The Role of Visual Perception in Data Visualization

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It is said that a picture is worth a thousand words. Why is it that we can understand complex information on a visual but not from rows of tabular data? The answer to this lies in understanding visual perception and a little bit about human memory.

So grab a cup of your favorite drink and read on.

This is what we will cover:

1. What is visual perception?
2. How does visual perception affect data visualization?
3. The power of data visualization
4. How human memory works and why is this important to visualization?

What is visual perception?

Wikipedia defines **Visual perception** as the ability to interpret the surrounding environment by processing information that is contained in visible light. The resulting perception is also known as eyesight, sight, or vision.

How does visual perception affect data visualization?

The main purpose of data visualization is to aid in good decision making. To make good decisions, we need to be able to understand trends, patterns, and relationships from a visual. This is also known as drawing insights from data. Now here is the tricky part, ***we don't see images with our eyes; we see them with our brains***. The experience of visual perception is in fact what goes on inside our brains when we see a visual.

Let's understand a little bit more about visual perception. There are 3 key points to note:

1. **Visual perception is selective**. As you can imagine, if we tune our awareness to everything, we will be very soon overwhelmed. So we selectively pay attention to things that catch our attention.
2. **Our eyes are drawn to familiar patterns**. We see what we expect to see. Hence visualization must take into account what people know and expect.
3. **Our working memory is very limited**. We will go in depth about memory in a bit, but just understand that we can hold a very limited amount of information in our memory when looking at a visual.

Data visualization is in many some ways an external aid to support our working memory.

The power of data visualization

Remember how some visuals give you an "Aha moment" instantly? These visuals correspond naturally to the workings of visual perception and cognition. What does that mean? Ok, let's break this down.

Visual perception is the act of seeing a visual or an image. This is handled by visual cortex located at the rear of the brain. The visual cortex is **extremely fast and efficient.**

Cognition is the act of thinking, of processing information, making comparisons and examining relationships. This is handled by the cerebral cortex located at the front of the brain. The cerebral cortex is **much slower and less efficient.**

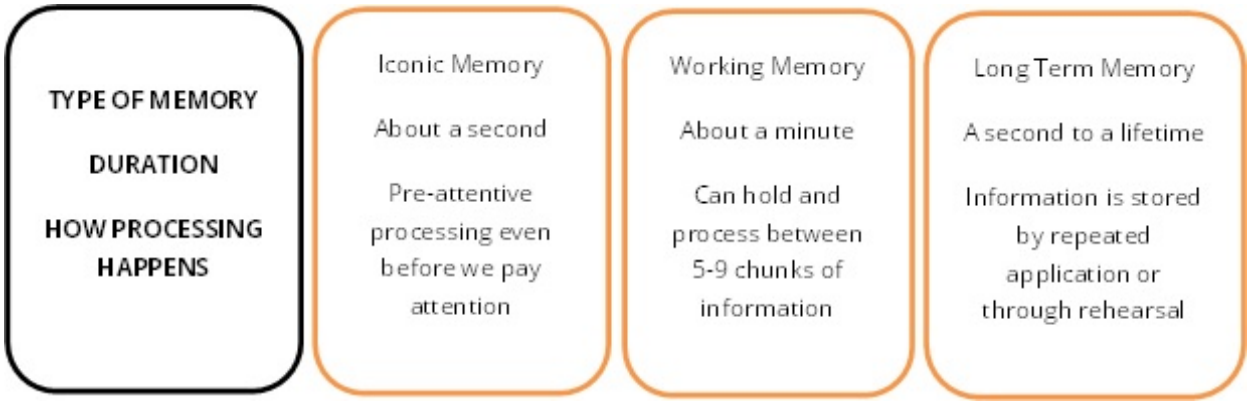
Here is where the magic happens. **Data visualization shifts the balance between perception and cognition to use our brain's capabilities to its advantage.** This means more use of visual perception and lesser use of cognition.

How do we achieve this? Before we answer this question, we need to understand how our memory works.

How human memory works and why is this important to visualization?

There are 3 types of memories that process information in our brain-

1. Iconic memory or Sensory memory
2. Working memory
3. Long term memory



The long term memory is where things we memorize or remember are stored. The iconic and working memories are the ones that interact with visualizations, so let's look at them in depth.

Iconic memory or Sensory memory:

When we see a visual, the information remains in the iconic memory for a tiny period of time, less than a second. We process and store information automatically in this fraction of a second. This process is called **preattentive processing** and it happens automatically, even before we pay attention to the information. The preattentive process detects several visual attributes. Hence understanding how to make a particular attribute stand out can help us create visuals that emphasize on the more important information.

Working memory or Short term memory:

This is the memory we use when we are actually working with a visual. The sensory information that is of interest to us is processed in the working memory. Information stays here for about a minute and the capacity of our working memory is between 5 to 9 similar items (Miller's Law).

The capacity of our working memory can be increased by a process called **Chunking**, which is grouping similar items together.

Data visualizations take advantage of chunking. When information is displayed in the form of visuals that show meaningful patterns, more information can be chunked together. Hence, when we look at a visual, we can process a great deal more information than what we can when looking at the data in the form of a table.

