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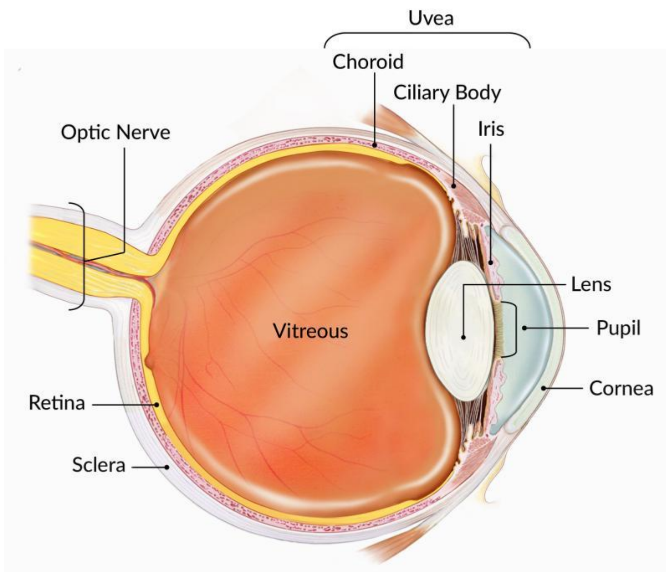
CIS 450-50

14 September 2025

Assignment 1

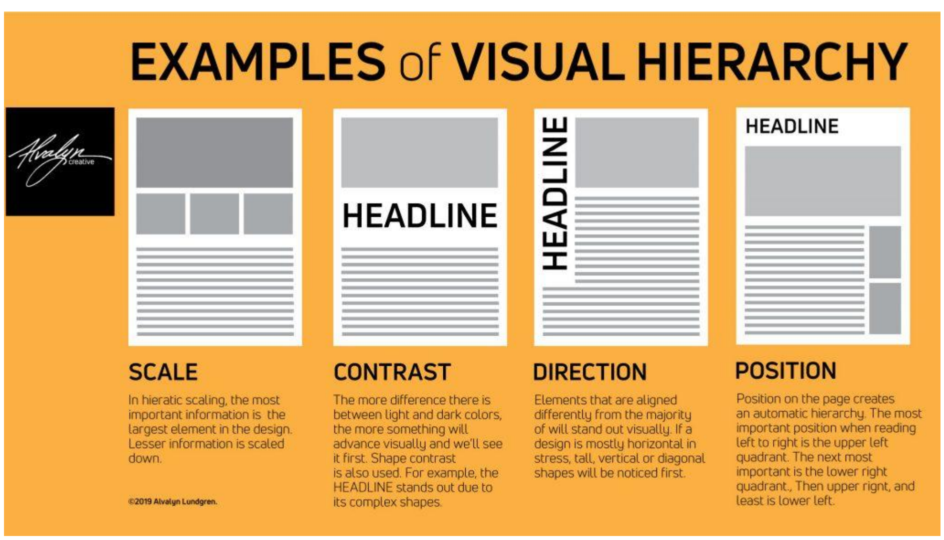
Mechanics of Sight

Mechanics of sight involves leveraging how the human eye naturally perceives and processes visual information to create graphics that effectively convey information. To understand how mechanics of sight work, one must understand the structures of the eye and how they work together to create an image in our mind. An article from the National Eye Institute perfectly describes how the different parts of the eye work together to help us see. Light first enters through the **cornea**, which looks like a transparent layer covering the eye. Its dome-like shape helps bend light to allow the eye to focus. Some of this light will then enter the **pupil**, which is a hole in the **iris**. The iris, the colored part of the eye, is what controls the amount of light that can enter the eye. The light then encounters the **lens**, a flexible disc that also helps to focus light. Light proceeds to hit the **retina**, a light-sensitive layer of tissue at the back of the eye, and **photoreceptors** within it convert the light into electrical signals. These signals then travel from the retina to the **optic nerve** in the brain, allowing the brain to convert the signals into images. The graphic below represents all of these parts.



