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Usability Principles and Visual Design

1 User-centric design

1.1 Introduction

The design of a system must satisfy the needs of the users that are going to use it. Since the application is a tool that must serve the users, and that users must perceive as a good application, it is not enough for the application to make its work properly. It has to provide good feelings to the users.

Some of the important requirements the application has to fulfil are:

- You have to make sure that the user feels he or she is controlling the application.
- Learning curve should be as planar as possible: the user must require the minimum possible time to learn how the application works. This can be achieved by avoiding unfamiliar behaviours from (known) menus or buttons.

We can only achieve this if we have an idea on the user, his profile, and his behaviour. Therefore, user interface design is related with other disciplines such as psychology, ergonomics, and so on.

1.2 User centric design

Several studies have concluded that left-handers tend to die younger than right-handers. There are different opinions, and some say that right-handers live from 2 to 9 years more than left-handers. Some people believe that left-handers live in a world mainly **designed for right-handers**, and this may be one of the reasons that make the difference.

When designing user interfaces, we have to concentrate on the potential users of our system, without restrictions. Taking into account the needs of a small group may benefit (or at least not generate problems) the whole amount of users. For instance, selecting colours that avoid problems for people with colour blindness does not hurt the other users.

The **user model** is the set of details that a user may have, from the point of view of user interface design. We have to analyse different aspects of the users that may determine how we design the interface, such as:

- **User's knowledge on computers:** If the user does not know how to use a computer, it may become difficult to perform a task.
- **The mental model of the system:** Having a clear idea on the objectives of the users' work, and the application expected outcome is essential to avoid erratic behaviour.
- **Physical and sensory abilities:** Different users may have different physical abilities. We do not have to produce Power Point slides that can only be read by people with perfect vision, but the letters must be big enough to make them readable by most of the people.
- **Cognitive abilities:** Different cultural levels or degrees of experience doing a certain work may make some users more able to work with a computer.

Our application should be useful for novice or inexperienced users as well as more experienced ones.

- **Capacity of identifying and performing tasks:** Sometimes the application or the user may be very specific. While for critical applications the user will have had a proper training, web-based applications may be tested by users without a clear knowledge on the application workflow, or if the application is suitable for the problem in mind.
- **Learning capacity:** Interfaces must be more informative if the user has lower learning capacities. For classical applications, where the user has a clear idea on the expected outcome, little information may be required.
- **Personality differences:** Shy people may not be willing to explore the interface, and therefore features may not be discovered.
- **Cultural difference:** Some aspects may or not be acceptable for different cultures. An example is the use of images of flags to identify a language. It may be controversial and therefore should be avoided if our potential users may be offended.

Other factors may help to define in a more adequate way the interface:

- Expectance
- Motivation
- Preferences

You cannot ask the users to change their expectances. For instance, it is a crazy error to ask the users to hold their phones in a different way than they do. If Apple makes a mistake in the design of their iPhones (e.g. the iPhone 4) and holding it the usual way (see Figure 1-left) causes a problem in signal reception (see the change in the reception in Figures 1-center and 1-right), don't blame the user.

Figure 1: Holding the iPhone 4 causes a decrease in signal reception.

The reason behind it was the wrong design of the iPhone antennas, which are placed at the X spot indicated in Figure 2.

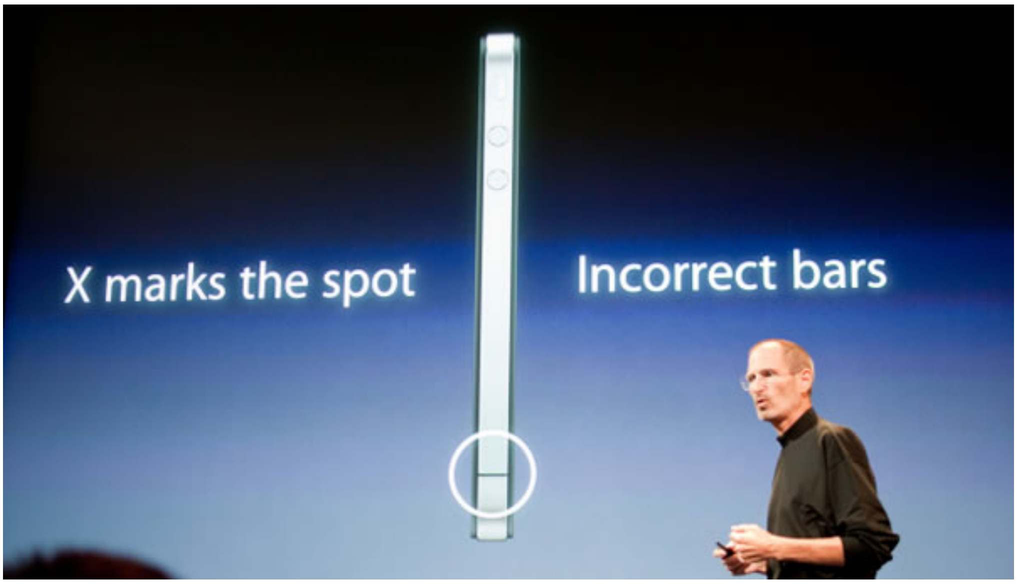

Figure 2: Antenna signal exit spot. Holding the iPhone at this region caused drop calls.

The first answer to this issue by Apple was *recognizing* that the number of bars indicating the quality of signal reception was wrong. But this was actually not true. Then, Steve Jobs had to stop his holidays to give a talk on, guess what…: how not to hold an iPhone! Practically asking the users to excuse themselves for holding the iPhone how they wanted…

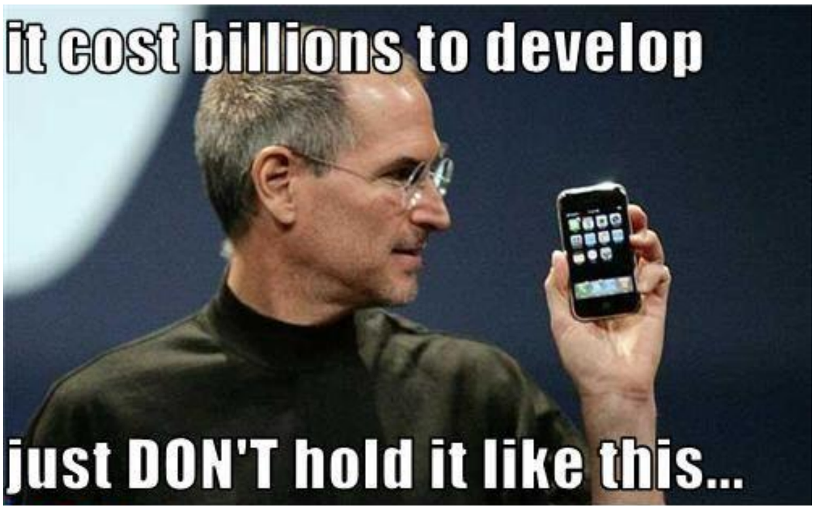

Figure 3: Steve Jobs telling the users how not to hold the iPhone.

