Int J Software Informatics, Volume 9, Issue 1 (2015), pp. 61–72
International Journal of Software and Informatics, ISSN 1673-7288

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Art and Chartjunk: A Guide for NEUVis

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Abstract In the fast-changing and multi-disciplinary practice of artful information visualization, the act of translating data into an image can be fraught with peril. There is considerable debate around modes of visualization and their relationships with the underlying data. This paper outlines the debate between the opposing ideologies through assessment of design considerations and comparisons of creative practice and visual analytics. The authors summarise the current nexus of influences and circumstances and proceed to formulate a set of guidelines for creative practitioners developing visualizations for Non-Expert Users (NEUVis).
Key words: visualization; non-expert users; NEUVis; affective design; visual analytics; chartjunk; information aesthetics; engagement; collaboration and communication

Gough P, Dunn K, Bednarz T, Ho X. Art and chartjunk: a guide for NEUVis. *Int J Software Informatics*, **Vol.9, No.1 (2015): 61–72. http://www.ijsi.org/1673-7288/9/i209.htm**

1 Introduction

Leaders of Google's "Big Picture" visualization group, Fernanda Viégas and Martin Wattenberg describe the practice of artful information visualization, or artful infoVis, as artists using data with the intent of making art[30]. They say these works must use actual data, not metaphor, since it is not a visualization without the mapping of data to image. Artful infoVis not only makes data seeable, but allows the structure of the data to emerge, and remain, in the mind of the viewer[19].

Hans Rosling, founder of the Gapminder Institute, compares the process of visualization to a performance of a piano concerto:

"Mozart was a wonderful composer; Steinway was the best piano maker of his time; and, today, there are a lot of musicians who use Steinway pianos to bring life to what Mozart once wrote. Those three people are equivalent to a statistician who gathers the data; the engineers at Google and Adobe who design the tool to filter, organize and present them; and the designers who create presentations that makes them understandable." [3]

From this wonderful analogy we can appreciate how artful infoVis is not just an act of one creative practitioner; it is a collaboration–directly, or indirectly–between

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Received 2014-12-19; Revised 2015-04-14; Accepted 2015-04-30.

the analytical and creative processes. The presentation must also show the focus of the visualization and must be understandable. This is essential to both a domain expert, a creative practitioner who makes artful infoVis from experimental data, and to non-expert users (NEUs) who have to be guided through not only the data, but how the visualization is to be read.

Data visualization is not exclusively used for spreading knowledge[5], for example, insight from visualization can make information the end-user already knows, more significant by placing it in a different or unfamiliar context. Deploying specialised visualizations to a general population may be beneficial for the purposes of raising public awareness, facilitating understanding, or inspiring a user to undertake action. This is particularly helpful because one concrete purpose of visualization is to save the user time when exploring data[5]. The challenging task of engaging a population with data may be helped by appropriate visualization practices, removing the demand on the time of the NEUs for whom it has been designed. The best way of going about this is unclear. Discussion about this topic has been called for (for example, see Ref. [7], and the editorial comment on it: Ref. [20]), but for some time it has been a topic of fierce debate.

2 The Chartjunk Debate

Research into the field of infoVis reveals two distinct philosophies of how data should be communicated. At the center of the debate is the argument over visual embellishments, or data-ink ratio: the use of visual icons or features that do not explicitly communicate data, but serves to attract, amuse or stimulate the reader.

Academic statistician, Edward Tufte, wrote in several books that one should use the least amount of ink to communicate the data to the reader, with the chart still reasonably decipherable[27], rendering all excess imagery as chartjunk:

"Lurking behind chartjunk is contempt both for information and for the audience. Chartjunk promoters imagine that numbers and details are boring, dull, and tedious, requiring ornament to enliven. Cosmetic decoration, which frequently distorts the data, will never salvage an underlying lack of content. If the numbers are boring, then you've got the wrong numbers. Credibility vanishes in clouds of chartjunk; who would trust a chart that looks like a video game[28]?"

Tufte's point is important: if the data does not appeal to the user, a chart will not be saved by embellishment; the right numbers are never boring. However, no style of presentation is inherently trustworthy, or deceitful. Tufte does concede that among the most powerful data exploration methods are appropriate, beautiful re-expressions and transformations of information[26].