For a visualization to be effective, we need to pay attention to not providing more data than what our brains can process. It is also important to display the visual on a screen or a single location, such that we can see it without having to scroll or bounce back and forth between multiple locations.

Conclusion

This is the real power of visualization – the ability to get across lot more complex information than what our visual or verbal memory can generally hold.
In part 2 of this post, we will see how to interact with our sensory memory and preattentive processing.

References and Further Reading:

There is a lot of great literature available on this topic. If you are interested in reading more on this topic, here are some reference textbooks and websites.

1. Chapter 5 of Show Me the Numbers by Stephen Few
2. Chapter 3 of Now you see it by Stephen Few
3. Information Visualization: Perception for Design, Colin Ware
4. https://www.interaction-design.org/literature/article/the-properties-of-human-memory-and-their-importance-for-information-visualization

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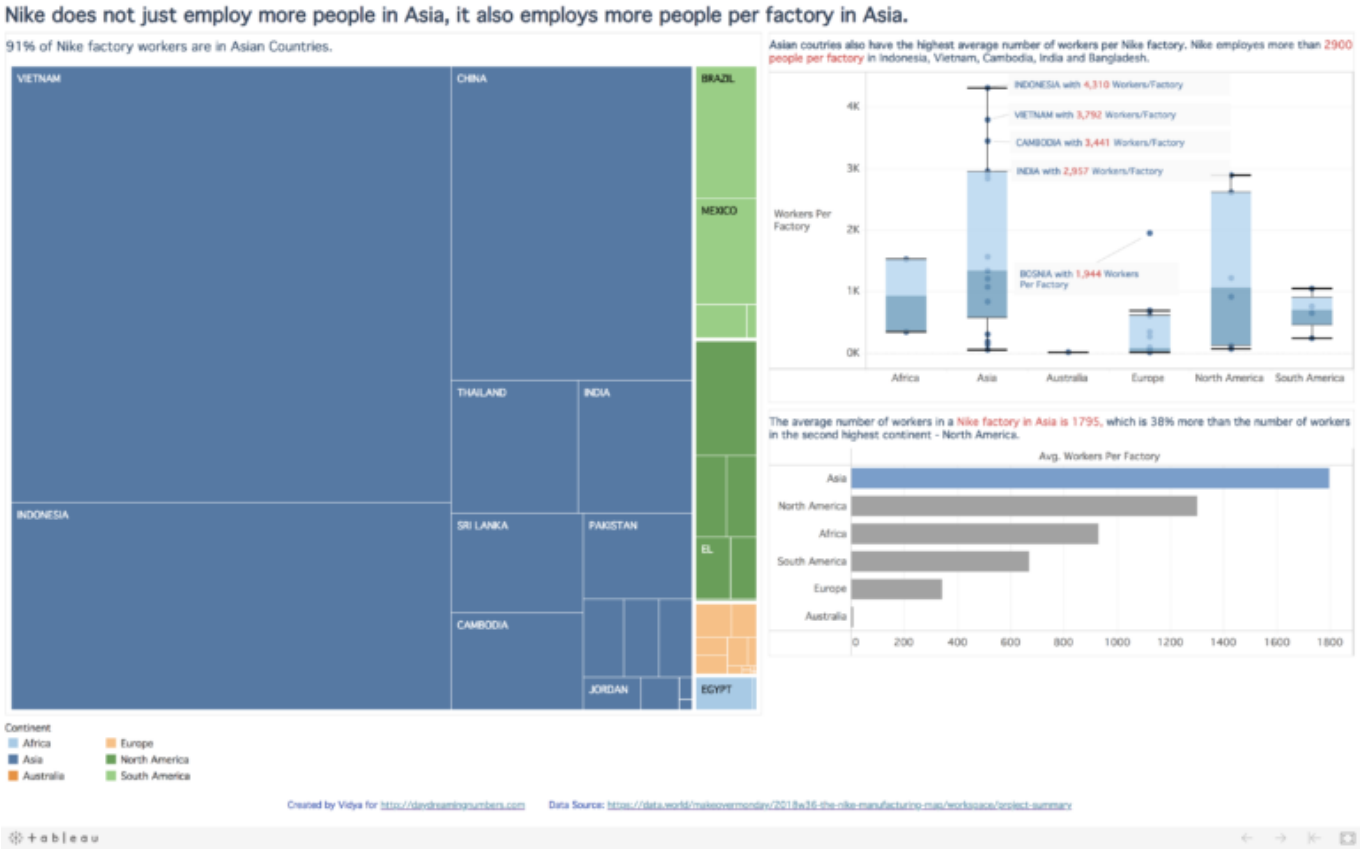

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UNIT:1
INTRODUCTION TO DATA VISUALIZATION AND PERCEPTION

INTRODUCTION

Data visualization is a graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.

DATA VISUALIZATION TECHNIQUES:

The type of data visualization technique you leverage will vary based on the type of data you're working with.

