Position Paper: Potential Areas of Bias in Visualization-as-Input Systems

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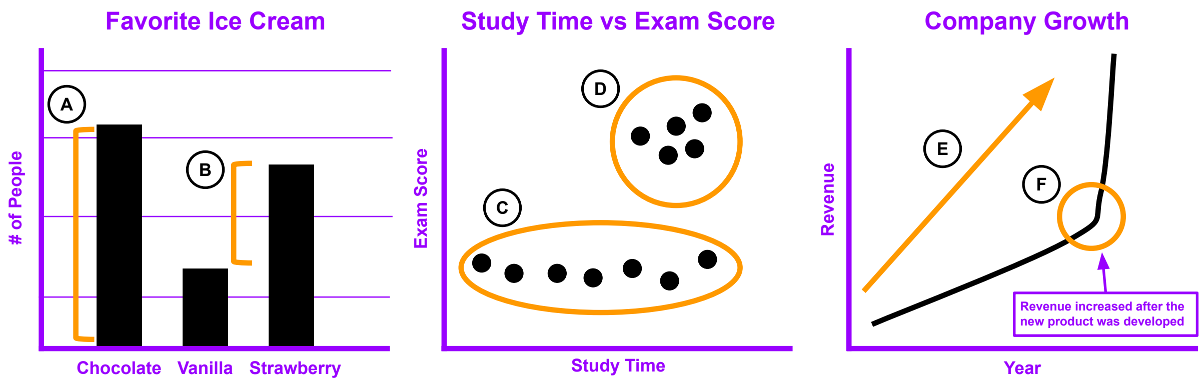

Figure 1: Examples of possible scaffolding elements (purple), visual structures such as titles, axes, and grid lines that frame the parameters and context for the user, and anchor points (orange), salient features that draw attention and serve as reference markers for interpretation, such as the length of the highest bar (A), the difference in bar lengths (B), recurring values (C), clusters (D), the overall direction of the data (E), or noticeable changes (F).

Abstract

Visualizations are typically seen as tools for interpreting and analyzing data, yet in visualization-as-input systems, where users enter information directly into a visual interface, the structure of the visualization may actively shape the data input by the user. This paper argues that visual aspects such as Scaffolding Elements (e.g., axes, ranges, and labels) and Anchor Points (e.g., visualized data) influence what users perceive as appropriate, complete, and accurate input. I outline a high level research agenda for the community to empirically study how these structural aspects guide user input. By reframing visualization-as-input as a dynamic way to elicit data, I highlight the need for design strategies that mitigate bias and promote more authentic and representative user data.

Index Terms: Visualization, Psychology, Design, Experimental design.

1 Introduction

Data visualizations are often used as analytical tools, enabling individuals to observe trends and patterns that may not be readily apparent from raw data. This use case is especially true for personal data, where visualizations are commonly used to support introspection and understanding of one's behaviors and history [4, 5, 13]. However, most of this work assumes that the data being visualized is already fixed and unbiased, treating the visualization as a passive lens through which the user derives meaning.

In visualization-as-input systems, where individuals contribute data directly through a visualization, the presentation of axes, ranges, comparative data, and other structural elements may influence how users interpret prompts and what they ultimately report. Rather than serving merely as a neutral output for data, the visualization becomes part of the data generation process itself, creating subtle biases.

There is a growing need to examine how the structure of the visualization itself influences the data that users choose to input in the first place. The framing provided by visualizations may strongly shape and bias what data the users input. In this paper, I call for deeper investigation into how visual frameworks guide, constrain, or bias user input during the act of data entry when using a visualization-as-input system.

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2 How Visualization-as-Input Influences Users

Unlike conventional forms of data input, visualization-as-input introduces a visual structure that potentially shapes the cognitive and behavioral processes of users as they enter data. Rather than starting from a blank field or an open-ended prompt, users engage with a pre-structured environment that includes both visual constraints and implicit reference points. This environment is composed of two primary mechanisms that guide and bias user input: Scaffolding Elements and Anchor Points (See Figure 1.

2.1 Scaffolding Elements and Anchor Points

Scaffolding Elements are the components of a visualization that organize, guide and annotate the visualization without being data themselves. These include axis lines, tick marks, value ranges, grid lines, labels, layout dimensions, and color schemes. Such elements signal to users the kinds of responses that are expected or valid, setting cognitive boundaries on what they consider as plausible inputs.

Prior work demonstrates that even seemingly minor Scaffolding Elements can exert measurable influence on user input. For example, one study systematically varied the visual appearance of sliders and found that features such as tick marks, labels, and banded designs significantly biased responses, even when they carried no functional constraints on interaction [9]. The simple presence and positioning of ticks created clustering effects around those points, altering the distribution of collected data. The visual encoding of the input space encourages users to fit their responses within the available structure, which can oversimplify or distort their internal understanding. Other research has also shown that axis ranges can significantly impact how people perceive and report their data, often shifting responses toward the center or endpoints of the scale depending on how values are visually framed [12]. These findings underscore the importance of treating Scaffolding Elements not as neutral design choices, but as active components that structure and potentially bias user input.