To reduce the impact of the case, that got to be known as iPhonegate, and thus implicitly recognizing their design mistake, they offered a free case for each iPhone4 bought until September 30.
Finally, as you may imagine, they were the goal of many jokes such as the ones appearing in Figure 4.

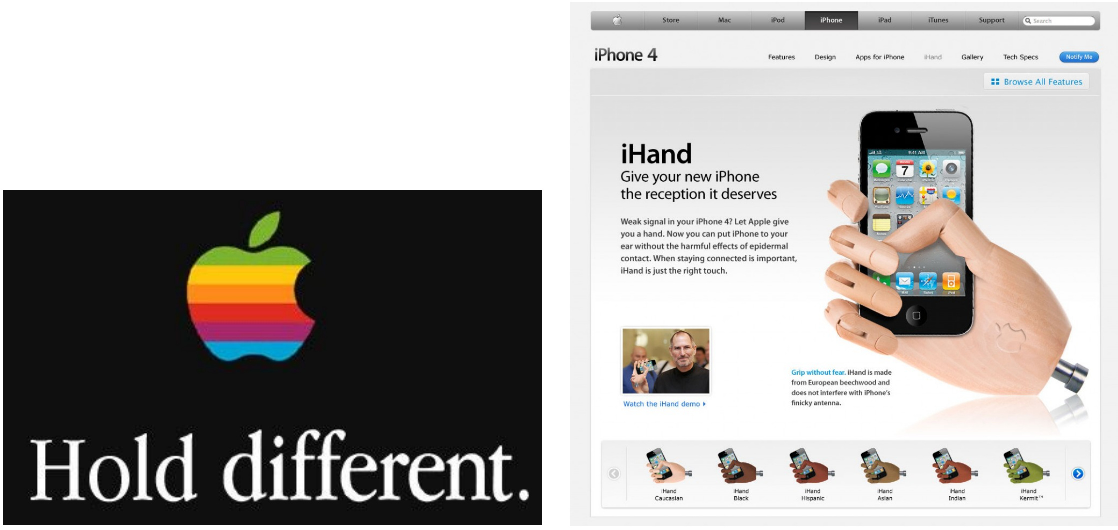

Figure 4: Different jokes mocking of the iPhone4 and Apple's answer to the problem.

By studying the user model, we may improve the interface in different ways: For instance, we may have different versions for different user profiles (novice to expert users), provide accessibility functions, such as different font sizes, and so on. However, it is not easy to obtain a user model, and when we have such model, it may be very difficult to act accordingly in order to improve the interface. Sometimes the information gathered might include much *noise* that does not help us. Moreover, some conditions may change along time, such as the cognitive capacities, and therefore our application may require adaptation to the new conditions.
Modelling all the possible users may become problematic, but if we are able to identify groups of users, this information may be important to improve our product. User interfaces may be designed in order to be adapted to different users. It is important to distinguish two different concepts:

- **Adaptability:** The possibility of modification of the application interface by the user.
- **Adaptativity:** The ability of a system to automatically adapt itself to the user.

In order to illustrate the differences between those, we may take the example of the Gmail application. This application is adaptable because we may change the look-and-feel and its behaviour (we may for instance create filters for incoming mails). The application is also adaptive because some features such as the spam filters or the Priority Inbox react to the users behaviours.

1.3 Tasks

We have to see a computer as a tool. Particularly, it is a tool that allows us to perform the tasks we already knew in a more efficient way. Most of the tasks we carry out on a computer (write a text, store information on customers, and so on), are common tasks that users had already been doing for a long time in a manual fashion. Thus, the user has acquired a way to work in order to achieve an objective that he or she knows has a number of steps.

When the user is in front of a computer, his tasks must reassemble the tasks he already knows. Thus, their appearance must be similar; their representation should also be similar, and so on. So, if in the *real world* a certain task requires three steps, these steps should be somehow represented in the work to be performed on a computer. Otherwise, the user must learn again new processes or to get familiar with new tools and command names.

Other aspects, more related with the physical or social environment should also be taken into account. This includes ergonomics. Applications must be designed in order to be portable between devices (this includes screen size changes, for instance), to support data interchange with other users, data safety, etc.

1.4 UI life cycle

The construction of any interactive system is usually carried out by a cyclic process that involves design, evaluation, and development. Design evaluation is very important towards the definition and proper fine-tuning user interfaces. Final users must be comfortable with the UI, since they are the ones who will use the application. Once the system is working, we can proceed to refine the interface by evaluating parameters such as response times and the adequacy of the feedback.

The user should be taken into account through all the process. We may see in Figure 5 the life cycle of a user interface and the intervention of the user in all the stages.

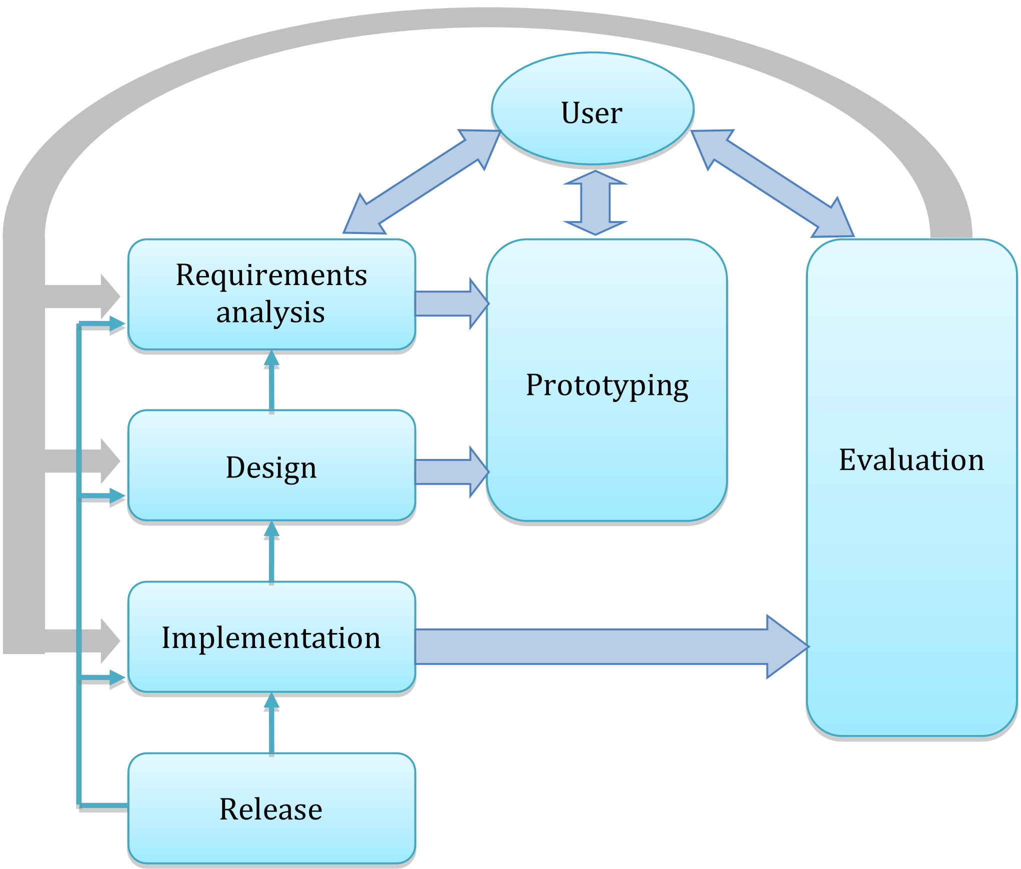

Figure 5: UI design. Participation of the user in the different stages.

