Preattentive Processing and Pattern Perception.

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Introduction.

The term visual perception encompasses both vision and thought. Indeed, the two are so tightly interconnected that "it is difficult to determine where the sensory aspect ends and the mental process begins" (Kanizsa, 1979, p. 1). However, it is often useful to think of perception to occur in stages. Colin Ware, in "Information Visualization: Perception for Design," proposes one such staged model[1]:

> "In Stage 1, information is processed in parallel to extract basic features of the environment. In Stage 2, active processes of pattern perception pull out structures and segment the visual scene into regions of different color, texture, and motion patterns. In Stage 3, the information is reduced to only a few objects held in visual working memory by active mechanisms of attention to form the basis of visual thinking." (p. 20).

This paper examines in detail Stage 1 (Parallel or preattentive processing) and Stage 2 (Pattern perception) of Ware's perceptual processing model, and applies the findings to evaluating the effectiveness of data-intensive displays at SmartMoney.com.

The Case: SmartMoney.com.

SmartMoney.com contains a multitude of screens where the sheer data density makes for an interesting study of the impact of design decisions on the overall comprehensibility of the display. Another reason why SmartMoney.com was chosen is that the site's audience is likely to include busy financial analysts and stock traders for whom rapid recognition of individual features and patterns of information from the display is critical.

Preattentive Processing.

Highly discriminable feature differences can be rapidly detected in the visual field without the involvement of (higher order) cognitive resources (Egeth, et al., 1989, p. 19-20). That is, a target will

[1] The model omits sensation—the first and most basic stage of perception—and instead focuses on describing the components of perceptual *processing* in the brain.

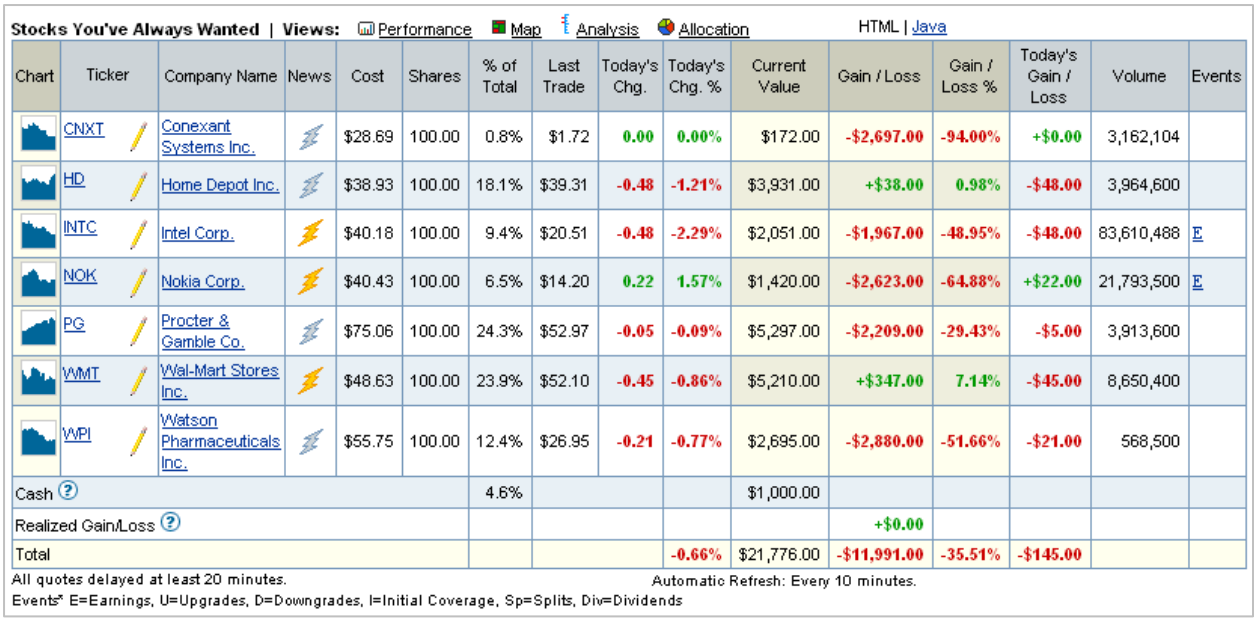
"pop out" if it is sufficiently different from the rest of the field with respect to a single simple feature (Ware, 2004, p. 149; Egeth, et al., 1989, p. 20). No focused attention is required for detecting the existence of such a target. Naturally, designers of information displays and human-computer interfaces want to exploit this capability to direct a viewer's attention to certain areas or features of the design. Two practical questions arise: which target features are preattentively processed and how different does the feature need to be for the target to be detected preattentively?