Designer Nigel Holmes opposes Tufte's minimalist view, advocating the use of symbols congruent with the message, which are easily recognised by a general audience. For this reason, his charts have been criticized by Tufte as exemplifying chartjunk. Holmes defends his use of decoration (Fig. 1 shows an example of such decoration); his visualizations were developed for an audience which was not unintelligent, but busy: he wanted to get people to look at them all[10].

As long as the artist understands that the primary function is to convey statistics and respect that duty, then you can have fun (or be serious) with the image: that is, the form in which those statistics appear[12].

Even with their different approaches, Tufte and Holmes agree that visualizations are fundamentally depictions of data; credibility cannot be substituted for embellishment.

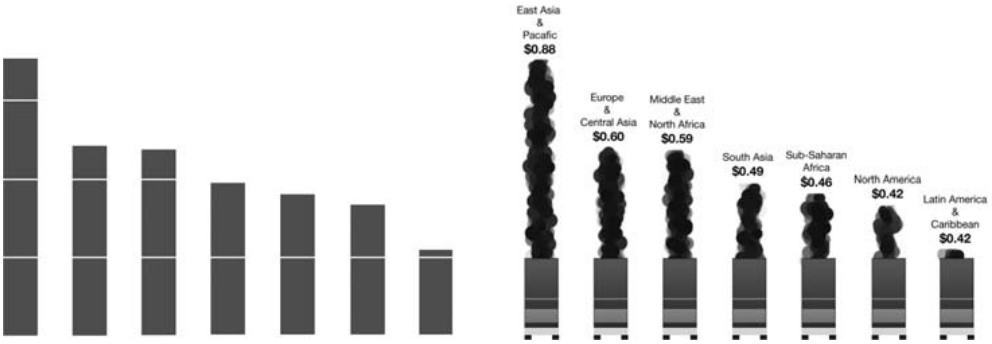

Figure 1. Examples of minimalist and embellished charts showing the amount of CO2 emissions PPP $ GDP by Xavier Ho ©. Data from Google Public Data Directory, available http://www.google.com.au/publicdata/directory.

2.1 Research on chartjunk

Chartjunk has been a topic of investigation in the last decade. Presenting a pair of charts, one designed by Nigel Holmes, and the other a minimalist version of the same "using Tufte's style" designed by the authors, one paper found no significant difference between the speed and accuracy with which users were able to read two versions of the same chart[1].

Another research project revealed user preferences for different types of charts. Minimalist designs following Tufte's principles were compared to more conventional representations of the same data. Users preferred the designs to which they were accustomed[13]. Their findings imply his principles were not inherently beneficial to non-expert audience, though Tufte had already suggested this would be because the the minimalist style is unfamiliar[27].

Embellishments may be advantageous, able to engage the audience and make the image more memorable[2], published at the IEEE VIS 2013, showed static visualizations were consistently memorable or not. Testing showed that users reliably recalled seeing the visualization, but were not tested on their comprehension of the data. This is beneficial, since many additional details of the image come for free when retrieving memorable items. The researchers say that this may become a baseline for leveraging cognitive capabilities.

[17] compared charts drawn by Nigel Holmes for his book[12], to minimalist versions, and found that embellished charts improved short-term recall, were more attractive and memorable to users, and led to a shorter time needed to review the information in the chart while answering the comprehension questions. It also states that the extra time users spent looking at the additional decoration does not significantly slow down how quickly users read the charts.

How should embellishments be leveraged? The question of 'can' or 'should' may be issues themselves, but Holmes states that a basic consideration of visualization is the tone of its presentation. He shows there is no reason that a design for specialists

must be dry and serious, and it is incorrect to assume that a NEU needs to be amused with unhelpful decoration[12]. Getting the right data–the most relevant to the creative practitioner's audience, intent, and context–is critical. By merging the needs and context of the user with the message or implications of the data, creative practitioners can create effective and engaging NEUVis, or non-expert user visualization.

