

SUPPLEMENTAL MATERIAL:

Support notes on the

Critical Design Strategy: a Method for Heuristically Evaluating Visualisation Designs

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Abstract— These notes offer a detailed explanation of each stage of the Critical Design Strategy (CDS), including additional questions and prompts for reflection. They serve as a resource for tutors integrating the CDS into their teaching and for appraisers applying it in their evaluations. By providing commentary on each stage, these notes support both tutors and appraisers in fostering more effective and thoughtful visualisation designs.

Index Terms—Visualisation design, Design critique, Pedagogy, Visualisation theory, Information visualisation, Teaching visualisation



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1 INTRODUCTION

The Critical Design Strategy (CDS) is a structured framework that guides designers in critically evaluating and refining visualisation designs through heuristic assessment. It is especially valuable for those creating new visual tools or experimenting with innovative visualisation methods, as it fosters critical thinking about the design.

The CDS consists of three key stages (overview, detail and review), with the detail section covering the critique through six perspectives: user, environment, interface, components, design, and visual marks.

These notes are intended to support the appraiser by providing a detailed breakdown of each stage, along with additional questions to facilitate a thorough critique. We strongly emphasise the importance of deeply engaging with the process. It should go beyond a quick glance at the design, requiring a deliberate and thorough evaluation instead. Only by actively questioning and critically analysing the work can we fully understand its purpose, anticipate its use, and determine whether the design is truly effective and suitable.

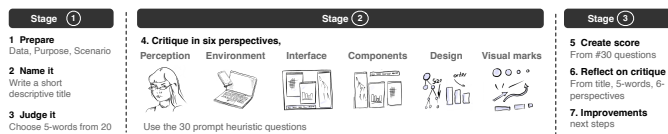


Fig. 1: The Critical Design Strategy consists of three stages: ● overview, ● detail, and ● review. The assessor begins by considering the design holistically—naming and summarising it while selecting five keywords from a set of twenty. Next, they conduct an in-depth evaluation across six perspectives, using 30 heuristic questions or directly engaging with semantic differential word pairs (opposite adjectives). Finally, the assessor reflects on their critique, assigns an indicative score, and determines areas for improvement.

2 THE CDS: SUMMARY AND TEACHING SCENARIO

Each stage is carried out sequentially: **overview**, **detail** and **review**, Fig. 1. The *appraiser* performs the CDS critique of a artefact, which could be a design sketch, paper prototype, physical prototype, poster display, visualisation, tool, application, user interface, etc. The *user* will utilise the artefact, which displays *data*, was crafted by a *designer*, and coded by a *developer*. These individual roles could be achieved by different people, or the same person; e.g., a learner designs a data visualisation and then develops the code to display it.

To achieve the CDS critique, follow the three stages in turn. To start the appraiser must understand the data and situation of where/how the artefact will be used. They need to prepared will be used, and understanding the data, scenario and how the visualisation will be used, then think what is important in the data (the design essence), and how to summarise the idea.

- **Overview.** After suitable preparation, assign a name, summarise its essence, and holistically critique by selecting five words.
- **Detail.** Critique artefact. Delve into detail by addressing the 30 questions (in six perspectives). The appraiser considers the visualisation from six perspectives using the 30 questions.
- **Review.** Lastly, the appraiser reflects on both the holistic critique and the detailed analysis to determine the next steps. The appraiser considers the whole critique, generates an overall score, and decides how to proceed.

To give an example of how the CDS could be used in education, we explain two **example education tasks that use the CDS**. An example task could be to “Design and implement a visualisation poster showcasing a chosen open-source dataset”, another could be to “design and implement a new interactive visualisation tool of a chosen open-source dataset”. The task is divided into two parts, requiring students to submit two reports along with code and any relevant images, as follows:

- **Technical Design Plan:** This document should include design sketches, consideration of the data story, and the overall layout of the solution. It should outline how the visualisation will

effectively communicate the data, explore alternative design approaches, and critically assess their suitability. The Five Design-Sheets (FdS) [16] method will be used to structure the design process, while the Critical Design Strategy (CDS) will guide reflection and critique.

- **Visualisation Report:** This report will present the final visualisation, accompanied by an in-depth discussion and critique. The CDS framework will be used to structure the evaluation, ensuring a thorough and reflective assessment of the work.

How do use this document. The detailed questions are designed to assist appraisers in evaluating the design thoroughly. The wording is also intended to guide the teacher in providing a suitable understanding of each section. If the appraiser is confident in understanding the meanings, they can proceed directly to assess each of the three parts and consider the design heuristic questions for each vignette (refer to Fig. 2, Fig. 3 and Fig. 4).

3 STAGE ● – OVERVIEW

The primary objective of the first stage is to ensure a thorough understanding of the topic and to make holistic assessments of the artefact. Critical thinking necessitates individuals to be “*well-informed*” [7]. Individuals should adequately **prepare** and ensure a thorough understanding of both the challenge and associated data. Data visualisation cannot be pursued without access to data. It crucial to consider the composition of the data and its organisational aspects, such as sparsity and structure. This involves identifying variables, understanding their nature (categorical, ordinal, quantitative, etc.), and recognising the purpose for which the data was collected. Additionally, comprehending the main objective of the visualisation and the intended user tasks is essential. Contextual information, including the creator’s intent and the environment in which the visualisation will be utilised, should be understood to ensure effective use.

