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### ► **To cite this version:**

Katerina Batziakoudi, Christophe Bortolaso, Jean-Daniel Fekete. We Need to Talk (more) About Numeracy! Toward a Numeracy-Informed Visualization Design Process. VisComm 2025 - 7th Workshop on Visualization for Communication, IEEE VIS Conference, Nov 2025, Vienna, Austria. <10.1109/VisComm69388.2025.00007>. <hal-05241509>

**HAL Id: hal-05241509**

**<https://hal.science/hal-05241509v1>**

Submitted on 5 Sep 2025

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# We Need to Talk (more) About Numeracy!

## Toward a Numeracy-Informed Visualization Design Process

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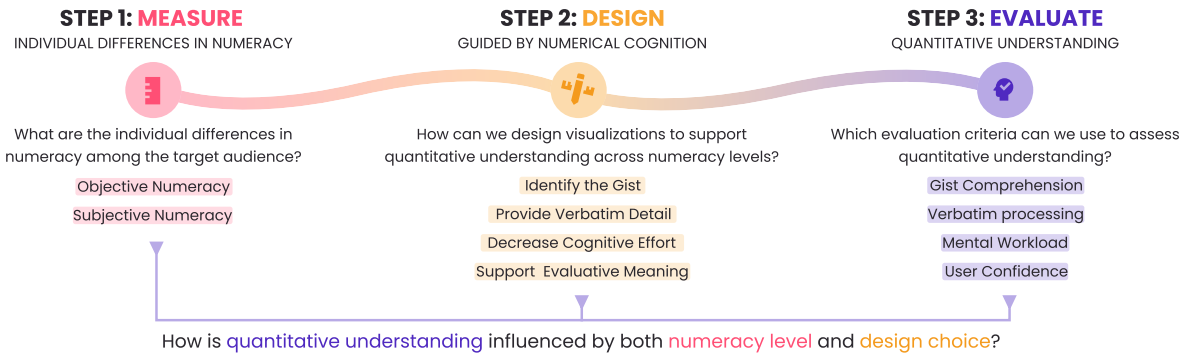


Figure 1: A numeracy-informed visualization design process consists of three key steps: (1) MEASURE individual differences in numeracy, (2) DESIGN guided by numerical cognition, and (3) EVALUATE quantitative understanding. Each step is grounded in concepts and communication strategies drawn from interdisciplinary research on quantitative understanding.

### ABSTRACT

Numeracy—the ability to understand and reason with numbers—is essential for interpreting and acting on quantitative information, yet it remains under-addressed in visualization research. In this position paper, we argue that numeracy should be a guiding principle in the design and evaluation of public-facing visualizations. Drawing on cognitive psychology and decision science, we propose a numeracy-informed design process: (1) measuring individual differences in numeracy, (2) designing visualizations that support gist and verbatim understanding, reduce cognitive effort, and provide evaluative meaning, and (3) evaluating quantitative comprehension across numeracy levels. Our goal is to spark a broader conversation about inclusive visualization practices that reflect numerical diversity and support public understanding of quantitative information.

**Index Terms:** numeracy, individual differences, general public, design guidelines, gist, verbatim.

### 1 INTRODUCTION

Numeracy—an individual’s ability to understand and reason with numbers—requires greater attention in visualization research. Numeric information is a cornerstone of visualization design, whether conveyed through visual channels or embedded in textual elements such as axes, titles, and captions. When designing visualizations for broad public audiences—such as government budgets on official websites, medical statistics in public health reports, or climate data in museum exhibits—the challenge of supporting diverse levels of numerical understanding is critical. Numeracy varies widely across the population [30]. In the U.S., three in ten adults are considered

innumerate, and only one in ten scores at the highest levels [29]. While educational attainment does not guarantee numeracy [37], high numeracy is disproportionately associated with being male, younger, more highly educated, and wealthier [35]. These disparities call into question how well public-facing visualizations serve the full numeracy range of readers—and underscore the need for more inclusive visualization practices that bridge the gap between highly and less numerate individuals.

