

Master's Thesis

Human centred Design for Graphical User Interfaces

Practical Guidelines

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Abstract

Good graphical user interface design is not a trivial task. This master thesis provides guidelines to solve this problem. It will give hints on how to structure each page, what to consider when using text and graphics, and how to ensure a good usability. Furthermore, icon and menu design are described in depth. These guidelines can be used for designing or evaluating an interface.

The principles described are generic and applicable to any existing graphical user interface standard. Finally, the guidelines are used to evaluate four different user interfaces. These analyses show that good designed interfaces fulfil most of the guidelines. Furthermore, it shows that flaws can be uncovered and corrected. The fourth analysis demonstrates that the guidelines can also be taken during the development phase of a user interface.

Kurzfassung

Gutes grafisches User Interface Design ist eine schwierige Angelegenheit. Diese Diplomarbeit soll, mit Hilfe von Richtlinien, helfen dieses Ziel zu erreichen. Es wird erklärt, wie man die Seiten strukturieren soll, wie man Text und Grafiken darstellen soll und wie man eine gute Benutzbarkeit erreicht. Ausserdem gibt es zwei Kapitel über Menü- und Icondesign.

Die Richtlinien können auch zur Bewertung von bestehenden Benutzerschnittstellen verwendet werden.

Grundsätzlich wurde der Inhalt allgemein gehalten und kann auf jeden bestehenden Benutzerschnittstellenstandard angewandt werden.

Im letzten Teil der Arbeit werden vier verschiedene Benutzerschnittstellen mit den Richtlinien analysiert. Diese Analysen sollen zeigen, dass gutes Design auch durch die Einhaltung der Guidelines charakterisiert ist. Ausserdem lassen sich anhand der Guidelines Designfehler finden und beheben. Die vierte Analyse zeigt, daß die Richtlinien auch während der Entwicklung eines Programmes eingesetzt werden können.

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1 Introduction

This master's thesis describes, with a set of guidelines, how to achieve a good graphical interface for interactions between computer and human. These instructions can be applied by anyone and are especially useful for designers, programmers, development managers, and in general everybody who has to do with the development of a graphical user interface. The principles described are generic and applicable to any existing graphical user interface standard. The principles can be applied on the following graphical user interfaces, for example:

- Desktop/laptop computers: Microsoft Windows, Unix/Linux with graphical desktop environments like KDE, Gnome, or Mac Os
- Personal digital assistants (PDA): Palm Os or Pocket PC
- Embedded systems: multimedia players (like mp3 or DVD players), network devices, navigation devices, board computers (for cars)

As you can see more and more computer interfaces step into our every day life. For example, every new car uses many programs that communicate with each other and with the user.

The user interface is a very important part of a program because it is the interface from the program to the user. The best program with a bad user interface will be considered as bad. This can be the difference between success and rejection on the market. Another fact, that shows the importance of the user interface, can be found in a study in [58] by Myers and Rosson in 1992. They found out that fortyeight percent of all code was devoted to the user interface. As more and more computers step into our everyday life, the importance of a good user interface still increases.

1.1 What is design of graphical user interfaces?

Design of graphical user interfaces can also be described as visual design. This can be seen as an integration of graphical components. Visual design disciplines are communication-oriented graphic design, industrial design and architecture. Other visual disciplines like painting, sculpture, figure, film making or photography have much in common but are less communication-oriented. In user interface design the interaction with the human is the primary concern. This is also the main difference to print media. Although new electronic media differs greatly from print media in resolution, interaction possibilities, and animation, the knowledge gained from the print industry is applicable.

As mentioned above visual design disciplines are communication-oriented, therefore the interaction between the human and the machine is the most important aspect. Interaction takes place with input and output devices. Typical input devices are a computer mouse, physical buttons, a touch screen, or a microphone. Typical output devices are screens, printers, or speakers. The user interface is responsible for connecting the input with the output devices.

What is good design? This question can be simply answered by one sentence: Good design should be functionally effective and aesthetically pleasing. Achieving this is not a trivial task because the designer has to consider the human cognition and the interaction between user and computer. This work tries to solve this problem by providing a set of guidelines that can be

used before, during and after the design of a user interface. The validity of the guidelines will be verified by analysing four user interfaces with them.

1.2 My motivation

I wanted to write about user interface design to get more information about how to design a good user interface. During my study I had one course about user interface design. I got interested in learning more about this subject and therefore I chose to write my master's thesis on this topic. It was a hard time finding good resources about it and the following work is mainly taken from the books [1], [2], [3], [5], [6], and [13]. After completing this work, I think my research for this thesis enabled me to create better user interfaces. Furthermore, I can now analyse existing interfaces with the guidelines presented in the following chapters and give hints how to improve weak points.

This thesis helped me recognizing and analysing user interface errors. Before writing this thesis I was only able to decide if I liked a user interface or not but I was not able to clearly state why something was hard to use or aesthetically displeasing. With the guidelines presented in this work I am now able to analyse a design methodically.

1.3 Structure of this thesis

First I want to introduce the human perception. This chapters are useful to understand some design guidelines, especially the colour guidelines. Afterwards I introduce the history of computer interfaces. This chapter introduces the evolution from hardware interfaces to graphical user interfaces.

The main part of my thesis consists out of the design guidelines. They are structured into how to structure a screen, how to use text and how to use graphics. Some more guidelines are also presented in the next two chapters: colour and usability. Icon design and menu design introduce these two fundamental elements of user interfaces.

In the last chapter I will apply the guidelines by analysing some websites. The first analysis, about the award winning website of IDEO, shows that good web design fulfils most of the guidelines. In the second analysis I will show that bad web design breaks most of the guidelines. Next, I will apply the guidelines to the highly praised interface of iTunes for Windows. In this section we can see that the guidelines can also be taken to rate program interfaces. The final analysis is about LinkVis, a program that was still developed during the evaluation. In this example the result of the analysis is taken to improve the final product.

The references, this work is based on, do only partially consider people with disabilities. I am aware of the fact that this is a very important part of user interface design. For more information about design for handicapped persons see [75], [76], and [77].

2 The human cognition

2.1 Perception

This chapter should introduce how humans perceive their environment. It is based mainly on [1] pages 44 – 47 and [2] pages 368 – 371. First, I want to introduce the process of seeing. This is parted into the physical background of light, where I want to introduce what light is and what properties it has. The second part deals with the human eye and our perception of light. Furthermore, I want to present the basic element of the human cognition.

2.1.1 Seeing

Physical background

Visible Light

Visible light consists of particles called photons. When a photon is emitted it moves instantly at the speed of light (about $3 * 10^8 \text{ m} * \text{s}^{-1}$). The flight path of a photon is called a ray. The colour of objects is related to the distribution of wavelengths of these photons.

The wavelengths of photons to which the human eye is sensitive are in the range of about 380 to 750 nanometre (nm).

In other words visible light for a human being is a electromagnetic radiation. This is only a very small part of the electromagnetic spectrum shown in Figure 1. The shortest perceptible wavelengths appear violet. As the wavelength is increased, the reddish component diminishes and at about 470 nm blue can be perceived. After blue follows green (unique green is at about 500 to 515 nm) and at the end of the visible spectrum comes yellow (approximately 575 nm) and then red.