Stage ① – Overview

Assign a name to the design: Summarise essence:

Circle 5 (first impression) words:

clear confusing sensible indifferent clever reliable pointless indistinctive
complex organised moderate spectacular useless average bad fulfilling
useful fair vague beautiful

Fig. 2: Following adequate preparation, assign name, summarise essence, conduct a holistic critique by selecting five descriptive words.

To confirm understanding, individuals should **name** the artefact/design, and summarise its **essence**. The act of naming the design commences the critical thinking process. Crafting a brief, concise title (of two or three words) compels consideration of what is crucial. Similar ideas exist in other design strategies, e.g., with the Five Design-Sheet method [16] designers are encouraged to name the design categories (on sheet 1) and name their designs (on sheets 2,3 and 4) for the same reason. Other meta-information, such as author name and data, can be added for future reference. The holistic critique continues, by **circling five** of the twenty words (Fig. 2). This task records an preliminary, intuitive assessment. While such instincts can be wrong, they will be reflected upon during stage ③.

4 STAGE ● – DETAIL

During the second stage, the aim is to conduct a comprehensive critique (Fig. 3), by considering 30 questions in six perspectives (**User, Environment, Interface, Components, Design, Visual Marks**), which is recorded using the Likert scale. Documenting the process and decisions can aid in justifying choices. Structure the critique in the order of the stages. The six perspectives encourage a top-down approach to the critique, whereby broad aspects are critiqued, like the user and environment, before diving into the specifics of visual elements. The questions

Stage ② – Detail (comprehensive critical evaluation)








Perspectives	Question on survey	-2 -1 0 1 2	Range of answers, from poor to good		
User 	#1 Is suitable for the user and task	○ ○ ○ ○ ○	Unsuitable	↔	Suitable
	#2 Is understandable for user and task to hand	○ ○ ○ ○ ○	Incomprehensible	↔	Understandable
	#3 It doesn't require guesswork	○ ○ ○ ○ ○	Requires guesswork	↔	Clear assumptions
	#4 Is trustworthy	○ ○ ○ ○ ○	Distrustful	↔	Trustful
	#5 Would be useful	○ ○ ○ ○ ○	Useless	↔	Useful
Environment 	#6 It would fit in with other technologies	○ ○ ○ ○ ○	Wrong setting	↔	Right setting
	#7 Uses suitable technology	○ ○ ○ ○ ○	Unsuitable technology	↔	Right technology
	#8 Has appropriate interaction	○ ○ ○ ○ ○	Unsuitable interaction	↔	Appropriate interaction
	#9 Its sizing is correct	○ ○ ○ ○ ○	Unsuitable size	↔	Suitable physical size
	#10 Gives a positive ambience	○ ○ ○ ○ ○	Poor vibe/ambience	↔	Positive ambience
Interface 	#11 Suitable user interface	○ ○ ○ ○ ○	Unsuitable GUI	↔	Suitable GUI
	#12 Ergonomic interface	○ ○ ○ ○ ○	Uncomfortable	↔	Ergonomic
	#13 Facets are sized suitably	○ ○ ○ ○ ○	Poorly proportioned	↔	Suitable sized facets
	#14 Interface suitably spaced	○ ○ ○ ○ ○	Poor facet spacing	↔	Relevant spacing
	#15 Suitable quantity of interface parts	○ ○ ○ ○ ○	Unsuitable facet quantity	↔	Suitable facet quantity
Components 	#16 Has all necessary components	○ ○ ○ ○ ○	Missing components	↔	All necessary components
	#17 Has all suitable output/view types	○ ○ ○ ○ ○	Unsuitable types	↔	Suitable view types
	#18 Clear relationships between parts	○ ○ ○ ○ ○	Unclear correspondences	↔	Clear view relationships
	#19 Task can be easily performed	○ ○ ○ ○ ○	Task unfulfilled	↔	Task easily performed
	#20 Suitable organisation of components	○ ○ ○ ○ ○	Poor component layout	↔	Good component layout
Design 	#21 Inspiring design	○ ○ ○ ○ ○	Uninspiring	↔	Inspiring
	#22 Aesthetic and visually attractive	○ ○ ○ ○ ○	Unattractive	↔	Visually attractive (aesthetic)
	#23 Good composition and space utilisation	○ ○ ○ ○ ○	Poor layout	↔	Good composition
	#24 Suitable coverage of data/underpinning facets/concepts	○ ○ ○ ○ ○	Unsuitable coverage	↔	Suitable coverage
	#25 Clear instructions, labels, legends to give context	○ ○ ○ ○ ○	Poor labels/legends	↔	Suitable legends/labels
Visual marks 	#26 Right choice of channels to communicate things clearly	○ ○ ○ ○ ○	Poor choice of channels	↔	Good channel choices
	#27 Communicates appropriate relationships/morphisms	○ ○ ○ ○ ○	Inappropriate mappings	↔	Appropriate mappings
	#28 The types of marks used, communicate things well	○ ○ ○ ○ ○	Inappropriate mark types	↔	Suitable mark types
	#29 Components are shown at the right level of abstraction/detail	○ ○ ○ ○ ○	Poor scale/zoom	↔	Good scale/zoom
	#30 Nothing is hidden that shouldn't be hidden	○ ○ ○ ○ ○	Overplotting	↔	Clear display, easy read