Individuals with higher numeracy are better equipped to comprehend and engage confidently with numerical information [34]. This allows them to make more informed decisions about their well-being and to form reasoned opinions on societal issues [33]. In contrast, individuals with lower numeracy are more susceptible to misleading data presentations and more vulnerable to cognitive biases such as framing effects and affective heuristics [45, 31]. Research in cognitive psychology and decision science consistently demonstrates that people perceive, interpret, and act on numerical information in ways that vary significantly by numeracy level. Building on this insight, researchers have developed evidence-based strategies for numerical communication that aim to bridge the interpretation gap between highly and less numerate individuals [31, 32]. Despite substantial interdisciplinary evidence highlighting the importance of accounting for numeracy, this perspective remains largely underexplored in visualization research.

Understanding numerical information in visualizations—whether conveyed visually or textually—engages multiple levels of cognitive processing: perception (e.g., recognizing visual quantities), cognition (e.g., interpreting numerical relations), and meta-cognition (e.g., confidence in understanding and communicating the information). Yet, the field of visualization has primarily focused on the perceptual level—for example, by identifying effective visual channels for quantitative attributes and developing guidelines based on the accuracy, discriminability, and separability of these channels [28, 17]. Meanwhile, the influence of individual differences in numerical cognition (e.g., objective numeracy) and meta-cognition (e.g., subjective numeracy) has often been overlooked. This oversight may not have been critical when

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Communication Strategy	Design Guideline	Starter Questions for Practitioners	Cognitive Insight
<b>Identify the Communication Goal</b>	<ul style="list-style-type: none"> <li>- Identify and prioritize the core message of the visualization. Use bold text in titles and reinforce it using preattentive visual cues.</li> <li>- Consider users' prior knowledge needed to interpret the takeaway, and offer support (e.g., hover explanations, tutorials).</li> </ul>	<ul style="list-style-type: none"> <li>- What is the key takeaway users should remember?</li> <li>- Will users grasp the message even if they ignore the numbers?</li> <li>- Do users need prior knowledge to understand the key message?</li> </ul>	People rely on qualitative meaning over precise numbers to interpret and remember quantitative information, especially under cognitive load or with low numeracy [39, 38].
<b>Provide Numeric Information</b>	<ul style="list-style-type: none"> <li>- Include the numerical values that support the key takeaway.</li> <li>- Provide additional details on demand to support transparency and trust for highly numerate users.</li> </ul>	<ul style="list-style-type: none"> <li>- Are numeric values clearly visible?</li> <li>- Can users compare values quantitatively without ambiguity?</li> <li>- Can users easily access more detailed information?</li> </ul>	Numeric information supports analytical processing, enhances transparency, and meets the precision needs of highly numerate users [39, 8].
<b>Decrease Effort</b>	<ul style="list-style-type: none"> <li>- Keep denominators and time spans consistent.</li> <li>- Use small and familiar magnitudes when possible.</li> <li>- Align visual encodings with the mental number line.</li> <li>- Use icon arrays to represent frequencies.</li> <li>- Present information sequentially to avoid overload.</li> </ul>	<ul style="list-style-type: none"> <li>- Can the information be understood without doing math?</li> <li>- Are users familiar with the magnitudes shown?</li> <li>- Is the most important data visually emphasized?</li> </ul>	Reducing mental calculations, minimizing memory load, and aligning with psychophysical principles like the mental number line help reduce interpretation barriers for less numerate users [31, 17, 6].
<b>Provide Evaluative Meaning</b>	<ul style="list-style-type: none"> <li>- Use comparisons to averages, goals, or baselines.</li> <li>- Use analogies, metaphors, or perspectives for large or unfamiliar magnitudes.</li> <li>- Incorporate storytelling and affective visual cues.</li> <li>- Tailor the design to the audience's demographics.</li> </ul>	<ul style="list-style-type: none"> <li>- Is it clear whether the numbers are good, bad, or concerning?</li> <li>- Can users make meaningful comparisons between values?</li> <li>- Is it clear why this information matters for the audience?</li> </ul>	Quantitative data is often affectless and difficult to interpret without context [43]. Narrative elements and affective cues can increase the motivation of low-numerate users to engage with information [31].

