Pre-Attentive Processing

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Abstract

What is pre-attentive processing? When we perceive information, certain simple shapes or colours ”pop out” prior to our conscious attention. In the following chapters we will introduce the concept of pre-attentive processing, present observations about form, colour, motion and spatial position about objects and explain the underlying phenomena from a neurological point of view. Further, we will discuss real-life applications where pre-attentive processing is in use.

Chapter 1

Definition of Pre-attentive Processing

Healey defines ”visualisation” as ”the presentation of data in a format specially designed to make use of the human visual system. In this way we take into account both the representation of data and the cognitive processing performed by the viewer.” Preattentive Processing now tries to find characteristics that make use of the potential of the low-level human vision.

For example, a subject is searching for a target item: The eye perceives a lot of data at the same time (parallel). The subject is not aware of all perceived information, which was filtered by the brain so just the relevant information is ”seen” by the subject (focus). If the desired item is not found at the first sight the subject has to look at each item one after another (serial). Normally this takes significantly more time to find a target item. Healey [1992]

1.1 Area of Application

Pre-attentive processing has drawn a lot of interest and attention since the late 1980s. Experiments showed three different visual tasks where pre-attentive processing could help to get better results:

- Target detection: a subject has to detect rapidly whether there is a defined target item (using pre-attentive properties) within a field of distractor elements (fig. 1.1).

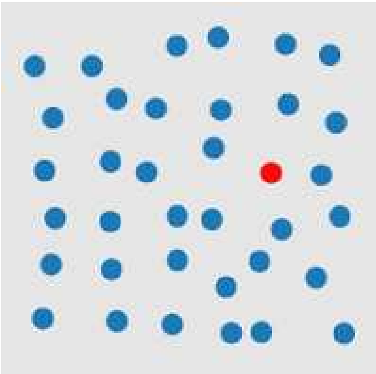

Figure 1.1: target detection, taken from Healey [2009]

- Boundary detection: a subject has to detect rapidly and accurately a boundary between two groups of elements (each group only contains elements with a common pre-attentive property) (fig. 1.2).

- Counting and estimation: a subject has to count or estimate the number of elements using a common pre-attentive property (fig. 1.3).

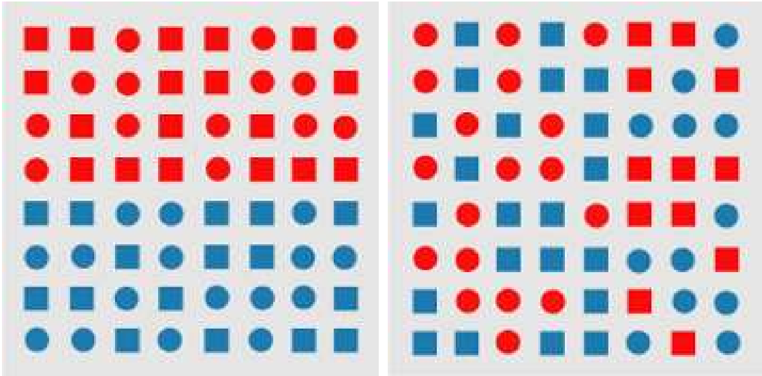

Figure 1.2: boundary detection: easy to detect left in the picture; vertical boundary between fifth and sixth coloum of the right picture is harder to detect (red circles and blue squares on the left, blue circles and red squares on the left), taken from Healey [2009]

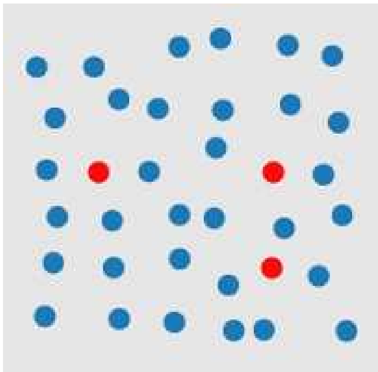

Figure 1.3: rapid estimation: the number of red dots can be counted at one glance, taken from Healey [2009]

1.2 Historical Overview

Figure 1.4 gives an overview of the most important pre-attentive properties and who was the poineer doing the research.

1.2.1 Feature Integration Theory

Treisman[1] tried to determine properties that are detected pre-attentively (she called them pre-attentive features). Through experiments using target and boundary detection Treisman tried to classify those features. During the experiments the number of distractors per scene was changed in several iterations. If the time to finish the task stayed rather constant over all iterations, this was an indicator for a pre-attentive feature. As a threshold 250ms per scene was used, to make sure the eye has no time to focus on an item. At this time conjunction search was seen to be pre-attentive.

Treismans feature list:

line length, orientation, contrast, hue, curvature and closure Treisman [1985]; Treisman and Gormican [1988] Beside the actual properties, Treisman found out that some of these features are asymmetric (Figure 1.5). A sloped line in a sea of vertical lines is pre-attentive, a vertical among sloped not. Another result is, that it does not only depends on the target item but also on the background distractors and their variety. The more different distractors the less pre-attentive the target can be.

[1] Anne Treisman was often mistakely referred to as Triesman, also as Healeys did in his early papers, in his later works the spelling was corrected. Even there Triesman still occurs on Healey's homepage Healey [2009]

Feature	Author
line (blob) orientation	Julész and Bergen [1983]; Wolfe (1992)
length	Triesman and Gormican [1988]
width	Julész [1985]
size	Triesman and Gelade [1980]
curvature	Triesman and Gormican [1988]
number	Julész [1985]; Trick and Pylyshyn [1994]
terminators	Julész and Bergen [1983]
intersection	Julész and Bergen [1983]
closure	Enns [1986]; Triesman and Souther [1985]
color (hue)	Triesman and Gormican [1988]; Nagy and Sanchez [1990]; D'Zmura [1991]
intensity	Beck et al. [1983]; Triesman and Gormican [1988]
flicker	Julész [1971]
direction of motion	Nakayama and Silverman [1986]; Driver and McLeod [1992]
binocular luster	Wolfe and Franzel [1988]
stereoscopic depth	Nakayama and Silverman [1986]
3D depth cues	Enns [1990]
lighting direction	Enns [1990]

Figure 1.4: overview, taken from Healey [1992]

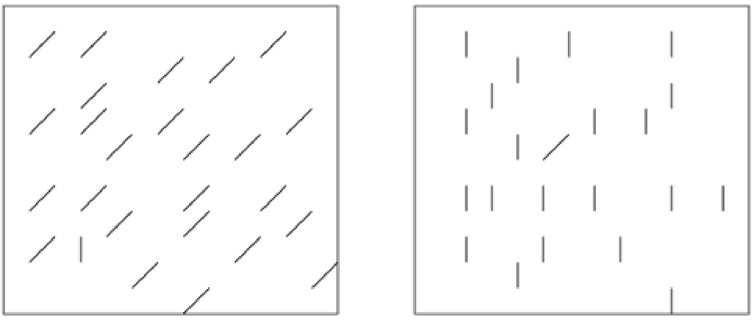

Figure 1.5: Treismans example for an asymmentric feature: left side is not preattentive compared to the right Treisman and Gormican [1988]

In later research Treisman found out that adding marks to highlight something is generally better than taking them away Treisman and Gormican [1988]. As an example think of a paragraph where you would like to highlight all important words. To do so it is more effective just to underline those words than underlining everything except for the target words Ware [2004].

The ”pop out” effect also depends on the number of target items. It is easy to recognize one to four objects in a group at a glance (”this ability appears quite early in human development” Dehaene [1997]). It gets usually a lot harder if the number of objects increases beyond four, because explicit counting gets necessary then Ware [2004].

Treisman attempts to explain the effect of pre-attentive processing with feature maps (Figure 1.6). According to Treisman there exist a map for each of the human colour primaries red, yellow and blue and additionally maps for shape, orientation, texture and other pre-attentive properties. The visual system of human splits up an image into the features which are encoded parallel at their corresponding feature map. Beside the feature maps Treisman hypothesis also contains a master map of location which is responsible for focused attention. While examining a certain location one gets automatically all the features of this area given by a set of links to the feature maps Treisman [1985].

If the target item has one specific feature, one can simply access the corresponding feature map to get immediate information about the presence of this feature. This also explains the problem of conjunction search, while each feature is encoded parallel, one has to access two maps and merge the results. While the detection is instantly, the merging is serial and slow because one has to decide on which feature to lay the focus on and iterate through the occurrences of the second feature. Treisman [1985]

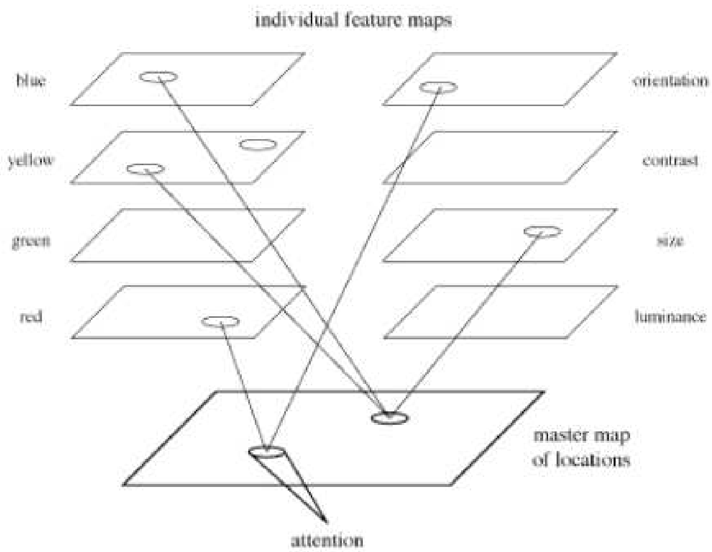

Figure 1.6: Treismans model of feature maps (where information is processed parallel) and the master map of location that can access the particular feature maps and put the information together (focus can be used here) Treisman [1985]

Some years after this pioneering research Treisman refined her first hypothesis Treisman and Gormican [1988]. She introduced a spectrum between the extremes parallel and serial and allows graduations. Through this adaptation the length of a line is not an absolute feature it depends on the length of the surrounding distractors (Figure 1.7).