3 Communication: Visual Analytics and NEUVis

3.1 Visual analytics

Visual analytics focuses on the modes of data visualization for decision makers and primary researchers, rather than domain-novice, NEUs. It combines the strengths of infoVis with analytical reasoning to aid decision making, understanding results of experiments and simulation, and showing the content of databases. In many cases, visualization is indispensable to both the verification process and the deep comprehension of data. The field emerged as a response to the information overload problem[15], and the way that decision makers are bombarded with irrelevant information or inappropriate data. Visual analytics allows exploration of data through both visualization and theoretical models to generate new knowledge. The result often produces a graphical interface illustrating the trends and change in data over time[25]. Visual analytics is not a crystal ball, value can only be extracted when there is a precise problem to be addressed. It may happen that only 5% of the data have a value that supports decision making, or explains a specific phenomena. However, this knowledge can be obtained in an environment where data sets are increasingly complex in terms of their size and source, including scientific models and spatial or time-series data.

Visualization hardware changes rapidly and uncertainty increases with more information flowing in. Therefore, a single approach that visualizes data is no longer sufficient to grasp the information needed for insight and discovery. As with NEUVis design, quantitative visual analytics, several elements should be considered to be effective in communicating information. Techniques and elements can include: uncertainty, integration, interaction, collaborations, multiple views of data, measurement techniques on the visualised data (one could look for instance to visualise distribution of a volume function between two three dimensional points, or measure distance between specific isolines). Then, the approaches presented in this paper on NEUVis could be used for more effective information communication to general audience.

3.2 NEUVis

A contrasting approach to visual analytics is centered on the needs of the general population. While visual analytics is a field helpful for specialists advising business and policy makers, the general audience does not make decisions exclusively based on logic[18,23] A domain expert user is not immune to their emotional response when making decisions either. Real-world decisions are not simply affected by emotions, rather, they play an integral part. Decision making may not be possible without emotions[21]. Thus, it is important to acknowledge the emotional effect of the visualization on the NEU audience, and to clarify the intent of the work. An

emotional effect may be intentional, since all visualization is mediated, and it is not possible to be entirely objective, or neutral[11]. The creative practitioner must consider the affective and cognitive response which the visualization will induce in the NEU. At PacificVis 2014, Non-Expert User Visualization (NEUVis) was first established as a wicked problem, and therefore a suitable pursuit of creative practitioners. This is in contrast to the nature of scientific visualization and visual analytics, which–though often complex–is a tame problem[8].

3.3 Translation for non-expert users

The challenge for visual analytics is to identify relevant data and effective algorithms to present information in a logical form. NEUVis faces a different challenge: how does a creative practitioner translate data for users who do not have the expertise in the subject matter or experience reading the visualization style. The contrast between visual analytics and NEUVis is analogous to the chartjunk debate; visual analytics presents data for exploration and analysis, while NEUVis, like Holmes, is aimed at an audience who needs to be guided through the visualization. Tufte's guidelines for charts describe a self-effacing presentation, getting out of the way of data, allowing access to information without the designer as a guide–an approach ideal for visual analytics. Non-expert audiences often requires this guidance, or introduction, to the domain of data through its presentation. Unlike visual analytics, NEUVis does not have a set of best practice guidelines for designers, except for tacit recommendations of 'good taste'.

The way that NEUVis can represent and transform knowledge from the scientific community to the general community means that it acts as a boundary object – an anchor or bridge that acts as an interface to distinct communities[4,24]. In order to be effective, Carlile, in Ref. [4], explains and contrasts three approaches to boundary objects: syntactic, semantic, and pragmatic. The syntactic boundary object creates a shared syntax or language for individuals to represent their knowledge. The semantic boundary object provides a way for individuals to outline and learn about differences in knowledge between different groups. The pragmatic boundary object that Carlile proposed facilitates the process of transforming knowledge between individuals of different groups[4]. If the NEUVis is the object, and the NEU's end is to understand scientific research, then it may be possible for NEUVis to act as a boundary object, giving the scientist and non-scientist a means of communicating through NEUVis. One example, shown in Fig. 2, Personal Care?, by Xavier Ho and Phil Gough, is an example that aimed to explain the scientific process, results, and implications from field experiments. The use of NEUVis as a boundary object is one potential area for further research.

Figure 2. Personal Care? by Phillip Gough and Xavier Ho ©. This image was designed as a digital poster for NEUs, using a novel format and context. Displayed on a CAVE2 system at OzViz 2013[9].

4 The Art of Engagement

Creative practitioners make works to express or communicate something to an audience. Much like infoVis, this can be personal, social or global. For example, Viégas and Wattenberg created Wind Maps, an artwork of the wind landscape over the United States[31]. This work, while based on accurate meteorological data, functions as beautiful artworks that have been exhibited at the Museum of Modern Art in New York.