Table 1: A starter design guide for public-facing visualizations, based on numeracy-informed communication strategies. Each strategy includes design actions, reflection prompts for practitioners, and cognitive insights grounded in interdisciplinary research.

supporting relatively simple visualization tasks, such as sorting values or comparing small magnitudes. However, as public-facing visualizations increasingly aim to communicate more complex numerical concepts—such as risk, uncertainty, and large or unfamiliar magnitudes—the cognitive demands on the reader grow, making it essential to account for differences in numeracy and expand existing design guidelines.

Acknowledging and measuring individual differences in numeracy is a necessary first step toward narrowing the interpretation gap between highly and less numerate readers of public-facing visualizations. In this position paper, we take the conversation further—advocating for numeracy to be treated not merely as a user trait, but as a guiding principle in visualization design and evaluation. In the following sections, we introduce key concepts and measures of numeracy and propose a numeracy-informed design process (Figure 1) grounded in evidence-based numerical communication strategies [32, 31]. To support practical application, we present a numeracy-informed design guide (Table 1) that translates theory into actionable questions and recommendations for improving quantitative understanding. We hope the proposed visualization design process and guidelines serve as both a resource for public visual communicators and a foundation for raising new questions and shaping future research directions.

## 2 UNDERSTANDING NUMERACY

Numeracy is more than just mathematical ability; the Organization for Economic Cooperation and Development (OECD) defines it as “the ability to access, use, interpret and communicate mathematical information and ideas in order to engage in and manage the mathematical demands of a range of situations in adult life [30].” This information may appear as exact numbers (e.g., frequencies, percentages, monetary values, trends), mathematical operations (e.g., subtraction, division), or descriptive terms (e.g., “few,” “higher,” “monthly,” “associated”) [31]. While numerical data are objectively defined, their interpretation is inherently subjective, shaped by how the information is presented and framed, and further influenced by individual abilities, experiences, and beliefs. A substantial body of interdisciplinary research explores how individuals perceive, interpret, and apply numerical information. In this context, we introduce four foundational concepts that can inform the design of

communicative visualizations: *Intuitive number sense*, *Fuzzy-Trace Theory*, *Objective numeracy*, and *Subjective numeracy*.

**Intuitive number sense**, also known as the approximate number system (ANS), refers to an evolutionarily ancient ability to perceive and compare quantities—whether in terms of discrete object counts or continuous magnitudes—without relying on counting or calculation [25]. This system supports fast, imprecise estimations and is linked to how humans spatially represent numbers. Although the ANS enables ordering of quantities, our perception of magnitude is subject to several psychophysical distortions [39]. For instance, we tend to perceive small magnitudes linearly, but as magnitudes increase, perceived differences depend more on ratios than on absolute values [16, 22]. Discriminability also decreases with larger magnitudes. For example, the difference between 0 and 500 is perceived as greater than the same objective difference between 500,000 and 500,500 [39]. These psychophysical patterns suggest that people do not perceive raw physical quantities directly, but instead translate them into mental representations of magnitude that are shaped by context. However, numeracy relies not only on an intuitive sense of number but also on judgment and decision-making processes, as explored in behavioral economics and cognitive psychology through theories such as Fuzzy-Trace Theory.

**Fuzzy-Trace Theory** explains that individuals form two types of mental representations of numerical information: *verbatim* and *gist* [39]. Verbatim representations capture the exact, surface-level details—such as specific numbers or exact phrases—without necessarily embedding meaning. In contrast, gist representations are imprecise but meaningful interpretations that distill the essential qualitative content of information (e.g., “some versus none” or “more versus less”). Gist representations are more likely to be retained in long-term memory and transferred to new contexts. According to this theory, people tend to rely more on gist than on verbatim when making judgments or decisions. This reliance affects quantitative understanding because it highlights how people infer meaning rather than merely recall data [38]. Importantly, the ability to extract and apply gist varies with numeracy levels, both objective and subjective, discussed in the next paragraphs.