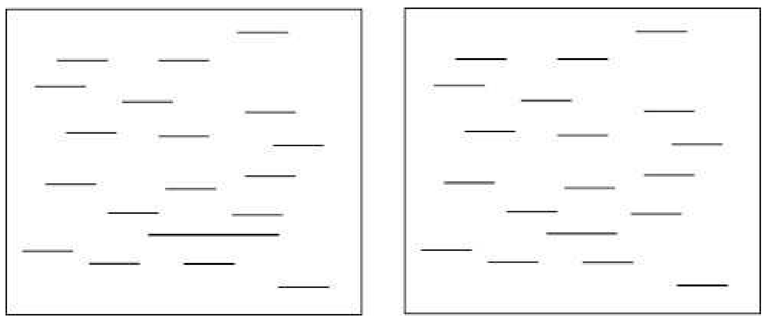

Figure 1.7: left Figure is "more" pre-attentive than the right one because the target has a higher degree of difference to its distractors Treisman and Gormican [1988]

1.2.2 Texton Theory

Bela Julèsz also did research in the area of the human low-level vision system. He tried to find which patterns in textures are seen or not seen. He does not speak from features but from textons which can be classified into three different categories Julèsz Bela and Frisch [1973]:

- Elongated blobs (e.g., line segments, rectangles, ellipses) with specific properties such as hue, orientation, and width
- Terminators (ends of line segments)
- Crossings of line segments

Julèsz' hypothesis says that only a difference in textons or in their density can be detected preattentively. Julèsz believes like Treisman that preattentive processing happens parallel while focused attention is serial, but focus is needed to get positional information about neighbouring textons.

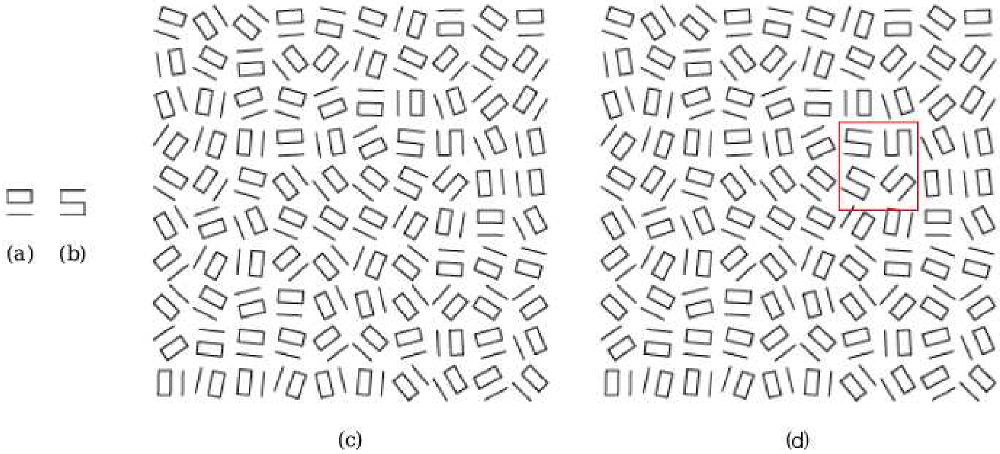

Figure 1.8: (a) and (b) look different in separation but as shown in (c) in a set of both elements it is they are hard to distinguish taken from Healey [2009]

In Figure 1.8 is an example that supports Julèsz texton theory:

Both objects look distinguishable in isolation (a) and (b). In (c) both objects are orientated randomly. It is not possible to preattentively detect the boundary between the two groups (d). Looking at the texton definition (a) and (b) are the same: both have the same height and width, have two terminators and the same set of line segments.

1.2.3 Similarity Theory

Duncan and Humphreys were not satisfied with the explanations of preattentive processing as a result from earlier research (Treisman) so they developed their own explanation of preattentive processing. According to their model search ability varies continuously, depending on both the type of task and the display conditions Duncan and Humphreys [1989]; Duncan [1989].

Search time is based on two criteria:

- T-N similarity: the amount of similarity between the targets and nontargets.
- N-N similarity is the amount of similarity within the nontargets themselves.

These two factors affect search time as follows Duncan and Humphreys [1989]; Duncan [1989]:

- as T-N similarity increases, search efficiency decreases and search time increases,
- as N-N similarity decreases, search efficiency decreases and search time increases, and
- T-N similarity and N-N similarity are related; decreasing N-N similarity has little effect if T-N similarity is low; increasing T-N similarity has little effect if N-N similarity is high

Figure 1.9 shows an example that supports Duncan and Humphreys theory. In (a) there is a hight N-N similarity, the target 'L' could be found easily. In (b) the low N-N similarity makes it harder to detect the target 'L'.

As an attempt to explain this search phenomena Duncan and Humphrey proposed a three step visual selection:

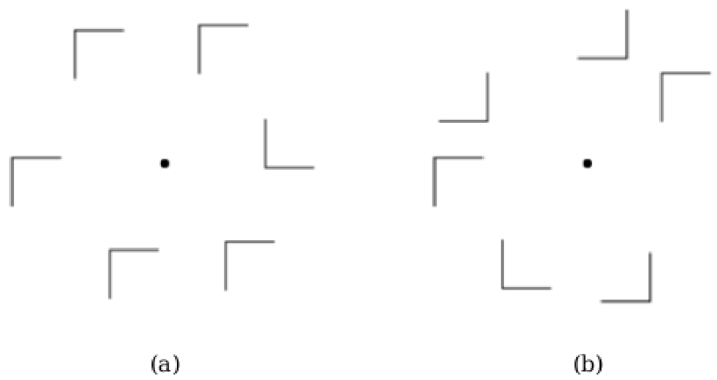

Figure 1.9: On both pictures is shown the same shape, but in different orientations. Because of the high N-N similarity the target can be found instantely in (a). In (b) the low N-N similarity causes longer search time

1. The visual field is segmented into structural units which share some common property (orientation, hue, motion). Each unit can be segmented again into smaller subunits sharing again some common property, creating a hierarchy. The process of separation occurs parallel.

2. During search a template for the sought unit is created. Each structural unit is compared to the template. To better the match the more resources of the limited short term memory is allocated for this unit.

3. Because units are organized in a hierarchy (step 1), a poor match of an unit and the template allows to reject other units that are strongly related to the rejected unit.

Structural units with a high amount of resources have a high chance to be presented to the visual short term memory first. So Duncan and Humphrey define the efficiency of a search as a ”function of speed of allocation and the amount of competition for access to the visual short-term memory”.

As a result decreased T-N similarity stands for less structural units matching the template, so competition for visual short-term memory access also decreases. Increased N-N similarity means we can efficiently reject large numbers of strongly grouped structural units, so resource allocation time and search time decreases.

1.2.4 Guided Search Theory

Jeremy Wolfe suggests during visual search an ”activation map” based on bottom-up and top-down information is constructed. Peaks of this activation map are representations of preattentive features.

As Treisman Wolfe works with the model of feature maps. Each map filters one specific type (e.g colour) but divide this type in subcategories (e.g green, red). While colour his the top-down activation in Wolfes model the orientation (subcategories: shallow, steep... Wolfe and Franzel [1988]) represents the bottom-up part.

Bottom up: is a measure of the difference of an element from its neighbours (e.g. how different are the elements in terms of colour)

Top down: user driven attempt to find items with specific properties (e.g. search for a blue item generates a top-down request to activate ”blue” locations). Previous research Wolfe and Franzel [1989, 1988] suggests to specify requests in terms of the categories of Treismans feature maps. So subjects can search for ”steep” but not for an object rotated by a given angle. By choosing a category that best differentiates the target from the distractors the subject will get the best results. To find the ”best” category is often hard, so this could explain, so Wolfe, that a subjects' performance improves over time.

The activation map is a weighted combination of top-down and bottom-up activation. It is task dependent which one has more weight. (Conjunction = top-down, target witch unique feature = bottom-up). Peaks in the activation map are indicators for either high bottom-up or top-down activation. A subjects attention is drawn from peak to peak in order of decreasing activation.