Radiation with wavelengths shorter than 400 nm are called ultraviolet-, x-, gamma- or cosmic rays. Radiation with longer wavelengths than 700 nm is infra red light. Even longer wavelengths are used for radio-, television-, and power transmissions.

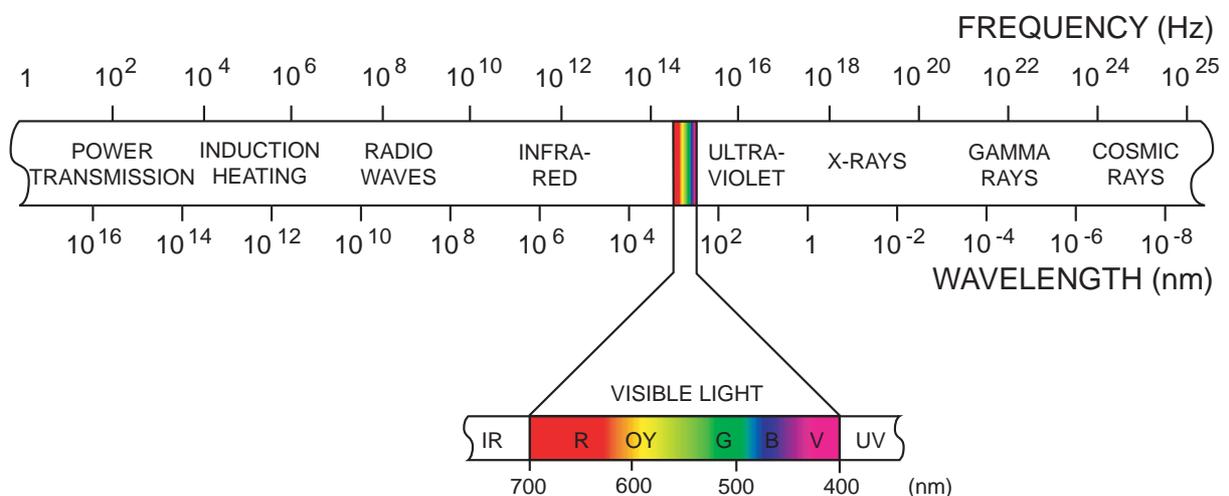


Figure 1: Spectrum of electromagnetic radiation

FM Radio waves for example have a wavelength of 3 m in comparison. See Figure 1 to get an understanding of the different wavelengths in the spectrum.

As you can see visible light for human beings is just electromagnetic radiation in a given part of the spectrum. There are many life forms that see more or less of the electromagnetic spectrum. The bees for example are able to see ultraviolet light, because they need this additional information to navigate with the sun even if it is cloudy.

A ray of light may contain many different waves with different frequencies and intensities. This distribution is called spectrum. In Figure 2 you can see the distribution of three different light sources. Daylight is distributed in the visible spectrum in form of a flat curve with the peak at approximately 460 nanometre. The curve is so flat that all colours are nearly evenly distributed with a peak intensity in blue. The distribution of a fluorescent tube lamp also looks like a curve with a peak at approximately 600 nanometre (orange). But the curve is much steeper and has some short wavelength elopers with full intensity. That is why we perceive this light as blueish white. The light distribution of an incandescent light bulb looks like a falling curve with maximum intensity at 700 nanometre (red) and the minimum intensity at 400 nanometre (violet). This is why light bulbs emit an orange looking light. In contrast to this, laser light consists out of light waves with only one specific wavelength.

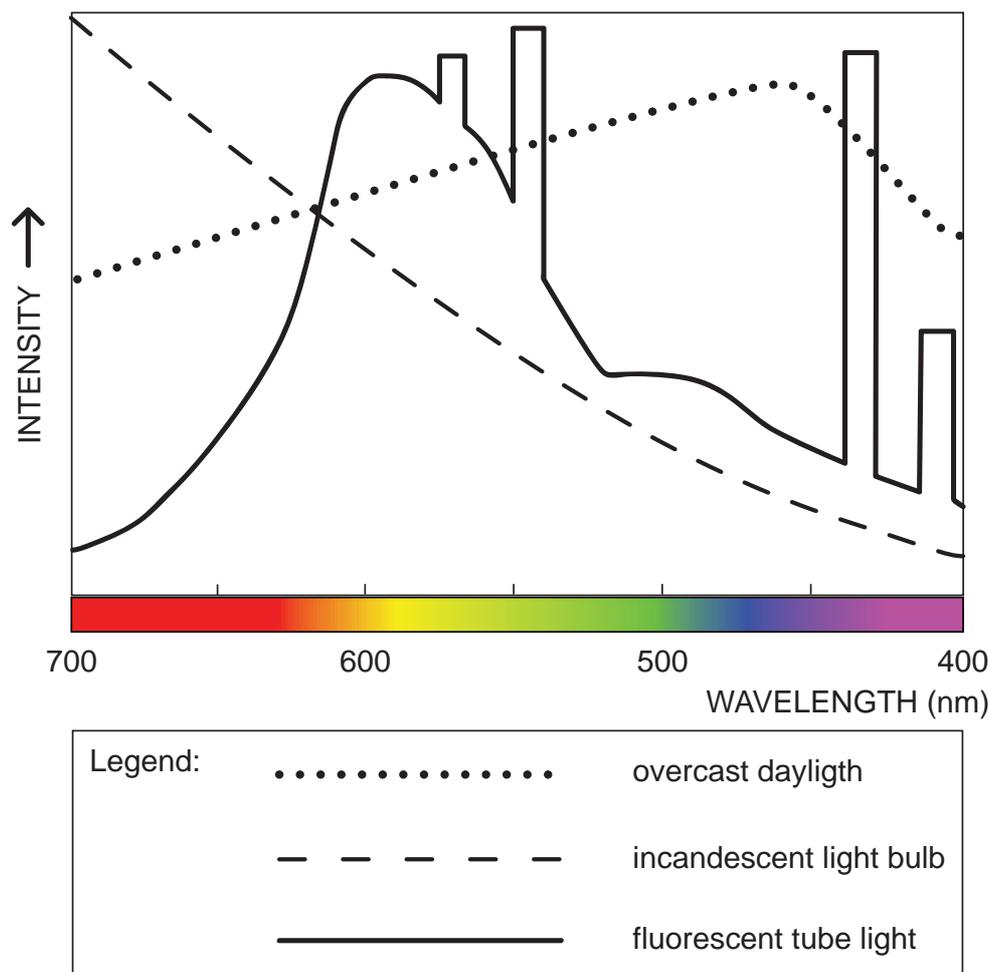


Figure 2: Spectrum of daylight, a light bulb and a tube lamp

So you can see that different light sources emit light with variable intensity depending on the wavelength. That is why objects may look differently under different light conditions. But why do we see coloured objects?

Why things have colours

Objects have colours because only parts of the white light find their way into the eye. If light hits an object it can be:

- absorbed
- reflected
- transmitted / refracted

For example an object could reflect green light while absorbing all other frequencies of visible light. In this case the object appears green to us.

Absorption

Atoms and molecules contain electrons. The electrons have a tendency to vibrate at specific frequencies. This is called natural frequency. When a light particle hits an electron with the same wavelength as the natural frequency of the electron, then the electrons of that atom will be set into vibrational motion (and absorb the energy of the light wave). During its vibrations, the electron interacts with its neighbouring atoms in such a manner as to convert its vibrational energy into thermal energy. This conversion of light into heat is called absorption. See also [13], chapter 2.1.1 *Absorption* on page 5, Page 137-138 and [14].