Fig. 3: Conduct a comprehensive critical evaluation of the artefact/design. Follow the questions (in the six perspectives: User, Environment, interface, components, design, marks), recording the answers in the Likert scale. Make notes that justify your decisions.

are crafted to encourage deep reflection, while the six perspectives help maintain focus on specific design viewpoints. Once a fair evaluation is reached, the overall score can be calculated.



User.
Critique the artefact or design for user suitability. Empathise with end-user's skills and experience.

When considering these questions, adopt a holistic perspective of the entire tool, visualisation, or system. Put yourself in the shoes of the end-user by empathising with their skills and experiences. Approach the questions from their point of view, keeping their needs and abilities in mind. The appraiser should reflect on the following questions.

#1 Is suitable for the user and task (Unsuitable ↔ Suitable). Is it suited to the situation and perfectly adapted for its intended purpose [17]? Consider the context in which the design will be used. Does it address the needs and requirements of the target audience effectively? Evaluate whether the design functions as intended and meets the goals set for it. Think about factors such as usability, accessibility, and relevance. Does the design solve the problem it was created for, or does it require adjustments to better align with the needs and expectations of the users? Reflect on whether the design successfully supports the objectives and whether any changes or improvements would make it more effective in fulfilling its purpose.

#2 Is understandable (Incomprehensible ↔ Understandable). Is the content easily grasped by the end-user? Is it presented in a clear and understandable way? Consider whether the content of the visualisation is easily understood by the end-user. Does it present the information in a manner that is intuitive and straightforward? Reflect on whether the design makes it easy for the user to grasp the key messages, data relationships, and insights. Is the language, structure, and visual design clear, or could it lead to confusion? Think about the user's potential knowledge level and cognitive load. Does the design cater to different

levels of expertise? Is the information logically organised, with a clear flow that guides the user through the content seamlessly? Ensure that the visualisation avoids unnecessary complexity and delivers the message in an easily digestible format.

#3 Does not require guesswork (Requires guesswork ↔ Clear assumptions). Does it make unwarranted assumptions, possibly relying on domain knowledge, and is this suitable in the context of the user/task? E.g., if intended for public display, clarity and absence of assumptions are required. Does the visualisation rely on assumptions that could confuse or mislead the user? Consider whether it asks the user to make inferences or apply external domain knowledge that might not be reasonable or accessible in the given context. If the visualisation is intended for a general audience or public display, it is crucial that the content is self-explanatory, with no prior assumptions about the user's background or expertise. Reflect on whether the design makes explicit what is being shown, ensuring that all information is clearly presented and no guesswork is necessary. If domain knowledge is required, is it clearly communicated or referenced, so that the user can easily understand the visualisation without making assumptions? Ensure the design is inclusive, accessible, and avoids leaving the user with questions that aren't answered by the visualisation itself.

#4 Is trustworthy (Distrustful ↔ Trustful). Does the visualisation inspire trust in its data presentation? (Cf. "Good data visualisation is trustworthy" [11]). Consider whether the data is presented transparently and reliably. Is it credible and dependable, as described by Meyer et al. [13]? Reflect on whether the results can be trusted and whether the design instils confidence in the viewer. Is the presentation honest and accurate? Would you feel comfortable recommending this visualisation to others or endorsing it for use? Evaluate whether the visualisation evokes a sense of trustworthiness, ensuring that the information it presents can be confidently relied upon.

#5 Would be useful (Useless ↔ Useful). Does the visualisation serve a practical purpose in its context? Consider whether it provides

value to the user or the task at hand. Is it likely to be used effectively, and does it enhance the understanding or decision-making process? Reflect on the context in which the visualisation will be applied. If for a specific project, presentation, or public display, and assess if it is appropriate and beneficial for that setting. Does it help solve a problem, answer a question, or provide insights that would be difficult to obtain otherwise? Is it intuitive enough to engage the user and facilitate interaction or interpretation? In short, does it add value to the task or situation, or does it fall short in meeting its intended goals?



Environment. Assess its suitability for proposed environment. Critique overall scenario, setting, and technology. Conversely, environmental obstacles could impact the artefact.

Evaluate if the artefact is appropriate for the intended environment. Assess the entirety of the scenario: setting, technology, and platform, whatever the environment such as print form, e-magazine, smartphone, tablet, desktop or powerwall. With the environment perspective, you need to imagine the environment, technology that will be utilised, circumstances of its use and how a user would operate it or interact with it in that situation. It is all about appropriateness for the environment.