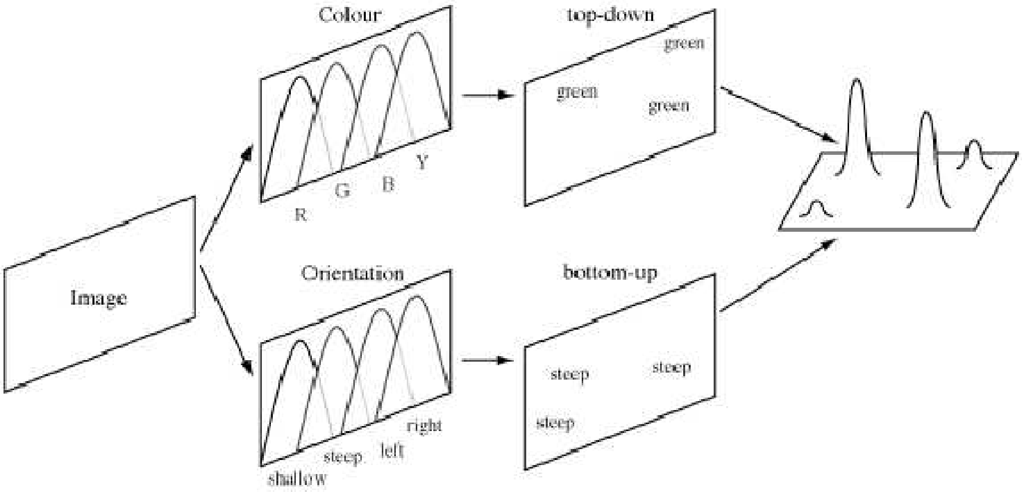

Figure 1.10: the model of guided search: both approaches top-down and bottom-up, are combined in the activation map, where a peak is an indicator for a pre-attentive feature, taken from Healey [2009]

Wolfe's theory explains the "parallel" visual search very well. Target elements generate the highest level of activation (they pop out of their surrounding elements) regardless the number of distractors. The theory also fits with Duncan and Humphreys similarity theory. Low N-N similarity causes higher bottom-up activation for distractors (they have higher difference from their neighbours). High T-N similarity causes low bottom-up activation of the target element.

1.2.5 Boolean Map Theory

Huang et al. Huang and Pashler [2007a,b] presented a more recent model of low level vision. This theory carefully divides a visual search task into two parts: selection and access. Selection involves choosing a set of objects from a scene.

Access determines what properties of the selected objects a viewer can apprehend.

Although both operations are implicitly present in previous theories, they are often described as a whole and not as separate steps.

Chapter 2

Categories of Pre-attentive Processing

Ware divides pre-attentive properties into four categories Ware [2004]:

1. Colour

2. Form

3. Spatial Position

4. Motion

2.1 Colour

Colour seems to be the most important factor when it comes to pre-attentive processing, as the most research has been done on the use of colour in visualisation compared to any other perceptual issue. Ware [2004]

Colour immediately pops outs from a set of other features, as seen in Figure 2.1.

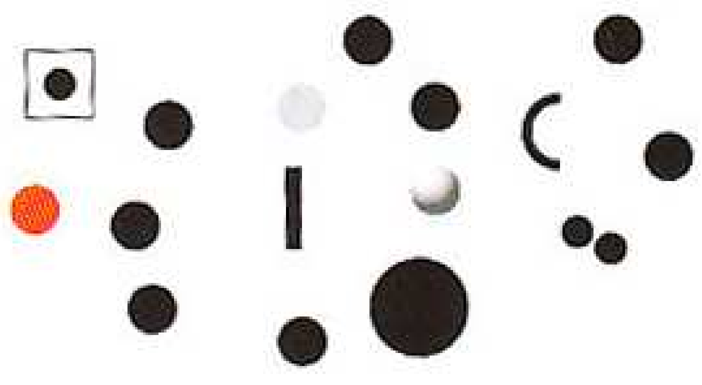

Figure 2.1: A set of symbols in which each of the nine symbol types is pre-attentively distinct from all the others Ware [2004].

Why is colour that important? It's an evolutionary advantage: The cherries in Figure 2.2 are much easier to spot if we have colour vision. Colour helps us find objects that only differ from their surroundings by their colour, it helps us to break camouflage. It is crucial in judging whether a fruit is ripe or not, if meat is fresh or rotten.

This is why colour is useful in information display, especially for labeling and categorization. On the downside, it colour is poor for isplaying shape, detail, or space. Ware [2004]

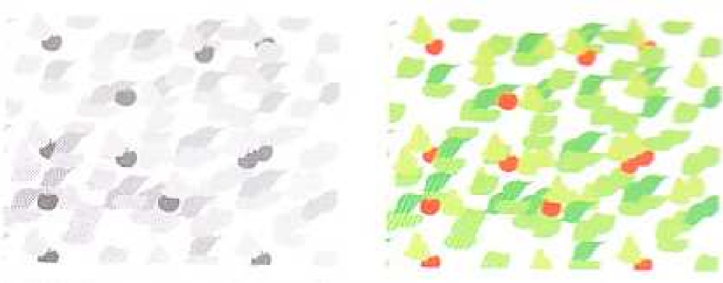

Figure 2.2: Finding the cherries among the leaves is much easier if we have colour vision Ware [2004].

Regarding pre-attentive processing of colours, it is crucial that the colours used are distinct from each other. This is where the concept of the convex hull is used.

> ”The convex hull of a set of colours is defined as the area within a rubber band that is stretched around the colours when they are defined in CIE [note: Commission Internationale de l’Éclairage] tristimulus space. [...] Gray is within the convex hull of red, green, yellow, and blue. Red lies outside the convex hull of green, blue, yellow, and gray. The gray dot is difficult to find in a set of red, green, yellow, and blue dots. [Note: Figure 2.3 on the left] The red dot is easy to find in a set of green, blue, yellow, and grey dots. [Note: Figure 2.3 on the right]” Ware [2004]

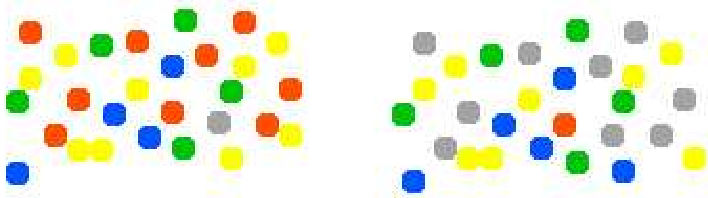

Figure 2.3: Convex hull, based on Ware [2004].

Other important aspects for the use of colours include unique hues (red, green, yellow and blue are better than multiple shades of green, for example), contrast with the background, colour blindness (to include people who are colour blind), number (only a small number of colour codes can be rapidly perceived), field size (colour-coded objects should not be too small) and conventions (red is thought of as hot or as an indicator for danger, blue equals cold, green equals life. However, cultural borders should be considered). Ware [2004]

A common usage of colour codes in real life examples is colour coding voting results. In Figure 2.4, we can see which how people from different regions voted predominantly for which party. Red represents the Republican Party, while the blue represents the Democrat party, an area with even results is indicated with a green hue. Further, the colour saturation designates the winning margin.

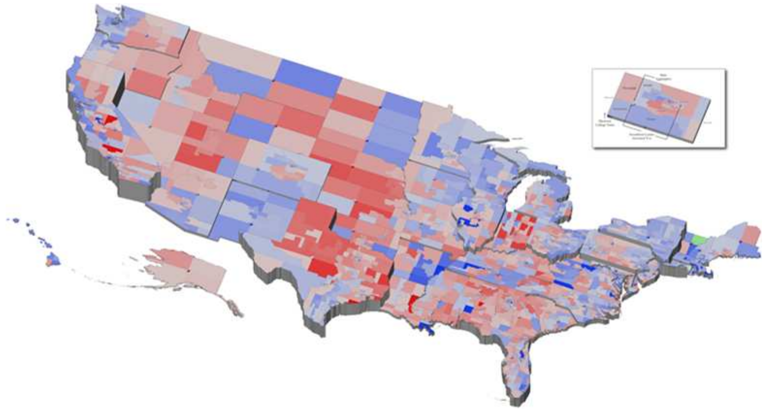

Figure 2.4: Elections in US, from Healey [2009].

2.2 Form

Using Forms is a very simple and efficient possibility to apply pre-attentive features. Here are some of the most important examples:

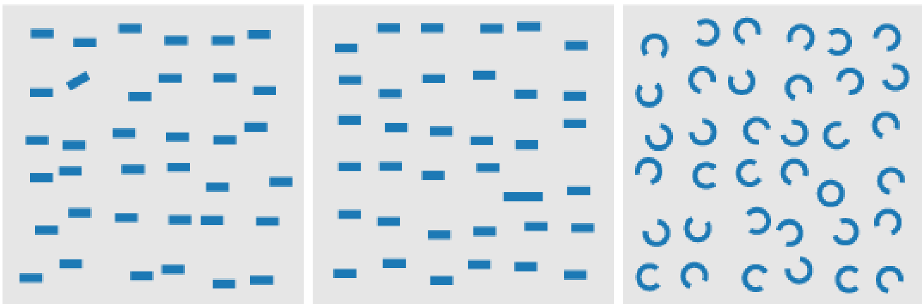

Figure 2.5: orientation, line length/width, closure

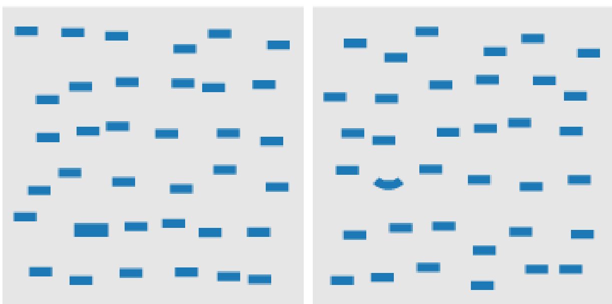

Figure 2.6: size, curvature

2.3 Spatial Position

It is very important to understand the position of objects and placing them so the human eye can preeatentivly process them as Healey, Booth and Enns said ”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. Multidimensional data visualization is concerned with the question ”How can we display high-dimensional data elements in a low-dimensional environment, such as on a computer screen or the printed page?” This goal is often pursued by attaching ”features” such as hue, intensity, spatial location, and size to each data element. Features are chosen to reveal properties of data elements as well as relationships among them” Healey Christopher G. and Enns [1996].