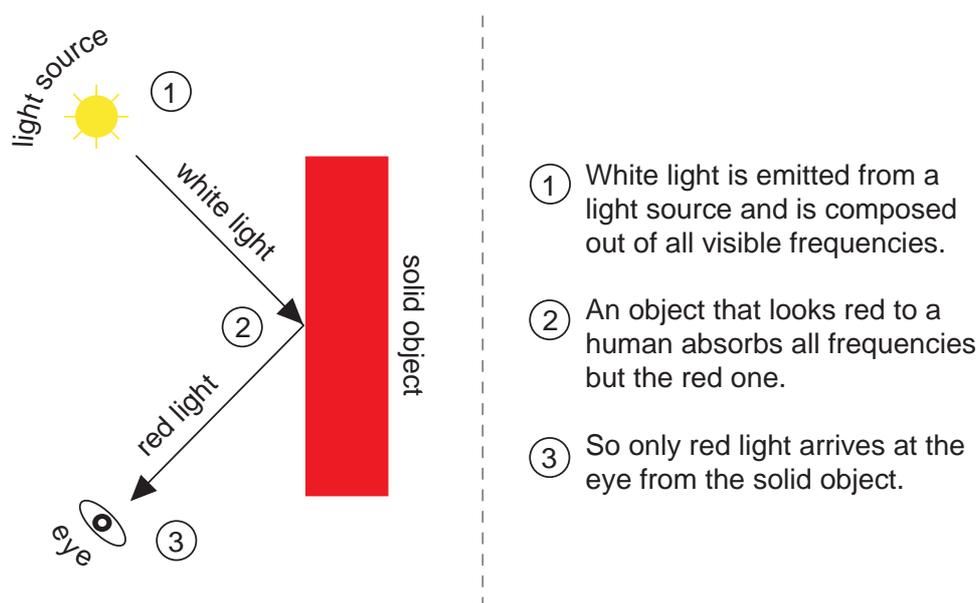


Figure 3: Absorption and reflection

Reflection

Reflection is the change of direction of a light wave when it hits an object. A mirror would be an example for a perfect reflection. There are two rules for reflection:

- 1) The reflected ray lies in the same plane as the incoming ray and the surface normal.
- 2) The incoming angle is the same as the outgoing angle.

Reflection of light waves occurs when the frequencies of the photons do not match the differences between the two possible energy states of the electrons. The hit electrons vibrate only for a short period of time and then reemit the energy as a reflected light wave.

For example in Figure 3 the red frequencies of the white light are reflected by the solid object.

Transmission / Refraction

If a material is transparent, then the light is not reflected but transmitted. In this case the frequencies of the photons also do not match the differences between the two possible energy states of the electrons (like with reflection). The hit electrons vibrate only for a short period of time and then pass the vibrations of the electrons on to the neighbouring atoms through the bulk of the material and are then reemitted on the opposite side of the object. This is called transmission of light.

Refraction is the change of direction of a light wave. The refraction occurs at the boundary and is caused by the change in speed of the light wave upon crossing the boundary. Because of the wave nature of light a part of the photon gets into the glass first and must slow down. The outside part still continues to travel at the previous speed. So the photon must change its direction to maintain its integrity. Photons that vibrate fastest, slow down the most. That is why the *index of refraction* of an optical medium varies as a function of the wavelength. This effect is also called *chromatic aberration* and occurs at cameras (where it is prevented by multiple lens constructions) and in the eye.

So only the reflected and transmitted frequencies of light will make it to our eyes and contribute to the colour appearance of that object.

The wave – particle duality

Light could be described both as waves or as particles. In fact every radiation can alternatively be described as a wave or particles .

Some properties can only be described with their wave properties. Examples are diffraction, interference, the doppler effect or polarization. In all these examples light behaves the same way, waves do.

Diffraction

Diffraction is the change of direction of a light wave as it passes through an opening or around an obstacle. In Figure 4 the diffraction around an obstacle leads to overlapping lightwaves also called interference.

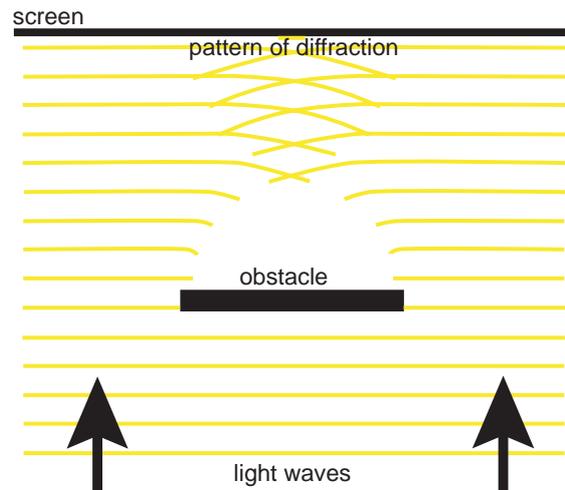


Figure 4: Diffraction, Interference: The diffraction around an obstacle and its interference upon a screen produces a pattern that can only be described by the wave nature of light.

Interference

Interference is the superimposition of waves. This phenomenon occurs when two waves meet while travelling along the same medium. There are two special types of interferences:

- constructive and
- destructive interference

Constructive interference occurs when the two interfering waves have a displacement in the same direction. The effect is that they form a larger and stronger wave.

Destructive interference occurs when the two interfering waves have a displacement in the opposite direction. Here the waves cancel each other out to make a weaker wave.

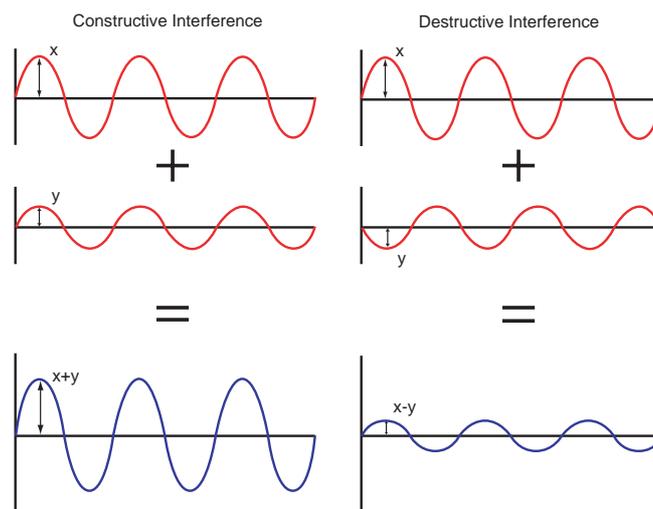


Figure 5: Constructive and destructive Interference

Doppler Effect

The doppler effect (also called doppler shift) happens when light is emitted by a moving object. The wavelength of the light is shifted toward shorter wavelengths when the object is moving towards the observer and shifted towards longer wavelengths when the object is moving away from the observer. This effect is used in the astronomy to determine the movement of stars (comparison of the known spectrum of the star with the received one).

Polarization

Polarization describes the alignment of the electrical field of a light wave. A wave is called polarized if it moves only in one plane. Daylight is unpolarized and changes its direction persistently.