The answer to the first question has been determined empirically, through a multitude of experiments that tested which features are processed preattentively (Ware, 2004, p. 151). Ware groups these features into four categories: form (size, curvature, tilt orientation, etc.), color (hue, brightness, saturation), spatial position, and motion (2004, p.151-152). As for the second question, two factors determine whether a target will be detected preattentively: (a) the degree to which the target is different from distractors in form, color, spatial position and motion, and (b) the degree to which the distractors are homogeneous (studies by Quinlan, et al. and Duncan, et al. cited in Ware, 2004, p. 152). In both cases higher means a target is more likely to be detected preattentively.

Are there any circumstances when a target that possesses a preattentively detected feature will not be detected? A target is not likely to be preattentively detected if it shares more than one "preattentive feature" with its distractors (study by Treisman cited in Healey et al., 1996, p. 110). Detecting such targets requires conjunction search—searching for a specific combination of two or more preattentive features—which is usually serial rather than parallel (Ware, 2004, p. 154-155; several works by Treisman, Gelade, and Sykes cited in Egeth, 1989, p. 23). In addition to conjunction coding, an absence of a feature may also prevent parallel processing from occurring (study by Treisman & Souther cited in Egeth, 1989, p. 21). Finally, in order for a color to be preattentively distinct, it "must lie outside of the boundary of the [the CIE color space] region defined by all the other colors in the local part of the display" (finding by Bauer et al. cited in Ware, 2004, p. 154). Let's apply these findings to our case.

A quick look at the CIE color chart reveals that orange, green, red, and blue—the main colors used for coding of data in the Portfolio Tracker stock table (Figure 1)—each lie outside the region formed

by the remaining three colors. Therefore, Bauer's findings would indicate that elements coded using each of these colors are detected preattentively. In the presence of these saturated colors the row and column shading are not detected preattentively since they lie inside the region defined by the data colors. This means that the shading will not "interfere" with the viewers' ability to quickly notice the brighter colors.



Stocks You've Always Wanted | **Views:** Performance Map Analysis Allocation HTML | Java