Here are some important data visualization techniques to know:

- Pie Chart
- Bar Chart
- Histogram
- Gantt Chart
- Heat Map
- Box and Whisker Plot
- Waterfall Chart
- Area Chart
- Scatter Plot
- Pictogram Chart
- Timeline
- Highlight Table
- Bullet Graph
- Choropleth Map
- Word Cloud
- Network Diagram
- Correlation Matrices

Advantages:

- Easily sharing information.
- Interactively explore opportunities.
- Visualize patterns and relationships.

Disadvantages: when viewing a visualization with many different data points, it's easy to make an inaccurate assumption. Or sometimes the visualization is just designed wrong so that it's biased or confusing.

- Biased or inaccurate information.
- Correlation doesn't always mean causation.
- Core messages can get lost in translation.

INTRODUCTION TO VISUAL PERCEPTION:

Definition:

How our brain perceives and interprets visuals

visual perception is the ability to interpret the surrounding environment by processing information that is contained in visible light. The resulting perception is also known as eyesight, sight, or vision.

The visual perception process is how the eyes and brain interpret information viewed on a screen.

Visual perception processing categories:

1.visual discrimination

2.visual memory

3.visual spatial relationships

4.visual form constancy

5.Visual sequential memory

6.visual figure/ground

7.visual closure

1.Visual discrimination

The ability to distinguish one shape from another.

2.Visual memory

The ability to remember a specific form when removed from your visual field.

3.Visual-spatial relationships

The ability to recognize forms that are the same but may be in a different spatial orientation.

4.Visual form constancy

The ability to discern similar forms that may be different in size, colour, or spatial orientation and to consistently match the similar forms.

5.Visual sequential memory

The ability to recall two to seven items in sequence with vision occluded.

6.Visual figure/ground

The ability to discern discrete forms when camouflaged or partially hidden.

7.Visual closure

The ability to recognize familiar forms that are only partially completed.

Our visual perceptual process occurs in three quick steps:

1. **Visual perception is selective**. As you can imagine, if we tune our awareness to everything, we will be very soon overwhelmed. So we selectively pay attention to things that catch our attention.
2. **Our eyes are drawn to familiar patterns**. We see what we expect to see. Hence visualization must take into account what people know and expect.
3. **Our working memory is very limited**. We will go in depth about memory in a bit, but just understand that we can hold a very limited amount of information in our memory when looking at a visual.

VISUAL REPRESENTATION OF DATA:

Data visualization is the process of creating graphical representations of information. This process helps the presenter communicate data in a way that's easy for the viewer to interpret and draw conclusions. There are many different techniques and tools you can leverage to visualize data, so you want to know which ones to use and when.

Importance of visual representation:

1. Comprehend information quickly.

2. Identify relationships and patterns.

3. Communicate the story to others.

4. Visual data help us to think and communicate.

5. A picture tells a story better than a thousand words could.

Visualization goals:

1.Understand the data you're trying to visualize,including its size.

2.Determine what you are trying to visualize and what kind of information you want to communicate.

3.Know your audience and understand how it process visual information.

4.Use a visual that conveys the information in the best and simplest form to the audience.

Data visualization Tools:

1.Tableau

2.JupyteR

3.Google charts

4.Visual.ly

5.Power BI

General Types of Visualizations:

- **Chart:** Information presented in a tabular, graphical form with data displayed along two axes. Can be in the form of a graph, diagram, or map.
- **Table:** A set of figures displayed in rows and columns.
- **Graph:** A diagram of points, lines, segments, curves, or areas that represents certain variables in comparison to each other, usually along two axes at a right angle.
- **Geospatial:** A visualization that shows data in map form using different shapes and colors to show the relationship between pieces of data and specific locations.
- **Infographic:** A combination of visuals and words that represent data. Usually uses charts or diagrams.
- **Dashboards:** A collection of visualizations and data displayed in one place to help with analyzing and presenting data.

Negative space has long been a staple of good design. Leaving white space around elements of a design is the first thing that usually comes to mind. But then there are designs that use that white space to infer an element that isn't actually there (the arrow hidden between the E and X in the FedEx logo immediately comes to mind as an example).

The human brain is exceptionally good at filling in the blanks in an image and creating a whole that is greater than the sum of its parts. It's why we see faces in things like tree leaves or sidewalk cracks.