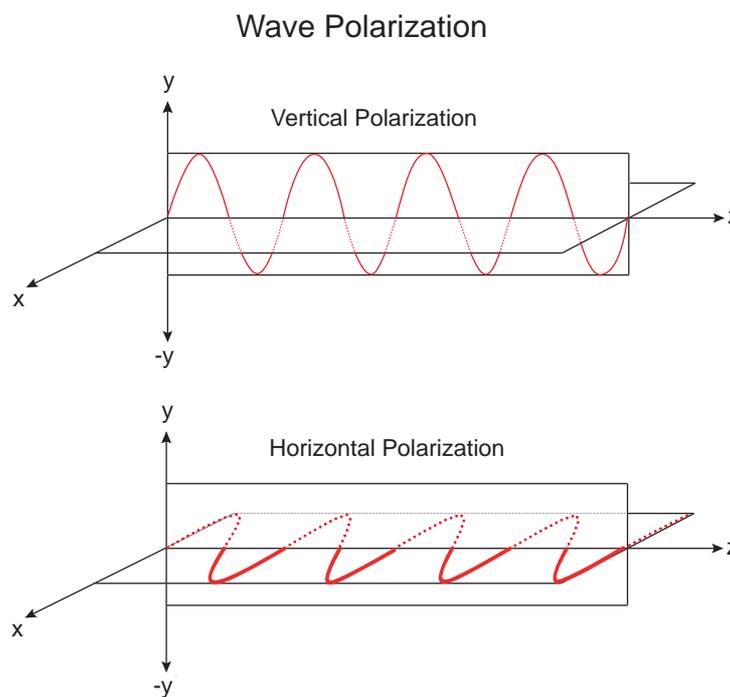


Figure 6: Wave Polarization

Polarization is used in the photography to increase or decrease reflections (with polarization filters on the cameras). Another example would be a TFT (Thin Film Transistor) monitor. Here two polarization filters are used. One to polarize the light and another one that is rotated either if the light is to be passed or not.

Shadows

The colours of an object are also influenced by shadows. An area, that can not be reached by light waves, is called shadow. There are two types of shadows:

- **Hard Shadows:** A point light source produces hard shadows. The edges of the shadow are clearly defined and there is a hard break between shadow and non shadow area. (Actually there is never a hard break because of diffraction, but this effect is very small)
- **Soft Shadows:** An area light source produces soft shadows. The edges of the shadow are soft. That means that there is a gradient from “no light” to “full light” at the edge. The size of this transition is defined by the size of the light source and the shadowing object.

The Anatomy of the Eye

The human eye is one of the most complex structures in the body. A healthy human gets more information from his or her eyes than from all other senses together (see [13] page 233).

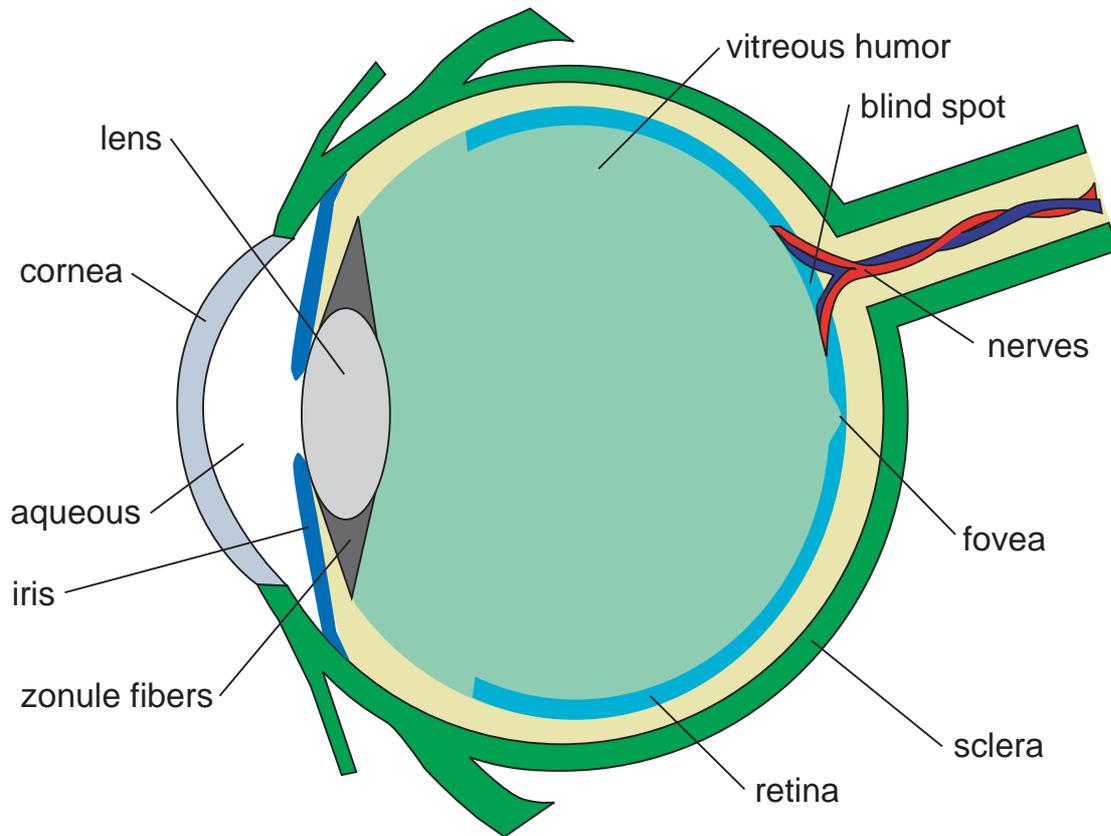


Figure 7: Structure of the human eye.

Each eye is located in the bony eye socket. The movement of the eye is controlled by three pairs of muscles, which are located outside of the eye. From the outside the eyes are protected by the eyelashes and the lids. The lids also have the function of distributing the tears over the eye. Tears are necessary to help maintain the normal exchange of oxygen and to control the water balance within the cornea. In Figure 7 you can see the structure of the human eye. On the outer side of the eye is the sclera.

Sclera

The white, opaque, fibrous scleroses which constitutes the tough outer tunic of the eyeball covers the entire eyeball. It has very few pain receptors and has no blood supply at all.

Cornea

The cornea is the transparent, vaulted part of the scleroses. It is richly endowed with pain receptors to help protect the eye (in conjunction with the eye lids).

Iris

The annular iris controls the amount of light that enters the eye without altering the field of view. In other words it regulates the illumination of the retina by altering its size. The iris is small in a very bright environment and big in a dark environment. It also determines the “colour of the eye”.

Lens

The lens is a complex multi layered, transparent, biconvex structure. It is situated behind the iris and in front of the vitreous humor. It can change its shape during the act of accommodation. This process allows objects at various distances from the eye to be clearly imaged. When a distant object is to be focused the zonule fibers exert their maximum pull. So the lens is relaxed. When a near object is to be focused the zonule fibers release some of the tensions to bulge the lens more. With ageing in humans the lens sometimes loses its capacity to bulge. This condition is known as presbyopia.

Vitreous and Aqueous Humor

The human eye would collapse if it were not filled completely. About two-thirds of the eyeball is filled with the vitreous humor. This is a clear gel mostly out of water. The anterior chamber of the eye, between cornea and the lens is filled with the aqueous humor. This fluid has the particularity that it is exceptional clear.

