

Pre-Attentive, Early-Stage
Perceptual Organization

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Introduction

When looking at online content, our brains tend to group things together and distinguish patterns automatically. This is called pre-attentive processing. How does this happen? According to Chen (2017) who wrote the article “Information Visualization Principles, Techniques, and Software,” “Pre-attentive visual processing occurs in the sensory memory, visual attributes are perceived by viewers almost instantaneously and without the intervention of consciousness.” This is fundamental for creating visual representations. One explicit goal of visualization is to present data to human observers in a way that is informative and meaningful, on the one hand, yet intuitive and effortless on the other (Healey, Booth, and Enns, 1996). When designing layouts, designers should note pre-attentive processing to ensure that consumers can easily see the information organizationally, this way users can distinguish between content. Understanding how pre-attentive processing works helps improve design processes. This entails connecting design components like patterns, whitespace, etc. From an evolutionary perspective, this paper highlights the characteristics of pre-attentive processing, using the knowledge from neuroscience studies and findings from psychophysical experiments.

Retinotopic Mapping

The journey of visual information begins with retinal ganglion cells transmitting signals through the optic nerve, which then undergo variations in the lateral geniculate nucleus. Gibson (1972) argued that perception is a bottom-up process, which means that sensory information is analyzed in one direction: from simple analysis of raw sensory data to the ever-increasing complexity of analysis through the visual system. As per Gibson, bottom-up processing begins with the photoreceptors (rods and cones) in the retina, which then sense basic light energy and translate it to neural signals. As the signals progress through areas like V1, V2, and beyond, specialized cells become involved (Lee, Mumford, Romero, and Lamme, 1998). According to the article “The Multifunctional Lateral Geniculate Nucleus” there are three types of cell layers. First is the magnocellular layers that carry information about large, fast objects (low spatial frequency, high temporal frequency) (Weyand, 2015). Parvocellular layers carry information about small, slow, colorful things (high spatial frequency, low temporal frequency) (Weyand, 2015). Lastly, the retinal processing stage, there are three primary pathways, the magnocellular, parvocellular and Koniocellular pathways. The magnocellular system primarily processes motion, the parvocellular handles color and fine detail, and the koniocellular pathway play a role in processing brightness and contrast (Weyand, 2015).

After visual information is projected in the Lateral Geniculate Nucleus (LGN), mapping

continues in the primary visual cortex (Schiefer & Hart, 2007). According to Hubel D.H., & Wiesel, T.N. (1959), the retinotopic organization preserves spatial relationships from the retina through to the visual cortex. LGN as an active processor, research by Sherman and Guillery (2002, 2006) has discovered that LGN actively modulates visual information. LGN serve as a “gatekeeper” that can enhance or suppress visual information. Maunsell and Newsome’s Research (1987) showed that LGN neurons maintain center surround receptive field properties same as retinal ganglion cells. The visual processing in the cortex involves four areas: V1, V2, V3, and V4. Area V1 “encodes orientation and spatial information, higher level perceptual computations and representations that involve high-resolution details, fine geometry, and spatial precision” (Lee, Mumford, Romero, and Lamme, 1998). V1(Primary Visual Cortex) receives direct input from LGN and it maintains a precise retinotopic organization. It creates the primal sketch of what our eyes see. It computes information at 40–350 ms post-stimulus time period” (Lee, Mumford, Romero, and Lamme, 1998). V1 performs the first stage of cortical processing, retrieving basic features, like Edge and orientation detection, spatial frequency analysis, basic color processing, etc. (Hubel D.H., & Wiesel, T.N. 1962). Area V2 (Secondary Visual Cortex) surrounds V1 and is the place where many grouping operations are performed, processing specific pattern types that facilitate perceptual organization. This includes illusory contours, border ownership, texture boundaries, contour integration, etc. (Zhou, H., Friedman, H. S., & von der Heydt, R. 2000). Area V3(Third Visual Area) “plays an important role in the visual processing of motion but also is involved in other aspects of visual processing and could play a role in linking higher-level parietal and temporal processing streams” (Arcaro and Kastner, 2015). Lastly, area V4(Forth Visual Area) “It is crucial for visual object recognition” (Arcaro and Kastner, 2015). Some of the functional properties of V4 are color processing, form processing, feature integration, attentional modulation, and Figure-Ground segregation (Zeki, S. M. 1973).