#6 It would fit in with other technologies (Wrong setting ↔ Right setting). Does the visualisation align with and complement the other technologies and systems in its intended environment? Consider if it integrates smoothly and facilitates effective interoperability. For example, a static display might be ideal for an e-book, while a 3D model would be better suited for an immersive head-mounted display. The design may be intended for a printed magazine or an interactive desktop tool; both could be appropriate in their respective contexts. However, an interactive tool may not work well in a print magazine, though a QR code that launches a 3D view on a head-mounted display could be a suitable alternative. Additionally, a 3D stereo design might be less appropriate for print media. Reflect on whether the visualisation is appropriately adapted to the setting and if it enhances the user experience within that specific context.

#7 Uses suitable technology (Unsuitable technology ↔ Right technology). Is the technology used in the design appropriate and well-matched to the intended purpose, environment, and user needs? Does it consider ergonomic factors? For instance, a static display may be ideal for an e-book, while a 3D environment would be better suited for an immersive head-mounted display. Does the chosen technology enable the intended actions effectively? For example, can the user perform tasks such as ordering, organising, or scaling using the provided technology? Consider whether a large-scale visualisation would work well on a small mobile screen or if it would lose its effectiveness. Reflect on whether the technology is the right fit for the context and task at hand.

#8 Has appropriate interaction (Unsuitable interaction ↔ Appropriate interaction). Can you perform the desired actions within the environment using the provided technology, and how well does it integrate with other technologies in the setting? The term interaction should be interpreted based on the specific context. Rather than only evaluating if it's a Human-Computer Interaction (HCI) tool (e.g., using a mouse), assess if the level and type of interaction suit the environment. For example, interacting with a physical book (turning pages or adjusting its position) is appropriate without needing a computer. In a different scenario, physical interaction with a powerwall might involve moving closer or farther away, but environmental factors could influence this. Similarly, using a dashboard with a mouse, pen interface, or voice commands should be evaluated in terms of its suitability for the given context. Does the interaction functionality meet the requirements of the environment? Is it organised effectively? Can you easily perform actions like scaling or zooming when necessary? Even in cases where there is no direct human/computer interaction, such as with a poster where people move closer or farther away, the interaction may still be appropriate.

#9 Its sizing is correct (Unsuitable size ↔ Suitable physical size). Is the size of the output appropriate for its intended use and context? Consider whether the size allows the user to view all the necessary information clearly and comfortably. If the size is too small, critical

data may be obscured or difficult to interpret. Conversely, if the size is excessively large, it may overwhelm the user, causing difficulty in viewing all the content at once or forcing unnecessary scrolling or zooming. The size should support effective data presentation while remaining user-friendly and accessible. Is it properly scaled to the device or medium in which it's displayed, whether that be a small mobile screen, a large display, or printed material?

#10 Gives a positive ambience (Poor vibe/ambience ↔ Positive ambience). Does the artefact convey the intended atmosphere or feeling to the user? Does it create an engaging, pleasant, and welcoming experience, enhancing the interaction rather than hindering it? Consider how the design's visual appeal, layout, colours, and interactive elements contribute to the overall user experience. Does it align with the context in which it's being used? For example, a financial dashboard may benefit from a clean, professional look, while an educational visualisation could use more engaging and playful aesthetics. Does the design help create a positive, motivating, or inspiring environment for the user, supporting the overall goal of the tool or presentation?



Interface layout.

Consider the organisation of the interface and the graphical user interface (if applicable) assessing its suitability for the intended purpose.

Consider the overall interface layout and how the user interacts with the visuals. For example, a computer screen might display visuals, with the user interacting through a keyboard and mouse, potentially accompanied by sound. On a tablet, users may swipe with their fingers, while in a virtual reality environment, physical movement is the primary form of interaction. Alternatively, a print magazine requires the user to physically engage with the content, such as flipping through pages or even cutting out articles with scissors.

#11 Suitable user interface (Unsuitable GUI ↔ Suitable GUI). Is the user interface appropriate for the task at hand? Consider the specific features it offers, such as menus, buttons, drag-and-drop functionality, and visual programming interfaces. Should the interface be static or dynamic? Does it allow for transparency, dynamic queries, direct manipulation, or data querying? If the interface uses tabbed, cascaded, or tiled layouts, are these suitable for the context? Evaluate whether the provided interface meets the task requirements and is fit-for-its-purpose. Does it allow users to query data when needed? Are tabbed, cascaded, or tiled interfaces appropriate for the visualisation? Consider whether the method of interaction (e.g., visual programming of data flow, defining queries by code, or scrolling to locate information) is suitable for the user and task. Does the interface support efficient interaction and data exploration in a way that aligns with the intended use?


#12 Ergonomic interface (Uncomfortable ↔ Ergonomic). Is the interface designed in an ergonomically-friendly way, ensuring ease of use and comfort for the user? Consider whether users have the necessary interface components easily accessible and within reach. For a hand-held physical device, does it fit comfortably in the user's hand? Is it easy to hold and use for extended periods? Evaluate whether the interface is well-structured, unobtrusive, and user-friendly. For example, a drag-and-drop command may create an ergonomic interface by making interaction intuitive and quick, whereas an interface requiring multiple menus or numerous button clicks may be less comfortable and more cumbersome to navigate. Similarly, selecting objects in a 3D VR world may initially be fine, but long periods of interaction could lead to fatigue. Does the interface facilitate seamless, comfortable use over time, or does it require adjustments that might affect user comfort and engagement?