**Objective numeracy** refers to formal mathematical skills typically acquired through education. These skills range from performing basic arithmetic operations with whole numbers (Level 0, based

on the OECD proficiency levels [29]) to reasoning about abstract and unfamiliar concepts, such as statistical inference and mathematical formulas (Level 5, based on the OECD proficiency levels [29]). Various standardized self-assessed tests have been developed to measure objective numeracy, often tailored to specific contexts such as statistical reasoning [26], risk assessment [12], or health numeracy [41]. The choice of test depends on the characteristics of the target population and the type of quantitative information involved. Among the most widely used measures are the Lipkus Numeracy Scale (low difficulty) [26] and the Berlin Numeracy Test (high difficulty) [12], both of which are designed to assess statistical reasoning.

**Subjective numeracy** refers to an individual’s confidence in their ability to understand mathematical concepts and their preference for engaging with numerical information [45]. While it is informed by objective numeracy, it is metacognitive and therefore vulnerable to self-assessment biases [39]. These include the Dunning–Kruger effect, where individuals with lower numerical skill overestimate their competence, as well as internalized ethnic or gender stereotypes that affect self-perception. Subjective numeracy is also linked to related constructs such as mathematical anxiety. These metacognitive aspects are crucial, as even individuals with high numerical ability may struggle to apply their skills effectively without sufficient confidence [36]. Subjective numeracy measures [45, 27] offer a proxy for objective numeracy: they are easy to administer and moderately correlated with objective ability.

Together, these concepts highlight the complex and multidimensional nature of quantitative understanding. They demonstrate that by just using “expressive” and “effective” visual channels for quantitative data attributes—while necessary according to established visualization guidelines rooted in principles of the ANS—is not sufficient for designing effective visualizations that communicate quantitative information. Numerical reasoning depends on how people perceive numbers in context, as well as how they interpret them based on their abilities, biases, and confidence in their understanding. People engage with numbers through both precise, literal representations and imprecise but meaningful gist interpretations, each of which plays a vital role in quantitative understanding, memory, and decision-making. Moreover, individual differences in numerical ability and confidence critically shape how information is interpreted, thereby influencing the effectiveness of communication strategies. To support meaningful engagement with numerical information, visualizations must therefore draw upon psychophysical principles of numerical perception, promote both accurate interpretation and meaningful gist extraction, and accommodate diverse numeracy levels.

### 3 A NUMERACY-INFORMED DESIGN PROCESS

In this section, we present a numeracy-informed visualization design process (Figure 1)—grounded in interdisciplinary research on numerical communication—to guide future efforts in designing public-facing visualizations that more effectively support quantitative understanding. While visualization research has addressed elements of this process individually—such as accounting for individual differences in numeracy [2, 23, 5], reducing cognitive load [9, 3, 1], or advocating for narrative and affective meaning [42, 21, 24]—to our knowledge, no existing work systematically integrates all three steps we propose: **measuring numeracy**, **designing with a focus on numerical cognition**, and **evaluating quantitative understanding**. We view these individual studies as foundational pieces of a larger puzzle, one that can help clarify the role of numeracy in visualization, inform how to design for varying numeracy levels, and establish how to assess the effectiveness of visualizations across audiences. The design process we present is primarily intended for visualization researchers conducting empirical studies with the general public. However, visualization designers

who do not conduct experiments may still benefit from acknowledging numeracy differences in the target population and from the subsection **Step 2: Design Guided by Numerical Cognition**, which offers practical strategies that can serve as design guidelines for effectively communicating quantitative information (Table 1).

#### 3.1 Step 1: Measure Numeracy

The first essential step in a numeracy-informed visualization design process is to account for individual differences in numeracy, particularly when evaluating the effectiveness of different visualizations or examining the influence of cognitive biases on sense-making and decision-making. Research has shown that individuals with low numeracy are more susceptible to cognitive biases and more influenced by narratives and emotional content [45, 31]. In contrast, highly numerate individuals are typically less sensitive to presentation formats and can more readily translate numbers into meaningful interpretations [34, 33]. Failing to measure numeracy levels risks obscuring important differences in how visualizations are perceived and understood. This can lead to findings whose validity across numeracy groups is unknown, potentially resulting in misleading design recommendations that serve only a subset of the population. To avoid this, it is crucial to *incorporate numeracy measures into study designs*. Further research is needed to understand when design interventions, embellishments, or interaction help enhance numerical reasoning across the board, and when they instead widen gaps by primarily benefiting the highly numerate.