Principles of Perception

As stated earlier, area V2 in the visual cortex is where many of grouping operations are performed. This includes illusory contours, border ownership, texture boundaries, contour integration, etc. These principles are important because they can be used to determine the effectiveness of an interface’s information grouping to trigger pre-attentive processing (Chen, 2017). Wong (2010) states that similarity is when readers “tend to see things that are similar to be more related than things that are dissimilar... We can apply this observation to all elements on the page; by repeating graphical treatments including font, type size, orientation, and white space, we can design elements, so they appear more related.”. Continuation is the tendency for elements to be grouped to form smooth contours (Wagemans, Elder, Kubovy, Palmer, Peterson, Singh, and Heydt, 2012). The human eye sees

continuous and smooth-flowing lines quicker than broken or jagged ones to form relationships between objects. Closure draws attention to a group of objects (Wong, 2010) because it activates pattern completion mechanisms in visual system. Our brains automatically attempt to close the gaps and complete pattern. Basically, objects are put in groups to make connections of their similarity and proximity. In proximity, we tend to group objects placed close together (Wong, 2010). In other words, if objects are close together, our minds group them.

Case Study

[MarketWatch.com](https://www.marketwatch.com) is a website that provides financial information and analysis, business news, and stock market data. It is a subsidiary of Dow Jones & Company.

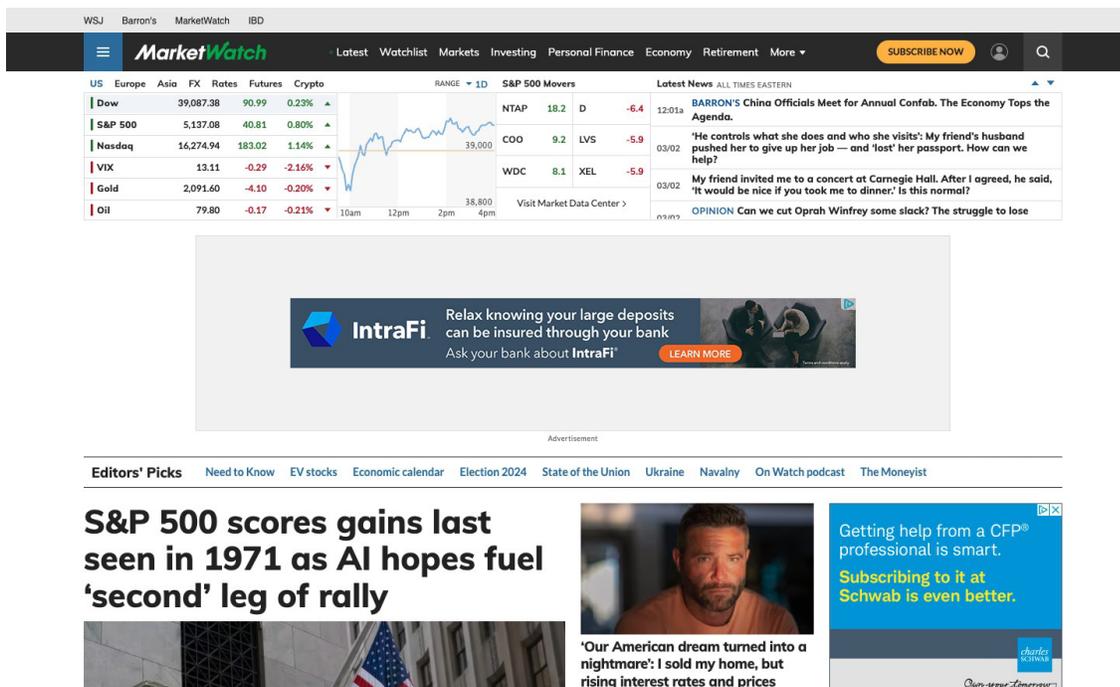


Figure 1: Front page of [MarketWatch.com](https://www.marketwatch.com)