Ware divides spatial position indo: 2D position, stereoscopic depth and convex/concave shape from shading.

2D position of documents has the advantage to map properties of the underlying document data on the two axes. It is easily to find most relevant documents and most important

On the other side using position to visualize makes difficulty to select documents with same relevance factor. Solution to this to avoid occlusion of documents is to translate them on one of the axes, inhibiting the mapping of a second property axis Deller Matthias and Barthel [2007].

Figure 2.7: On the left side is shown less important documents are tilted away from the user, on the right side the effect of colour and intensity is used (example yellow)

Stereoscopic depth Elements placed in a different depth layers are preattentivly identified regardless of distractors placed in other pepth layers. It is hard so visualize in a 2D environment without the necessary equipment for visualizing stereoscopic depth

Convex/concave is produced from shading elements. The human visual system tends to consider that shadows are produced by light coming from above. For this reason objects with their upper part brighter than the lower appear as convex or protruding objects.Â

Those objects that are illuminated concavity are easily detected among objects of convex appearance. The other way around is also true a convex object pops out from other concave objects , Rodrigues Jos F. and CaetanoTraina [2006].

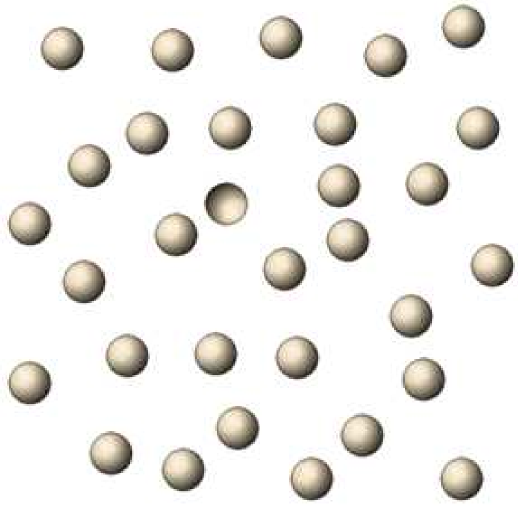

Figure 2.8: Concave element surrounded by convex elements.

2.4 Motion

Motion is another feature that is known to be pre-attentively processed. In visualisation, motion is in common use. Healey notes that motion transients are used to highlight changes in a dataset across user-selected data axis and for animating particles, dye, or glyphs to represent the direction and magnitude of a vector field Healey [2009]. Huber and Healey list three motion properties which have been extensively studied by psychophysics: flicker, direction of motion, and velocity of motion. These studies have shown that ”properties of motion are detected by the low-level visual system” Huber and Healey [2005].

2.4.1 Flicker

Flicker refers to an element that appears and disappears. This pattern is normally measured in cycles per second, the frequency of repetition. For visualisation purposes the interest of researchers in this field ”is the rate at which images must be redrawn to appear continuous” Huber and Healey [2005]. As an outcome of Browns studies it has emerged that the frequency must vary from 2-5% to perceive a difference in flicker at the centre of focus Brown [1965]. Huber and Healey ran a flicker experiment to study ”a viewer’s ability to distinguish the presence or absence of a small group of target elements that flicker at a rate different from the background elements.” Huber and Healey [2005] The initial position of the experiment was a 20 x 20 regular grid of yellow squares on a black background filling a 19-inch screen. The target was represented by a 3 x 3 group of elements. For target present trials, the target group was randomly selected to flicker with a different flicker rate as the background. One of the results was that the target elements or the background elements have to complete at least half a cycle before a viewer perceives a difference in the target and background flicker rate Huber and Healey [2005].

2.4.2 Direction of Motion

This motion property refers to an object moving against a still background or in relation with a homogeneously moving background in a different direction. This is also detected pre-attentively. In a set of experiments of Nakayama and Silverman, observers had to detect the target which moved in the opposite direction than the others Nakayama and Silverman [1986]. The reaction time was below a second and stayed constant, even if the number of elements in the target set raised. An indication that this pattern is pre-attentively processed. Figure 2.9 shows a schematic description of the ”direction of motion” property in the left pattern.

2.4.3 Velocity of Motion

An element that moves much faster than the background in the same direction fits to the velocity of motion pattern. Several researchers analysed the reaction time after changing direction or speed of moving objects Ball and Sekular [1980]; Tynan and Sekular [1982]; Dzhafarov and Allik [1993]. Figure 2.9 shows a schematic description of the ”velocity of motion” property in the right pattern.

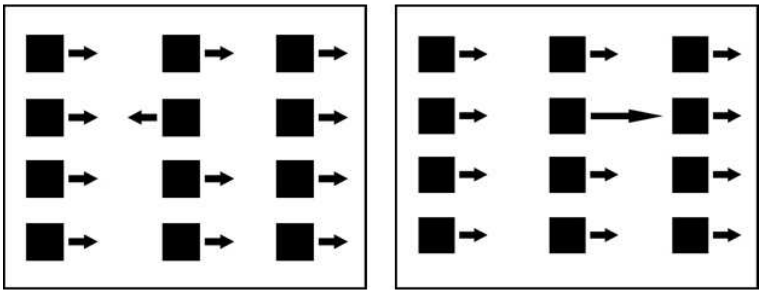

Figure 2.9: Property direction of motion (left) based on Nakayama and Silverman [1986], and velocity of motion (right) based on Ball and Sekular [1980]

Motion as a pre-attentive feature is used in daily life i.e. highlighting danger areas by flashing lights, or is used in promoting products for drawing peoples attention on it. Chan notes that an animated banner advertisement on a Web page is more prominent than a static one because of the perceptional feature of motion. It will be more easily detectable when individuals scan the environment Chan [2007]. Ware warns that the use of animations in the Web exceeds what is necessary. Ware disapproves that many Web page designers ”generate a kind of animated chart junk: small, blinking animations with no functional purpose are often used to jazz up a page” Ware [2004]. However advertising organizations are aware that motion is more effective in presenting their ads than other pre-attentive features. Bartram, Ware, and Calvert showed in a series of dual task experiments that this assumption is true Bartram and Calvert [2003]. Their subjects carried out ”a primary task, either text editing or playing Tetris or Solitaire, while simultaneously monitoring for a change in an icon at the side of the display in the periphery of the visual field” Ware [2004]. The results showed that having an icon change colour or shape was far less effective than having the icon move. When the signal was farther from the focus of attention in the primary task, the advantage of motion increased.

Ware describes another advantage of moving or blinking signals. They ”can persistently attract attention, unlike a change in an icon, such as the raising of a mailbox flag, which fades rapidly from attention” Ware [2004].

Chapter 3

Conjunction Search

A critical issue for information display is whether more complex patterns can be pre-attentively processed. A unique visual property in the target like a curved form as shown in Figure 3.1 allows it to ”pop out” of a display. We see the red circle at the first glance. If the target is made up of a combination of non-unique features, the viewer normally cannot detect it pre-attentively.

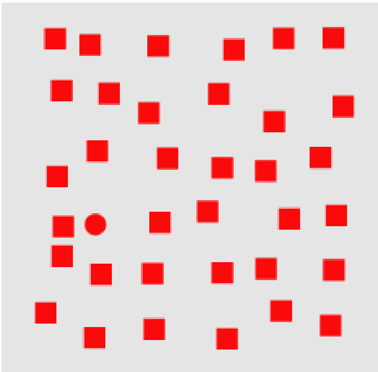

Figure 3.1: Unique visual property in the target, taken from Healey [2009]

Figure 3.2 shows an example of such a combination. The target is know made up of two properties: red and circular. The problem is that the surrounding objects are either blue (but circular) or squares (but red). Thus one of this features is present in each of the distracting objects. If the viewer looks for red objects the visual system returns true because there are red squares all over the display. Similarly when searching for circles the visual system also returns true because of the blue circular objects. Our visual system detects both features even if the target object is absent as shown in the left pattern of Figure 3.2 Healey [2009].

To find the red circle target we have to perform a serial search through either the red objects or the circular ones. This search is very time-consuming, the more distracting objects are in the display the more time it takes Treisman and Gelade [1980]. This is called a conjunction search.

3.1 Conjunction with Spatial Dimensions

Although early research suggested that conjunction searches were never pre-attentive, it has emerged that there are a number of pre-attentive dimension pairs that do allow for conjunctive search. This is possible if the first of two features in combination is spatially coded information whereas the second attribute is such as colour, shape, or motion Ware [2004]. Ware addresses three examples in this context where the spatial information is either position on the XY plane, stereoscopic depth, or motion.