Retina

The retina can be thought as part of the brain because it does more than coding optical stimulus to neural impulses like simple preprocessing of the visual information. It is a light sensitive tissue at which the image is projected.

Structure of the Retina

The retina consists of the following layers (from the outside of the eye to the inside):

1. Photoreceptors: There are two types of photoreceptors in the retina. The cones, which respond to red, blue and green light in the range of intensities from twilight to sunlight. And the rods that are responsible for low-intensity, colourless vision from twilight to starlight.
2. Horizontal cells: These cells provide light contrast detection between neighbouring photoreceptors.
3. Bipolar cells: The bipolar cells connect the horizontal cells with the ganglion cells and release the excitatory neurotransmitter glutamate upon excitation.
4. Amacrine cells: There are over 20 types of amacrine cells that process aspects of light information such as motion, contrast and starlight.
5. Ganglion cells: Ganglion cells encode light information within action potentials to be processed and reconstructed by the visual cortex in the brain.
6. Optic nerve fibers: The nerve fibers route the action potentials to the visual cortex.

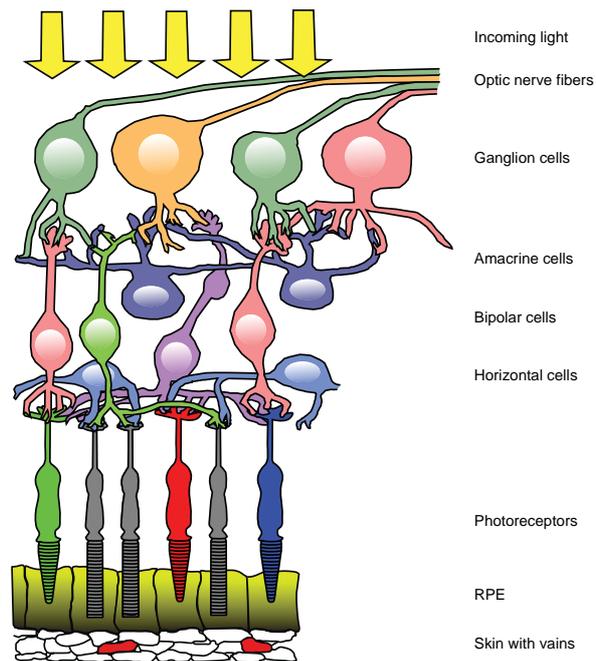


Figure 8: Structure of the human retina.

Photoreceptors

Rods

There are about 120 million rods in one human eye. They are very sensitive to light and enable us to see in nearly dark environments. Because there is only one type of rod we are not able to distinguish colour with them. That is why we have a nearly black and white vision in the dark. Every rod includes about 100 million molecules of rhodopsin. Only one photon is enough to resolve one molecule of rhodopsin and enable an electric reaction of the rod. The rods are most sensitive at approximately 500 nanometre (blue light) and respond very little to red light.

Cones

There are much less cones than rods in the retina (about 6 million per eye) and they are much less sensitive to light (about 100 000 times). There are three different types of cones in the human eye:

Name	Alternative Name	Sensitive for wavelength
L(ong)-Cones	Red cones	Long wavelength approx. 575 nanometre (yellow light)
M(edium)-Cones	Green cones	Medium wavelength approx. 535 nanometre (green light)
S(hort)-Cones	Blue cones	Short wavelength approx. 445 nanometre (violet light)

Table 1: The three different cones in the human retina.

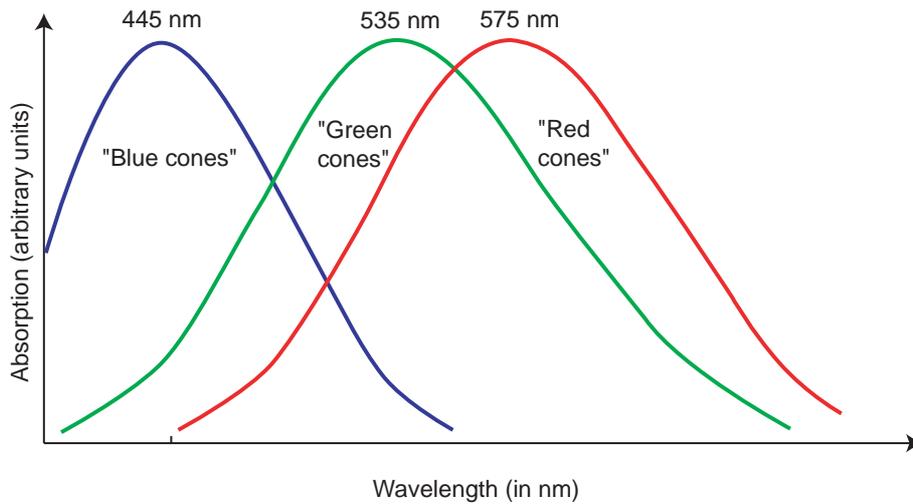


Figure 9: Absorption of the cones

Distribution of the Photoreceptors

The cones and rods are not placed equally on the retina. Cones are placed mostly in the central region of the eye (around and in the fovea centralis) where else rods are primary in the peripheral region. There are about twice as much red cones than green ones. Blue cones are only in the peripheral region and have a very small density (about 9 percent). Interestingly we do not realize this lack of blue cones. For a human observer blue can be perceived as bright as green or red. That is due to the preprocessing of visual information in the human eye. What we do perceive is a reduced sharpness of blue images. This reduced resolution is necessary to reduce the chromatic aberration of the eye (light of different wavelength can not be focused at the same time on the retina because of the different refraction of different wavelengths in the eye, see 2.1.1 Transmission / Refraction on page 6). The irregular placement of the cones also prevents aliasing artefacts due to the bad resolution in the peripheral region. As you can see in Figure 10 the number of cones is very high in the central region of the eye. This region is called fovea centralis.

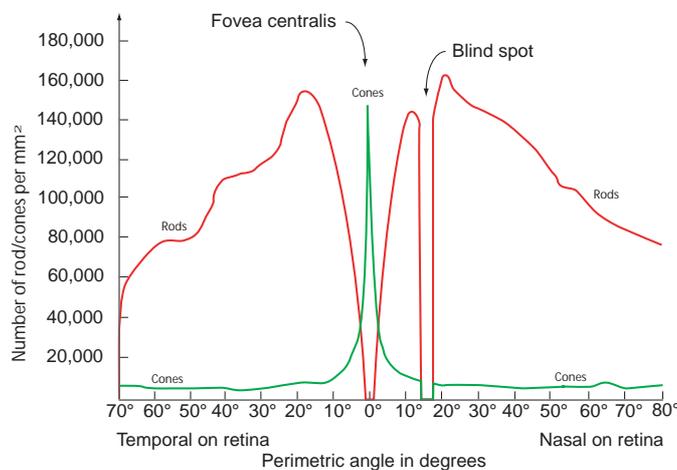


Figure 10: Distribution of the cones and rods on the retina

Fovea centralis

This is a small, pit like area in the optic centre of the eye's retina with about 1.5 mm in diameter. This means every point we fixate is projected on the fovea centralis. As mentioned above the highest density of cones is in the fovea centralis. Interestingly there are only red and green cones and no rods or blue cones in this most acute area of vision. Another remarkable area on the retina is the blind spot at approximately $10^\circ - 20^\circ$ in direction of the nose.