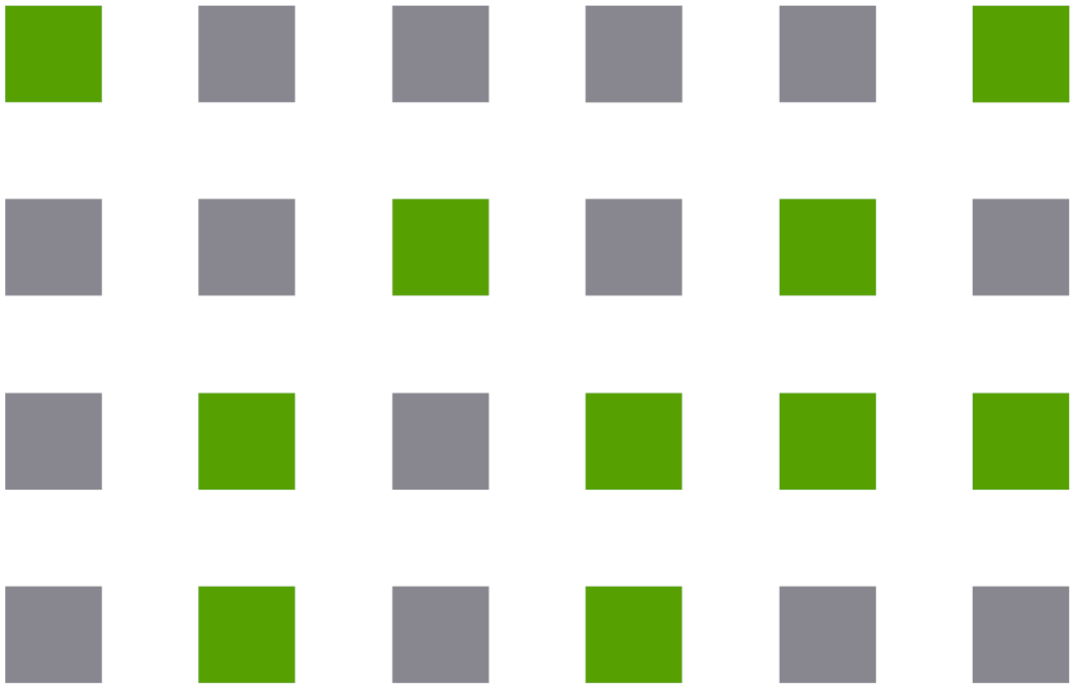
This principle is one of the most important underlying ideas behind the gestalt principles of perception. The most influential early proposal written about the theory was published by Max Wertheimer in his 1923 *Gestalt laws of perceptual organization*, though Wolfgang Köhler's 1920 discussion of *Physical Gestalten* also contains many influential ideas on the subject. Regardless of who first proposed the ideas (there have been essays dating back as far as 1890), gestalt theory principles are an important set of ideas for any designer to learn, and their implementation can greatly improve not just the aesthetics of a design, but also its functionality and user-friendliness.

In the simplest terms, gestalt theory is based on the idea that the human brain will attempt to simplify and organize complex images or designs that consist of many elements, by subconsciously arranging the parts into an organized system that creates a whole, rather than just a series of disparate elements. Our brains are built to see structure and patterns in order for us to better understand the environment that we're living in.

There are six individual principles commonly associated with gestalt theory: **similarity**, **continuation**, **closure**, **proximity**, **figure/ground**, and **symmetry & order** (also called *prägnanz*). There are also some additional, newer principles sometimes associated with gestalt, such as common fate.

Similarity

It’s human nature to group like things together. In gestalt, similar elements are visually grouped, regardless of their proximity to each other. They can be grouped by color, shape, or size. Similarity can be used to tie together elements that might not be right next to each other in a design.



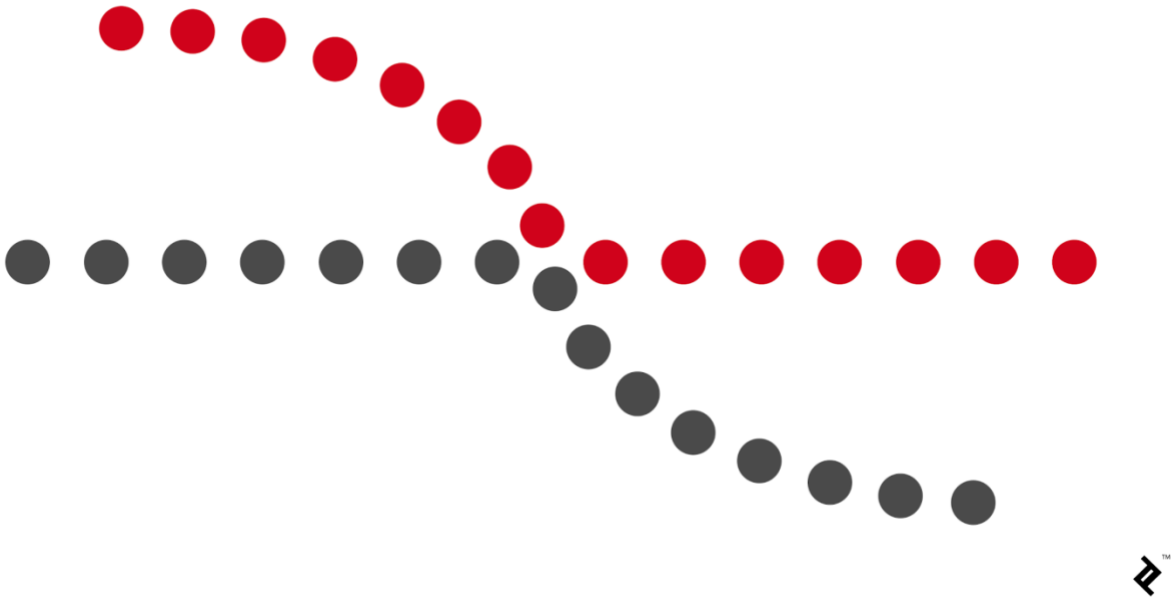
Of course, you can make things dissimilar if you want to make them stand out from the crowd. It’s why buttons for calls to action are often designed in a different color than the rest of a page—so they stand out and draw the visitor’s attention to the desired action.