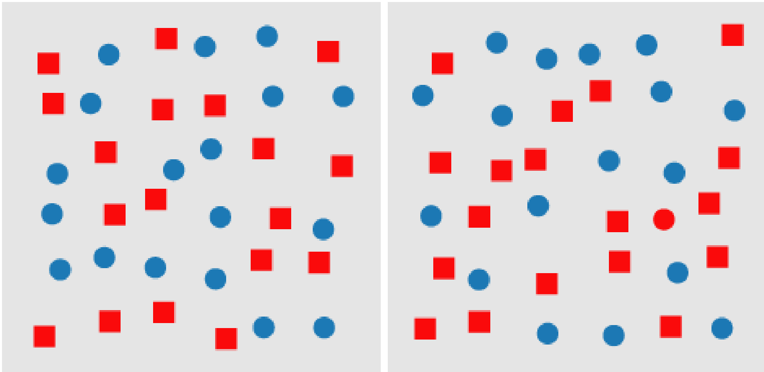

Figure 3.2: Combination of colour and shape in the target, target is absent (left) and present (right), taken from Healey [2009]

3.2 Spatial grouping on the XY plane

Treisman and Gormican argue that pre-attentive search can be restricted by the identification of visual clusters. This is a form of conjunction search, the conjunction of space and colour Treisman and Gormican [1988]. Figure 3.3 shows a spatial conjunction. To find the grey elliptical target in the left pattern we have to search either the grey objects or the ellipses. In the right pattern the elements are spatial grouped. This causes a much lower reaction time finding the target. If the attention is directed to the lower cluster, perceiving the grey ellipse is pre-attentive. Thus this conjunction of spatial location and colour can be pre-attentively processed Treisman and Gormican [1988]; Ware [2004].

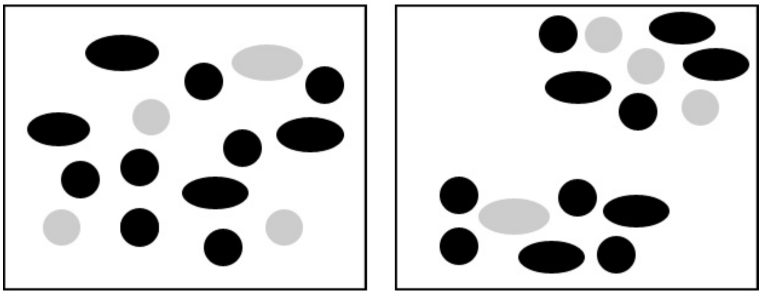

Figure 3.3: Spatial conjunction, taken from Healey [2009]

3.3 Stereoscopic Depth

Nakayama and Silverman state that ”if one of the dimensions in a conjunctive search is stereoscopic disparity, a second dimension of either colour or motion can be searched in parallel” Nakayama and Silverman [1986]. Figure 3.4 shows schematic descriptions of two experiments they ran. The left pattern displays a conjunction search for stereo and motion. The distracting elements in the front plane are moving up, those in the back plane are moving down. The observer has to find the relevant target either in the front plane moving down or in the back moving up.

The right pattern shows a conjunction with stereo and colour. The distracting objects in the front plane are blue, those in the back plane are red. The relevant to be found by the observer is either red in front or blue in back.

The result shows that these conjunctive tasks were very easy for the observers to solve. The reaction time functions ”for each of these searches are constant over set size” Nakayama and Silverman [1986]. Thus stereoscopic depth and colour as well as stereoscopic depth and motion can be pre-attentively processed.

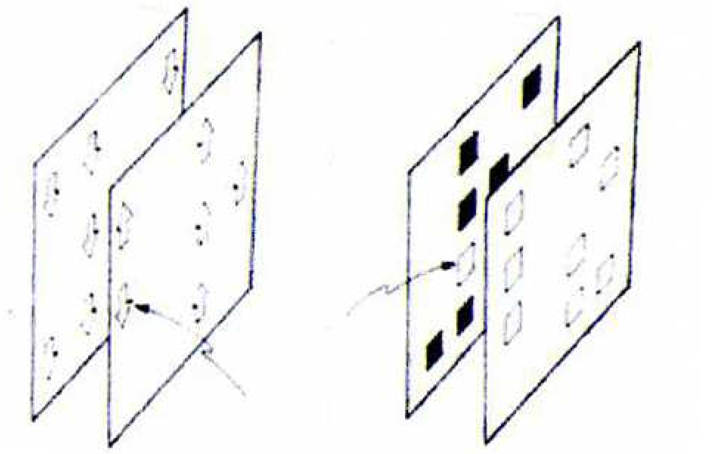

Figure 3.4: Schematic descriptions of experiments, done by Nakayama and Silverman, taken from Nakayama and Silverman [1986]

3.4 Motion

According to Driver, McLeod and Dienes, motion and target shape can be pre-attentively scanned conjunctively. They describe that ”conjunction search is relatively easy, provided that search can be restricted to a group of items that share one feature, within which the target is uniquely defined by its value on another dimension” Driver and Dienes [1992]. In other words, if the whole set of targets is moving, we do not need to look for non-moving targets Ware [2004]. Figure 3.5 shows an example of target-present display used by Driver, McLeod and Dienes. The target was a vertically oscillating X among vertically oscillating Os and horizontally oscillating Xs Driver and Dienes [1992].

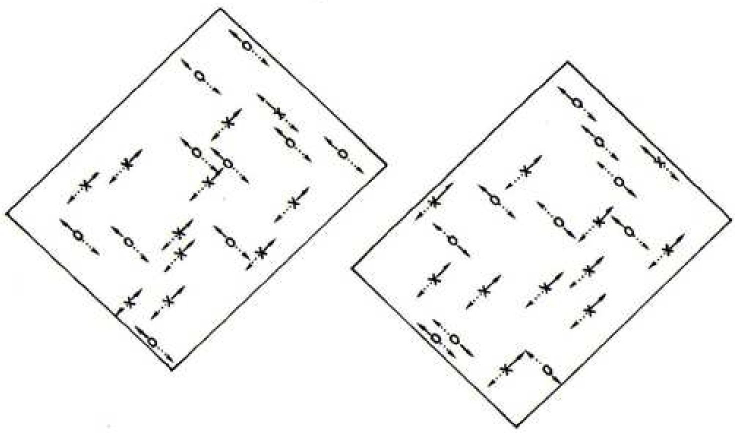

Figure 3.5: Example of a target-present display, taken from Driver and Dienes [1992]

Chapter 4

Neural Processing

Problems described in the previous chapters are now explained from the neurological point of view. Treisman tries so describe and claim that preattentive processing is due to visual processing: ”Preattentive processing of visual information is performed automatically on the entire visual field detecting basic features of objects in the display. Such basic features include colours, closure, line ends, contrast, tilt, curvature and size. These simple features are extracted from the visual display in the preattentive system and later joined in the focused attention system into coherent objects. Preattentive processing is done quickly, effortlessly and in parallel without any attention being focused on the display”. [Treisman 1995] as quotes by Ware [2004]

Lennie explains the whole process of preattentive proccesing as follows: First the information is gathered in the eye and then leaves through ”retina” going from the eye nerve through neural junction at the lateral geniculate nucleus (LGN) and finally arriving the ”cortex”. Lennie devide the visual proccesing in the cortex into two areas Visual Area 1 (V1) and Visual Area2 (V2), difference beetween is that the V1 is the first one to recive the information and then pass forward towards V2. Both this visual areas make up 40% of visual proccessing Peter [1998]. Ware does an excellent work explaining Livingston and Hubel's Simmons [2009] diagram about neural architecture and features proccessed in V1 and V2. Figure 4.1 shows Ware's summarizes diagram. Tuned receptive field is necessery for understanding Ware's diagram. Tuned receptive field describes those neurons in the cortex that react to specific patterns for example black dot surrounded by white. Basicly it is a tuned filter that reacts to different shapes, moving direction and colour.

Sections below explain in detail these tuned filters that are in V1 and V2.

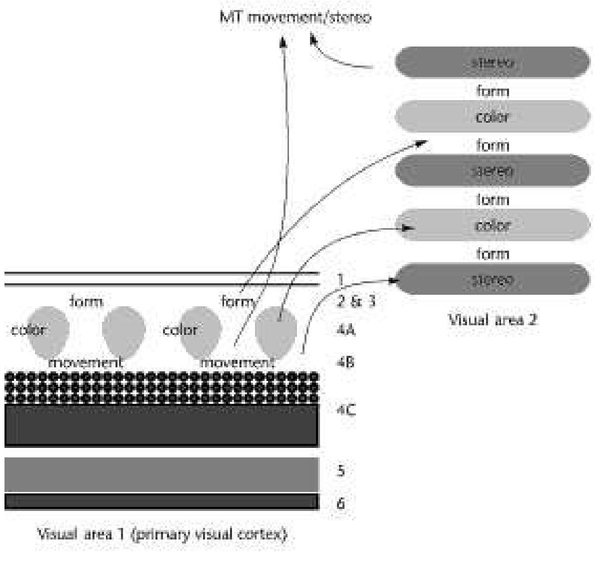

Figure 4.1: Architecture of primary visual areas Ware [2004]

4.1 Orientation and Size

Visual area 1 and 2 contain huge amount arrays of neurons that filter information based on orientation and size in every point of the visual field. These neurons have preferred orientation and size which concludes that they have orientation and spatial tuning Ware [2004]. What makes these neurons interesting is that they react only on luminance changes and not on colour.