Blind spot

The blind spot is the point where the optic nerves of the retina lead back into the brain. At this place there are no light-sensitive rods or cones.

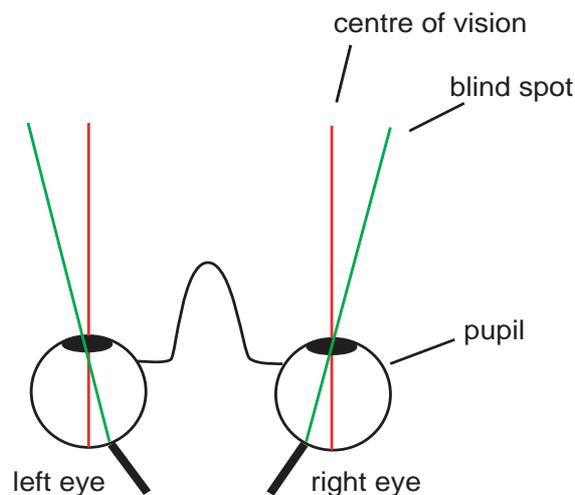


Figure 11: Position of the blind spot in the human eye.

Blind spot test:

Look
Here!



1. Sit about 50 cm away from the picture above
2. Completely cover your left eye.
3. With your right eye, stare directly at the „Look Here“ text
4. Now move your head towards the picture.
5. At about 40 cm the black square should disappear (still focusing at the „Look Here“ text!)
6. It should reappear at about 30 cm distance.

Adaption

Adaption is necessary when a change of lightning occurs. The photo pigment of the cones and the rods have a certain regeneration speed for their pigments. This is matched to the particular illumination. As soon as the rate of use of photo pigments and the rate of reproduction is equal the retina is adapted to the illumination. Because this change of rate takes time the human eye has a particular adaption-time when a change of illumination occurs.

Preprocessing of visual information

The rods and cones are mutually interconnected to perform preprocessing tasks like

- edge enhancement
- colour separation
- data reduction
- movement detection

The rods and cones are wired separately.

Edge enhancement

The receptors are bundled in groups to provide edge detection mechanisms. The adjacent ganglion cells influence the signal by adding negative values. These negative values depend on the incoming light intensities. Ganglion cells that are stimulated highly, inhibit their adjacent ganglion cells very much. On the other side a small stimuli leads only to a small inhibition. This way contrasts are boosted and edges can be perceived easier. This effect is called lateral inhibition and makes it easier for the following systems to separate objects (recognise edges). In Figure 12 is a simplified example that shows the principle in only two dimensions (only two adjacent ganglion cells are influenced by one particular cell).

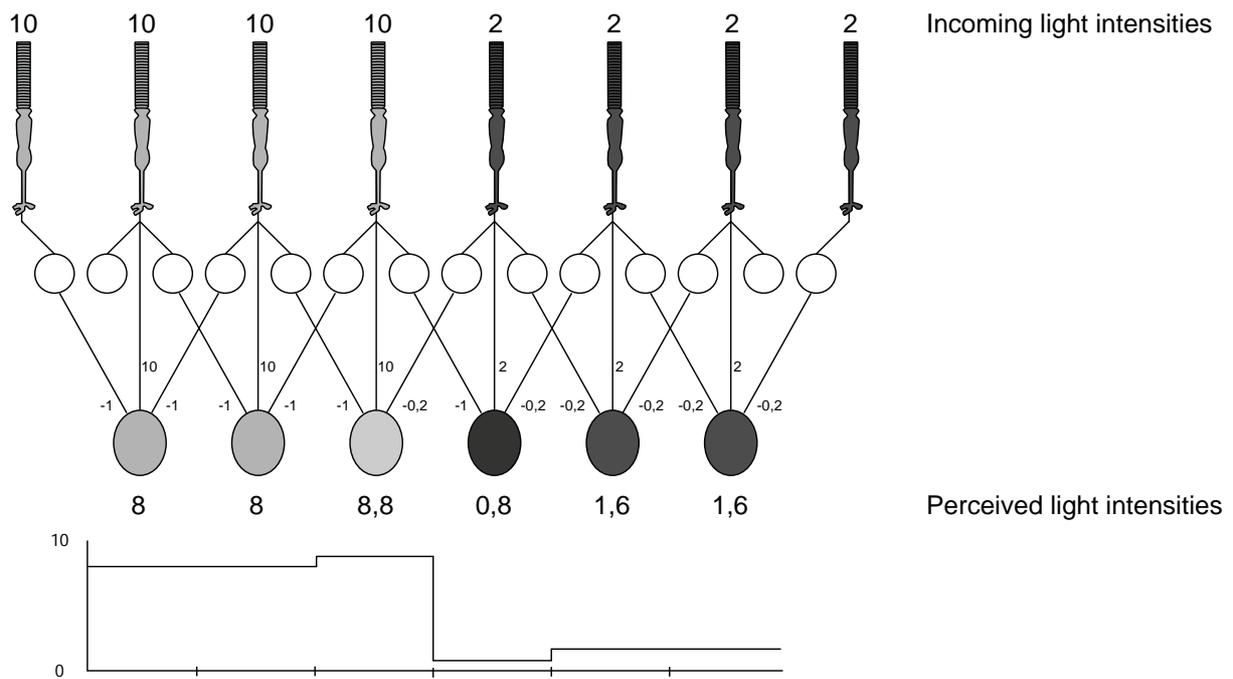
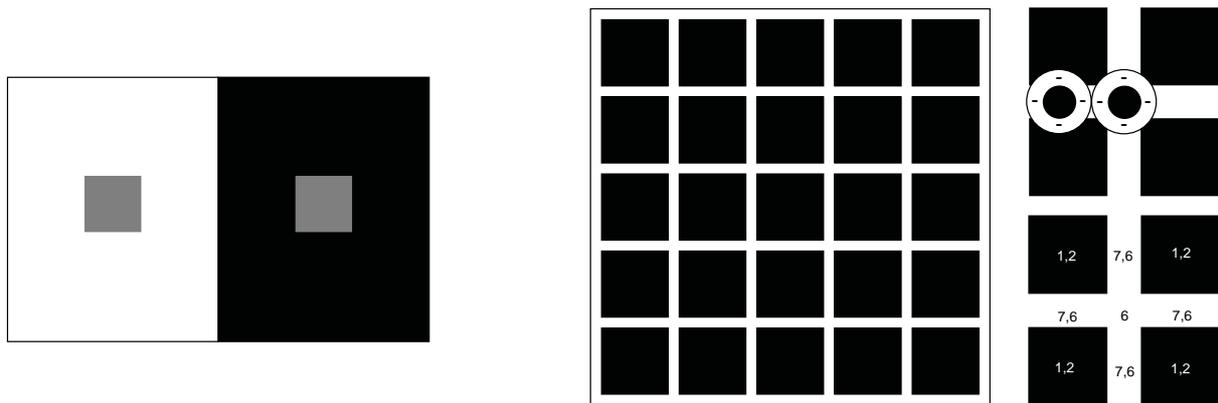


Figure 12: Simplified principle of lateral inhibition.