1.5 UI design

Several years ago, the same person that analysed and developed the application carried out the design. Although this is less frequent currently, it still happens. But it has become more common to have professional designers for this task.

Designs must be focused to people with different abilities and knowledge of the application. Ideally, we must think both of novice users and power users.

There are three sources of information that designers may use in order to learn UI design: Principles, guides, and standards.

- **Principles:** They are general objectives that may be useful for the design. They give advice on how to proceed at a high level, but have to be adapted to the low-level problems we address in any concrete application.
- **Guidelines:** Design guidelines are a set of recommendations that should be applied when designing an interface. They are often measurable quantities (i. e. how many millimetres of spacing are enough for the proper reading of text, how many items are enough for a menu…). Guidelines must be general, and are often the result of extensive evaluations, together with the knowledge from ergonomics, cognitive theories, and so on.
- **Standards:** These are principles and guides that must be followed. Some standards are *de facto* (such as the ones imposed by important companies), and are used to protect the uniformity of the different products under the same OS, for instance. This has some benefits for the user, such as the familiarity with the icons and tasks. Other standards are called *de iure* and are the ones promoted by institutions like ISO (European), ANSI (EEUU), or AENOR (in Spain). Their objective is to establish a common set of rules in order to preserve uniformity (i. e. electric plugs…).

2. Usability and Design Concepts

There is a large amount of knowledge in different areas of design that may help us when designing user interfaces. In this section we will introduce some of the principles that have arose from many years of practice from different areas. Most of them come from the famous *Universal Principles of Design* book, from where we extracted the ones we found were more notable or useful. Some principles have already been visited, but will be illustrated here with a more detailed explanation or examples.

2.1 The 80/20 Rule

The 80/20 rule asserts that approximately 80 percentage of the effects generated by any large system are caused by only the 20 percentage of the variables in that system.
This rule is observed in all large systems, including economics (i. e. 80% of a company revenue comes from 20% of its products), computer systems (80% of errors are caused by 20% of the components), and so on. In our case, 80% of the usage in an application will be focused on only 20% of its features.

It is a useful rule for focusing resources, that is, we must focus most of our attention to the 20% of the features that are mostly used, to the 20% of the features that are critical, and so on. Focusing on aspects of the system that are beyond the critical 20% rapidly yields diminishing returns.
The rule must be used to assess the value of elements, and determine the target of our efforts in design and optimization.

2.2 Barrier-free design

Accessible or barrier-free designs have four characteristics:

- **Perceptibility:** Everyone can perceive the design, regardless of sensory abilities. This feature is achieved when everyone correctly understands the user interfaces. We must design interfaces with colour-blind friendly designs, with redundant visual indicators (such as text and colour), and so on.
- **Operability:** It indicates that anyone, regardless of physical abilities, is able to work with our system. In User Interface design, this means that we must take care of people with motor inabilities or slower response times (such as for double-click, as a typical case in elder people or children). This can be achieved by facilitating the access to controls (i. e. avoiding key combinations that require the use of two hands).
- **Simplicity:** It is achieved when everyone can understand the design regardless of experience, literacy, or concentration level. Unnecessary complexity must be removed. Designs must be clear, concise, and consistent, and feedback must be provided clearly.
- **Forgiveness:** It is achieved when the design minimizes the occurrence of errors and, in case of error, it also minimizes the errors' consequences. The use of good affordances, constraints, proper input formatting, and confirmations when required help to achieve forgiveness.

2.3 Aesthetic-Usability Effect

Aesthetics play an important role in the way designs are used. Aesthetic designs look easier to use, and encourage its use more than non aesthetic designs. This effect produces the perception that an aesthetic design is easier to use than a non-aesthetic design. However, you can find many examples that indicate the contrary. For example, the iPhone Calendar, though beautifully designed, makes a poor use of space, thus avoiding the visualization of a complete day in our calendar. On the other side, WebOS calendar is able to show a higher amount of information in a smaller space due to some elements such as an intelligent free-time collapsing option (see Figure 6). In use, the iPhone Calendar also requires a higher amount of clicks to generate an appointment, as compared to other calendars such as Android's or WebOS.

Figure 6: Left: iPhone Calendar. Right: Palm's WebOS calendar. WebOS Calendar makes a much smarter use of the space with the collapsing free-space regions and the overlapping of the view changing buttons. All in all, more things are shown in a 3.1-inch screen (right) than the famous 3.5-inch screen of the iPhone (left).

Since aesthetic designs are perceived as easier to use, we must devote important efforts to improving our designs. They are usually more readily accepted and user over time, and also foster positive relationships with people.

2.4 Correct alignment

We have already seen the infamous *butterfly ballot* from the US presidential election in 2000. One of the main problems was alignment.

Elements in a design must be aligned to each other. This creates a sense of unity and cohesion, as well as facilitates reading. When using grid or column-based alignments, we are also guiding the reading directions of the users. This is important because we may guide the attention, as well as induce the relation between the different elements.

Most common and useful alignments are rows and columns. Although more elaborate designs can exist, it may be necessary to add other visual cues to enforce the alignment direction.

2.5 Chunking

The term chunk is used to refer to a unit of information in short-term memory. Chunking is a technique that seeks to place the information in a way that accommodates to the limits the humans have to process bits of information. The famous paper by George Miller *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information*, studies the capabilities of human brain in recalling performance. Essentially, smaller chunks are easier to remember

than larger lists, for example, most people can remember a list of 5 words for 30 seconds, but few can remember a list of ten words for 30 seconds.
Chunking is a technique that refers to elements that must be memorized, such as menu items, telephone numbers and so on. It is not required to divide all the elements in a screen or page in groups of 5 or so, since this can yield no benefits at all. Tasks such as text scanning do not require recalling the text that has been analysed; therefore, elements such as dictionary pages must not be chunked.

2.6 Cognitive dissonance

Cognitive dissonance is a psychological phenomenon that refers to the discomfort felt at a discrepancy between what you already know or believe, and new information or interpretation. It therefore occurs when there is a need to accommodate new ideas, and it may be necessary for it to develop so that we become "open" to them.
This discomfort is released usually in one of these three ways:

- Changing our behaviour.
- Justifying our behaviour by changing the conflicting cognition.
- Justifying our behaviour by adding new cognitions.