Gabor function is a model that is widely used to describe the receptive field properties of these neurons A. and Palagi [1994].

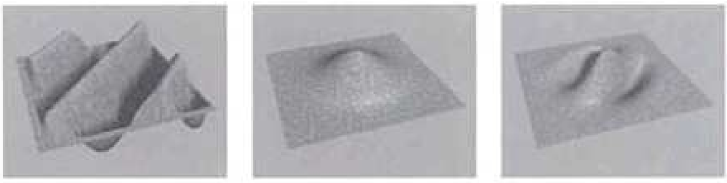

Figure 4.2: 1st is the cosine field, 2nd is the Gaussian field and 3rd is the Gabor field composed from the 1st and 2nd field by multiplying Ware [2004].

Figure 4.2 shows the Gabor field that has a clear orientation and it has an excitatory center flanked by inhibitory bars. There are also opposite neurons with an inhibitory center and an excitatory surrounding.

Gabor model is used to explain low level perception. It is used in theories for detecting contours at the boundaries of the object also detection of regions that have different visual textures, stereoscopic vision and motion perception Ware [2004].

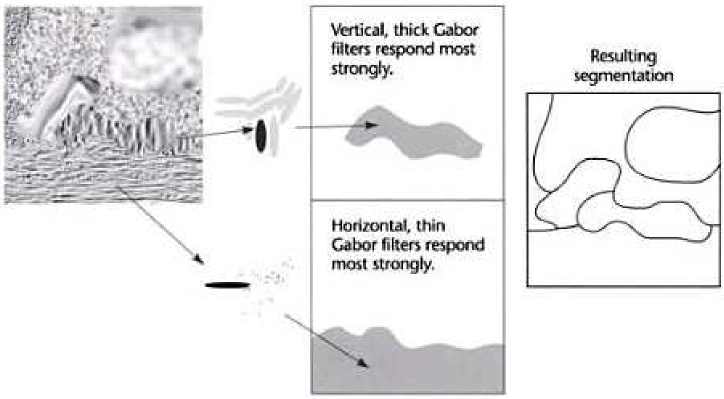

Figure 4.3: Gabor model used for segmentation Ware [2004].

Figure 4.3 shows the Gabor model used for segmentation resulting on the fully segmented image on the right Mundhenk [2009]. This model can be used to generate textures by randomly splattering down the Gabor function depending on orientation size and contrast determined by data values for the region [Ware Knight 1995] as quoted by Ware [2004].

4.2 Colour

The association of colour with objects in our language, seen in statements such as ”this object is red”, is misleading for it is undeniable that the colour that we perceive exists only in the brain. It is commonly stated that colour vision is the result of the nature of the physical world, the physiological response of the eye (more strictly the retina) to light, and the neural processing of the retinal response by the brain Goda and Komatsu [2009].

Since the retina contains four different types of receptor it might be thought that the neural pathways would carry four different signals to the brain. It is generally believed, however, that colour information is coded by the retinal and post-retinal neural structures as just three types of signals that are often called ”channels”. A channel is a conceptual processing route and thus for the visual system we can say that the information from the cones is processed in three separate channels. Remembering that colour perception is only one function of the visual system, there are other channels that are responsible for providing other information about the outside world that enables the perception of form, motion, and distance for example. The existence of channels for the processing of colour information helps explain the two contradictory theories of colour vision that were prevalent during the 19th century the trichromatic theory and the opponent-colours theory Kim and Kautz [2009].

The trichromatic theory was postulated by Young and later by Helmholtz and was based upon colour matching experiments carried out by Maxwell. Maxwell's experiments demonstrated that most colours can be matched by superimposing three separate light sources known as primaries; a process known as additive mixing. The Young-Helmholtz theory of colour vision was built around the assumption of there being three classes of receptors although direct proof for this was not obtained until 1964 when microspectrophotopic recordings of single cone cells were obtained. The roots of trichromacy are firmly understood to be in the receptoral stage of colour vision. It is important to realize that a yellow stimulus produced by the additive mixture of appropriate red and green lights does not simply match monochromatic yellow light but is indistinguishable from it. Thus, the trichromatic nature of vision is essential for the operation of many colour reproducing processes such as television, photography, and three-colour printing Kim and Kautz [2009].

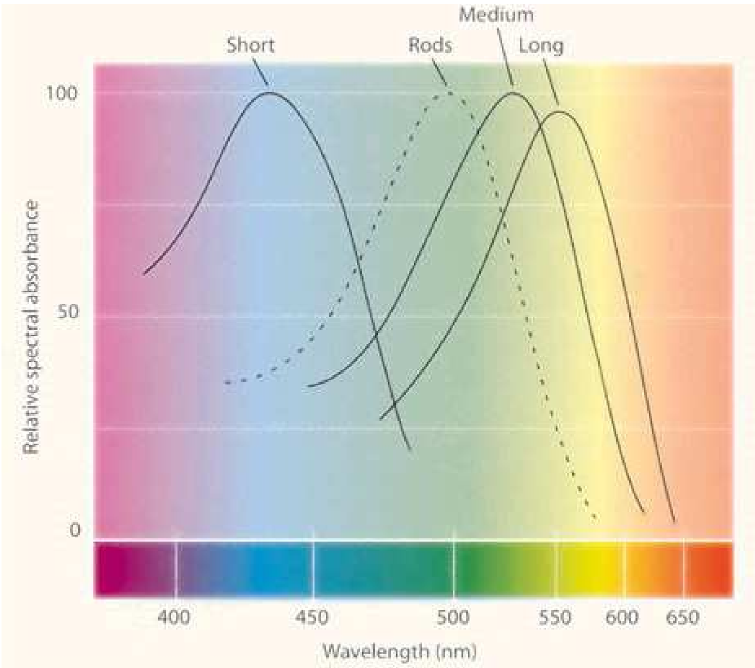

Figure 4.4: Three types of cones basen on trichromatic theory: short is blue colour, medium is yellow and long is red Robinson [2009].

The opponent-colours theory of colour vision, proposed by Hering, seemingly contradicts the Young Helmholtz trichromatic theory. It was advanced to explain various phenomena that could not be adequately accounted for by trichromacy. The colour opponent process is a colour theory that states that the human visual system interprets information about colour by processing signals from cones and rods in an antagonistic manner. The three types of cones have some overlap in the wavelengths of light to which they respond, so it is more efficient for the visual system to record differences between the responses of cones, rather than each type of cone's individual responses. Examples of such phenomena are the after-image effect (if the eye is adapted to a yellow stimulus the removal of the stimulus leaves a blue sensation or after-effect) and the non-intuitive fact that an additive mixture of red and green light gives yellow and not a reddish-green. Hering proposed that yellow-blue and red-green represent opponent signals; this also went some way towards explaining why there were four psychophysical colour primaries red, green, yellow, and blue and not just three. Hering also proposed a white-black opponency but this third opponent channel has been abandoned in most modern versions of the theory. It is now accepted that both the trichromatic theory and the opponent colours theory describe essential features of our colour vision with the latter theory describing the perceptual qualities of colour vision that derive from the neural processing of the receptor signals in two opponent channels and a single achromatic channel Kim and Kautz [2009].

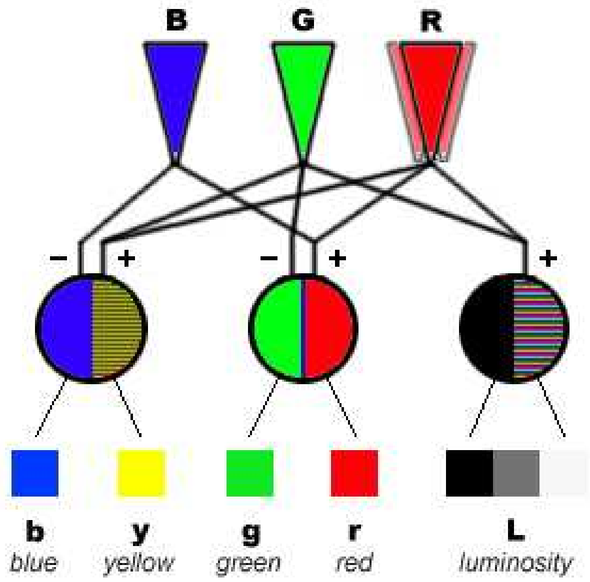

Figure 4.5: Opponent Theory showing the mixture of colours Kim and Kautz [2009].

4.3 Elements of Local Stereoscopic Depth

Three-dimensional (3D) vision relies on monocular cues such as perspective, shading and texture as well as binocular cues; understanding the chronology and location of 3D processing is a major research area in visual science. The cortical processing of monocular depth cues has been less studied when compared with the processing of binocular cues such as disparity. Yet monocular depth cues are basic and critical to normal vision, for example, we still have efficient depth perception if we close one eye Cauquil and Taylor [2005].