The header provides primary navigation which uses grouping principles to display different categories of content. The sticky header on the top of the website uses a dark background that distinguishes between the main content. The call-to-action (CTA) button on the header, the subscribe now button, requires users to take action before continuing on the other sections of the website. As the CTA button is visually distinct from surrounding elements it draws attention to users. The principle of Similarity applies here as the elements using a consistent color, shape, or style for all CTA buttons on the website makes them visually similar. This consistency helps users recognize and understand the function of the

buttons more easily, promoting a cohesive and intuitive user experience. The website groups related elements in close proximity to each other. For example, headlines, articles, latest news and stock indexes related to the same topic are often grouped together spatially, making it easier for users to identify and navigate through related content. The hamburger icon on the left with a blue color background does this as well. The website also uses principles of perception effectively to increase pre-attentive processing. The section headings use the principle of proximity to distinguish between the different categories. The headings also take advantage of the principle of continuation using active white space and horizontal alignment so the user's eyes flow continuously through the page.

The border groups the information on stocks, latest news, stock market indexes, etc. through the principle of proximity. Information about the stocks and their performance will stand out in green or red text. The use of these colors creates a region, and a color feature brings awareness of important information, even when the user is not paying attention. This uses the principle of similarity to group important information regarding market data. One of the noticeable flaws of this website is the advertisement banners. It takes up too much vertical space and distracts users by continuously changing the advertisements. Users may believe that an advertisement is related to the website's content if it shares visual features (such color scheme or animation style) with other items on the page. It could, however, detract from the user experience and be distracting if the advertisement's animation and design are noticeably different from the rest of the content. To fix this issue, the advertisements should stay on the vertical side or column of the page. Continuity Principle suggests that elements arranged in a continuous line or curve are perceived as more related than those arranged randomly. Stacking the advertisements vertically on the right column will be a clear visual flow from one element to the next, users will perceive them as part of a cohesive group. The eye tends to follow the vertical alignment, creating a sense of continuity. Another problem is the sticky bar (Trending Tickers) at the bottom of the page which doesn't have contrasting color, it blends with the page content hence not noticeable to the users. By applying the principles like the contrast, continuity and closure thoughtfully, designers can create a sticky bar that seamlessly integrates with the content while remaining distinct and functional. This will ensure a positive user experience and facilitates easy navigation and interaction with the website. By applying contrast between the sticky bar and the content it stands out without overpowering the rest of the page. Using borders or shadows can help define the edges of the sticky bar, making it stand out while still integrating smoothly with the page. Despite having a large amount of content on its home page, MarketWatch.com attempts to organize it into recognizable informational segments based on proximity, shape, closure, and motion. This facilitates the user's ability to recognize the page structure in advance. In the end, this method of information organization facilitates user search and identification of target information.

Conclusion

To give users an easier time navigating a website, creators should keep in mind pre-attentive processing. This helps users distinguish what information they should be looking at. Through retinotopic mapping, we see that distinguishing patterns involves a long process before we can interpret them. Starting at the ganglion cell to the LGN to the visual cortex then to a creation of meaning of what our eyes and mind took in through the principles.

To apply the science behind pre-attentive processing, MarketWatch.com was used. It effectively uses principles of continuation, proximity, and similarity to organize its information. This gives users an easier time to digest information without feeling overwhelmed. However, there are some flaws in the bottom sticky bar and the plethora of advertisements shown. To conclude, pre-attentive processing happens subconsciously. Understanding how pre-attentive processing works improves the design process. When designing layouts, designers should note pre-attentive processing to ensure that consumers can easily see the information organizationally, this way users can distinguish and digest information successfully.

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