#13 Facets are sized suitably (Poorly proportioned ↔ Suitable sized facets). In visual displays, different facets or components are often used to present information. The size of these facets plays an important role in ensuring the clarity and effectiveness of the display. Are the sizes of these facets appropriate for the task at hand? For instance, when comparing two datasets (e.g., data A vs. data B), the size allocated to each dataset should be relatively equal to avoid unintentionally biasing

one over the other. Similarly, in a web viewer where a central display area is accompanied by advertisements, it's crucial to consider if the size of the adverts is appropriate in relation to the main content. If the adverts are too large or too small compared to the central display, it may disrupt the balance and overall user experience. Therefore, sizing must be carefully considered to maintain harmony and facilitate effective communication. Does the size of each facet align with its intended purpose and contribute to a clear, well-organised visual presentation?

#14 Interface suitable spaced (Poor facet spacing ↔ Relevant spacing). Does the interface make effective use of space within the layout, facets, or frames? Consider how white space is employed, or used appropriately. Spacing can improve clarity, enhance readability, and highlight key elements, contributing to a calm and organised visual aesthetic, as advocated by Dieter Rams [15] – and the calming nature of simplicity. The Gestalt psychologists also emphasised the importance of spacing (through the law of proximity). Their work describes that items placed close together are perceived as connected and related, while elements that are spaced further apart appear less connected and more distinct from one another [21]. However, it is important to avoid excessive space, as this may create unnecessary gaps that disrupt the visual flow and hinder user comprehension. For example, too much space between related elements can confuse the viewer and undermine the intended relationships between them, violating the Gestalt principle of proximity. Effective spacing should maintain a balance, providing enough room to differentiate between elements while ensuring that related items remain visually connected. Does the spacing between facets and content help organise information efficiently, allowing the user to navigate and interpret the design with ease?

#15 Suitable quantity of interface parts (Unsuitable facet quantity ↔ Suitable facet quantity). Is the number of interface components or facets appropriate for the task at hand? An excessive number of windows or facets can overwhelm the user, adding unnecessary complexity and making it difficult to focus on the key elements. On the other hand, too few facets may result in the lack of critical information, limiting the effectiveness of the display. It is essential to strike a balance where the quantity of facets supports clarity and functionality without causing cognitive overload. Consider how the interface components work together to provide a coherent user experience, ensuring that every part serves a distinct purpose and contributes to the overall task.

 **Components.** Components are specific visual elements or depictions that can be identified and isolated for individual consideration. Identifying and understanding these components is essential for analysing the structure and effectiveness of the design/ visualisation as a whole.

Each component within a design, artefact, or visualisation has a specific role and contributes to the overall presentation, conveying particular information to the viewer. These components can take various forms, such as charts, graphs, tables, icons, or other visual data representations [5]. They also include elements like menus, labels, and help information. Components may be arranged in different formats, such as a grid layout (a matrix of small, multiple views) or within a tabbed interface [1]. These components serve as the building blocks of the design, often placed within frames or windows. Examples include bar charts, timelines, treemaps, scatterplots, and others. Each component is distinct and identifiable, contributing to the overall function and user experience of the visualisation.

#16 Has all necessary components (Missing components ↔ All necessary components). Does the design include all the essential components needed to effectively convey the information? Are any crucial elements missing or unavailable? For example, if the design is intended to display temporal data but a timeline is absent, it may hinder the user's ability to interpret the data. Similarly, certain options, such as the 'delete' function, may be grayed out or unresponsive, preventing users from performing necessary actions. It's also possible that a component might be obstructed or hidden behind another element in the interface, leading to its absence from the user's view or interaction. The completeness of the interface is essential for ensuring a seamless and intuitive

experience, where all required functionality is accessible and visible to the user.

#17 Has all suitable output/view types (Unsuitable types ↔ Suitable view types). Does the design incorporate the appropriate output or view types to support the task and enhance interpretation? The choice of visualisation type is crucial for facilitating the user's understanding and task execution. For instance, continuous data is best represented using a line graph, while categorical data is typically shown using a bar chart. The visualisation type should align with the goal of the task; whether it's comparison, identification, or interpretation of values. For example, if the goal is to compare two items, placing them close together in the design can aid comparison. However, if items are too far apart, comparison becomes difficult, making the visualisation type unsuitable. Similarly, highly aggregated visualisations or those with large data bins may make it difficult to extract exact values. Therefore, it's important to assess whether the selected visualisation type, such as a bar chart, line graph, or image, is best suited for the intended task and the data being presented.