Adding 3D perspective cues to visual stimuli significantly modified the second component of the cortical response: the posterior neuronal peak was always larger for the 3D than the 2D stimuli but the processing of perspective cues did not delay the cortical response to the visual stimuli. Attention to the stimulus category modified the waveforms only at a later, post neuronal stage. The two approaches used to analyze the cortical activity led to the same conclusion: processing 3D information from perspective cues involves the same cortical areas as matched 2D stimuli, with an increase in activity of the regions contributing to the N1 component, and a preferentially greater increase in right parieto-occipital Areas Cauquil and Taylor [2005].

4.4 Elements of Motion

Motion processing is an important function for the survival of most living beings and so their visual systems have specific areas dedicated to this task alone. Primary visual areas are modelled using space-time receptive filters to compute motion as suggested by neuro-physiological data Mota Sonia and Prieto [2005].

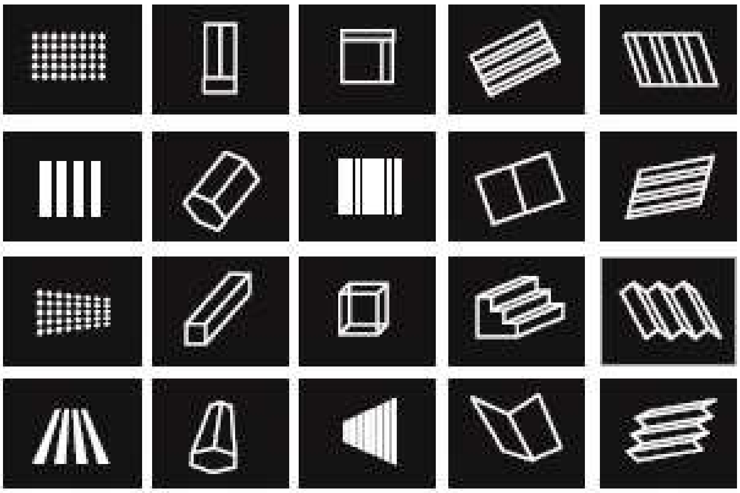

Figure 4.6: Two upper rows are experimental images and lower two rows are matched 3D images Cauquil and Taylor [2005].

On the right-hand column of Figure 4.7 it can be seen that the overtaking cars are accurately egmented from the background motion as homogeneous rightward-moving patterns. The computational time of the processes is quite high. The motion-detection layer is the most computationally demanding stage Mota Sonia and Prieto [2005].

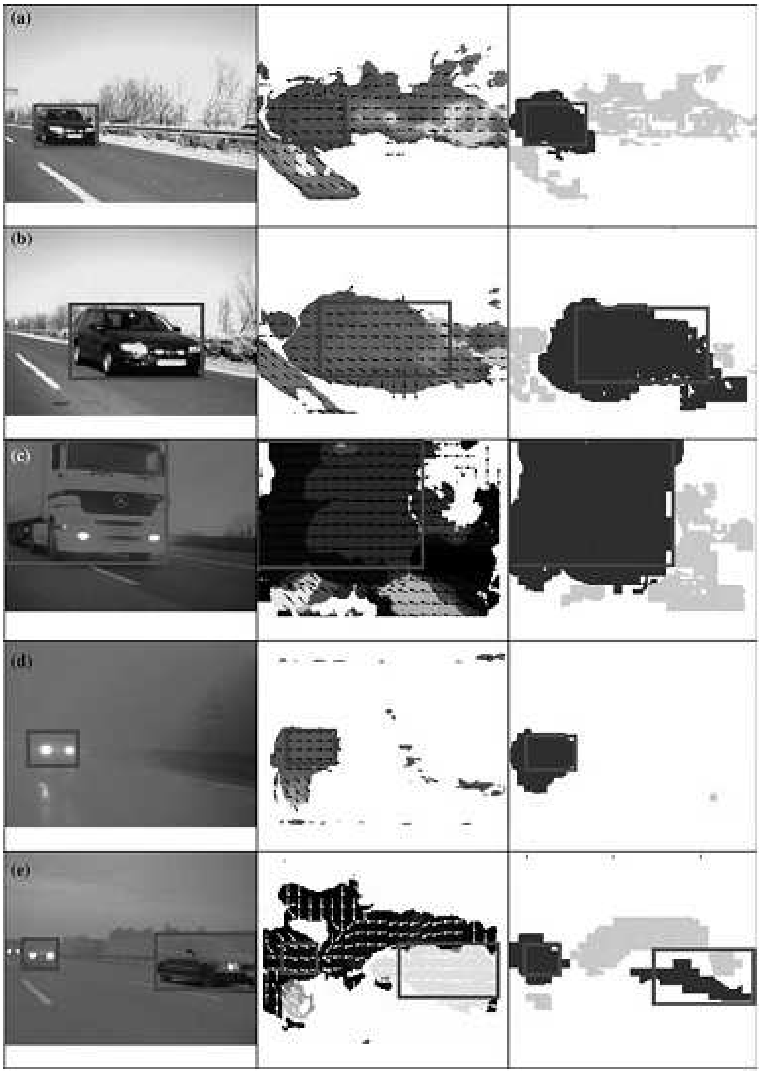

Figure 4.7: Overtaking on the highway on a sunny day (a, b); on a cloudy day with slight mist (c, e); on a foggy, rainy day (d). The rectangles have been added manually to facilitate the performance evaluation procedure Mota Sonia and Prieto [2005].

Chapter 5

Reallife Examples

5.1 Everyday Life

- Maps
  - City Maps
    - Forms used to help one orientate (the red dot: ”you are here”)
    - Coloured lines for public Transport: (tram, train, dotted line for underground)
  - tactical maps (Figure 5.1)

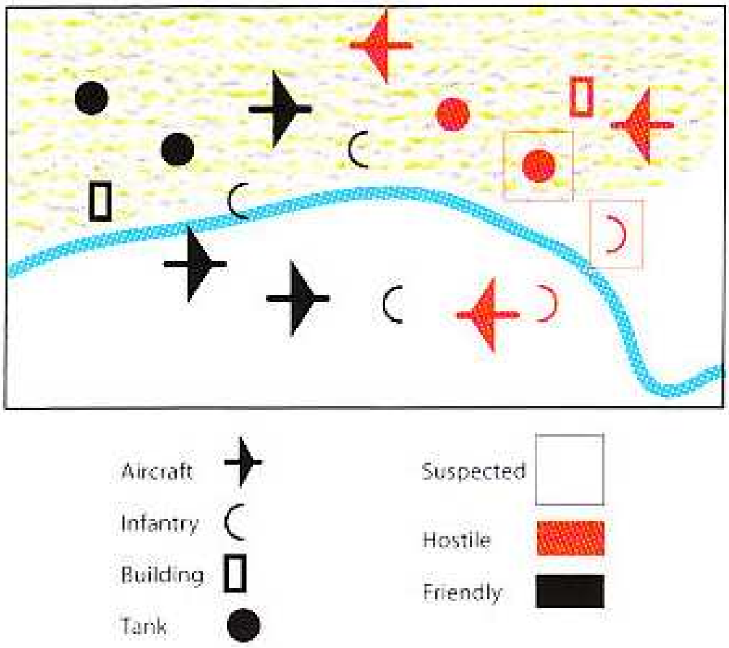

Figure 5.1: Good example for using different pre-attentive features in interaction. Forms, for types of units, colour (for distiguish reenforcements and enemies) and texture for areal information Ware [2004].

  - weatherforecasts (Figure 5.5 and 5.6)

- Signs
  - Traffic Signs: the blue ones tell you what to do (give priviledges), the red ones tell you what you are not allowed to do (prohibition)

    - Direction Sign: important to be distinguishable ona glance (normal:white, redirection yellow, motorway blue

- Grouping Things Together
    - Football teams with uniforms
    - Police, fire brigade, military uniforms
    - Hospital: doctors, nurses, security team to know whom to ask in case of emergency
- Print Media and Advertisement
    - News Papers: header to catch the attention (font size)
    - Atlas: colored plots for population, climate, political views
    - Webbanner: using motion to catch attention
- Trademarks
    - Mc donalds ”M”
    - Apple
    - Nike

5.2 Computer Aided Visualisation

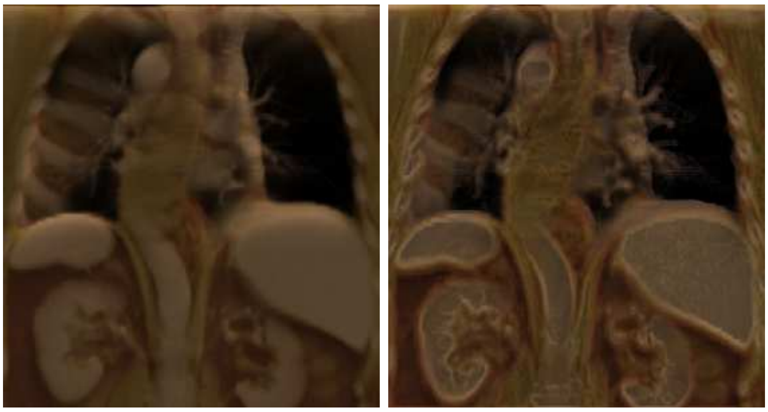

Figure 5.2: Original Gaseous Rendering (left), Boundary and Silhouette Enhancement (right) Ebert and Rheingans [2009]