4.1 Data informing the creative process

Viégas and Wattenberg noted that data has become part of the cultural discourse: real-world data and issues such as climate change, human development and disease are of concern for all[30]. In their desire to express or communicate significant issues, artists have turned to science and data to inform their creative practice. Abstract visualizations can be informed by accurate research data, even if presentation is not literal.

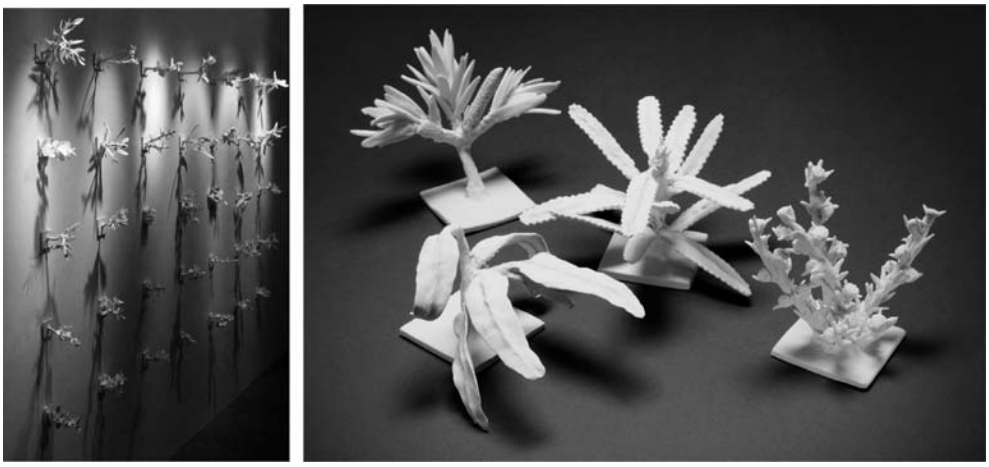

Figure 3. a & b: The Garden of Earthly Delights 2012, (porcelain, W:4m × H:2m × D:25cm) by Kate Dunn ©(photos by Kate Dunn and Greg Piper) Exhibited at Metalab Gallery Sydney, September 2012.

4.2 Collaboration and interaction

Interdisciplinary collaboration can result in meaningful and memorable visualization, catalyzed by intellectual and sensorial experiences with an evocative manner of presentation[11]. Examples of this model of collaboration are works by Kate Dunn (Fig. 3 a & b) in collaboration with botanist Caroline Lehmann, representing Australian plant species that are under threat due to urban expansion and climate change. The exhibition is not intended to be the mouthpiece for scientific data, rather, to create sites of engagement for increased scientific literacy, acting as a portal to scientific data. The act of collaboration can take many different models. For example, an exhibition may be accompanied by a talk from a scientist on the data informing the artworks; in effect, a cross pollination of information and

audiences. Prior to public display, the intent of the work and the source of the data is clarified through an artist's statement while the context is defined by the gallery display.

4.3 Opportunities for interaction

Dunn created a second series of objects informed by data. The works were based on graphs of extreme weather pattern changes between 1970 and 2005, sourced from the United Nations International Strategy for Disaster Reduction. The graph shows the increased flooding, windstorms, drought and related disasters activity over a 35 year period (Fig. 4). The 3D printed objects can be viewed from different angles and most importantly, handled, enabling multiple levels of audience engagement and interaction.

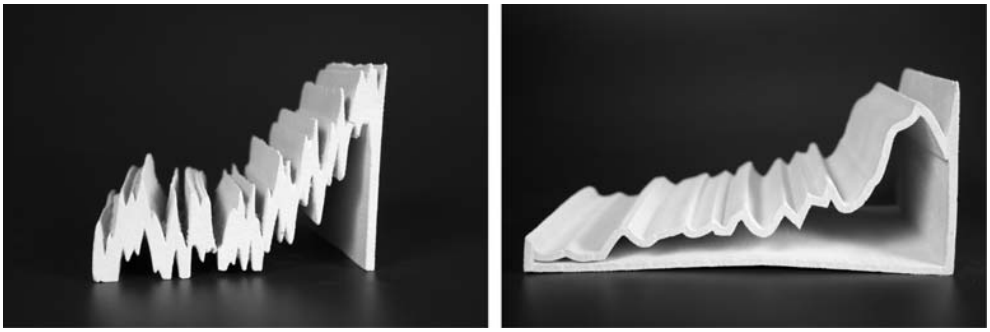

Figure 4. a & b: Graphs extruded and 3D printed in recyclable ceramic powder by Kate Dunn 2013 ©, (photos by Phillip Gough).