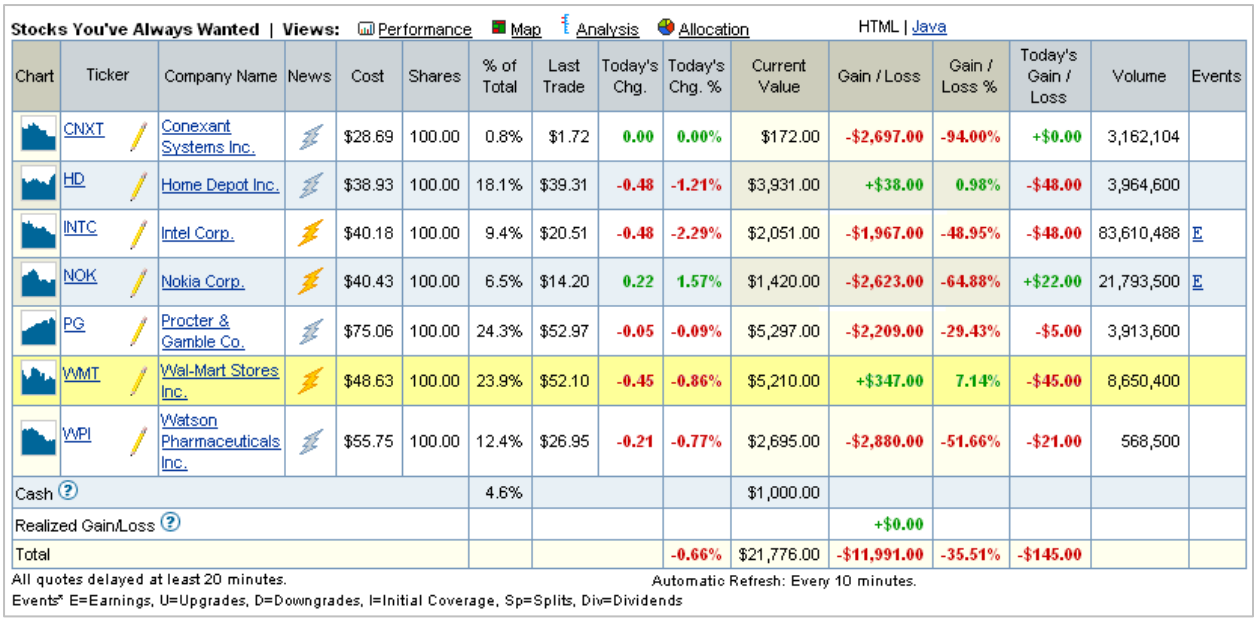
Chart	Ticker	Company Name	News	Cost	Shares	% of Total	Last Trade	Today's Chg.	Today's Chg. %	Current Value	Gain / Loss	Gain / Loss %	Today's Gain / Loss	Volume	Events
	CNXT	Conexant Systems Inc.		$28.69	100.00	0.8%	$1.72	0.00	0.00%	$172.00	-$2,697.00	-94.00%	+$0.00	3,162,104	
	HD	Home Depot Inc.		$38.93	100.00	18.1%	$39.31	-0.48	-1.21%	$3,931.00	+$38.00	0.98%	-$48.00	3,964,600	
	INTC	Intel Corp.		$40.18	100.00	9.4%	$20.51	-0.48	-2.29%	$2,051.00	-$1,967.00	-48.95%	-$48.00	83,610,488	E
	NOK	Nokia Corp.		$40.43	100.00	6.5%	$14.20	0.22	1.57%	$1,420.00	-$2,623.00	-64.88%	+$22.00	21,793,500	E
	PG	Procter & Gamble Co.		$75.06	100.00	24.3%	$52.97	-0.05	-0.09%	$5,297.00	-$2,209.00	-29.43%	-$5.00	3,913,600	
	WMT	Wal-Mart Stores Inc.		$48.63	100.00	23.9%	$52.10	-0.45	-0.86%	$5,210.00	+$347.00	7.14%	-$45.00	8,650,400	
	WPI	Watson Pharmaceuticals Inc.		$55.75	100.00	12.4%	$26.95	-0.21	-0.77%	$2,695.00	-$2,880.00	-51.66%	-$21.00	568,500	
Cash						4.6%				$1,000.00					
Realized Gain/Loss											+$0.00				
Total									-0.66%	$21,776.00	-$11,991.00	-35.51%	-$145.00		

All quotes delayed at least 20 minutes. Automatic Refresh: Every 10 minutes.

Events* E=Earnings, U=Upgrades, D=Downgrades, I=Initial Coverage, Sp=Splits, Div=Dividends

Figure 1. Portfolio Tracker at SmartMoney.com.