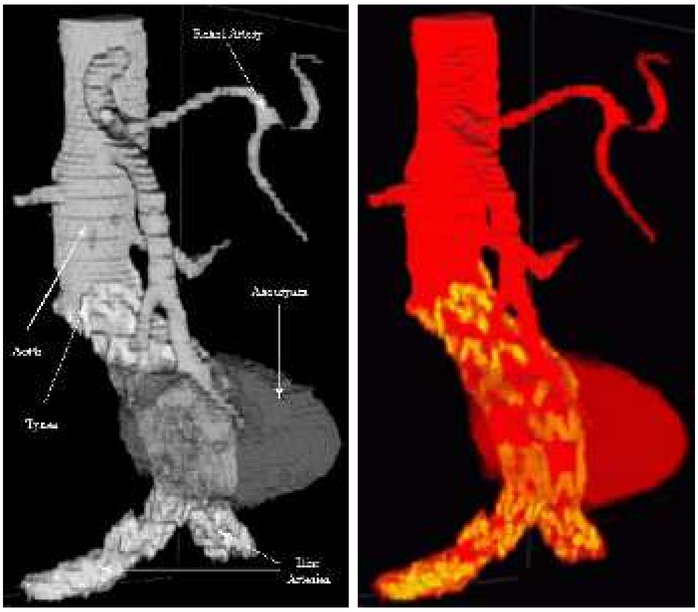

Figure 5.3: grayscale image (left), enriched witch colour to highlight the boundaries (right) Tam Roger C. and Cahoon [1997]

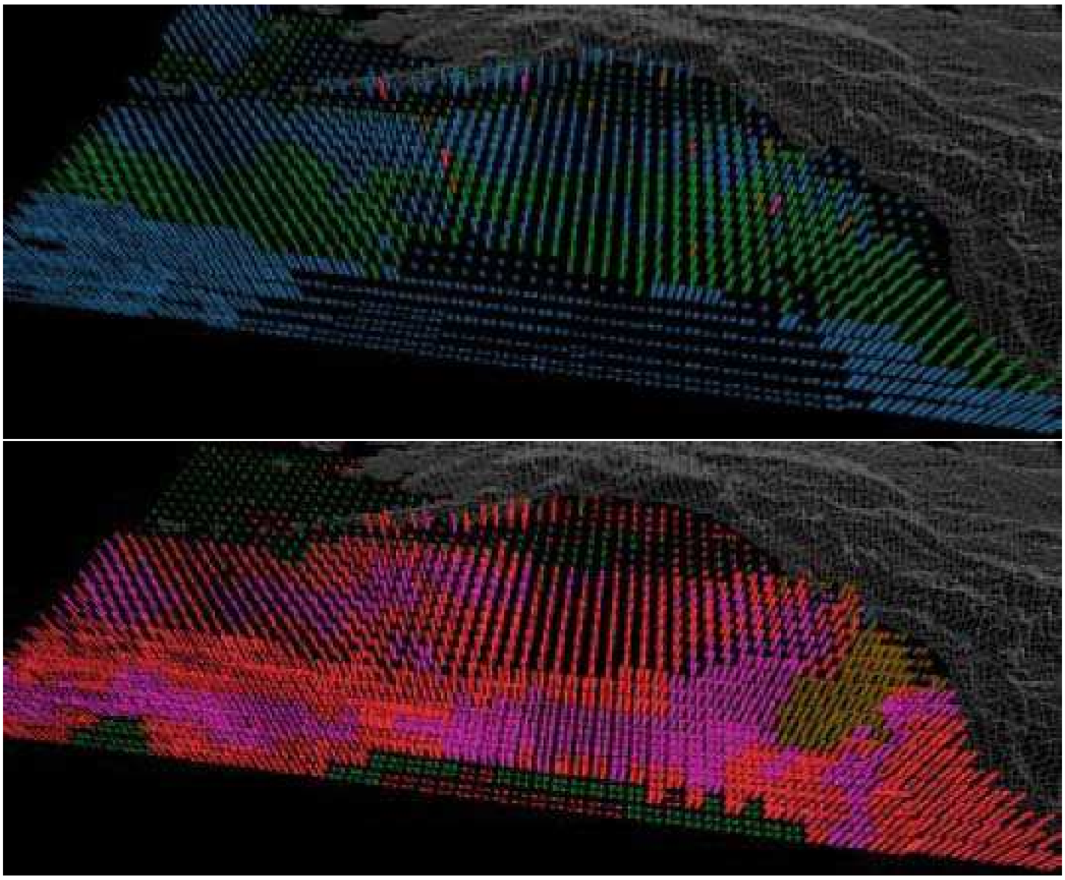

Figure 5.4: Visualisation of oceanography datasets. Image on top represents February 1956 and image on bottom represents June 1956, taken fromHealey [1998]

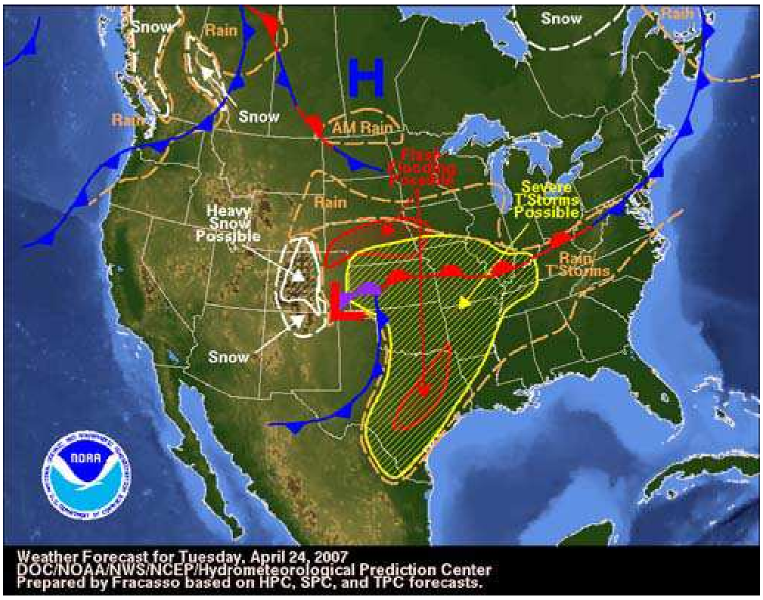

Figure 5.5: weather forecast for April 24, 2007 Preattentive features: forms for pressure ares and colour for distinguishing condensation typesNOAA [2009]

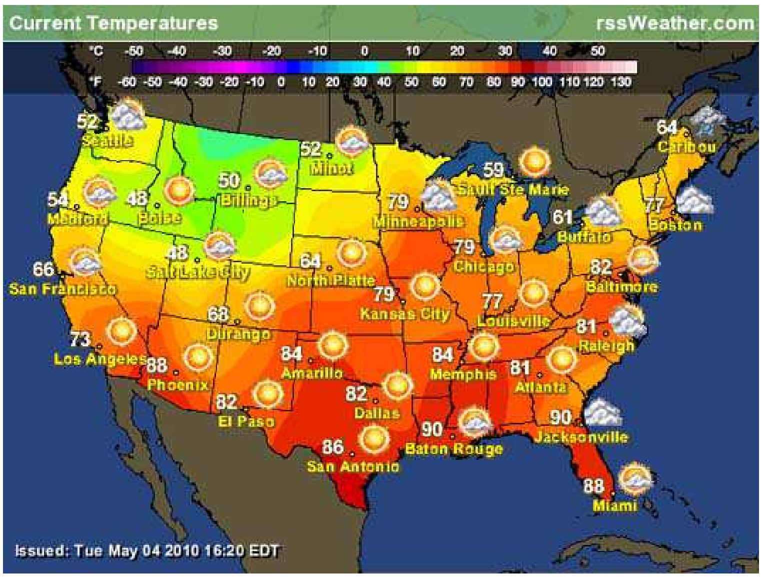

Figure 5.6: temperatires May 04 - USA. Preattentive features: colour for temperatures icons for weather conditionsrssWeather [2009]

Chapter 6

Concluding Remarks

As shown in examples and explanations above, we are faced with objects with pre-attentive features in everyday life. Most of us don't even know what causes our perception of pre-attentive detection of elements, but we use this ability for advertisement, warning signals, trade marks etc. Psychophysics have researched what types of elements we can recognize immediately. There are also some conjunctions of features we can process pre-attentively, although early research suggested that conjunctions can never be detected pre-attentively. For further research it may be important to know much more details about how our brain especially the perception of our environment works.

The human brain is composed of approximately 100 billion neurons. These neurons are nerve cells that individually serve a simple function of processing and transmitting information.

It is very important to understand the medical aspect how the brain analyses and filters information gathered from the eye. In such situation offloading brain and targeting patterns that are easier to recognize will make visual representation systems easier to construct and understand. When the nerve cells transmit and process in clusters, called a neural network, the results are complex, all this make us decide faster and more intuitive towards colour changes, movement, hue and depth perception.

There are still open questions like: Which colour theory is more adaptable for visual information representation? How far is Gabor model suited to calculate brain segmentation? Can cars or other safety systems benefit from pattern filtering?

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