In UX design, using similarity makes it clear to your visitors which items are alike. For example, in a features list using repetitive design elements (such as an icon accompanied by 3-4 lines of text), the similarity principle would make it easy to scan through them. In contrast, changing the design elements for features you want to highlight makes them stand out and gives them more importance in the visitor’s perception.

Even things as simple as making sure that links throughout a design are formatted in the same way relies on the principle of similarity in the way your visitors will perceive the organization and structure of your site.

Continuation

The law of continuity posits that the human eye will follow the smoothest path when viewing lines, regardless of how the lines were



actually drawn.

This continuation can be a valuable tool when the goal is to guide a visitor's eye in a certain direction. They will follow the simplest path on the page, so make sure the most vital parts they should see fall within that path.

Since the eye naturally follows a line, placing items in a series in a line will naturally draw the eye from one item to the next. Horizontal sliders are one such example, as are related product listings on sites like Amazon.

Closure

Closure is one of the coolest gestalt design principles and one I already touched on at the beginning of this piece. It's the idea that your brain will fill in the missing parts of a design or image to create a whole.

In its simplest form, the principle of closure allows your eye to follow something like a dotted line to its end. But more complex applications are often seen in logos, like that for the World Wildlife Fund. Large chunks of the outline for the panda are missing, but your brain has no problem filling in the missing sections

to see the whole animal.

Closure is quite often used in logo design, with other examples including those for the USA Network, NBC, Sun Microsystems, and even Adobe.

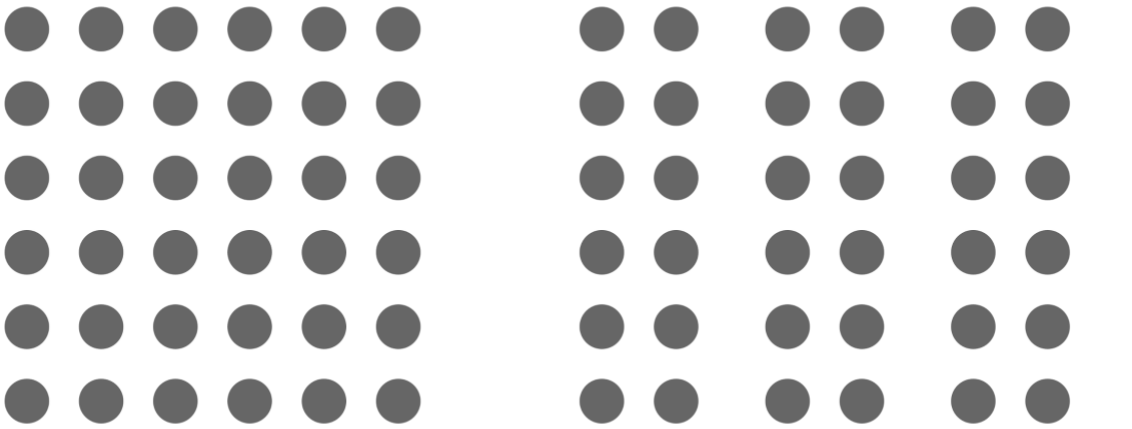
Another very important example of closure at work in UX and UI design is when you show a partial image fading off the user's screen in order to show them that there is more to be found if

they swipe left or right. Without a partial image, i.e., if only full images are shown, the brain doesn't immediately interpret that there might be more to be seen, and therefore your user is less likely to scroll (since closure is already apparent).

Proximity

Proximity refers to how close elements are to one another. The strongest proximity relationships are those between overlapping subjects, but just grouping objects into a single area can also have a strong proximity effect.
The opposite is also true, of course. By putting space between elements, you can add separation even when their other characteristics are the same.

Take this group of circles, for exampl



e:

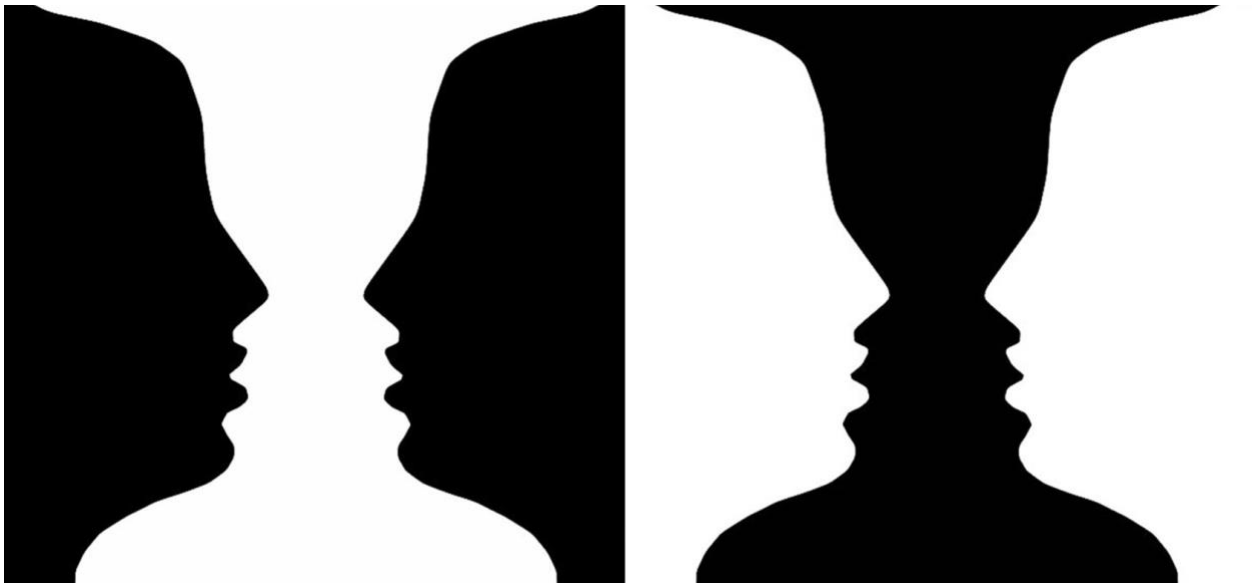
In UX design, proximity is most often used in order to get users to group certain things together without the use of things like hard borders. By utilizing gestalt grouping principles and putting like things closer together, with space in between each group, the viewer will immediately pick up on the organization and structure you want them to perceive.

Figure/Ground

The figure/ground principle is similar to the closure principle in that it takes advantage of the way the brain processes negative space. You've probably seen examples of this principle floating around in memes on social media, or as part of logos (like the FedEx logo already mentioned). Your brain will distinguish between the objects it considers to be in the foreground of an image (the figure, or focal point) and the background (the area on which the figures rest). Where things get interesting is when the foreground and background actually contain two distinct images, like

this:

A simpler example can be seen with this image, of two faces creating a candlestick or vase between them:

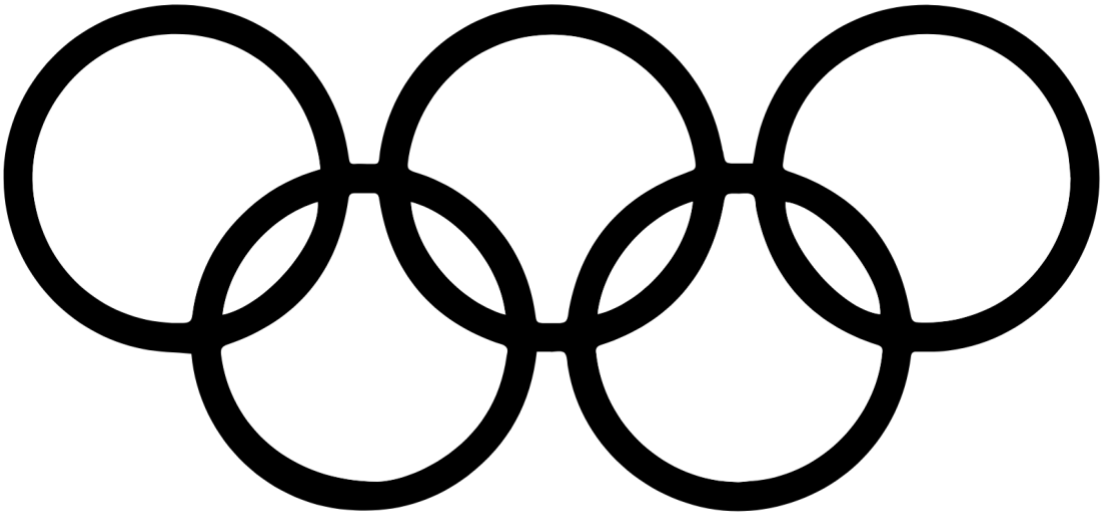


In general terms, your brain will interpret the larger area of an image as the ground and the smaller as the figure. As shown in the image above, though, you can see that lighter and darker colors can influence what is viewed as the figure and what is viewed as the ground.

The figure/ground principle can be very handy when product designers want to highlight a focal point, particularly when it is active or in use—for example, when a modal window pops up and the rest of the site fades into the background, or when a search bar is clicked on and the contrast is increased between it and the rest of the site.