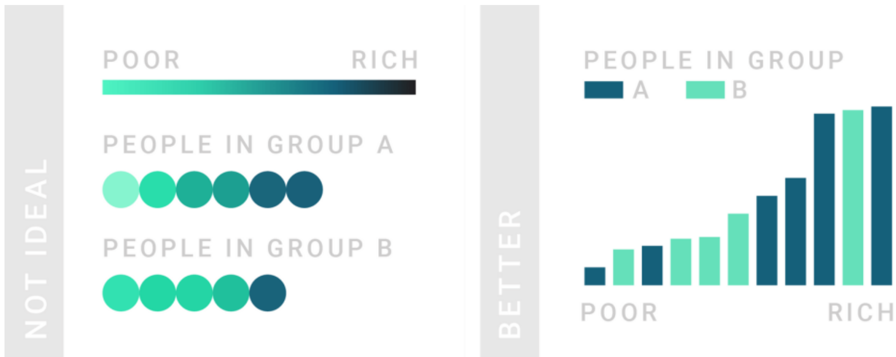
Source: National Eye Institute

There are key considerations when utilizing mechanics of sight:

- **Visual Hierarchy** is organizing data elements in a hierarchical fashion based on importance to draw the viewer's attention to a specific point. This is typically through a logical structure that helps users navigate.
    - 

Source: Alvalyn Studio

        - This graphic is a great example of how visual hierarchy can work using different methods. For instance, with scale, users are automatically drawn to larger elements and thus making one element significantly larger will place emphasis on it.

- **Color Perception** uses color to highlight key points, categorize items, or indicate trends.
    - 

      Source: Data Quest
        - This graphic shows color being used to categorize items (groups A and B) which is then able to indicate a trend of a greater proportion of the rich being people from group A.
- **Use of White Space** prevents a cluttered and distracting dashboard by emphasizing the need for empty space. While too much white space is inefficient, just enough white space helps in organization and clarity.
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      Source: Medium
        - This demonstrates a successful and failed use of white space. In the successful example, there are no overlapping layers that distract viewers from the true meaning of the visual. However, in the failed example, the

layers overlap, distracting the viewers with the vast number of elements incorporated into one space.

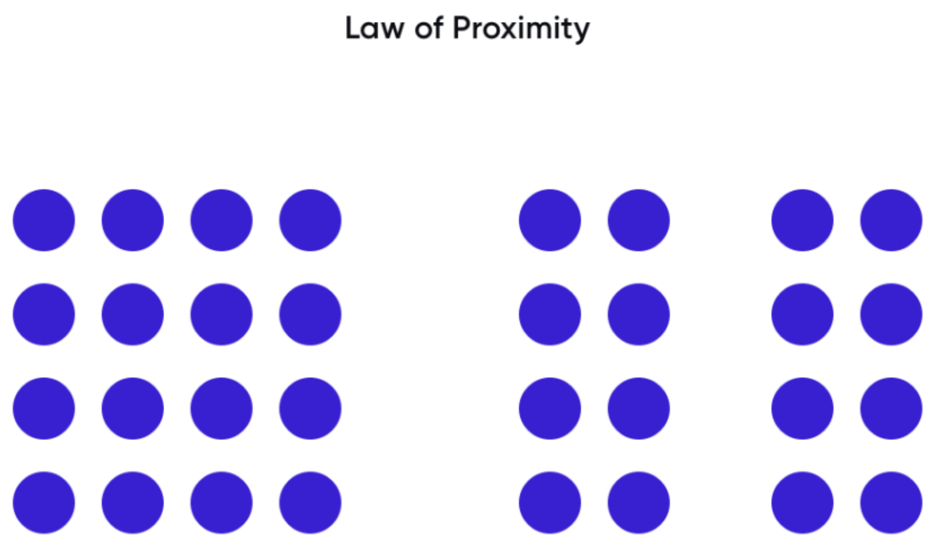
There are many other key considerations, such as attention span, eye movement in charts, data density, and more. Overall, it is clear how understanding how the human eye naturally perceives information helps to create a more effective visualization. These key aspects are used in many ways in the real world. Some examples include:

- **Data-Driven Decision Making, Enhancing Presentations, and Improving Stakeholder Engagement,** where managers use data to make key decisions and need to visualize this to audiences who may lack data analysis skills. Managers can then utilize mechanics of sight to create simple visualizations that stakeholders can understand and are impacted by, and lead to accurate decision-making.
- **Optimizing Resources** goes into the idea of preventing clutter with the use of white space. By understanding visual perception, managers organize visuals in a way that keep viewers attentive towards meaningful actions and avoid confusion.
- **Streamlining Communication Across Teams**. This concept is key for the overall purpose of data visualization – turning complex data into simple visuals that helps all audiences understand it. As various teams have differing experiences, managers creating dashboards will help bridge gaps between understandings and ensure all are on the same page.