A typical example of cognitive dissonance is smoking. Many smokers feel some discomfort with the fact that smoking will shorten their lives and that they want to have long and healthy lives. There are different ways to reduce cognitive dissonance among smokers:

- Changing the behaviour: Quitting smoking.
- Justifying the behaviour by changing the conflicting cognition: Denying the evidence that smoking produces cancer.
- Justifying the behaviour by adding new cognitions: Rationalizing their behaviour by saying that only a few amount of hard smokers actually become ill.

A typical example of cognitive dissonance is a service that offers a free trial period but that requires a long time and effort to make the service properly work for you. When the free time expires, it will be a hard work to change the system and therefore, the larger the cognitive dissonance that will lead to a large amount of people to accept the price to continue with the service. Cloud services integrated into computers or mobile phones may produce a high cognitive dissonance if we want to change our system with a different one, since moving all our music, folders, configurations, and so on, may be time costly, and therefore we might prefer to buy a new product from the same company. The larger we are involved (the higher number of services we use), the higher the cognitive dissonance to change the trademark.

2.7 Colour

Colour is an important feature that can make a design more visually pleasing and aesthetic. They can be used to reinforce layout design and the meaning of elements. Some aspects must be taken into account when using colours.

- **Number of colours:** The number of colours must be kept low. Commonly, up to five is enough. Do not rely on the colour to provide information, always use a second cue because there are users with some sort of colour-blindness.

- **Colour combinations:** When using different colours for adjacent elements, we may take different approaches. The most common, and widely accepted are the use of analogous colours (adjacent colours on the colour wheel), complementary colours (opposing colours on the colour wheel), colours at the corners of a symmetrical polygon circumscribed in the colour wheel, triadic (triangle) or quadratic (square), or combinations of colours found in nature (see Figure 7).
- **Saturation:** Attention attraction can be achieved using saturated colours (pure hues), when performance and efficiency are important, the use of desaturated colours may help. Desaturated colours are perceived as more professional, while saturated colours are perceived as more exciting and dynamic.
- **Symbolism:** The meanings of colours may vary among cultures, therefore, one should not try to use a certain colour to produce some feeling (i. e. dark colours are assumed to make people sleepy) without a previous verification of the target audience.

Figure 7: Colour combinations found in nature: The right image shows a portion of Irish coast, and some of its colours have been picked for the Dublin website.

2.8 LATCH

The organization of information is a powerful way to improve understanding as well as influencing the way people think. The LATCH principle (Location, Alphabet, Time, Category, Hierarchy) is a slight redefinition of the *Five Hat Racks*. The five organization modes are described next.

Location

Location is chosen when the information you are comparing comes from several different sources or locales. Doctors use different locations of the body to group and study medicine. Concerning an industry you might want to know where on the world goods are distributed.

Alphabet

Alphabet is best used when you have enormous amount of data. For example words in a dictionary or names in a telephone. As usually everybody is familiar with the Alphabet, categorizing by Alphabet is recommendable when not all the audience is familiar with different kind of groupings or categories you could use instead.

Time

Time is the best form of categorization for events that happen over fixed durations. Meeting schedules or our calendar are examples. The work of important persons might be displayed as timeline as well. Time is an easily framework in which changes can be observed and comparisons made.

Category

Category is an organization type often used for goods and industries. Shops and services in the yellow pages are easy to find by category. Retail stores that sell clothing have separated parts for men, woman, and children clothing. This mode works well to organizing items of similar importance.

Hierarchy

Hierarchy organizes by magnitude. From small to large, least expensive to most expensive, by order of importance, etc. Hierarchy is to be used if you want to assign weight or value to the ordered information.

2.9 Garbage In – Garbage Out

This principle refers to the long-time experience of computer scientists that have found out that good input produces good output while bad input often produces bad output. It is often abbreviated GIGO. This metaphor refers to two common input problems:

- **Problem of type:** This problem appears when the incorrect type of input is provided to a system. Sometimes the type problem can be detected, but may produce the high level of garbage if it goes undetected. Elements such as numerical fields that can be fed with a phone number or a credit card number are examples of this type problem.
- **Problem of quality:** It occurs when the correct type of input is fed into a system but it has some defects. This type of errors may often be caused accidentally, and one way to minimize problems is the use of previews and confirmations.

The best way to avoid garbage out is to properly avoid garbage in: Type checks, input formatting, default values, or example inputs may help to reduce the input of garbage data.

2.10 Iconic Representation

It is the use of images to represent objects, actions and concepts. There are four types of iconic representations:

- **Similar:** They try to represent the action or object by an image that is visually similar to the element they try to represent. It is often useful for simple objects or actions (right turn) but less effective when trying to represent complex concepts.
- **Example:** They use elements that can be related with the object or action that they represent, such as a plane to indicate an airport.
- **Symbolic:** Images have a high level of abstraction. They are more effective when the symbol is well-established (such as the unlock icon with an open lock).
- **Arbitrary:** They are icons that use images with no relationship with the element or action, such as the male/female symbols.

3. Gestalt Laws and Perception

3.1 Law of Prägnanz

The word *prägnanz* is a German term meaning "good figure." The law of Prägnanz is sometimes referred to as the law of good figure or the law of simplicity. It is referred to as one of the Gestalt Principles of perception.

This law holds that objects in the environment are seen in a way that makes them appear as simple as possible.

3.2 Other Gestalt Laws

We tend to order our experience in a manner that is regular, orderly, symmetric, and simple. Some of the Gestalt Laws relevant for visual design are:

- **The law of closure:** The mind may experience elements it does not perceive through sensation, in order to complete a regular figure (that is, to increase regularity).
- **The law of similarity:** The mind groups similar elements into collective entities or totalities. This similarity might depend on relationships of form, colour, size, or brightness.
- **The law of proximity:** Spatial or temporal proximity of elements may induce the mind to perceive a collective or totality.
- **The law of symmetry:** Symmetrical images are perceived collectively, even in spite of distance.
- **The law of continuity:** The mind continues visual, auditory, and kinetic patterns.
- **The law of common fate:** Elements with the same moving direction are perceived as a collective or unit.

Some examples of these laws are shown in Figure 8.

Figure 8: Examples of the Gestalt principles of similarity (left), proximity (centre) and closure (right).

3.3 Occam's Razor

Occam's Razor (also Ockham's Razor) is sometimes expressed in Latin as *lex parsimoniae* (the law of parsimony, economy or succinctness). It is a principle that generally recommends selecting from among competing hypotheses the one that makes the fewest new assumptions. In design it is applied to indicate that it is preferred the simplicity over the complexity.
Occam's original statement was "Entities should not be multiplied without necessity". Albert Einstein's formulation was: "Everything should be made as simple as possible, but not simpler".
Unnecessary elements decrease design's efficiency. If we compare Yahoo's search page with Google's search page, we should prefer the second to the former. However, we should not forget that Yahoo's webpage also provides other services than search.