Ideally, researchers should *assess both objective and subjective numeracy* [13]. However, both approaches come with limitations. Peters notes that as objective numeracy tests become more widely used, participants—especially in online studies—may already know the answers or search for them during the experiment [31]. To mitigate these concerns, researchers are advised to clearly instruct participants not to look up answers or use calculators and to report if they do [31]. Many objective tests are also domain-specific, limiting their applicability across different contexts and populations. Additionally, objective tests can increase study length and participant fatigue, particularly in crowdsourced experiments. To address these challenges, some researchers turn to subjective numeracy measures [45, 27], which are quicker to administer and have been shown to correlate moderately with objective numeracy. While not without caveats (as discussed in the previous section), subjective measures offer a practical way to integrate numeracy into visualization studies. Still, more research is needed to determine the optimal use of both objective and subjective assessments across different experimental setups, participant pools, and visualization goals.

#### 3.2 Step 2: Design Guided by Numerical Cognition

The second step in a numeracy-informed visualization design process is to guide design decisions using principles from numerical cognition and insights from numeracy research. The guidelines we present are adapted from established strategies for communicating numerical information, grounded in findings from cognitive psychology, decision science, and science communication [32]. We build on the taxonomy proposed by Peters [31], tailoring each strategy to the context of visualization design. As noted earlier, these guidelines are not new to the visualization domain—many are already reflected in existing studies and design practices [24, 17]. However, our goal is to prompt critical reflection: What might current visualization guidelines be overlooking when it comes to effectively communicating numbers? And how might they be enriched by adopting an interdisciplinary, numeracy-informed perspective?

### 3.2.1 Identify the Goal of Communication or “The Gist”

A numeracy-informed visualization design process begins with clearly identifying the communication goal, or the gist—the bottom-line meaning the audience should take away. Rather than letting arbitrary rules about how data should be objectively displayed dictate design decisions, cognitive psychologists argue that the gist should shape the visualization, not the other way around [39]. *Prioritizing the qualitative message*—what the numbers mean and why they matter—can prevent visualizations from obscuring meaningful differences or overemphasizing trivial ones. When visualizations are designed to convey this core meaning, rather than merely displaying precise values, the result could be more accessible, interpretable, and actionable. This shift in focus moves the goal of communication beyond correcting biases, toward fostering a deeper connection between the data and the real-world values or decisions it informs. The gist can be conveyed both verbally, through the title or caption of the visualization, and visually, through cues that reinforce the intended message. As Fischhoff notes [15], communicators must also *consider what people already know, what they do not know, and what they need to know* to make informed decisions. Acknowledging these dimensions early in the design process helps guide critical decisions, such as the choice of visualization idiom, the use of interaction, the presence of explanatory text, or the inclusion of tutorials. Neglecting users’ prior knowledge or numeracy levels risks misinterpretation and cognitive overload. Throughout the design process, communicators should continually reflect on whether their choices remain aligned with the original goal and the audience’s interpretive needs.

### 3.2.2 Provide Numeric Information or “The Verbatim”

While designing for gist ensures that audiences grasp the essential meaning of quantitative information, this does not diminish the importance of also *presenting precise numerical values*: the verbatim. As Reyna and Brainerd [39] emphasize, both verbatim and gist representations are encoded in parallel and serve complementary roles in reasoning and decision-making. Verbatim information supports analytical processing, enhances transparency, and accommodates users with higher numeracy who rely on numerical precision. Including exact numbers could foster trust by signaling openness and allowing verification, which is particularly important in public contexts where perceived bias or oversimplification can erode credibility [14]. Empirical studies further support the value of presenting numeric information. For example, supplementing qualitative labels like “low chance” with numerical ranges has been shown to improve public understanding and alignment with expert guidelines, such as those issued by the IPCC [8]. Similarly, individuals—regardless of numeracy level—made more accurate risk estimates and better-informed decisions when provided with numeric data rather than non-numeric descriptors [33]. In visualization, combining categorical or ordinal gist cues (e.g., annotations or labels) with precise numerical data enables users to engage at their preferred cognitive level. Providing precise numbers is especially important when dealing with large or unfamiliar quantities where established *reference points* are often missing (see section 3.2.4). For example, the public may struggle to interpret figures related to government budgets or carbon footprints without a prior sense of scale. In such contexts, meaningful gist extraction becomes difficult. Studies show that individuals frequently overestimate or underestimate the carbon emissions of everyday actions, and this misjudgment is more strongly correlated with numeracy than with political or environmental values [44]. Consistent exposure to specific numerical values over time could foster a more calibrated quantitative understanding of different scales, supporting public numeracy.