#18 Clear relationships between parts (Unclear correspondences ↔ Clear view relationships). Are the relationships between different components of the display clearly communicated? Is the legend or key clearly associated with the visual elements it describes? Does the title logically correspond to the content? In any visualisation, parts typically relate to one another, either implicitly or explicitly, so does the design make these connections clear? For example, in a multiple-view visualisation, is the relationship between different views immediately obvious? These linkages could be made apparent through annotations, or colouring, or visual links (so called meta-visualisation techniques [23]). Relationships can be conveyed through various design techniques, such as proximity (in line with Gestalt principles [14, 22]), bounding areas, explicit arrows, or other visual cues like speech bubbles to reinforce connections between elements.

#19 Task can be easily performed (Task unfulfilled ↔ Task easily performed). Can you perform the task you need to do effectively? Consider the specific task and how the user interface and its components facilitate completing it (see Shneiderman [17]). For instance, if the task involves telling a story of change over time, does the visualisation use a plot that clearly shows the progression over time? If the task requires illustrating three distinct phases, are these phases represented clearly and visually distinct within the plot? Are the components, such as plots or charts, fulfilling their intended purpose in a way that supports the task at hand? For example, if you're using a dashboard, is it clear what actions the dashboard is designed to perform? Can you easily take the necessary actions within the interface? If a pie chart is chosen, does it effectively convey the data and align with the task's goals [12]? Each component serves a unique purpose—one component may illustrate time, while others may detail data within specific phases. Are these visual components intuitively presented, ensuring users can easily interpret the information without confusion? Additionally, does the interface design adhere to usability principles, such as providing the right level of detail without overwhelming the user? The effectiveness of the task hinges not only on the appropriateness of the chosen visualisation types but also on how well the user can interact with the interface components. This includes ensuring that the controls (mouse movement, button presses, touch gestures, or 3D interface elements) are intuitive and enable users to complete the task smoothly (see also heuristics #11 to #15).

#20 Suitable organisation of components (Poor component layout ↔ Good component layout). Is the arrangement and ordering of the components in the visualisation effective and logical? For instance, if there's a timeline alongside other visual elements, where should it be positioned for optimal clarity (e.g., at the top or bottom of the display)? When comparing two items, what is the best positioning? Should they be placed next to each other, stacked vertically, or positioned side by side for easy comparison [8]? For example, placing two bar charts close to one another allows for a more straightforward comparison, in line with the Gestalt principle of proximity [14, 22]. If components are spaced too far apart, it can make comparison more difficult, potentially hindering the user's ability to extract meaningful insights. Therefore, is

the component layout designed in a way that enhances comparison and clarity? Does the structure align with the task and the user's ability to interpret the information efficiently?



Design.

Design encompasses organising any part of the system, which involves considerations like colour balance, item alignment, and styling.

Good design encompasses the effective organisation of all elements within a system. For traditional visualisation on a desktop computer, this involves considering aspects such as the balance and use of colours, the alignment of components, styling, and other visual details that contribute to a cohesive and intuitive experience.

#21 Inspiring design (Uninspiring ↔ Inspiring). Did the design immediately capture your attention, leaving you thinking, “Wow”? Does it motivate you to apply its concepts to future projects? Does it align with established design principles, such as the Golden Rules [18] or Dieter Rams’ good design principles [15]? Upon encountering the design, do you feel an immediate urge to interact with it and explore its features? Good design is made up of many elements, and in this case, we focus specifically on the layout. Are design elements organised consistently and thoughtfully? Are comparable items placed close together, making comparisons intuitive? Are the colours used effectively, without overwhelming the user? Does the design make you want to share it on social media because of its appeal?

#22 Aesthetic and Visually Attractive (Unattractive ↔ Visually Attractive (Aesthetic)). While the perception of attractiveness can be subjective, research shows that people tend to favour designs that are balanced, harmonious, and well-proportioned [22]. A visually appealing design should feel cohesive and comfortable to the eye, avoiding visual clutter or overwhelming elements. Does the design utilise a colour palette that is appropriate for the topic and context, without using an excessive number of colours that might distract or confuse the viewer [9]? Is the colour scheme thoughtfully selected, enhancing the content rather than competing with it [4]? Is the colour combination web-safe, or accessible [9]? In addition, consider whether the visual appeal of the design would make you confident in presenting or using it in a professional setting. Would you feel comfortable sharing it with clients, colleagues, or stakeholders? An aesthetically pleasing design can foster trust and engage users more effectively, encouraging them to interact with the content and absorb the information presented. Does the overall look of the visualisation inspire positive reactions or convey professionalism and attention to detail?

#23 Good composition and space utilisation (Poor layout ↔ Good composition). Does the design demonstrate a thoughtfully arranged composition, with well-organised elements, colours, and visual components that clearly communicate the intended message or information? Consider how the individual components are arranged: Are they placed strategically to create a harmonious and efficient layout? Is space optimally utilised to avoid clutter or waste? For example, in a book, generous gutter spacing ensures a comfortable reading experience. A magazine layout might feature two main columns with picture insets flowing between gutters, creating a dynamic and visually balanced structure. Some publishers allow text to flow around images, while others prefer fully justified text for a clean, uniform look. Does it fulfil the requirements of the output? E.g., a poster display may be required to be a certain size? Does it allow the quality of output at that resolution? E.g., if a pixel format is used, then it may not scale well. In some cases, overlapping or cascading elements might be appropriate for certain designs, but excessive overlap can lead to a chaotic and disorganised appearance, which may detract from the overall clarity of the presentation [18] (see also #30). A well-composed layout ensures that every element serves a purpose while maintaining visual clarity and balance, guiding the user's attention effectively through the content.