In some cases, Scaffolding Elements may unintentionally suppress meaningful variability. If the structure over-constrains the input, such as through overly coarse bins or an overly narrow axis range, it can restrict expression and push responses toward visual or categorical norms. On the other hand, when Scaffolding Elements are too vague or open-ended, it may lead to hesitation or confusion, where users feel uncertain about how to respond within the system's framework. Scaffolding Elements therefore do not merely support input, they also shape perception, reinforce assumptions, and can introduce unintended biases into the data collection process.

Anchor Points, in contrast, refer to features of the data that are being visualized and serve as referential markers against which users compare their own input. These Anchor Points can take the form of peer data, population averages, expert benchmarks, prior entries, or any pre-existing visual data shown alongside the user's current input task. Anchor Points play a subtle but powerful role in shaping user judgments. A user viewing a population average for blood pressure might report a slightly lower or higher personal value, depending on whether they want to signal typicality, deviation, or improvement. Similarly, when past entries are visible, users may consciously or unconsciously strive for consistency or continuity, even if their current experience differs from prior states [8].

Although technically all data within the input-visualization system could act as an Anchor Point, the more pronounced or salient a feature is, the more likely it will be used to anchor an individual's attention. It is also possible that different features could anchor at different levels depending on the user's task. For example, the overarching slope of a line chart might serve as the anchor for one individual, while the extremes of the same line chart could act as anchors for another.

In visualization-as-input systems, the influence of Anchor Points is amplified by the salience of the visual reference, which can shift the user's mental model in real time. Anchors can nudge users toward certain value ranges, subtly framing the answer space even in the absence of explicit instruction.

Scaffolding Elements and Anchor Points interact closely with users' mental models, reconstructing the frame through which questions are understood and responses are formulated. Scaffolding sets the visual boundaries and affordances for action, while Anchor Points populate that space with contextual cues that guide interpretation. Together, they shape how the user makes sense of the input process itself. Understanding this interaction is essential for evaluating the validity and reliability of data collected through visualization-based input systems.

2.2 Existing Biases

While Anchor Points and Scaffolding Elements provide valuable structure for personal data input, there are additional biases to consider that may influence user behavior. These biases can shape not only the distribution of input values but also the very way users conceptualize what they are reporting. Below, I outline a non-exhaustive set of potential biases that may arise in this context and warrant consideration.

Variable Coupling vs. Separation: The way input dimensions are scaffolded can influence how users relate variables to one another. For example, specifying two variables within a single 2D input field may implicitly suggest an interdependence between them, while presenting two separate 1D sliders frames them as independent dimensions. This structural choice may bias users toward perceiving or reporting relationships that do not exist in their actual experience.

Framing Bias in Available Inputs: The Scaffolding Elements of input ranges, categories, or scales constrain the possible values users can enter. A Likert scale, for instance, enforces a discrete, linear framing of a phenomenon that might be nonlinear or categorical in practice. Similarly, axis ranges can exaggerate or minimize differences in the data, anchoring users toward particular interpretations. By restricting the space of possible answers, input visualizations may inadvertently steer users toward biased or incomplete representations of their experiences.

Social and Comparative Influences: Anchor Points derived from social data (e.g., peer averages, population benchmarks) can trigger conformity bias, where individuals shift their input toward perceived norms. Even when these references are presented as optional or informative, they act as subtle nudges that reshape user input through social comparison.

Complexity and Cognitive Load: Scaffolding Elements that increase visual or conceptual complexity can overwhelm users, leading them to adopt heuristics rather than carefully considering their inputs. For example, overly dense tick marks or multiple overlapping Scaffolding Elements may nudge users toward simplifying their responses, biasing the data toward more "available" values.

Taken together, these biases highlight the dual role of Scaffolding Elements and Anchor Points, as they are not neutral containers for input but active design choices that can support, constrain, and bias how users express their personal data. Designing input visualizations therefore requires careful attention to these potential biases, balancing the benefits of structure against the risks of distortion.

3 Related Theories

In this section, I ground the proposed research in established theoretical frameworks.

3.1 Affordances and Signifiers

Similar work has been conducted more broadly within Human-Computer Interaction. The concepts of Scaffolding Elements and Anchor Points in visualization-as-input systems connect closely to established theories of affordances and signifiers in interaction design [11]. Gibson's original theory of affordances described the set of possible actions that an environment enables for an agent, whether or not those actions are perceived [3]. Norman [10] extended this concept to design, emphasizing perceived affordances as cues that guide users toward appropriate interactions.