In summary, by leveraging how our eyes absorb light and convert it into signals which become images, viewers are able to simply detect key takeaways from a graphic.

Gestalt Principles of Visual Perception

Gestalt principles explain how people organize and interpret visual information into meaningful patterns and groups. The name comes from the German word “gestalt,” translating to shape or form. However, we interpret it as a way to understand how our brains take what is in front of us and give it meaning. It was then found that our brain organizes items according to these principles. The principles are proximity, similarity, continuity, closure, figure-ground, common fate, and pragnanz. Focusing in on one element, **proximity** is the brain's tendency to perceive items closely together as a group. By imposing these categories in our mind, it is easier to understand and interpret what is being shown.



Source: Pro Creator

Using the figure above, our brain automatically groups the square of 16 together as one group, the rectangle of eight as another group, and the other rectangle of eight as the last group. Just simply by the tightness of these dots together, our brain already perceives them as a group or category. Applying this to more real-world examples:

- We see letters groups together form a word, and a break between these letters indicates a new word.
- If people are standing near each other in a photo, we perceive them as a group.

Applying this to a more data visualization example, close dots on a scatter plot would be perceived as one group and those separate as outliers.

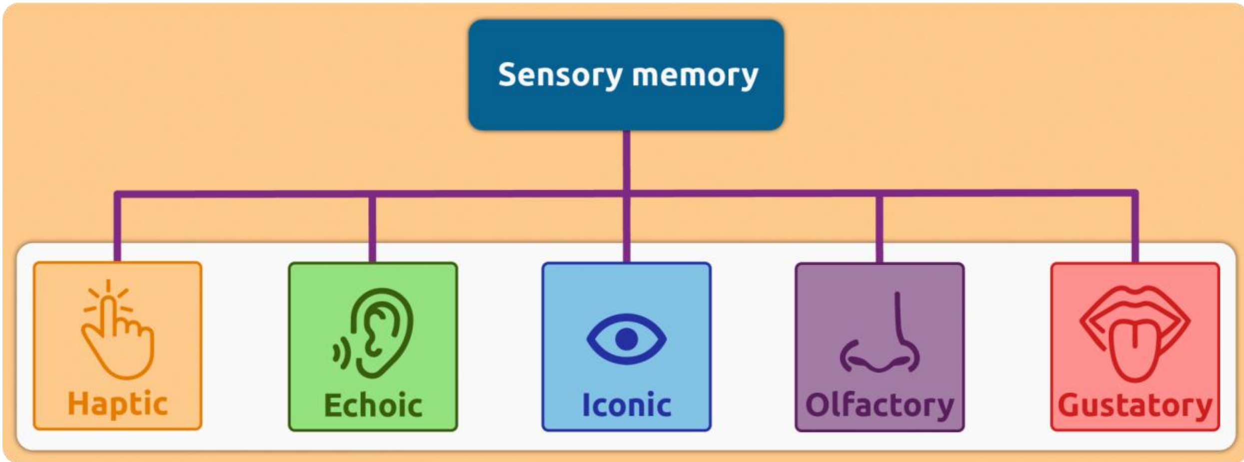
A different gestalt principle is **closure** where incomplete figures are mentally completed by the viewer, which is used to create simpler visuals. The brain is always searching for patterns to perceive, so it will automatically fill in gaps to make complete shapes. For instance, a dashed arrow would still be perceived as a full arrow, despite white space in between the design. This helps to make elements impactful with little detail needed. A real-world example would the World Wildlife Fund's logo of a panda, as shown below. The panda is not entirely connected/a closed figure, having gaps between the ears and body. However, the brain is able to envision a connection and thus perceive it as a panda.

Source: Medium

This can be used in data visualization by simplifying complex dashboard layouts by leaving some room for the viewer to fill in the gaps themselves, perceiving patterns without excessive detail. This will reduce the clutter of the dashboard but still allows the viewer to gain the meaning. For instance, partial outlines can be used in place of full outlines and will still be perceived as complete.