3.4 Orientation Sensitivity

The efficiency with which we can perceive the orientation of lines is limited. Humans easily distinguish or can judge vertical or horizontal orientations while oblique orientations are more difficult to distinguish. Usually 30 degrees is the minimum recommended difference in orientation for the users to perceive it properly. This is due to two main phenomena in visual perception:

- **Oblique effect:** The relative deficiency in perceptual performance for oblique contours as compared to the performance for horizontal or vertical contours. It is caused by a greater sensitivity of neurons to vertical and horizontal stimuli than to oblique stimuli.
- **Pop-out effect:** It is the tendency of certain elements in a display to pop out as figure elements, and therefore be easily detectable. For instance, in a set of lines, targets are more easily detectable if they differ a minimum of 30 degrees over the other background of lines. When combined with the oblique effect, it becomes stronger: it is easier to distinguish a line with a subtle difference in orientation if it is close to a vertical or a horizontal line rather than close to a set of oblique lines.

3.5 Pictorial superiority effect

Concepts are much more likely to be remembered experientially if they are presented as pictures rather than as words. In many cases, information recall is superior when the information is presented in pictures. However, this happens after thirty seconds, that is, when the information is recalled before 30 seconds, the same amount of information can be recalled in text than in pictures. However, after 30 seconds, it is easier to recall pictorial information.

This also happens when the time of exposure is small, images can be better recalled than text.

3.6 Progressive Disclosure

It is an interaction design technique that sequences information and actions across several screens in order to reduce feelings of overwhelm for the user. It keeps displays clean and uncluttered. By disclosing information progressively, you reveal only the essentials and help the user manage the complexity of feature-rich sites or applications to reduce confusion, frustration, or disorientation. Progressive disclosure is not just about displaying abstract then specific information, but rather about getting the user's attention by going from simple to more complex actions.

Sometimes, designers present too much information in order to reduce kinematic load. Since not all the elements in an interface will be equally used, progressive disclosure will move complex and less frequently used options out of the main user interface and into secondary screens.

3.7 Rule of thirds

The rule of thirds is a compositional rule of thumb in visual arts such as painting, photography and design. The basic principle behind the rule of thirds is to imagine breaking an image down into thirds (both horizontally and vertically) so that you have 9 parts. With this grid in mind the *rule of thirds* identifies four important parts of the image that you should consider placing points of interest in as you frame your image: the two central vertical edges, and the two horizontal edges of the grid. Then, important compositional elements should be placed along these lines or their intersections.

An example of this rule of thirds is shown in Figure 9, where the important objects (the landscape line, the surf table, and the surfer) are aligned with these three mentioned axes.

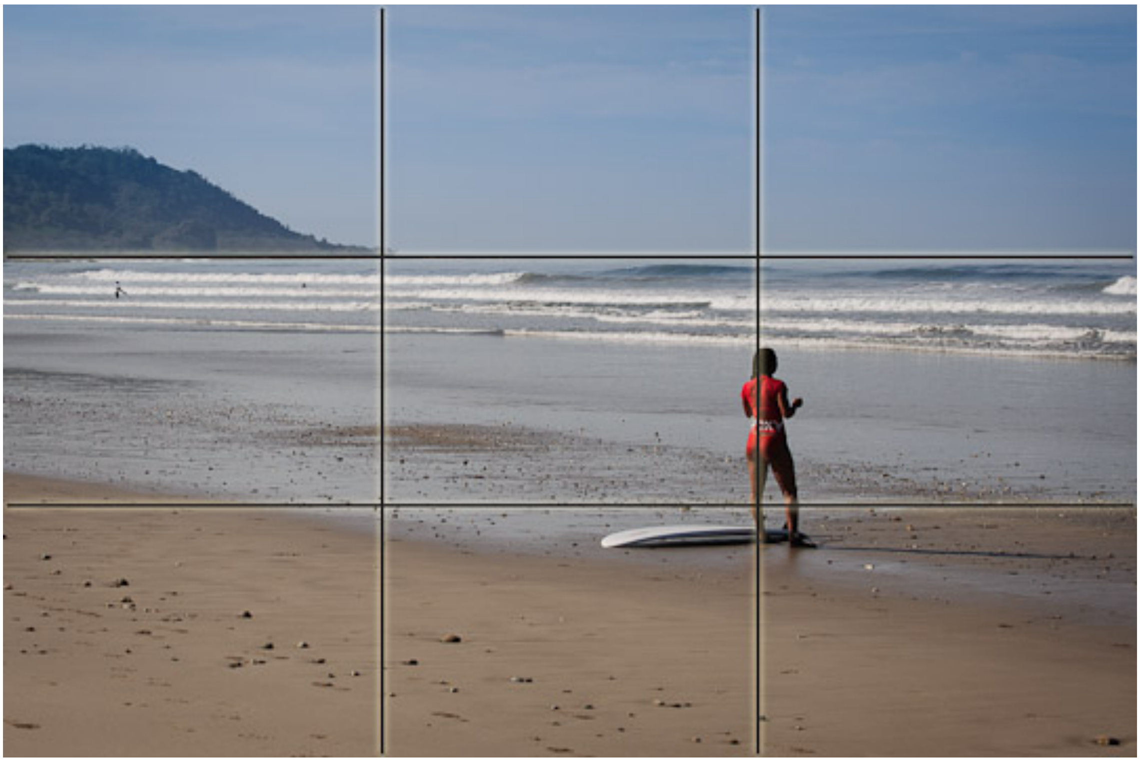

Figure 9: Example image following the rule of thirds.

3.8 Signal to noise ratio

Signal-to-noise ratio is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power. A ratio higher than 1:1 indicates more signal than noise. The goal of communication is maximizing signal and minimizing noise.
We can improve the signal to noise ratio in our designs by keeping them simple. We can enhance information by using redundant coding and highlighting, and we can remove noise by eliminating unnecessary elements. For tabular data, for example, lines may sometimes be removed if proper alignment or other background solid colours are used to enhance alignments. Bar charts, for instance must avoid textures.

3.9 1+1 = 3

Since all the elements in a design are perceived together, some of them, although not designed initially this way, interact. This may create non-information patterns and texture.
This effect is properly illustrated in Figure 10.

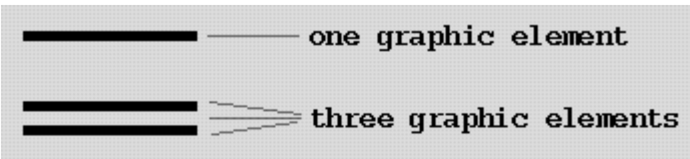

Figure 10: Example image showing the 1+1 = 3 effect.

The single line is clearly a single graphic element, while when we add a second line, the empty space lying in between creates a third visual element although it was not intended to. As a consequence, we have three graphical elements, each of the lines and *the space between them*.
This effect is called 1 + 1 = 3. The general result of this effect is that there is an extra effort of the visual system processing something that is not information, but noise and clutter. The noise produced by the 1+1=3 effect is directly proportional to the contrast in value (light/dark) between figure and ground. Therefore, different contrast colors might alleviate the incidental clutter.
A particularly common example is caused by the use of boxes around text, which are commonly discouraged.