Within Norman's framework, Scaffolding Elements such as axes, ranges, or grid lines can be understood as signifiers. They do not merely afford input but actively signal boundaries and expectations for how data should be entered. Anchor Points, in turn, can be viewed as a form of social signifier. Visualized peer averages or population benchmarks act as cues about what values are typical, appropriate, or desirable. Even when not explicitly designed to influence behavior, these Anchor Points can shape interpretation by leveraging users' social comparison tendencies.

3.2 Nudge Theory

The concept of Anchor Points also aligns with Thaler and Sunstein's framework of nudges in behavioral economics [7, 1]. A nudge is any aspect of a system that predictably alters behavior without forbidding options or significantly changing incentives. Anchor Points such as population averages or peer data function in this way as they do not restrict what value a user can input, but they subtly shift perception and decision-making through the anchoring bias. For example, presenting a benchmark value within a visualization primes users to treat it as a plausible reference, often leading them to adjust their input closer to that anchor than they otherwise would.

Framing Anchor Points as nudges situates visualization-as-input within broader conversations about behavioral influence. From this perspective, Scaffolding Elements define the choice environment (e.g., ranges, axes, scales), while Anchor Points act as nudges within that environment, steering users toward certain interpretations or behaviors without explicit coercion. This framing highlights both the potential benefits and risks of design. Well-chosen nudges can encourage more accurate or reflective self-reporting, but poorly chosen anchors may distort input or reinforce harmful norms.

3.3 Default Effects

Finally, another relevant perspective is research on default effects, the tendency for people to stick with pre-set options rather than actively change them [6, 2]. Unlike nudges or signifiers, defaults shape interpretation through framing and signaling, they structure behavior by making one option the path of least resistance. In visualization-as-input systems, defaults might appear as pre-filled values, suggested scales, or automatically generated starting points. While defaults can reduce cognitive load and streamline entry, they also risk biasing users toward values that do not fully represent their lived experiences. Considering default effects alongside nudges and signifiers underscores the need for careful evaluation of how Scaffolding Elements and Anchor Points influence input, not only by supporting usability but also by mitigating unintended cognitive bias.

4 Proposed Use Case: Sketching Health Histories

To illustrate the interaction of Scaffolding Elements and Anchor Points on users, consider a prototype system where individuals input their health histories into a visual sketching tool. As users respond to a series of prompts about their medical history, the system dynamically constructs a timeline or visual narrative of their health events.

In such a system, the visualization updates in real time and provides immediate visual feedback based on the user's inputs. This live rendering may unintentionally shape the way users interpret questions or recall experiences. For example, users may become more detailed in their responses in order to fill perceived gaps or make the resulting visualization feel more complete. Others might change or omit information based on how their input appears on screen, perhaps modifying symptom descriptions to match what they perceive as important based on how elements are emphasized.

This iterative feedback loop could mean that visualization-as-input is not a neutral act of recording, but an active, interpretive process. The evolving visualization can subtly influence what users choose to share, how they prioritize certain experiences, and whether they feel their input has been adequately represented. In this way, the system's dynamic rendering becomes a behavioral influence, shaping both how data is visualized and how it is produced.

5 Future Research Avenues

Understanding the biases of visualization-as-input systems requires empirical study. I propose future research that integrates both quantitative and qualitative methods to explore how Scaffolding Elements and Anchor Points influence user input.

5.1 Scaffolding Element Experiments

To better understand the role of Scaffolding Elements in visualization-as-input systems, quantitative lab studies can be systematically designed to isolate and manipulate different Scaffolding Elements. These experiments would vary parameters such as axis range, granularity, visual hierarchy, chart type, and even layout density, in order to observe how each factor influences the way individuals perceive, interpret, and ultimately input their data.

For example, altering the scale of an anxiety rating chart from a 1–5 scale to a 1–100 scale does not simply change the precision of input, it also redefines what users perceive as a "normal" or "acceptable" response range [12]. A user might rate their anxiety as a "3" on a 1–5 scale, but may shift toward a more specific "55" on a 1–100 scale, not because their experience has changed, but because the Scaffolding Elements alter the expressive granularity and perceived social framing of the number. This type of distortion becomes even more significant when users interpret larger or more precise scales.

Other variations could include the presence or absence of grid lines, the use of linear vs. logarithmic scales, or the ordering of categorical options. Each of these design choices implicitly communicates assumptions about the data being collected and may guide users toward certain interpretations or away from others. For instance, presenting a question with a stacked bar chart may emphasize proportion and comparison, while a slider may encourage users to treat the value as continuous and fine-tuned.