A side effect of the edge enhancement process is that the intensity of colours is influenced by the surrounding. The two grey patches on the left image in Figure 13 have equal intensity values but are perceived differently for example. On the right side of Figure 13 the Herman Grid is displayed. Grey dots appear in the intersections of a grid when the fields have a high contrast in comparison to the grid lines. This is because in the intersections the lateral inhibition is so high that grey dots appear. The effect does not appear in our central vision, because this area in the eye has a very good resolution.



Herman Grid

Figure 13: The left image shows an effect of the edge enhancement mechanism. Both grey squares have equal intensity values but the right is perceived brighter than the left. On the right image the Herman Grid is shown. Grey dots appear at the white intersections because of the influence of adjacent ganglion cells. The effect only appears in our peripheral vision, because the fovea centralis has a very good resolution that prevents this effect.

Colour separation

The red, green and blue values of the photoreceptors are recoded to a luminance channel, a red-green channel and a blue-yellow channel. The luminance channel consists out of the signals of the L-cones and M-cones (sensitive to red and green light). The red-green channel is composed out of the signals from the L-cones and M-cones and the yellow-blue channel is composed out of the L-cones and S-cones (sensitive to red and blue light). In Figure 14 shows the conversion from the signals of the cones into the three channels. The luminance channel is the sum of the red and green information. The red-green channel is composed out of the green minus the red information and the yellow-blue channel is composed out of the blue information minus the luminance channel. This conversion is done because of high correlation of the L- and M-cones (red and green). For more information see [13] page 252.

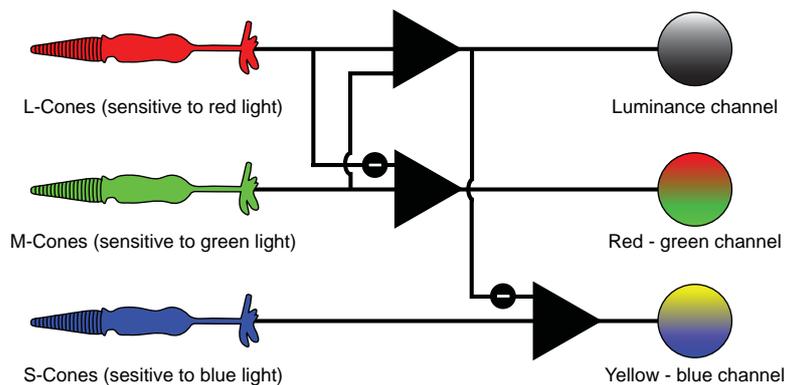


Figure 14: Colour separation in the human retina.

Data reduction

A set of photoreceptors is connected with one ganglion cells (especially in the peripheral region). This way an effective data reduction is done. For example there are 150 million cones but only 1 million ganglion cells that process the signal.

Movement detection

The ganglion cells also have a built in movement detection. They even can detect the direction of the movement.

The process of vision

Light waves from an object or a light source enter the eye through the clear cornea and then through the circular aperture in the iris. The light waves are converged by the lens to a nodal point located immediately behind the lens. From now on the image is inverted. The light travels through the gelatinous vitreous humor and is then ideally clear focused on the retina. In the retina the light particles are transformed into electrical signals by the rods and cones (red, green and blue values at daylight and / or hue information at night). Still in the retina the signals are preprocessed by the retina (edge enhancement, colour separation, data reduction and movement detection) and then sent along the optic nerve to the visual centre in the brain (located at the back of the brain). There the electrical signals are interpreted as visual images.

As mentioned in chapter 2.1.1 *Transmission / Refraction* on page 6 chromatic aberration also occurs in the eye. However, the following factors seem to be involved that this effect can not be perceived:

- Yellow pigments on the retina absorb blue light and thereby reducing the effectiveness of blue light.
- The blue-sensitive cones enter importantly into the perception of hue, but very little into the perception of contour.
- The directional sensitivity of the cone photoreceptors reduces the effectiveness of rays entering the margins of the pupil. These rays produce the greatest amount of chromatic aberration.
- The neural machinery is able to repress part of the message that carries no real information. For example when you mount prisms before the eye, the chromatic fringes produced by the prisms are at first very evident. The longer the prisms are worn the less evident the fringes become and may even disappear.

2.2 Cognition

Cognition involves the cognitive processes such as thinking, remembering, learning, decision making, problem solving, planning, reasoning, seeing, reading, writing and talking. To save the acquired information the human memory is used. It consists of the sensory memories, the short-term memory (STM) and the long-term memory (LTM) (see [64]).

The sensory memories act as a buffer for all stimuli received through the human senses.

The short-term memory keeps information only a short time. It is used as a working memory. It has only a limited capacity and saves whole chunks. A chunk would be for example the arrival time of a train at 16:35. It can hold approximately seven chunks (plus or minus 2) for a period of about 20 seconds (see [1]).

The long-term memory stores information for a longer period depending on the amount of invocations. The three main activities are storage, deletion and retrieval. Deletion is mainly caused by decay. It is not fully clear if we actually ever forget anything or it just gets harder to access the information. From the first saving the 100 percent of the recallable information falls down to about 10 percent after one month, if the information was not accessed in the meantime. A phenomenon of the human memory is, that it is easier to recognize something

than fully recall. The power of the human long-term memory is its remarkable flexibility. The same information can be combined in many different ways.

Generally we can think of the long-term memory as a network of linked concepts. For example if we think of a particular concept (like data visualization) we can easily bring other related concepts into our mind (like computer graphics, data analysis, visualization algorithms,...). Figure 15 shows the connections between the three memories.

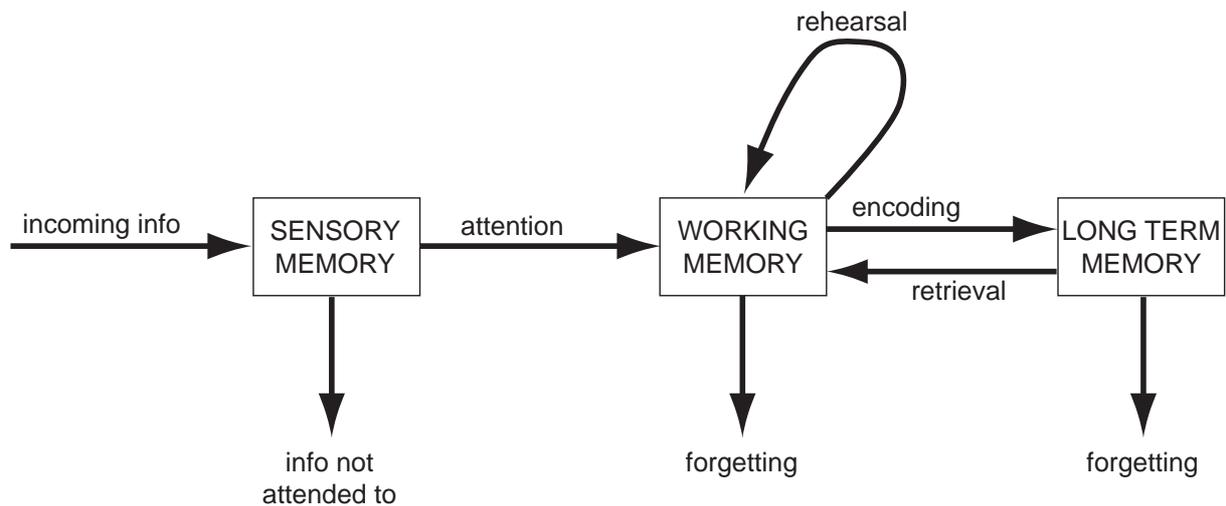


Figure 15: The three human human memories (sensory, short-term and long-term memory).