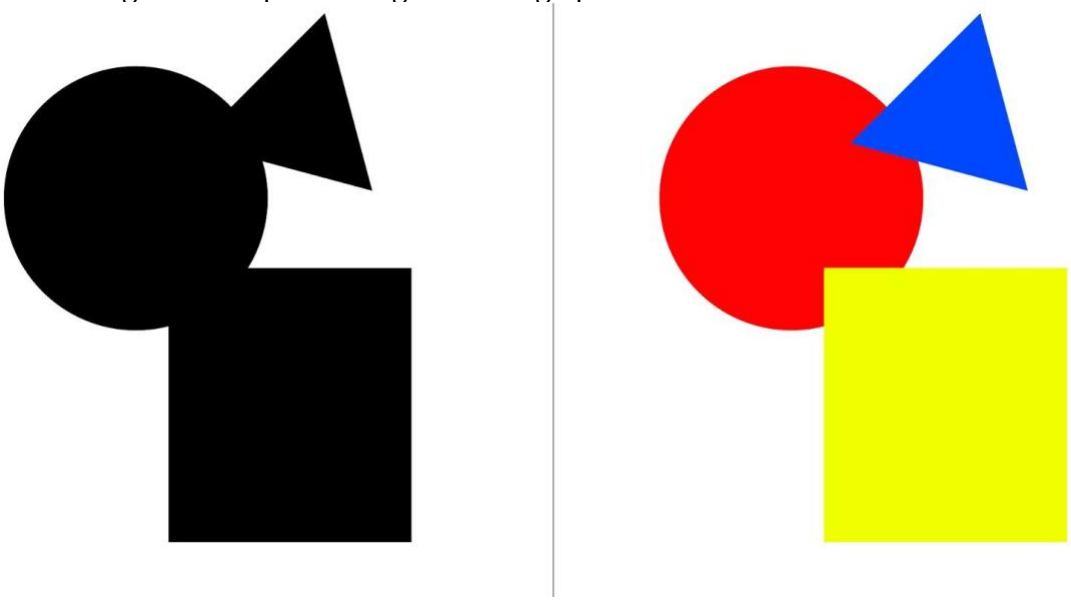
Symmetry and Order

The law of symmetry and order is also known as *prägnanz*, the German word for “good figure.” What this principle says is that your brain will perceive ambiguous shapes in as simple a manner as possible. For example, a monochrome version of the Olympic logo is seen as a series of overlapping circles rather than a collection of curve



d lines.

Here’s another good example of the gestalt design prin



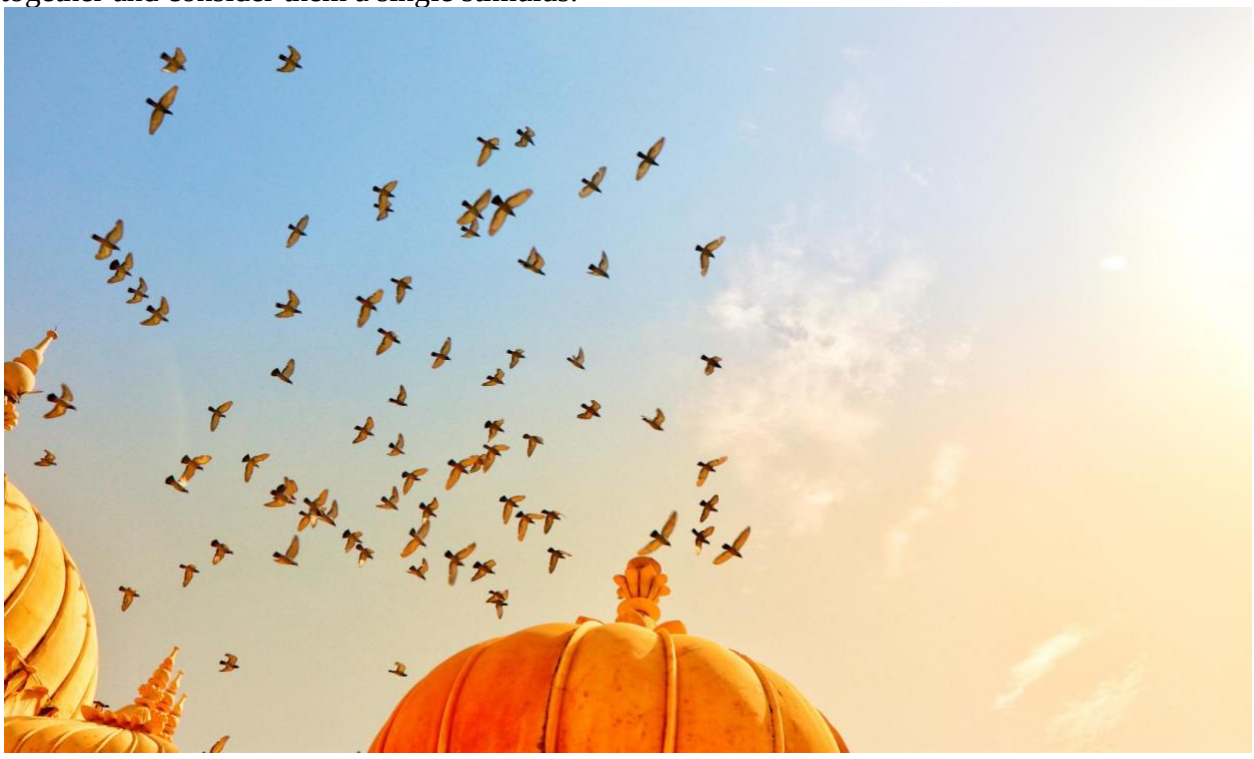
ciple “*prägnanz*”:

Your brain will interpret the image on the left as a rectangle, circle, and triangle, even when the outlines of each are incomplete because those are simpler shapes than the overall image.