### 3.2.3 Decrease Cognitive Effort

Even when both gist and verbatim representations are addressed, numerical communication can still fall short—particularly when it imposes excessive cognitive demands or conflicts with the psychophysical principles of numerical perception. Reducing cognitive effort involves *simplifying numerical content* and *minimizing the mental computations required*. For example, communicators should favor absolute over relative risks: stating that a risk increases from 0.01% to 0.02% conveys far more meaningful context than saying it “doubles,” which could equally apply to a shift from 30% to 60%. Similarly, keeping denominators and time spans consistent (e.g., comparing 5 out of 100 to 25 out of 100 is easier than comparing 1 out of 20 to 1 out of 4) avoids the need for mental conversions, supporting magnitude understanding, especially for less numerate individuals. A visualization example is the use of icon arrays to represent frequencies; this imaginary visual approach supports proportion comparisons and reduces the need for mental computation [19]. To prevent magnitude neglect, large values should be framed in more relatable terms, and smaller magnitudes should be used to enhance discriminability—for example, by presenting budgetary data per capita instead of total amounts [7].

Cognitive effort can also be reduced through structural strategies, such as *presenting information sequentially*. The visualization domain offers rich insights into how design can reduce cognitive load and guide attention. Franconeri et al. [17] emphasize that effective visualization design must respect the limits of visual working memory and attentional control, which are core bottlenecks in human information processing. Designs that overwhelm users with dense or comparison-heavy content can easily exceed these cognitive limits, especially for individuals with lower numeracy. Furthermore, visualization designs that *align with the mental number line* can reduce perceived effort and increase confidence in quantitative estimations across numeracy levels [6]. For instance, piecewise-linear bar charts—designed to reflect how people mentally represent large magnitudes [22]—facilitate quantitative comparisons more effectively than dominant formats like logarithmic scales [5, 6], which are often difficult for the general public to interpret [11, 40] and typically favored by highly numerate individuals [6]. Together, these principles can reduce cognitive load and enhance the communicative power of public-facing visualizations. However, future studies should investigate whether these strategies are equally beneficial across numeracy levels or whether they may hinder understanding, engagement, or trust for some segments of the population.

### 3.2.4 Provide Evaluative Meaning

The final, essential ingredient in truly making numbers count in public-facing visualizations is providing evaluative meaning—what a number implies, whether it is desirable or concerning, and why it matters in context. Numbers, particularly large or unfamiliar ones, are often affectless and difficult to interpret without additional framing [32]. As Thaler’s theory of *mental accounting* explains, people interpret values not in isolation but relative to internal reference points [43]. These frames help assess whether an outcome represents a gain or loss, good or bad. Comparative *reference points*—such as national averages, policy goals, or personal baselines—can transform abstract quantities into meaningful evaluations. For instance, stating that a specific French citizen emits 3 tonnes of carbon annually is not inherently informative unless it is contextualized against benchmarks like the national average (4 tonnes) or the Paris Agreement’s recommended limit (2 tonnes). Such *comparisons* help readers situate the number within a meaningful frame, making it easier to understand, evaluate, and act upon.