Types of Memory

Sensory memory is the brief retention of information gained through the five senses of sight, hearing, touch, smell, and taste. This type of memory is most utilized when designing visualizations.



Source: Simply Psychology

The graphic above from Simply Psychology indicates the five types of sensory memory that each link to one of those senses.

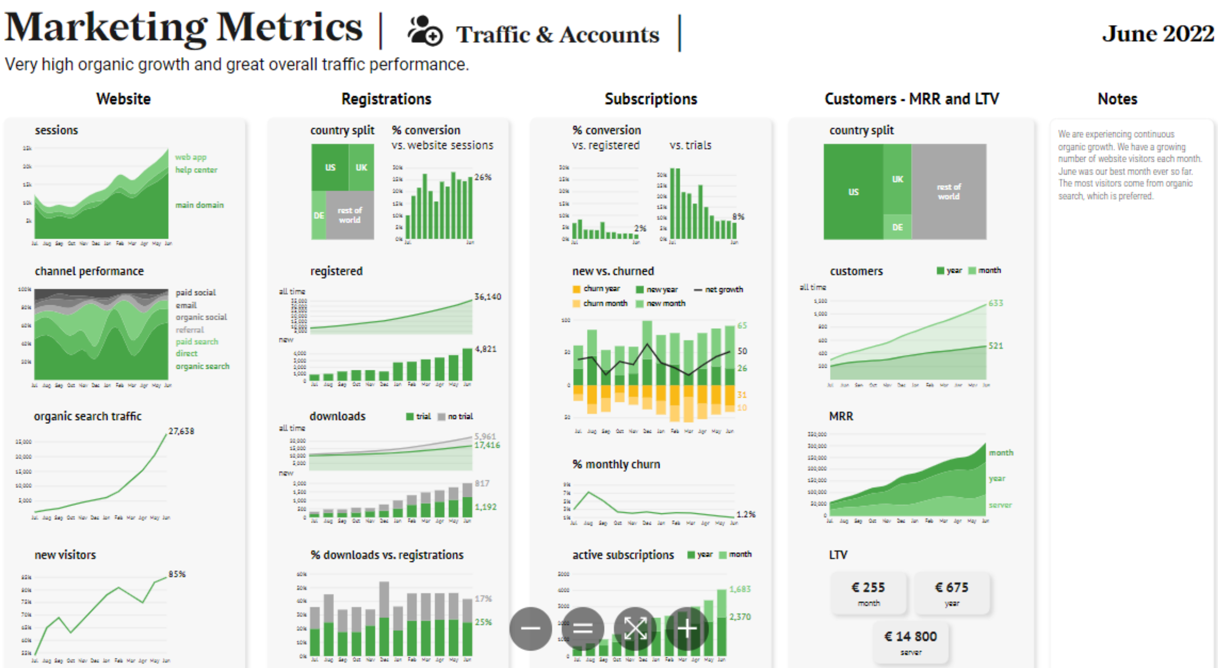
- **Haptic memory** is produced from sensory receptors receiving the sense of touch, which creates sensations such as pain, pressure, pleasure, or itching. These last about two seconds. An example is feeling a key when you type on a keyboard.
- **Echoic memory** relates to auditory information, or sounds. This can last several seconds as the brain can process this even after the source disappears. One example is hearing the strum of a guitar.
- **Iconic memory** relates to visual memory that stores visual images. This disappears within half a second, depending on its brightness. An example is seeing a firework in the sky.
- **Olfactory memory** deals with the sense of smell and allows us to process odors momentarily. An example is smelling chlorine and being reminded of the pool.
- **Gustatory memory** then corresponds to storing and recalling tastes after we have experienced them. This is closely linked to olfactory memory and can help recall entire events. An example includes tasting an exotic fruit that reminds you of a memory on vacation where you had the same fruit.

The Cleveland Clinic explains it working as experiencing a sense, the brain responsible for that sense then activates, attention is with important pieces of information gathered, and then this becomes short-term memory. Essentially, anything that quickly captures their attention and is key information becomes quickly retained into short-term memory. This is held for a very short duration, but is highly detailed and has a large capacity, so it is key for designers to be able to use this to their advantage. Out of these, iconic memory will be most beneficial.