4 Colour Perception and Colour Design

4.1 Introduction

The perception of colours is depends on many factors. In particular, the final appearance of colours depends is a combination of perceptual and cognitive effects. Perceptual effects are generated by the processing in the brain of the original retinal signals. Cognitive effects are based on our knowledge of how objects and lights behave in the world.
Obviously, humans do not describe colours in terms of red, green, and blue contributions. People usually describes colours in terms of a hue, such as red, purple, orange or pink. Then, we further describe the colour as being light or dark, vivid, and so on… Colour spaces that imitate this perceptual organization are said to be more "intuitive".
CIE is not totally uniform colour space, since two neighbouring colours may not be at the same perceptually perceived distance. However, there are two uniform colour spaces defined by the CIE for the measurement of colour differences: CIELAB and CIELUV. They are non-linear transformations of the CIE tristimulus values. They have been defined such that a unit step in the space is considered a "just noticeable difference" or JND.
Apart from colour, size or spatial frequency have also a strong impact on the perception of a colour. For instance, the higher the spatial frequency the less saturated the colour. *Chromatic adaptation* describes the visual system's ability to adapt to the colour of the light illuminating the scene. Most colour is created by shining light off of objects. While the reflected spectrum can be measured with colorimetric instruments, changing the light will change the measured colour, sometimes dramatically. But, as we view the world, we do not generally perceive objects changing colour as the light shifts. It is similar to an automatic *white-balancing* function for the visual system. That is, the gain controls for the three cones are adjusted separately. Modelling chromatic adaptation is very important for the accurate reproduction of images.
These and other effects affect how users perceive interfaces. For instance, forms with a lot of black separating lines may appear much more cluttered than if such lines are removed.

4.2 Colour blindness

When dealing with colour in interface design, we must take into account colour vision deficiencies. Some people are unable to perceive differences between some of the colours that non-coloured impaired users can distinguish. These problems are usually caused because one type of cone in the retina is either missing or weak. The most common problems are anomalies in the red-green opponent channel, where either the ability to see red or to see green is impaired. This type of deficiency is called colour blindness.

Red-green problems appear in approximately 5 to 10% of men. A much smaller percentage (1-2%) are weaknesses in the blue-yellow channel. There are very few people actually "colour blind," or unable to see any hues at all. While most colour vision problems are genetic, they can also appear as a side-effect of medication or illness. On the other side, women are less affected by this deficiency, as it only affects less than 1% of females.

4.3 Detection

Colour blindness is relatively easy to detect. There are some tests such as the Ishihara test that can even be carried out in a computer screen. The Ishihara Colour Test was named after its designer, Dr. Shinobu Ishihara, a professor at the University of Tokyo, who first published his tests in 1917.

The test consists of a number of coloured plates, called Ishihara plates, each of which contains a circle of dots appearing randomized in colour and size. Within the pattern are dots that form a number visible to those with normal colour vision and invisible, or difficult to see, for those with a red-green colour vision defect. The full test consists of 38 plates, but the existence of a deficiency is usually clear after a few plates, and most tests you will find will show only 6 or 8 colour plates. Testing the first 24 plates gives a more accurate diagnosis of the severity of the colour vision defect.

Figures 11, 12, and 13 show different examples of the plates used in this test.

The most typical images you find for the tests are:

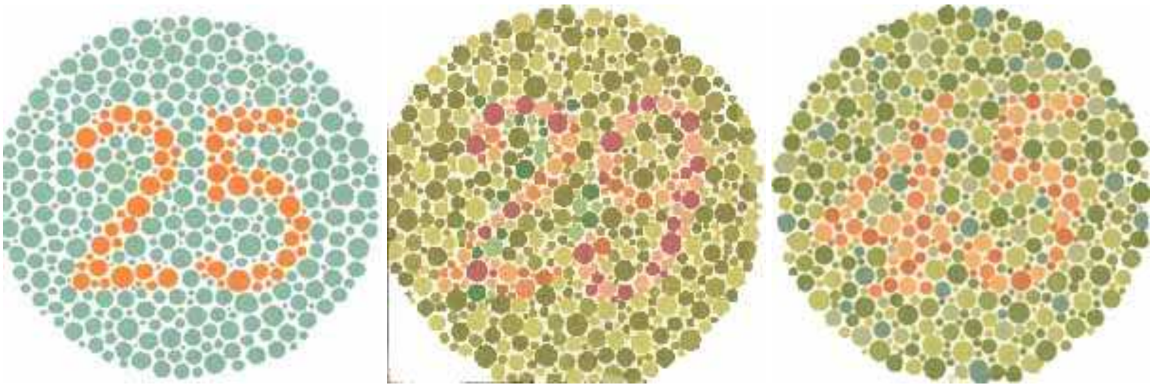

Figure 11: Most of the observers should see the numbers 25, 29, and 45, respectively. However, a person with red-green colour blindess will only see spots on the center and right images.

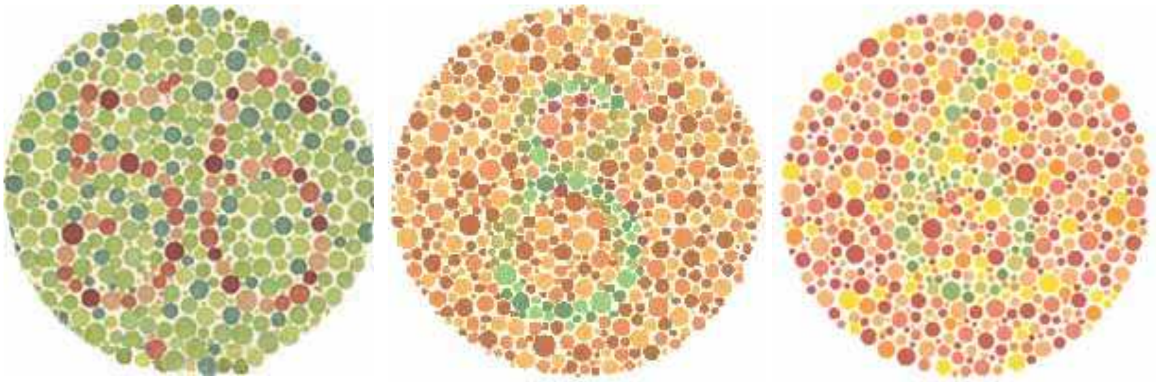

Figure 12: The numbers shown here are 56, 8, and 6. A person with red-green colour blindness should see the two rightmost numbers incorrectly.

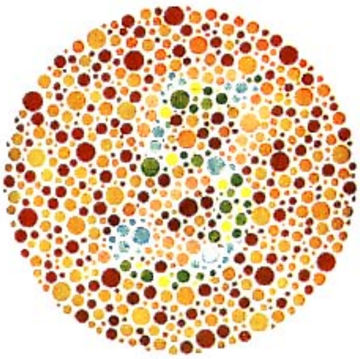

Figure 13: A person without colour blindness should see the number 5. A person with red-green colour blindness would see the number 2 in between spots.

4.4 Colour Friendly Design

There are many benefits designing taking into account colour deficiencies. A Web site, for instance, apart from being more accessible, it may also get better ranking in search engines.