#24 Suitable coverage of data/underpinning facets/concepts (Unsuitable coverage ↔ Suitable coverage). Does the design effectively display all the necessary data? Is the quantity of data presented appropriate for the task? Is the data aggregation method used correct and

appropriate for the context? For example, is it suitable to compress an axis in some cases, or could this approach potentially confuse the user? Does the visualisation properly represent all required transformations and relationships in the data? Is sparse or missing data clearly represented in a way that doesn't mislead the viewer? Does the visualisation convey the full story it aims to tell, presenting a comprehensive picture? Moreover, is the chosen approach for data representation the most effective for the intended narrative or message, ensuring clarity and understanding?

#25 Clear instructions, labels, legends to give context (Poor labels/legends ↔ Suitable legends/labels). Is the contextual information provided sufficient to help users clearly interpret the displayed data? For example, if a visualisation is labelled “oil usage” the meaning could be misunderstood if the context suggests “cooking oil” rather than a broader term. Similarly, a vague instruction like “move forward” could create confusion, where more specific phrasing such as “move forward five steps” or “move forward 5 meters” may be necessary depending on the context. If no labels or legends are provided, is their absence justifiable? Can they be added to improve clarity? Are the existing labels, legends, titles, or other explanatory elements [6] accurate and sufficient in helping to explain the data? If these elements are missing, does it leave users uncertain about what the visualisation is conveying, or does it make sense to omit them? For example, scatterplots often omit labels on individual points. Is this omission acceptable, or does it hinder understanding? Would adding labels improve clarity, and if so, how could they be positioned and formatted to avoid overcrowding and maintain readability? The number, placement, and clarity of labels are crucial for effective communication; are these considerations addressed in your display?



Visual marks. Visual marks encompass graphical elements like lines, shapes, colours, and textures [2]. Their layout should avoid overcrowding and ensure accurate representation of data. Correct data morphisms are essential for conveying information effectively.

In this context, the focus is on the appropriate use of graphical marks to effectively represent data. Are the correct marks chosen for the data type, and are they positioned accurately with the right attributes to clearly communicate the intended message? Additionally, evaluate whether any design elements hinder clarity or overcomplicate the visualisation. Graphical marks are fundamental properties of the visual system, often referred to as retinal variables by Bertin [2]. These marks encode data through attributes such as size, orientation, colour, texture, and transparency. They can range from basic elements like lines, polygons, and circles, to more complex pictures, icons, or multidimensional glyphs [20]. It is important to assess how these marks are arranged—whether they are appropriately placed, not overcrowded, and whether they effectively convey relationships between the data. Bertin's concept of retinal variables highlights how certain graphical marks are more suitable for specific tasks depending on the data being represented. For example, size is particularly effective for conveying quantitative values: larger objects can represent larger values, making it easier for viewers to intuitively grasp relative magnitudes. Similarly, certain visual attributes, such as colour or shape, may be better suited for identifying or distinguishing between categories or groups within the data. However, not all retinal variables can be mapped to every type of data or understood visually in the same way. For instance, while colour can be used to represent categorical data, it may not effectively convey this information, and using it for that purpose could lead to confusion. Bertin's theory emphasises the importance of selecting the right visual attributes that align with the nature of the data and the task at hand, ensuring that the chosen graphical marks effectively communicate the intended message without introducing misinterpretation or ambiguity. Furthermore, consider if any visual elements are redundant or unnecessary, such as “chartjunk” [19], and how the design aligns with established visualisation principles [22]. Keep in mind that not all extra visual elements are detrimental; in some cases, they can enhance the memorability and impact of the visualisation [3].

#26 Right choice of channels to communicate things clearly (Poor choice of channels ↔ Good channel choices). Different channels, such as position along an aligned scale, shape, size, orientation, and colour, are used to encode data values and convey information. How well are these channels being utilised? Do they effectively match the data being presented? These channels engage various sensory modalities: for instance, colour is perceived through sight, while vibration can be felt, as seen in vibrotactile interfaces. Are the chosen channels compatible with the user's sensory experience? Depending on the design context, could audio be a more effective medium? Is it the best choice in this scenario, or might it be overwhelmed in a noisy environment? When selecting channels, is the environment considered? For example, is the visual information readable in a well-lit or dim setting? If you are using audio, is it clear enough for users to discern the message? Are there alternatives that might be more inclusive or accessible for those with sensory impairments? Does the chosen channel ensure that the information is easily understood by the intended audience, and are these channels contributing to a more inclusive experience [10]? Ultimately, do the channels enhance the user's comprehension without introducing confusion?