This is key because sensory memory is activated when viewers first glance at a visualization. Being able to emphasize the key takeaways in your dashboard to communicate your storyline across. For instance, to have effective communication using iconic memory, you want to use clear and visually appealing mediums to ensure important messages are noticed. This could be with a bright color to draw attention towards a data point or large text to emphasize statistics, using the sense of sight. A real-life scenario would be training users through a program. By making these lessons engaging and interactive with carefully designed visuals, you draw out the participants' sensory memory for better engagement and greater impact.

Short-term memory is the ability to both remember and process information at once. According to Cleveland Clinic, it relies on attention, focusing on something in your environment, and recognition, being able to connect new information to information you already have. Information is temporarily held for a few seconds to minutes and can eventually be processed to become a long-term memory. On average, our brains can hold five to seven items in our short-term memory. However, various techniques like organizing items into groups can move this short-term memory into long-term memory. This draws back to the gestalt principle of proximity that automatically groups near items together.

Keeping this in mind when creating data visualizations is key because viewers need to be able to quickly understand and retain data in short increments, as our short-term memory is so limited. As dashboard designers, we can then apply this to data visualization by intentionally making decisions that minimizes **cognitive load**, the amount of effort required from short-term memory. When data is displayed in a way that shows meaningful patterns, more information can be grouped to interpret. This prevents providing more data than the brain can process. Using pre-attentive attributes, which is elaborated in the following header, will be essential for optimizing short-term memory. These attributes are processed quickly and automatically, allowing viewers to quickly spot trends without needing to analyze every detail. For instance, differentiate categories using distinct colors to represent categories so the viewer can compare data groups. Referring back to cognitive load, there are many strategies to use to limit cognitive load. Some include providing a clear title and subtitle that clearly describes the visual, limiting color and using a consistent font type/size to prevent distractions, or using filters to narrow what the viewer sees at once.

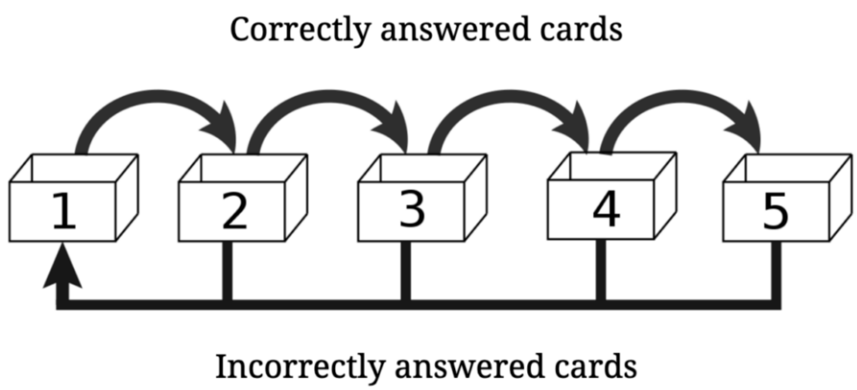


Source: Datylon

This is a great example that has a clear title with subtitles that categorize each section. At a quick glance, viewers are able to easily understand what the dashboard is about and the categories that will be explored within.

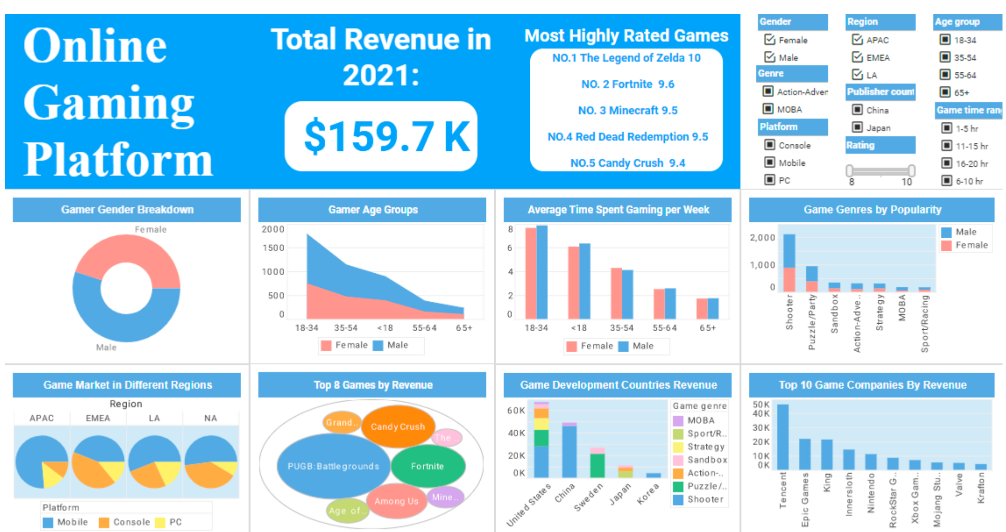
Long-term memory then holds information for extended periods of time, whether it be minutes or for a lifetime, and has a larger capacity than short-term memory. By creating a well-designed visualization, short-term memory converts to long-term memory through various techniques, such as repetition, chunking, and more. To leverage long-term memory, focusing on touching your audience’s emotions will also be key, as this helps make a lasting impact for them to walk away with.