For example, it is easy to preattentively detect stocks that gained value: color coding allows the viewer to scan a column (or the entire display) and preattentively detect all of the green numbers without having to read the actual numbers. However, the existing color coding does not support the task of finding the highest gainer: the viewer would actually have to read the numbers to determine that. If locating the highest gainer was a important task that a user would be required to perform, then an additional design treatment would be warranted to make the number (or the entire row) stand out. For example, varying the highest gainer's row's highlight color in hue, saturation, or lightness would make it preattentively distinguishable from all other rows. See Figure 2 for an example.



Stocks You've Always Wanted | Views: Performance | Map | Analysis | Allocation HTML | Java

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Figure 2. The yellow row highlight make the WMT row preattentively distinct.

No discussion of preattentive processing would be complete without mentioning a concept called useful field of view (UFOV). UFOV plays an important role in understanding how attention is allocated within the visual field, because it defines "the size of the region from which we can rapidly take in information (Ware, 2004, p. 147). We can think of UFOV as a an adjustable-beam spotlight, "with stimuli outside of the spotlight receiving little or no processing save for their most primitive sensory features" (Johnson & Dark cited in Pomerantz, et al., 1989). The "width" of the "beam" is adjustable, because it depends on the user's cognitive load, the nature of the user's task, the data density of the display (Ware, 2004, p. 147). Increasing the cognitive load, making the task more complex, and making the data display more dense all reduce the size of UFOV (Ware, 2004, p. 147). Reduced UFOV means that fewer display features can be processed in a single glance, increase the number of fixations—and, therefore, time[2]—required to attend to the entire data display. This is exactly the implication of small UFOV for SmartMoney.com's home page—a paradigm of high information density (Figure 3).

[2] Studies show that even in rapid search the eye can shift to no more than 3 to 4 locations per second (study by Moray cited in Wickens, 2004, p. 79). Smaller UFOV will require more eye shifts to "cover" the same area.

