathematical operations to complete a task, thereby putting high demand on the limited resource of working memory, perhaps the display could instead show the steps and intermediate answers to support the user or, better still, the display could eliminate the need to make calculations by providing the information directly to the user.

Summary

To summarize, it is critical that display designers not only understand the task requirements, number types, and presentation format factors that can influence comprehension of numerical information, but that the target users also be understood. Specifically, the following should be considered when designing a display containing numerical information:

1. Understand who the users of the display will be: Leverage existing knowledge.
2. Recognize that not all people are comfortable dealing with numbers (math anxiety): Design the display accordingly.
3. Reduce working memory demands.

HUMAN FACTORS PRINCIPLES

Number type, task requirements, and person characteristics must all be considered when designing a numerical information display. These factors that influence comprehension cannot be easily untangled. Each aforementioned factor can be studied and manipulated, but the whole display-user interaction is more than the sum of the parts.

Consequently, general human factors principles should guide the design process. A primary tenet of human factors is to "know thy user." It is imperative that designers understand who their target audience is from a physical, perceptual, and cognitive standpoint. Moreover, it is crucial that the target users are involved in testing the display throughout the design process. Such user testing must be conducted with representative users, tasks, and contexts. Design is an iterative process that can be informed by following the guidelines set forth in this report and by involving target users early in the design process.

GUIDELINES FOR DISPLAY OF NUMERICAL INFORMATION

Once designers have determined that the information they want to convey should be numerical, these guidelines can provide a starting point for the development of the display. Guidelines for designing a numerical information display are organized by critical factors as follows:

- **Number type**
  - Natural numbers are the easiest type of numbers for people to understand.
  - Ratio concepts, such as fractions (e.g., 1/6), frequencies (e.g., 3 out of 1000), percentages (e.g., 74%) and decimals (e.g., 35.8) are more difficult for people to understand.
  - Number type should be kept consistent; requiring people to translate between number formats (e.g., between percentage and fraction) will decrease comprehension.
  - Numbers should be meaningful to the users: When scaling numerical information, higher numbers should mean "better," whereas lower numbers should indicate "worse."
- **Task requirements**
  - The display should provide numerical information that is readily available.
  - The user should not have to manipulate or integrate information.
  - Cognitive demands increase as the problem complexity increases (e.g., comparing values is easier than executing multi-step mathematical operations).
- **Interaction between number type and task requirements**
  - The numbers should match the task requirements. For example, if the task requires an answer as a decimal, then the numbers presented should be decimals.
  - Do not present numerical data that must be manipulated between formats (e.g., frequency to percentage).
  - Present fractions and frequencies with same denominators.
  - Using low cognitive demand number types such as natural numbers for a low cognitive demanding task such as magnitude comparison should yield good performance.

    - Conversely, using difficult to process number types such as percentages for a difficult problem type, will likely yield poor performance.

- **Presentation format**
    - Task requirements should guide the presentation format.
    - Optimal displays reduce cognitive demands by providing relevant information quickly and easily to the user.
    - Prose texts (e.g., for instruction manual design):
        - Make the text easy to read (e.g., elementary grade level of reading).
        - Use expository texts to convey numerical information.
    - Document texts (tables):
        - Minimize visual clutter.
        - Use meaningful titles and headers to organize the numbers.
        - Relevant numbers should be readily available to complete tasks.
        - Do not include irrelevant numbers.
        - Mathematical operations should be reduced or eliminated.
    - Graphs:
        - Refer to the technical report, "Visual Graph Display Guidelines," HFA-TR-0803 (Fausset, Rogers, & Fisk, 2008).

- **Person characteristics**
    - Leverage existing knowledge.
    - Recognize that some users may experience math anxiety: May have to reduce or eliminate numbers from the display.
    - Reduce working memory demands.

- **General human factors principles**
    - Understand the physical, perceptual, and cognitive abilities of the target user group.

- Test the users' ability to comprehend the numerical information throughout the design process, not just with the final product.
- Conduct user testing with representative users, tasks, and contexts.
- Consider training and instructional needs for the target population throughout the design process.

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