As stated before, repetition is one of the most well-known techniques for turning short-term memory into long-term memory. A real-world example would be studying for a vocabulary test – you would go through flashcards numerous times until you could confidently and instantly remember each term.



Source: NessLabs

In the visual above, correctly answered cards are consistently moved until they have been correctly answered five times, meaning they have become long-term memory. Incorrectly answered cards are then moved to the start until they become correctly answered five times, or in other words become long-term memory. Applying this to data visualizations, repeat the colors, shapes, and arrangements used. For instance, using an NFL analytics dashboard, if the color green is consistently used to represent "high scoring games," then viewers will automatically make that correlation elsewhere in the dashboard. Furthermore, if a star consistently represents a quarterback, viewers will automatically associate those together.



Source: InetSoft

This dashboard utilizes repeating colors used – pink represents female and blue represents male throughout.

Another technique is chunking, where individual pieces of information are grouped into meaningful chunks. The patterns and similarities made then reduce cognitive load, making it easier to store as long-term memory. One well-known example of this is phone numbers. Chunks of numbers are separated by hyphens that make them easier to remember. Another example is using acronyms, such as PEMDAS for order of operations being taught as Please Excuse My Dear Aunt Sally to memorize or NESW for the cardinal directions being Never Eat Soggy Waffles. In data visualization, this can be used by using a certain color for a distinct cluster to automatically create a chunk for users to memorize, rather than many data points.

Lastly, touching on emotions connects the narrative to the viewers in a more meaningful way. Viewers automatically relate the storytelling to their own lives and are thus more likely to store it in their long-term memory. Lexis Nexis has a quote from MIT Sloan lecturer Miro Kazakoff stating that if you want people to make the right data decisions, you need to get it to them in a way they will understand, which is often with stories and preferably pictures. Understanding your audience is key to accomplishing this. Set the tone with certain colors like cool colors for calmness or use shapes that elicit a mood like stars for key points. Overall, it is clear how data visualizations can be converted into long-term memory through various techniques. While this one is the least prioritized, a well-designed storyboard will be able to make a lasting impact in viewers' memories.

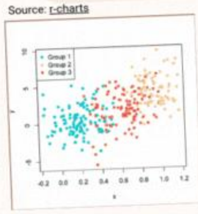
Pre-Attentive Attributes

Pre-attentive attributes are visual qualities that the brain can process instantly and without conscious effort. These allow viewers to quickly perceive patterns and notice key details without needing to analyze much, minimizing cognitive load which we know plays a crucial role in memory. As viewers are drawn to the critical components of the dashboard, visualizations become more effective and engaging. The various components will be listed below in an infographic.

PRE-ATTENTIVE ATTRIBUTES

HELEN LE

Source: r-charts



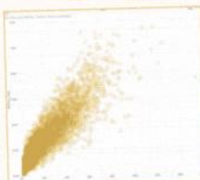
1 COLOR

Color is used to contrast between categories or emphasize specific points. Color differences are automatically spotted and pop out. The graph to the left displays three colors being used for three groups with each group being easy to spot.

Source: NetSuite

2 SIZE

Size is used to contrast between quantitative values. For instance, a larger bubble would indicate a larger value. The graph to the right shows SF Bay Area as the largest market for technology jobs.