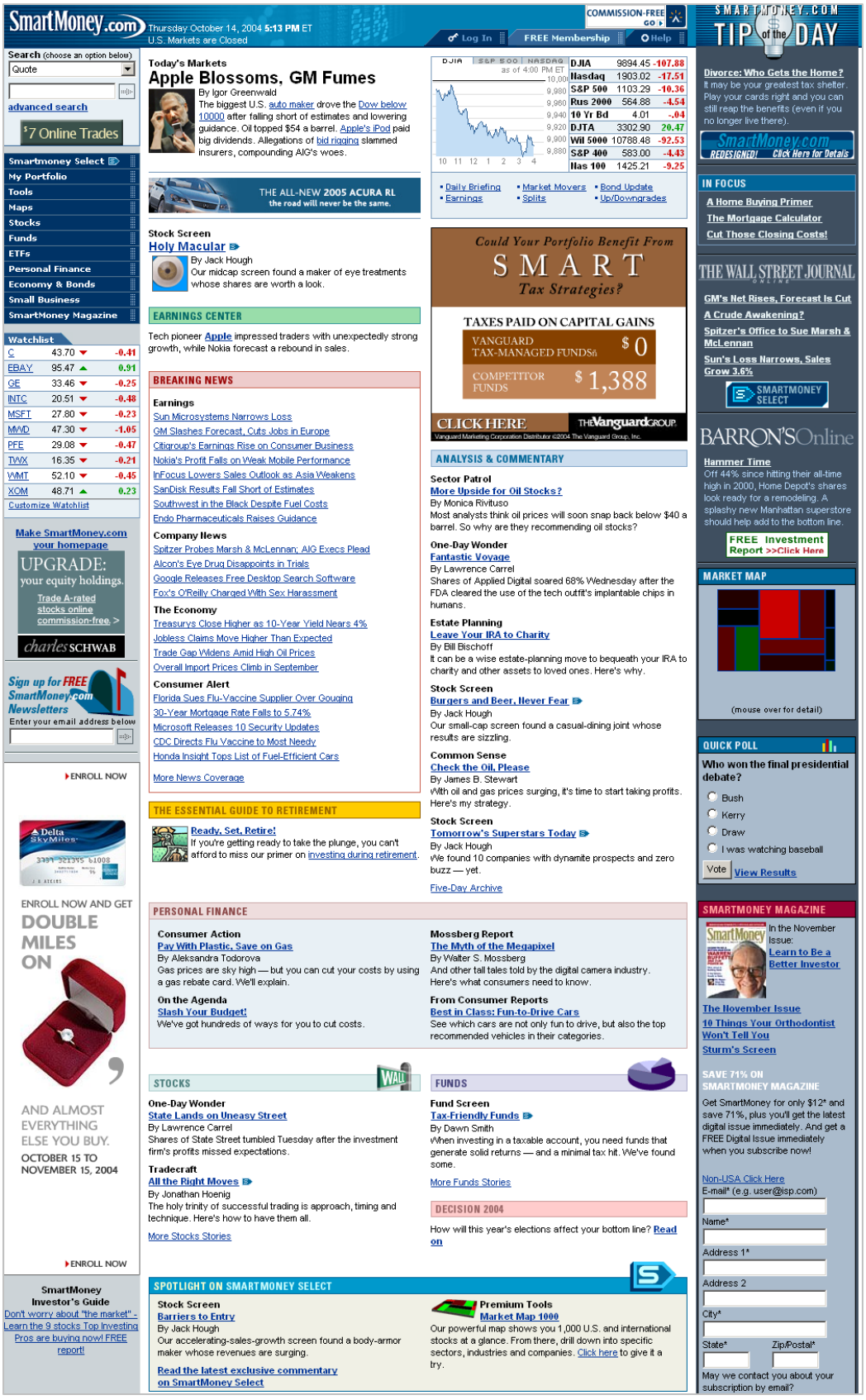

Figure 3. SmartMoney.com home page.

Before leaving the topic of preattentive processing, let's look more closely at motion as a preattentively detected feature. The reason why motion deserves a separate treatment here is that studies have shown that the presence of moving targets widens the UFOV considerably (work by Peterson & Dugas cited in Ware, 2004, p. 147). Since preattentive processing "determines what visual objects are offered up to our attention" (Ware, 2004, p. 149) the presence of moving targets will attract focused attention. The unfortunate consequence of this for SmartMoney.com is that the numerous animated ad banners—there's five of them, dispersed all over the home page—will draw the viewer's attention toward them and away from reading the actual content of the site (Figure 4). Therefore, SmartMoney.com should try to avoid using animated banners on its pages—a recommendation supported by the results of a recent study that show banners (both animated and static) to "interfere with a user's primary visual search task" (Burke M., Gorman N., Nilsen E., & Hornof A., 2004, p. 1142).

Figure 4. Animated banners at SmartMoney.com

Pattern Perception.

In a December 17th, 1924 address before the Kant Society in Berlin Max Wertheimer summarized "the fundamental 'formula'" of Gestalt theory as follows: "There are wholes, the behaviour of which is not determined by that of their individual elements, but where part-processes are themselves determined by the intrinsic nature of the whole" (Wertheimer, 1925, p. 2). As he explains in *Untersuchungen zur Lehre von der Gestalt*, "one sees a series of discontinuous dots upon a homogeneous ground not as a sum of dots, but as figures" (Wertheimer, 1923). That is, we no longer perceive the dots themselves, but rather the patterns they form. This notion is at the foundation of the Gestalt laws of pattern perception.

Gestalt Laws of pattern perception.

The brain's natural pattern-finding ability helps us divide the world around us into visual objects (Ware, 2004, p. 225-226), which is essential for our ability to make sense of our environment. This makes the Gestalt laws of pattern perception extremely important in visualization, because they provide a guide to mapping information structures to easily perceived patterns so that these structures can be more easily interpreted (Ware, 2004, p. 188). The implication of this for screen design is obvious: arranging data into easily perceived patterns can help a user quickly "deconstruct" a busy layout to see what things go together, what's a part of what, and so on. Let's take a detailed look at several of the Gestalt laws of perceptual grouping and their application in the design of information spaces at SmartMoney.com.