Common Fate

While common fate was not originally included in gestalt theory, it has since been added. In UX design, its usefulness can't be overlooked. This principle states that people will group together things that point to or are moving in the same direction.

In nature, we see this in things like flocks of birds or schools of fish. They are made up of a bunch of individual elements, but because they move seemingly as one, our brains group them together and consider them a single stimulus.



This is very useful in UX as animated effects become more prevalent in modern design. Note that elements don't actually have to be moving in order to benefit from this principle, but they do have to give the *impression* of motion.

Gestalt Principles in UX Design

As with any psychological principle, learning to incorporate the visual perception principles of gestalt into your design work can greatly improve the user experience. Understanding how the human brain works and then exploiting a person's natural tendencies creates a more seamless interaction that makes a user feel comfortable on a website, even if it's their first visit.

Gestalt laws are relatively easy to incorporate into just about any design and can quickly elevate a design that seems haphazard or like it's fighting for a user's attention to one that offers a seamless, natural interaction that guides users toward the action you want them to take.

Further Reading on the Toptal Blog:

What is Information Overload?

Information overload refers to overwhelming the brain with a huge amount of information data than it can handle and process. Information overload occurs when task inputs to the mind exceed its ability to synthesize. The information overload definition refers to the technologically oriented world where too much information is available about a topic or context. It constitutes excess information available for a person to decode and comprehend. Therefore, information overload causes brain fatigue, limits brain focus, and impedes decision-making. Product designers are always careful to avoid information overload in their product design not to jeopardize the user experience. Simple and precise information about a product is enough to help users understand how a product works.

The phrase 'information overload' was first used by Bertram Gross, a political science professor at Hunters College, in his 1964 article "The Managing of Organizations." The phrase was later promoted by an American futurist and writer known as Alvin Toffler in his book *Future Shock* in 1970. However, the phrase *information overload* is believed to have existed as early as the 3rd century BCE.

Some of the common causes of information overload include:

- Pressure to create and compete in the provision of information.
- A considerable amount of new data is continually being created.
- Huge volumes of contradicting and old inaccurate information.
- Lack of more straightforward methods to process, compare and evaluate information.
- The increasing weight of historical data is being discovered daily.
- Rapid increase in information media channels like print media, electronic media, etc.

Modern information technology has impacted information overload both positively and negatively. The invention of artificial intelligence and other modern technologies, for instance, has led to efficiency in handling massive information sources, narrowing them down to whatever is most important. Contrastingly, modern technology has enabled more access to information, thereby increasing information overload.

- **Lesson**
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Effects of Information Overload

Communication overload is when too much communication takes place simultaneously to the extent that one is overwhelmed and cannot process and handle it simultaneously. For example, several email notifications, phone calls, and texts pop up simultaneously on the phone, so the user is frozen deciding which one to respond to and which to leave pending.

Information overload can lead to the following effects:

- **Textual overload**- This refers to the multiple and simultaneous receiving of data beyond one's capacity to handle it. Textual overload causes frustration and confusion as one cannot prioritize which data to manage.
- **Analysis Paralysis**- This is the inability to make better decisions due to overthinking a problem. When bombarded with vast amounts of data options, an individual or group wrangles about each option's pros and cons, therefore causing more confusion on which option to pick.
- **Outcome overload**- Information overload compromises the outcomes of processes and slows down the productivity and decision-making of an employee. When employees are overwhelmed by information overload, they become fatigued, leading to errors and mistakes in their work.

Long-time subjection to information overload causes negative impacts on mental well-being due to disillusionment. Excess work and too much information overload lead to confusion (disillusionment) while searching for information. **Disillusionment** is the disappointment that arises after discovering something is not as good as one might have believed. During data handling, disillusionment can make people feel lost, confused, and disconnected from their social environments.

Strategies to Cope with Information Overload

It is possible to cope with and overcome difficulties associated with information overload. Some effective strategies that can help individuals cope with information overload include:

- Avoid multitasking- Multitasking or juggling is unhealthy for a good mental state and, to a greater extent, worse for an individual's productivity. One needs to focus on one task for a specified time limit for more significant progress. Concentrating on one activity is less tasking than multitasking.
- Using the organization's systems- Involves utilizing technology to store extra data that one cannot handle instantly. This enables one to take what is essential and keep the rest for a later time, hence reducing work overload.
- Taking a break- It enables one to deal with stress, fatigue, and emotional distress that often develop when overwhelmed with too much information about a task. Coping with information overload involves structuring a timetable that allows one to have commercial breaks to refresh their brain.
- Attention management strategies- Involves controlling working environments through technology, breaking down tasks, and setting aside time to rest and refresh the brain. Attention management enables one to focus on a particular task, become proactive, and maintain control.
- Limiting options- Can be achieved by being choosy in the available options. It is crucial to narrow down tasks that are of great importance. Choosing what is relevant through priority listing enables individuals to limit themselves to the most critical options.