If we take into account that colour blindness could involve up to 1 in 20 users, if the GUI we design is for a large group of people, discarding an appropriate colour design may leave many users apart.

Although it is not simple to design for colour blindness because it is difficult to determine what colour-blind users see and there are different deficiencies, we may take some safe paths. There is a lot of literature on colour design for colour-blind people. In Figure 14 you can see the difference of an effective design (top) and an improvable design.

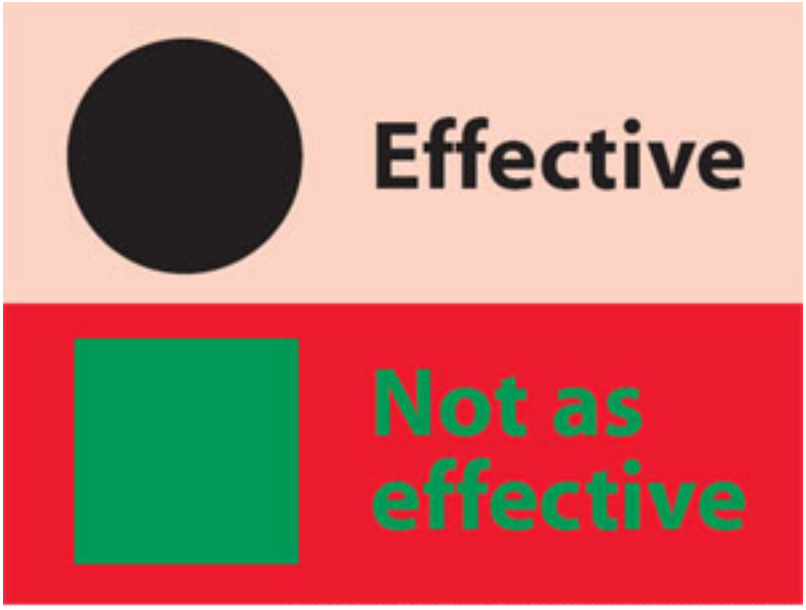

Figure 14: Two different designs using colour-blind friendly colours (top) and not so friendly colours (bottom).

Some advices for a proper colour design are:

- Exaggerate lightness differences between foreground and background colours, and avoid using colours of similar lightness adjacent to one another, even if they differ in saturation or hue.
- Contrast dark colours against light colours (see Figure 15). Use colours placed at distance in the colour circle.
- Content areas should be monochromatic with the font colour and background at the opposite ends of the colour saturation poles (i.e., black text on a white background).
- If we have elements of navigation such as menus, headers and sub-headers, they must have some extra visual enhancement since users seldom devote long periods of time to such elements.

Figure 15: Colour wheel properly orientated to show light colours (top) and dark colours (bottom).

Contrasting colours or colours on the opposite ends of the colour spectrum usually work best for colour-blind users (e.g., white and black is the best example). Widgets should have more than one cue: images, buttons, and other elements should be enhanced with an image, shape or text.
Each element should have more than one cue. Images, links, buttons, and other similar elements should be enhanced with an image, shape, positioning or text. For example, a link should be highlighted by colour as well as underlined. Take away the colour treatment and the underline will let visitors with colour blindness know that it is a link.

4.5 Colour selection strategies

There are several ways to select different colours for your interface. However, some strategies may work and some will definitely not.
You can read about different colour relationships in the following page: http://www.brandigirlblog.com/2012/11/why-do-some-color-schemes-work-and-others-dont.html, where you will find some advice on which strategies to use under certain circumstances.
Some relevant colour selection strategies are:

- Analogous colours
- Split-analogous
- Complementary
- Split-complementary
- Triad
- Tetrad
- Rectangle

Analogous colours are those that sit next to each other in the colour wheel, such as in Figure 16-left. You may use this colour set when you need more than one colour but still provide a sense of unity.

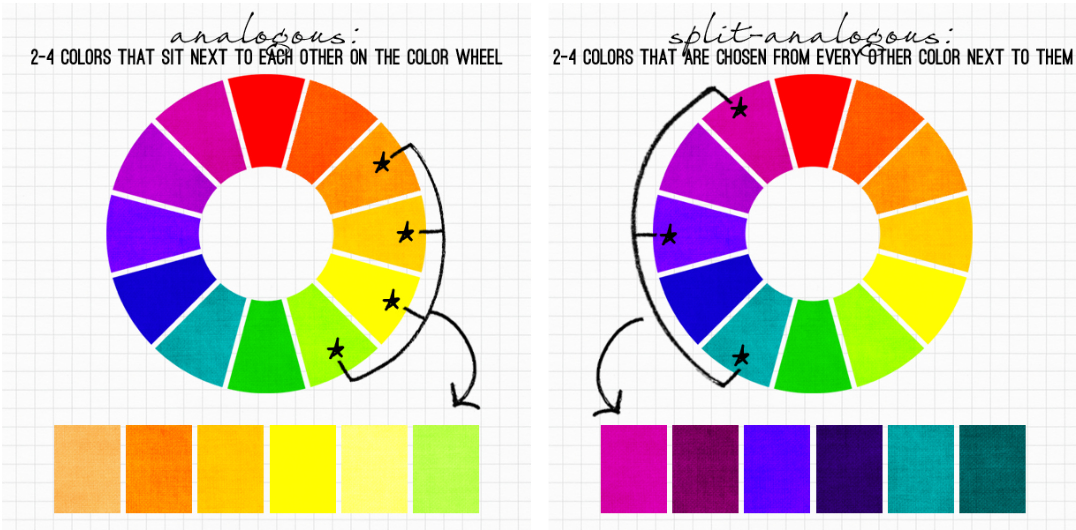

Figure 16: Analogous (left) and split-analogous (right) colour selection.

The split-analogous colour selection (Figure 16-right) is equivalent to the previous one, but skipping one colour of the colour wheel.
To draw the attention over a certain area of your design, we can use contrasting colours, such as the ones that result in the selection of opposite colours in the colour wheel. This strategy is called *complementary colour* selection. You can see several selections in Figure 17.
Since this strategy generates some tension in the image, it is intended, as said, to draw attention, so you should not use them in combination if you want the user to calmly be able to inspect a full interface, just when a certain element requires or deserves a certain degree of attention. The use of different saturations may further reinforce the contrast.
Split-complementary colour selection plays a similar role and thus can be used in similar occasions.