These quantitative manipulations should be paired with qualitative methods to capture the user's internal reasoning. Post-task interviews and think-aloud protocols can reveal how users perceived the boundaries, granularity, and intent behind the Scaffolding Elements. Participants might reflect on whether they felt constrained or guided by the visual layout, whether certain ranges felt more appropriate than others, or whether they second-guessed their inputs due to how the system presented the information.

Additionally, mixed-method approaches can help uncover mismatches between designers' intent and users' interpretation of Scaffolding Elements. For instance, designers may choose a simplified visualization to reduce complexity, while users might perceive the simplicity as a signal that nuance or detail is unwelcome. By surfacing these interpretations, researchers can refine how Scaffolding Elements are used to support clarity without unintentionally introducing bias or suppressing meaningful variance.

Ultimately, these experiments will contribute to a more nuanced understanding of how Scaffolding Elements function as both a visual aid and behavioral influences within data entry systems. Such insights could be important for improving the validity of visualization-as-input systems.

5.2 Anchor Point Experiments

In addition to Scaffolding Elements, Anchor Points play a pivotal role in shaping how users input data within visualization-as-input systems. Anchor Points serve as visual reference markers, such as benchmarks, prior entries, or norms that inform the user's understanding of what values are expected, common, or desirable. Further experiments can be designed to investigate how different types of Anchor Points influence the user's input.

Comparing Anchor Points to user input can be particularly influential in domains involving subjective input, such as self-assessments of pain, mood, physical activity, or symptom frequency. The presence of a visual anchor not only offers a point of comparison, but also subtly implies a value judgment about where one should fall within that space.

One proposed approach is to systematically compare the effects of different anchor point conditions in relation to personal data input. These conditions aim to uncover how different forms of comparative reference influence the way users report on their own experiences, behaviors, and states.

- **Only their own past data:** Users are shown their historical responses, enabling longitudinal comparison and potentially encouraging consistency or self-correction.

- **Aggregated peer data:** Users see anonymized responses from others in similar demographic or situational groups, allowing for social comparison.

- **Population benchmarks:** Users are presented with standardized or expert-defined values, framing input around what is statistically or clinically considered ”normal.”

- **No comparative data:** Users provide input without any external reference, creating a baseline condition for evaluating the influence of Anchor Points.

These conditions allow researchers to examine how self-based, social, and normative comparisons differentially shape user input. For example, users exposed to peer data might feel compelled to align their input with the group, either consciously, to fit in, or unconsciously, due to perceived norms. In contrast, those shown population benchmarks might adjust their responses upward or downward depending on whether they want to express normality, deviance, or improvement. Users presented with their own past data may demonstrate anchoring effects that prioritize consistency, even when current states differ significantly from prior ones.

To complement these controlled comparisons, follow-up qualitative methods such as retrospective interviews or think-aloud protocols can probe participants' internal reasoning. Questions might explore whether they noticed the comparative information, whether it influenced their interpretation or response, and how they felt about deviating from visible norms. These reflections can provide insight into how Anchor Points are not just visual artifacts but also psychological cues that interact with users' mental models, identities, and goals.

Finally, it is crucial that these studies account for the interplay between Scaffolding Elements and Anchor Points. Scaffolding Elements do not exist in isolation, but instead provide the visual context within which Anchor Points are interpreted. For instance, a population average marked near the end of an axis might be perceived as abnormally high, while the same value placed at the midpoint might appear normative. Therefore, anchor point experiments must carefully control for surrounding Scaffolding Elements to avoid confounding effects. Disentangling these two mechanisms is challenging but necessary for accurately diagnosing how visual systems shape the construction of user-generated data.

6 Towards a Broader Understanding of Visualization-as-Input Biases

Exploring visualization-as-input expands our understanding of visual systems from tools of analysis to tools of expression and creation. In this interactive framing, users do not simply reflect on data, they construct their data through choices that are mediated by the visualization system's presentation.

This reframing adds new dimensions to research in personal informatics, self-tracking, and human-computer interaction by emphasizing how visual design can shape the production of data, not just its interpretation. These biases also raise critical questions about the influence of structure: When does a visualization framework encourage more complete or accurate input? When does it distort the information provided? And how can we design input systems that guide users without constraining or biasing the data they contribute?

7 Conclusion

Visualization-as-input introduces a unique way of shaping input data, transforming data entry into an interaction between the user and the visualization system. Rather than passively recording information, the visualization-as-input system actively participates in the construction of the data through the visualization's structure, feedback, and presentation.

Through Anchor Points and Scaffolding Elements, visualizations can subtly steer the form, content, and meaning of the data that users provide. To design these visualization-as-input systems responsibly, we must better understand how users interpret Scaffolding Elements and Anchor Points and how they influence reflective practice. As visualizations appear increasingly at the point of data entry, more research needs to be done to understand how the visualization-as-input system's environment influences the user.

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