5 Designing for Information Aesthetics

Communication is two acts of translation, first from a person putting into language, gesture or printed medium, and then the receiving person translating in their mind. It is crucial for both people to share some common understanding or language, be it graphic or textual, to avoid the message being lost in translation. Of course, as Karl Popper notes: "Always remember that it is impossible to speak in such a way that you cannot be misunderstood: there will always be some who [will] misunderstand you"[22], but designing for information aesthetics can help.

Visualization, in particular NEUVis for scientific communication, shares the same traits as giving directions to tourists in a foreign country. They might not know the streets by name, but they know how to navigate maps and adhere to rules of traffic lights. Similarly, the general audience might not understand the significance of a certain limit in chemical wastes poured out into the ocean, but they understand the dangerous implications of fish floating belly-side up in muddy lakes.

Establishing and utilising a common language of understanding, in the context of visualization, is designing for information aesthetics. Aesthetics in our scope is beyond beauty, but a set of metaphors and styles that concern the protocol of communication of information and provoking thoughtful experience in the mind of the audience[16].

The availability of tools, such as Processing (http://www.processing.org), and reliable, accessible data sets, such as Data.gov.au (http://data.gov.au), have allowed

creative practitioners to create infographics, interactive displays and animated artful infoVis for the general public. This not only narrows the gap between scientific data and the NEUs, but also created a new platform for users to engage within the data and other users regardless of their level of understanding. The abundance of open-source tools created a place for a community to grow and discuss environmental issues.

For the creative practitioner with a deep understanding of their data, the key goal of designing for information aesthetics is to invoke experience for their audience. Learning is an experience, and with that learned knowledge comes motivation, engagement and understanding. Just as speaking a common language is a prerequisite for understanding, the visual style and metaphors should match the meanings with their appearances and interactions. Appropriate aesthetics in information design can engage the audience and provoke actions, and ultimately provide the experience that is crucial for learning and making sense of artful infoVis.

5.1 Selecting appropriate visual styles and metaphors

Conventional representations are familiar and more accessible. For example, because maps are commonly understood, a GPS interface is easily learned by new users[14]. Visualization is the first step to translate step-by-step information into graphical form, utilising our spatial understanding. Spatial dimensions are more distinct than colors and texture, making them the perfect candidate for representing maps. Clustering related elements between data points can provide better understanding of their relationships[19]. Lines and curves provide boundaries and enclosed spaces that can denote separation or groupings.

5.2 Provoke curiosity with data aesthetics

Wider fields of visualization implicitly recognize that information is beautiful. Artful infoVis is intrinsically aesthetic[29]. Let data speak for itself. Show the critical path to understanding the data at hand by presenting information gradually with highlights of importance. Users are more likely to engage with beautiful artworks. Utilise principles of aesthetics such as contrast, scale, arrangement, composition, and colours to convey the meaning and provoke curiosity in their mind.

5.3 Design for learning and user experience

Inform the audience with data and facilitate insight by choosing an affective visual mapping[16]. Design to provoke certain emotions for an affective experience. Ensure the message is sound, useful, and beautiful[29], building a solid relationship with your audience and the artwork. Allow your audience to discover and learn at their own pace, but always keep a momentum. By providing an accessible and engaging experience, NEUVis can facilitate learning, empowering the audience by providing access to new knowledge.

Just as architects use visualization to communicate to prospective clients their creative visions, the science visualization community has already begun working with the art community[14]. As a result, design challenges are shifting from data-centric to user-centric[29]. Instead of wondering "how can we best visualize this data?" we must ask "will NEUs understand what this visualization is saying?"