Proximity: objects that are placed close together will be perceived as a group (Ware, 2004, p. 189). Of course, in order for this principle to work there must be a density difference between the group and the surrounding area. The stocks table in the portfolio tracker does a great job of using the combination of proximity and "white" space to arrange the number into easily recognizable rows, and alignment to arrange the same data into columns (Figure 1). In fact, the proximity (and similarity of alignment, discussed next) are so "strong" here that if the cell borders and even the row highlights are removed, the data is still clearly organized into rows and columns (Figure 5).

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Cash						4.6%				$1,000.00					

Figure 5. Table borders and row shading are removed. Proximity and alignment "holds" the table together. Edward Tufte would "approve" of this approach as it eliminates the "chartjunk"—graphical decorations that carry no data—in this table (e.g. Tufte, 1990, p. 105).

Unfortunately SmartMoney.com's home page does not have the luxury of using as much white space to strengthen grouping by proximity: just about every patch of screen real estate is filled with information of some kind. Nevertheless, proximity is still used, even if minimally. For example, the bullet items in Figure 6 are distinguishable from one another because the leading (line spacing) between the bullets is slightly greater than between the lines that make up each bullet.

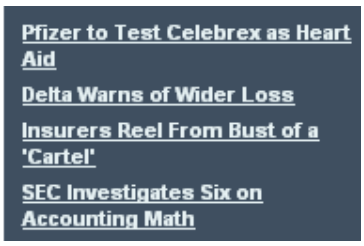


Figure 6. Proximity at work to separate bullets from each other in this list.

In addition, what little white space there is does work together with alignment (mostly left-aligned headings, text and links) to separate the entire page into four distinct columns (see Figure 3). The dark background of the right column helps here too, making the entire column perceived as a single unit.

Similarity: things that look similar are grouped together in the viewer's eye (Ware, 2004, p. 189). On SmartMoney.com's home page many things get a similar treatment. For example, the site's major content headings share size and typeface with each other (Figure 7). They're perceived to be related even though they differ in color from each other. The site's graphical "navigation" links are another example: the entire collection of eleven links is perceived as a group. Of course, in this case proximity is also at play, reinforcing similarity in grouping the items (Figure 8).

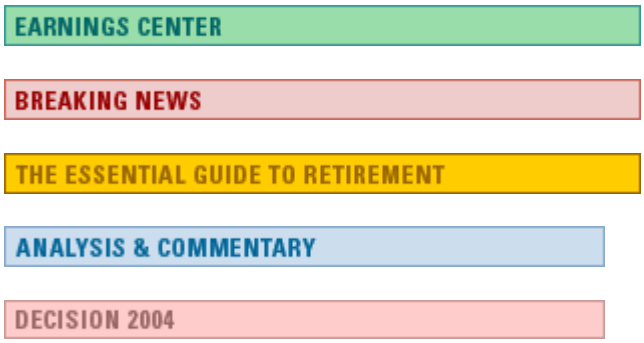
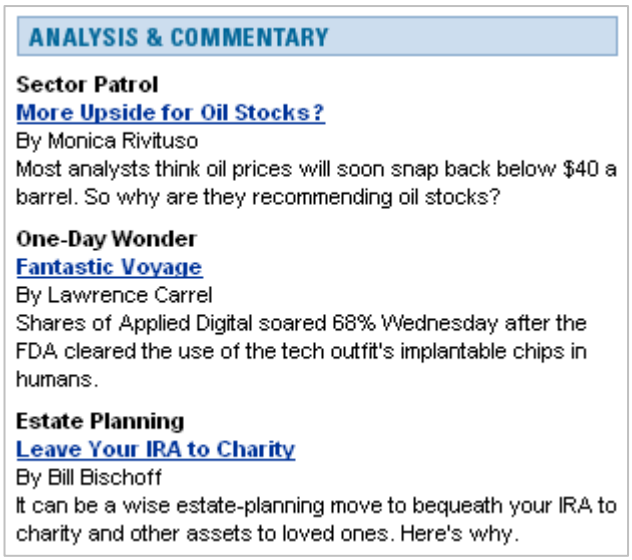


Figure 7.