#27 Communicates appropriate relationships/morphisms (Inappropriate mappings ↔ Appropriate mappings). Is the mapping, or transfer function, aligned with the data, and does it accurately reflect the underlying relationships? Are the choices made for visualising the data appropriate in terms of the relationships they intend to convey? For example, when mapping continuous data, is it represented in a continuous way, or does using discrete categories or binning distort the data's true nature? If categories are represented, is the grouping meaningful, or does it obscure important variations? For instance, in a bar chart, does the grouping of values into ranges (e.g., 1-5, 6-10, 11-15) appropriately reflect the characteristics of the data, or does it introduce unnecessary abstraction? How do the mappings affect user understanding? Are they intuitive and clear? For instance, does colour or size effectively represent data values, or are these elements misleading? Can the user easily make connections between data points and visual elements? Does the design ensure the right balance between simplicity and accuracy? Does the visualisation help the user draw meaningful conclusions without overcomplicating the task? Does the mapping enhance the clarity of relationships, trends, or patterns within the data?

#28 The types of marks used, communicate things well (Inappropriate mark types ↔ Suitable mark types). Are the marks used in the presentation appropriate for the data and the task at hand? In a scatterplot, for instance, different types of marks (such as points, circles, triangles, or lines) are employed to represent data. Are these marks the right choice for effectively conveying the relationships and characteristics of the data? Are symbols, lines, or areas used in a way that makes sense within the context of the visualisation? Do attributes such as line style (dotted, dashed, or solid) or colour (representing categories, values, or gradients) help to communicate the intended message? Is it clear what each mark represents, and is there any potential confusion caused by using similar or overly complex marks? Do the marks enhance the clarity of the visualisation or do they distract from the main message? For example, are the shapes or colours intuitive to users, and are they consistent across the visualisation? Consider if certain marks are overused or redundant and if alternative marks might communicate the data more clearly. Does the choice of marks reflect the nature of the data, such as using continuous marks for continuous data and categorical marks for discrete data? Key questions to consider: Are the chosen marks appropriate for the data type? Are any visual elements unclear or difficult to interpret? Do the marks and their attributes support the task effectively? Is there consistency in the use of marks throughout the visualisation?

#29 Components are shown at the right level of abstraction/detail (Poor scale/zoom ↔ Good scale/zoom). Are the visual marks presented at the appropriate level of abstraction or detail? For instance, are the sizes, shapes, or colours of the marks used at the correct scale to effectively communicate the data? Would zooming in on specific visual marks or adjusting their size enhance clarity, allowing the user to focus

on finer details without losing context? Are there any non-linear zoom options, like distortion views, that could make the data more interpretable while maintaining the overall structure of the visualisation? Should certain visual marks, such as lines or points, be emphasised by scaling them larger or smaller for better comprehension? Consider whether the marks are too abstract or too detailed for the task at hand and whether their level of granularity is consistent and appropriate for the data being communicated.

#30 Nothing is hidden that shouldn't be hidden (Overplotting ↔ Clear display, easy read). When plotting data, overlapping points can obstruct each other, making interpretation difficult. Is the arrangement of marks appropriate, or are they too close together, resulting in visual clutter? Could a different transfer function improve clarity by either separating the points or aggregating them in a more meaningful way? Consider whether filtering options might help reduce overplotting and provide a clearer view of the data. In 3D visualisations, occlusion can occur when objects are hidden behind others, or sounds overlap in an audio space, interfering with clarity. Is this type of occlusion acceptable, or could it be managed better? Would a different layout, such as repositioning elements or introducing transparency, help mitigate the issue? Additionally, there may be cases where intentional partial occlusion is used for specific purposes: Does this make sense in the context, or does it hinder understanding? Evaluate whether partially hidden elements improve or hinder the user's ability to interpret the visualisation effectively.

Stage ③ – Review	
Create score.	Reflect on parts:
Improvements and next steps:	

Fig. 4: The final stage involves synthesising the various perspectives and insights, gathered throughout the critique.

4.1 Stage ● – Review

The goal of the final stage (Fig. 4) is to synthesise key findings and observations, turning these insights into actionable steps that contribute to refining and improving the design or artefact. The first step involves calculating a score by summing the Likert scale values and reflecting on each component of the critique, such as the name, essence, and six perspectives. While the average score from the Likert scale can provide useful guidance, it may not fully capture the depth of the critique and could be misinterpreted, as it masks the complexities of individual aspects. Therefore, it's crucial to interpret the score alongside other insights. Review the six perspectives and the 30 questions, identifying any particularly noteworthy strengths or weaknesses. Highlight areas that require improvement and pinpoint elements that should be enhanced.

Once the critique has been thoroughly assessed, the next step is to decide on appropriate actions. A redesign may be necessary to address the identified issues and improve the design. This could involve refining the layout, adjusting visual elements, enhancing usability, or incorporating user feedback. The next steps should include developing a detailed plan for the redesign, such as conducting further research, gathering more user input, creating prototypes, and implementing changes iteratively. Establishing clear objectives for the redesign is essential, and regular evaluations should be conducted to ensure that the new design effectively addresses the identified issues, improving overall usability and user experience.

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