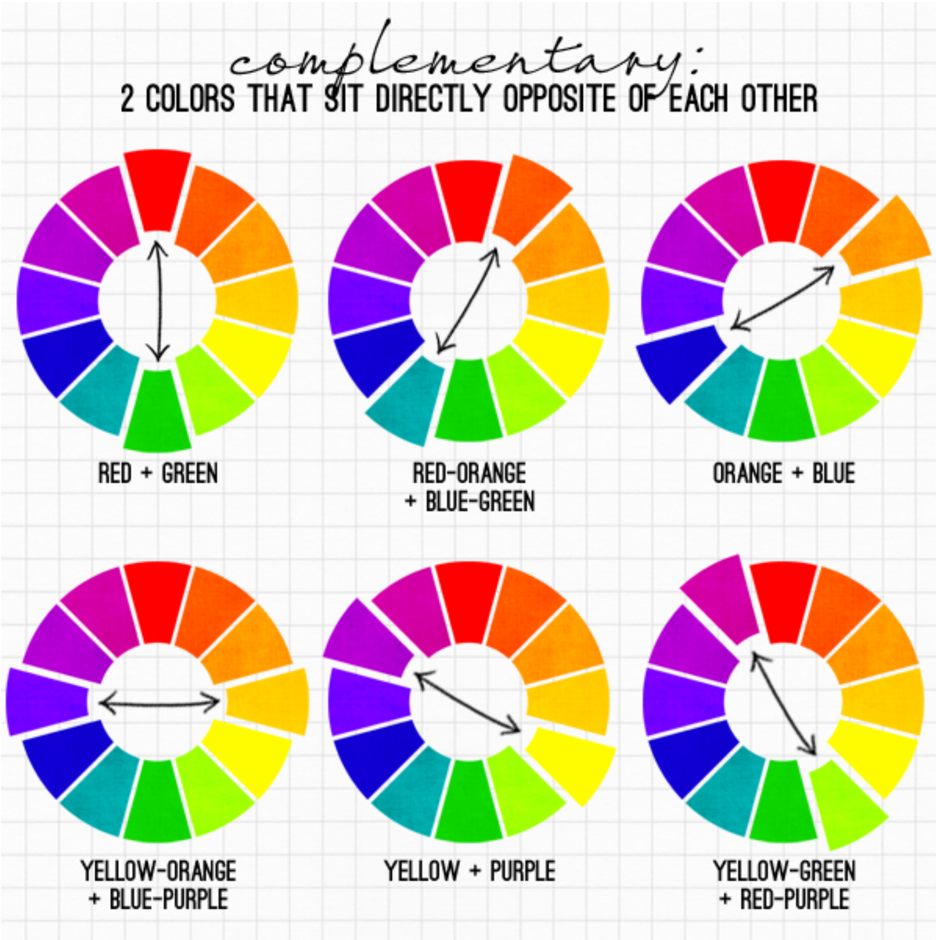

Figure 17: Complementary colour selection.

Triad colour selection achieves a sensation of harmony which is pleasant to our perceptiual system. Triad selections can be made by choosing three different colours regularly paced in the colour wheel. An example is in Figure 18.

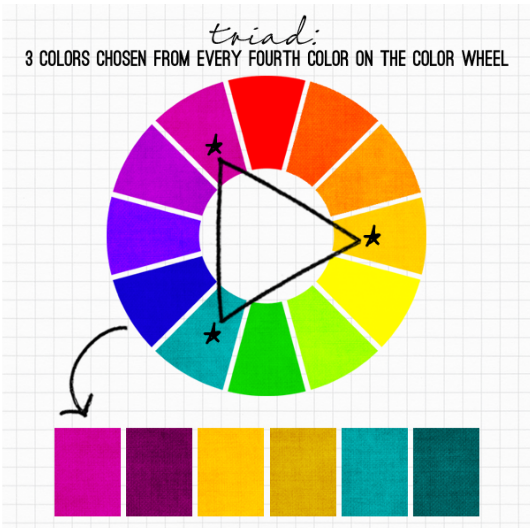

Figure 18: Harmonic selection of a triad colour set.

Finally, another harmonic colour selection is the tetrad relationship. In this case, we select four instead of three colours placed at regular distances in the colour wheel. We can see an example in Figure 19.

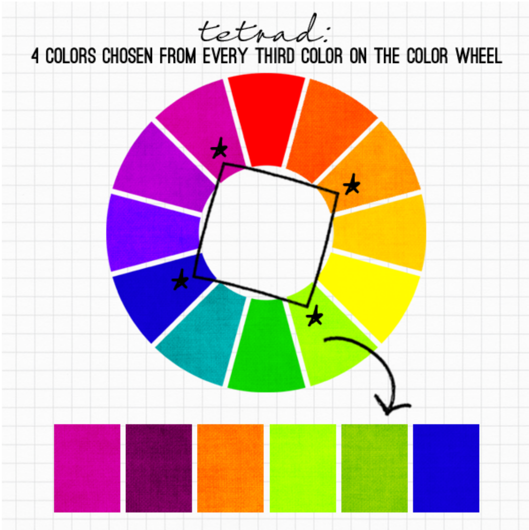

Figure 19: Selection of four harmonic colours using the quad strategy.

5. Further Reading

5.1 Compulsory readings

The following articles are compulsory. You must read them, since they are complementary to these course notes.

- D. Mishunov, Why Performance Matters: Part 1, The perception of time, http://www.smashingmagazine.com/2015/09/why-performance-matters-the-perception-of-time/
- Nielsen, J., First Rule of Usability? Don't Listen to Users, Jakob Nielsen's Alertbox, August 5, 2001: http://www.nngroup.com/articles/first-rule-of-usability-dont-listen-to-users/
- J. Girard, 9 responsive design mistakes you don't want to make, can be found in: http://thenextweb.com/dd/2015/10/28/9-responsive-design-mistakes-you-dont-want-to-make/
- Color Palettes Matter - Martin Krzywinski. It is a presentation, that can be in: http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf

5.2 Extra readings

We believe those readings can also be useful, although they are not compulsory:

- Nielsen, J., Mobile Content Is Twice as Difficult, Jakob Nielsen's Alertbox, February 28, 2011: http://www.nngroup.com/articles/mobile-content-is-twice-as-difficult/
- Miller, G.A., The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information, The Psychological Review, 1956, vol. 63, pp. 81-97,

http://www.psych.utoronto.ca/~peterson/psy430s2001/Miller%20GA%20Magical%20Seven%20Psych%20Review%201955.pdf

- Nielsen, J. Mental Models, Jakob Nielsen's Alertbox, October 18, 2010: http://www.nngroup.com/articles/mental-models/
- Nielsen, J., Scrolling and Attention, Jakob Nielsen's Alertbox, March 22, 2010: http://www.nngroup.com/articles/scrolling-and-attention/
- Nielsen, J., Horizontal Attention Leans Left, Jakob Nielsen's Alertbox, April 6, 2010: http://www.nngroup.com/articles/horizontal-attention-leans-left/
- Nielsen, J. Kinect Gestural UI: First Impressions, Jakob Nielsen's Alertbox, December 27, 2010: http://www.nngroup.com/articles/kinect-gestural-ui-first-impressions/
- Michael Zuschlag, Achieving and Balancing Consistency in User Interface Design, http://www.uxmatters.com/mt/archives/2010/07/achieving-and-balancing-consistency-in-user-interface-design.php
- Nielsen, J. Fresh vs Familiar. How aggressively redesign?, http://www.nngroup.com/articles/fresh-vs-familiar-aggressive-redesign/
- Chen, J. The impact of Aesthetics on Attitudes Towards Websites, http://www.usability.gov/articles/062009news.html