Figure 8.

We can see proximity and similarity working together in the following list of articles in the analysis and commentary section of the home page:



Here, the increased leading above each article's "department" heading (one-day wonder, estate planning, etc.) acts as white space to allow the reader to group the article's department heading, title, author, and blurb into a single chunk. The bolding of each article department heading and linking the headline are repetitive elements that together make the article list perceived as a group of similar items.

Similarity is also at work in the Portfolio Tracker table. For example, all of the stocks that have a blue news item lightning bolt are grouped together, as are the ones that have an orange one. From the standpoint of the meaning conveyed by the icons—orange is used to mark stocks that have breaking news and blue to mark the ones that don't—these grouping are indeed helpful. On the other hand, highlighting alternating rows goes against what is may be suggested by a simple Gestalt similarity rule: the rows that share the highlight color (blue) may be grouped at the basic pattern recognition level, but are not, in fact, related in meaning. Alternating row highlights are used to merely separate the rows from each other visually. The implied vs. real meaning discrepancy would be even more disorienting had the rows changed highlight at random. SmartMoney.com designers must be keenly aware of the "Gestalt" effects

of the design treatments they use and make sure these effects help the user extract meaning from the display not just act as a reading aid (in this example: to let the eye "track" rows better) or as decoration.

Continuity: "we are more likely to construct visual entities out of visual elements that are smooth and continuous, rather than ones that contain abrupt changes in direction" (Ware, 2004, p. 191). While there was no clearly identifiable example of this law at SmartMoney.com, we may envision a stock price chart for several stocks where only smooth moving averages are plotted. In this case, unless the lines intersect in places where they are too close to being parallel to each other, a portion of one line will not be mistaken for completing a piece of another. Of course, using different colors, line thicknesses, etc. would also help to correctly relate the line pieces—the law of similarity would apply here. These line treatments would also allow plotting more lines on the same graph, without creating an incomprehensible mishmash of lines (Ware, 2004, p.196).

Closure: we have tendency to "close contours that have gaps in them" (Ware, 2004, p. 191). There is a simple (and strategically trivial) example of this right one the home page (see Figure 9, next page). The outline around the words "Funds" is perceived to continue unbroken behind the pie chart. Technically, this would be an example of amodal completion—where a portion of an object that is obscured by another is completed in the mind's eye based on the shape suggested by the visible portion of the partially obscured object. (Lehar, 2003, p 55; Kanizsa, 1979, p. 6).

Figure 9. The outline is "amodally" completed behind the pie chart.

There are also many "freestanding" closed contours, which, according to Ware, are "extremely important segmenting the monitor screen in windows-based interfaces" (2004, p. 196). Examples from the SmartMoney.com home page include the contours around "Breaking News" "Personal Finance" and "Spotlight on SmartMoney Select" sections (see Figure 3). The addition of a background color in the latter two sections augments the "segmenting" effect of contour line.

Recommendations for SmartMoney.com.

Overall, SmartMoney.com handles the challenge of organizing information on its dense pages well. The main suggestions coming out of this evaluation are more along the lines of "tweaks" rather than major design changes. They are:

- enhance perceptual grouping of items on the home page by using more white space to separate groups of objects, strengthening grouping by proximity;
- avoid animated banner ads if possible. This continuous distraction makes it more difficult for the viewer to "comprehend" the already dense layout.
- do not use cell borders in the stocks table the Portfolio Tracker. This would reduce visual clutter in these tables. The Gestalt laws of proximity and similarity (along with good alignment) are enough to organize the data in distinct columns the rows here.

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