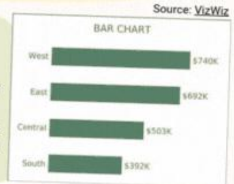


Source: Microsoft Learn

3 POSITION

Position is for the placement of elements in strategic locations to add further meaning. One example is how the Y axis represents a dependent variable and X axis represents an independent variable. The graph to the left demonstrates position as the positioning, or spatial grouping, of the dots being cluttered immediately stands out.

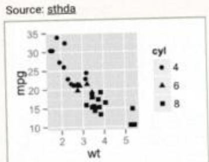
Source: VizWiz



4 LENGTH AND ORIENTATION

Length and orientation are used to represent unique data values. For length specifically, a great example is heights of bar charts representing magnitudes of values - a high bar indicates a high value. The graph on the right demonstrates this. For orientation, the slope on a scatter plot indicates an increase or decrease that the viewer notices.

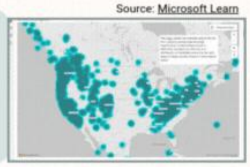
Source: sthda



5 SHAPE

Shape can be utilized in data visualizations by using different shapes to represent different categories. The graph on the right shows this with circles representing one category, triangles representing another, and then squares representing the third.

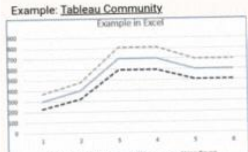
Source: Microsoft Learn



6 INTENSITY

Intensity relates to the intensity and saturation of colors in a graph, which draws attention to specific data points. Intensity is able to represent magnitude, similar to length such as higher intensity representing high magnitudes. The map on the right has hot spots where color is concentrated to show a large quantity of data points present.

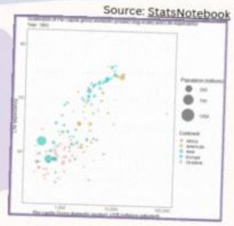
Example: Tableau Community



7 TEXTURE

Texture uses varying patterns to highlight patterns and differentiate categories. While not used often, when used properly, it can provide great value. One great example is using a dashed or solid line. For instance, a dashed line can represent predicted, while a solid line represents actual. The graph on the left uses a dashed line to represent bounds and a solid line to represent the actual value.

Source: StatsNotebook



8 MOTION

Motion is most often used to represent changes over time, revealing patterns, trends, and relationships to create a more engaging visual. The graph on the right represents how Per capita Gross domestic product impacts life expectancy over the years.

Canva Link to Infographic Made

These elements are applied to enhance communication, engagement, and decision-making. The elements of position and length are used for effective communication by emphasizing key points to audiences and ensuring the intended message is shared. When results of employee surveys are received, intensity and position can bring attention to problem areas. Overall, I personally find pre-attentive attributes to be the most important for designing effective dashboards. They allow us to instantly detect key information, guiding attention to critical aspects of data and the important message of the plot.