*Visual analogies, metaphors, and perspectives* are also crucial tools for providing evaluative meaning. Barrio et al. [4] demonstrated that using “perspective sentences”—for example, “300 million firearms is about one per person in the United States”—can en-

hance people’s comprehension of unfamiliar numbers, aiding memory, estimation, and error detection. Galesic and Garcia-Retamero similarly found that presenting the consequences of risky behaviors in terms of months of life lost or gained improved recall more effectively than expressing the same information in terms of disease likelihood [18]. These analogies proved especially helpful across numeracy levels: they benefited high-numeracy participants when problems were difficult and low-numeracy participants when problems were easier [19]. *Narrative framing and affective cues* also shape interpretation, particularly for less numerate individuals, who appear to better engage with and understand quantitative information when storytelling and emotional resonance are involved. Furthermore, *tailoring evaluative cues* to specific communities or demographic groups can enhance perceived relevance and boost motivation. As Peters notes, numeracy differences are less likely to affect understanding when motivation is high and when comparisons are concrete and easily evaluated [31].

These techniques are not unfamiliar within the visualization community. For example, Chevalier et al. [10] explored how unfamiliar magnitudes can be grounded using concrete scales, such as visualizing sugar content with unit-based sugar cubes. The field also boasts a rich body of literature on storytelling, user engagement, and the role of affect [42, 24]. However, it remains unclear whether these techniques are effective across numeracy levels or whether they meaningfully improve quantitative understanding for less numerate individuals. Based on findings from other fields, one might hypothesize that evaluative meaning based on comparisons would benefit the highly numerate more, while narrative and more imaginable formats would help the less numerate. However, further research is needed to examine the specific impacts of various evaluative strategies on audiences with different numeracy levels.

### 3.3 Step 3: Evaluate quantitative understanding

The final step in a numeracy-informed visualization design process is to evaluate whether a visualization effectively enhances quantitative understanding across different levels of numeracy. Traditional evaluation metrics, such as task completion time or error rates, can capture aspects of *verbatim processing* or comparative cognitive effort between visualization types. However, they often fall short in assessing whether users truly grasp the intended message. *Gist comprehension*, which is critical for meaningful quantitative understanding, may require complementary qualitative methods such as open-ended summaries, recall tasks, or scenario-based activities in which participants must use numerical data to solve real-world problems. These approaches can reveal which designs support interpretive insight, rather than mere information retrieval.

To understand how visualization design interacts with cognitive effort—an important barrier for individuals with lower numeracy—it is essential to assess both subjective and objective *indicators of mental workload*. Self-report tools, such as the NASA-TLX [20] or subjective cognitive load ratings grounded in Cognitive Load Theory [9], can provide insight into perceived effort. Objective measures, such as eye-tracking, pupillometry, or electroencephalography, can offer complementary physiological indicators of cognitive load. These metrics are particularly valuable if interpreted alongside individual differences in numeracy. This multidimensional approach could help clarify how visualizations perform across cognitive and numeracy profiles and could identify design guidelines that reduce effort for low-numeracy users without compromising the experience for highly numerate audiences.

Equally important is accounting for *user confidence*, a critical but often overlooked factor in numerical interpretation. Confidence influences whether individuals act on their understanding; even accurate interpretations may fail to lead to insight or decision-making if confidence is low [39, 36]. Confidence should be evaluated alongside cognitive load and numeracy, as it shapes how effortful under-

standing translates into action and potentially into trust. Ultimately, a multidimensional evaluation approach can identify which visualization strategies most effectively support inclusive and meaningful quantitative understanding. Further research is needed to develop robust evaluation protocols that advance this goal.

## 4 CONCLUSION

As visualization researchers and designers, we are increasingly called upon to make numbers meaningful for the public; yet we often overlook the very factor that determines whether people will understand them: numeracy. In this position paper, we argue that numeracy should not be treated merely as an individual difference in user studies, but as a central principle guiding both design and evaluation. Drawing on interdisciplinary research, we propose a three-stage design process—measure, design, and evaluate—that could support the creation of more inclusive and effective communicative visualizations. This design process calls for a shift in mindset: from designing for an “average” user to recognizing differences in numeracy; from optimizing perceptual precision to supporting meaningful gist; and from evaluating performance in isolation to assessing interpretive insight, cognitive effort, and user confidence. Our aim is not to prescribe definitive solutions for how best to measure, design, or evaluate, but rather to highlight the pivotal role of numeracy, to connect our field with insights from other domains, and to propose an initial set of guidelines informed by this perspective. Most importantly, we hope to raise questions and invite the visualization community to more fully integrate numeracy into its research agenda.

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