6 A Guide for NEUVis

From the analysis of the chartjunk debate and with review of the differences between visual analytics, NEUVis, and artistic infoVis, the authors propose the following NEUVis guidelines:

6.1 Use accurate data

Embellishment cannot replace credibility. No matter how elaborately decorated or graphically engaging a visualization is, if the data informing the visualization is inaccurate, the visualization is irrelevant and can be misleading. Tufte and Holmes share this point. Tufte shuns chartjunk as a lack of respect for the intelligent reader, as the numbers are most important. Holmes, in contrast, leverages appropriate visual construction to attract the attention of the busy reader. Both agree that the data is most important, and it is the job of the designer to communicate the data honestly. The means that the creative practitioner uses to communicate the data should show sensitivity to the data being communicated.

6.2 Design consciousness

Be aware of the impact of your chosen design on the reading of the data; no symbols or images are benign. In NEUVis, designers benefit from easily recognised symbols and data with a clear message. In this context, data is intrinsically interesting, but design should focus on the user needs. Many examples of chartjunk show a lack of understanding of visual construction, which is an indication of poor design. Visualization researcher Colin Ware[32] commented that training in art and design is at least as useful to a visualization designer as training in perceptual psychology. Leveraging appropriate graphical elements will have a positive effect on users. Colour, form, typography and interactivity are all tools at the disposal of a creative practitioner.

6.3 Clarify the intent

Define the intent of the visualization or image: is the visualization designed to communicate precise data, or is it an abstract representation? Is the data intended to be a precise reflection of a spreadsheet with numerical content included or is it intended to an artwork that can be used to engage a larger and more diverse audience through artistic visualization techniques?

6.5 Clarify your audience and context

Who is your intended audience and how will they be experiencing your work? For example, the audience experiencing an image in an art gallery may read it differently to an audience seeing the image at a medical conference. Good visualization design requires that the practitioner consider the intended audience, and their context in order to establish the parameters of the design.

A balance then needs to be found between the needs and context of the user with the message and implications of the data, which may be challenging.

Therefore, the process of designing NEUVis should address some of the following questions:

- How does this new knowledge benefit the user? (Addressing user need and context)
- What about this data is relevant, or important? (Addressing data message and user context)
- What can the user access for themselves? (Addressing data message)
- What is otherwise inaccessible to the user? (Addressing data message)

6.6 Present Novel Information

The Audience should be presented with data that is otherwise difficult to access for themselves. Open-access journals like Plos One (www.plosone.org) are accelerating the publication process and allowing access to peer-reviewed research without subscription. However, these articles are still composed in a scholarly format, and it cannot simply be assumed that the general population is engaged with this academic research. It is a step in the right direction, but does not mean the general population is engaged with the content. Engaging NEUVis presents the audience with new knowledge that is relevant to the audience and context. This allows the user to connect the information presented to their own experience, and learn from it. Data visualization should answer difficult questions, show causality and correlation, explain why the user may benefit from acting on the message behind the data and answer questions that users may not be able to answer for themselves, or even know to ask. This will act as a hook to engage the user. In order to keep the user engaged, the visualization can leave the user with information still to uncover. By leaving implicit, follow-on questions such as "how" or "where," that are easily answered, the audience are able to continue engaging with information on their own terms.

Figure 5. The Hungry Microbiome, available at http://youtu.be/NI3KtR3LoqM, animation by Chris Hammang, funded by CSIRO and Inspiring Australia. CC BY.

One good example of allowing the user to engage with a simple question is the animated visualization The Hungry Microbiome, produced and published by CSIRO[6] (see Fig. 5). This video addresses two questions: "Why is resistant starch

an important part of my diet," and "Where do I get it?" The first question is not simple to answer, and it may be that many people do not know that it is one that should even be asked. The second question follows on from the first, and is quite obvious that it should be asked. The animation addresses the first question, but leaves the second for the user to ask themselves, and solve. This allows the user to engage with the data in their context: the video is hosted on YouTube, so most viewers will be able to answer the simple follow-on question with a web search. This is empowering for the user, as it brings novel information to a user in their own context, increases accessibility of scientific research and knowledge. Leaving simple and interesting questions unanswered is also a way to engage and motivate an audience to action, motivating them to engage with the information on their own terms.

7 Future Work

These guidelines provide clarity for the emerging practice of NEUVis. They are developed to facilitate design focus and enhance audience engagement and interaction. Experimentation, research and exhibition by other creative practitioners will build an understanding of the functional considerations for NEUVis practice.

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