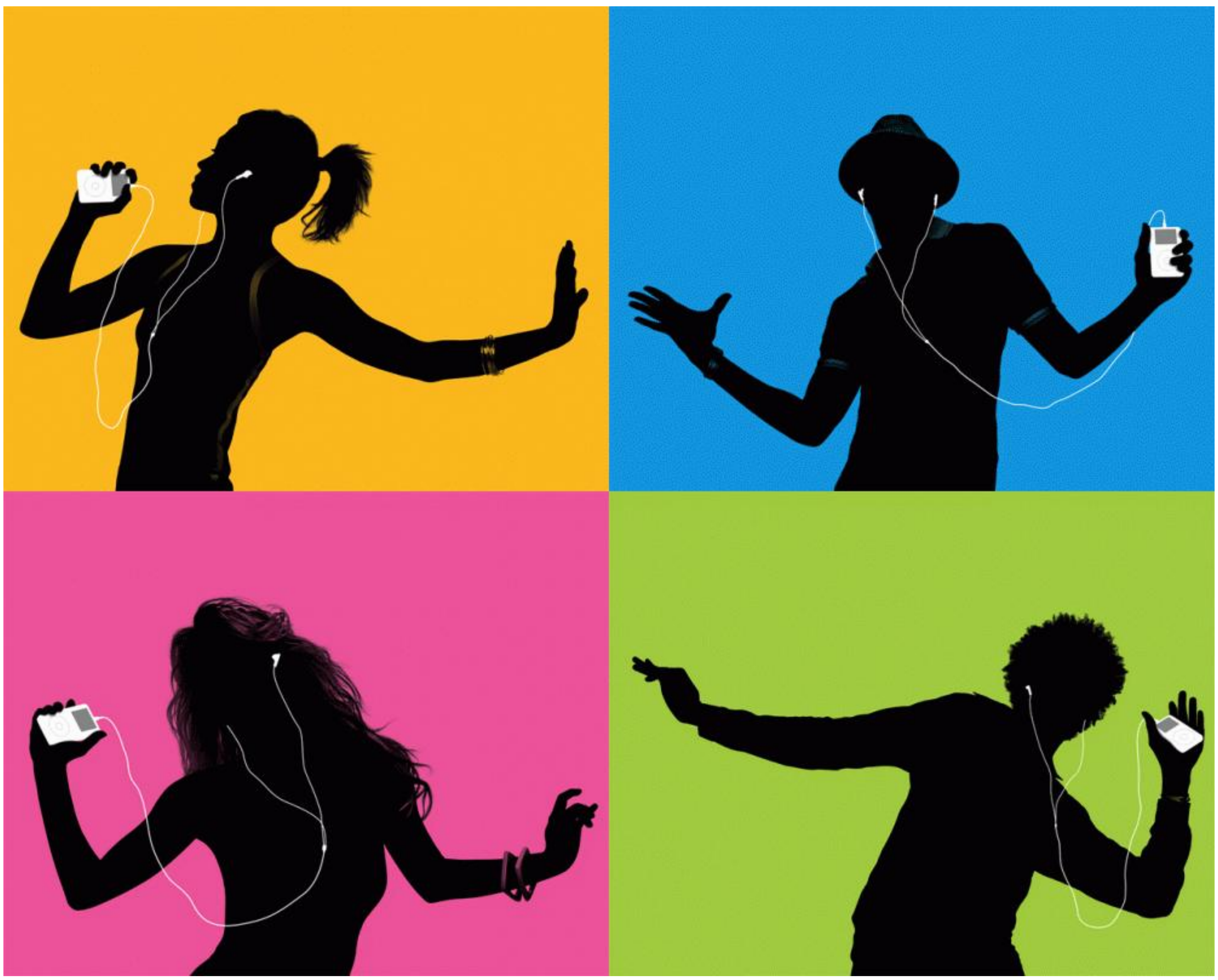
Visual Encoding

Visual encoding is the process of representing information through visual attributes like size, color, and shape, to transform data into something easily interpretable. It takes complex information and presents it in a way that those lacking analytical experience could understand it for decision-making. Knowing how to use this concept is extremely important because it makes data easier to understand and remember by activating memory and recall. Generally, it simplifies complexity, turning an abundance of numbers into a clear, but comprehensive visual format. This then helps in making comparisons, something that would have been more difficult when just given an arrangement of numbers. There are many key aspects to perform visual encoding. Some are:

- **Shape/Color Encoding** – using different colors/shapes to represent different groups, such as using red to represent one category and blue to represent another or a star to represent one category and a square to represent another.
- **Temporal Encoding** – this relates to the pre-attentive attribute of motion and represents data changes over time through animated visuals. For instance, to show a change by the year, an animated graph will be able to show new patterns or trends that emerge as time goes on.
- **Pattern Encoding** – this is similar to the pre-attentive attribute of texture where a dashed and solid line would each indicate a different data series.

There are many more visual encoding key aspects, but overall, the importance is clear. Visual encoding is at the heart of data visualization, where the goal is to turn complex data into simple visualizations that allow a diverse audience to understand and make key decisions.

An advertisement known for its use of visual encoding is the Apple iPod silhouette ad campaign in November 2001. Pictured below, you can easily see many key aspects of visual encoding. **Color encoding** is used in the four quadrants to differentiate between each listener. Each silhouette of a person listening to music on their iPod represents **shape encoding** with the black shapes being simple, but still clear to see it is people enjoying music. **Position encoding** is then seen with the white iPod and earbuds being contrasted against the silhouettes, emphasizing the product being advertised.



Source: MBA Knowledge Base

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