3 History of interface design

In the history of computing there have been considerable changes. With the vast changing hardware also the user group changed. Along with the change of the user was also the change of the user interface. Table 2 shows the generations of computers and user interfaces so far.

Generation	Hardware technology	Operating mode	Programming languages	Terminal technology	User types	Advertising image	User interface paradigm
-1945 Pre-history	Mechanical, electro-mechanical (Babbage, Zuse Z3)	Calculations	Plugboard, jumpers, cable	Lights	Inventors	-	-
1945-1955 Pioneer	Vacuum tubes, huge machines, short mean time between failures	One User at a time at machine	Machine language	Punch Cards, typewriter, TTY	Experts, pioneers	Calculator	Programming, batch processing
1955-1965 Historical	Transistors	Batch System	Assembler	Line-oriented terminals	Technocrats, professional computerists	Information processor	Command languages
1965-1980 Traditional	Integrated circuits (IC)	Time-sharing	High-level languages	Full-screen terminals, alpha-numeric characters only	Normal Users with special knowledges	Enhance Productivity	Full-screen hierarchical menus and form fill-in
1980-Now	VLSI, Wafer-scaled integrations	Network, single user and embedded systems	Problem oriented languages	Graphical Displays, Desktops, Laptops, embedded systems, cellulars, ...	Everybody	Computer for everybody (without knowledge)	WIMP (Windows, Icons, Menus, Pointing Device)

Table 2: Generations of User Interfaces

3.1 Hardware Interface

The first generation of user interfaces was located at the hardware itself. The users were the inventors or engineers who worked directly with the hardware. Only easy problems could be solved (for example computing a table of $\sin(x)$ values). To compute these little programs, machine code had to be used. The program memory was filled with a plugboard. A manually set jumper would set one bit in the program memory. So the user interface was the plugboard and a reset mechanism (started the program processing).

3.2 Batch System

The second generation of user interfaces could already be used by other people than the inventor or engineer. The plugboards were replaced by punch cards. Small loader programs loaded one punch card after another from a pile and wrote the program on the card into the program memory. After the program had executed, the loader program took the next card from the pile.

This mechanism had the drawback that it was not interactive. The users had to submit the batch jobs (on the punch cards) and got the results after all cards were processed. So both the computer and the users were not working at full capacity. On the other hand, the batch jobs had the advantage of being able to run without the user's supervision. That is why modern operating systems are offering some form of batch functionality.

In this stage the user interface was improved by freeing the user, namely the programmer, from having to know about the hardware. This was done with the invention of higher level hardware languages.

3.3 Line-oriented interfaces

Around the 1960s time-sharing systems were invented. They allowed the users to simultaneously use one big mainframe. This was possible because of the invention of the multiprogramming. With this technique, several programs could be loaded into different partitions of the main memory. Every user had his or her own terminal with monitor and keyboard (in- and output) that had the function of the punch card and the printer of the batch system.

This line-oriented interface was basically a one-dimensional interface. The user could only interact with the system at one input line. After he or she sent the command to the computer, he or she was not able to modify it further. In a similar case, the output of the computer could not be modified. This interaction technique was mostly used for question-answer dialogues.

In this stage the user interface was also changed in allowing non programmers to use the system. The question-answer dialogues were simple enough for normal users to operate with it.

As the hardware evolved to single user systems the line-oriented interfaces still were used. Examples would be DOS (Disc Operating System) or UNIX (from UNICS, UNiplexed Information and Computing Service).

3.4 Full-screen interfaces

Soon the line-oriented interfaces were modified so that the entire screen could be used for modifications. A typical application of the full screen are the form filling dialogues. Now the usability of the interface was much better because the user could see what to come, the screen could be structured, and the information on the screen was modifiable.

The full-screen interfaces also lead to the invention of the menus.

Menus are functions that are continuously listed on-screen. First these functions could be called into action with key combinations. This was, for example, commonly used in defence computing by the 1960s. Later the menus could be accessed with a pointing device. These technique is still an integral part of the user-friendly interface.

The full-screen interfaces often depended heavily on hierarchically nested menus. So the questions arose how to best arrange the menu hierarchies. See [3] page 55 for more details about menu hierarchies.

3.5 Graphical user interfaces

The grandfather of the graphical user interface was the Sketchpad. Ivan E. Sutherland built it as a Ph.D. in 1962. The Sketchpad was a program that enabled the user to draw points, line segments, and circular arcs on a cathode ray tube with a light pen. In addition to this, the user could assign constraints to and relationships among the drawn objects. Another new concept

that was introduced with the Sketchpad was the use of windows. The program could split its screen horizontally into two independent sections. It is indubitable that Sketchpad's design and algorithms had a primary influence on an entire generation of research into user interfaces.

There were several other research systems but the graphical user interface did not see widespread commercial use until the 1980s. This was the time of the Xerox Corp Star in 1981 and the Apple Computer Inc. Lisa (1983) and Macintosh (1984). These computers also introduced a further advance: a menu bar, essentially a row of words indicating available menus that could be popped up for each window. Especially the Macintosh brought the WIMP (windows, icons, menus, and a pointing device) to the people.

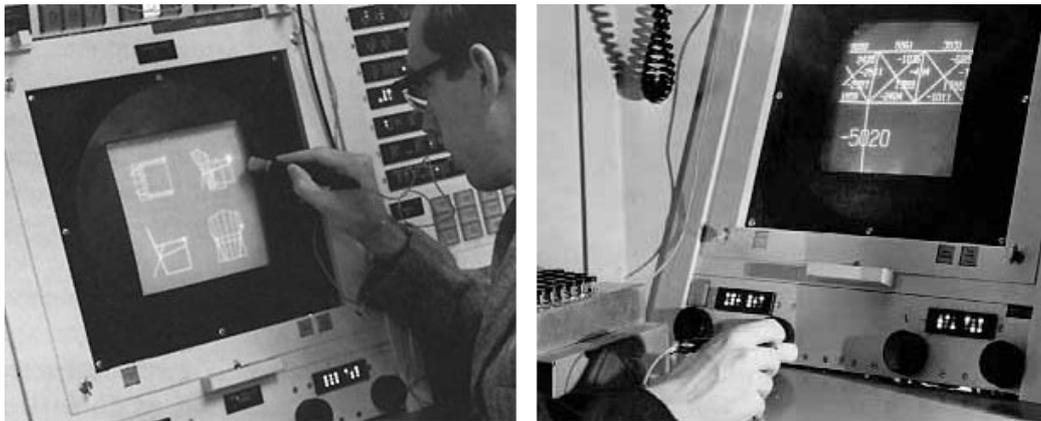
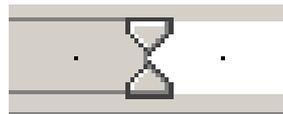


Figure 16: Two images of the Ivan E. Sutherland's sketchpad (taken from [80]).

The interaction style used in the most graphical user interfaces is direct manipulation of the dialogue objects. An example of direct manipulation would be the changing of the left margin in a modern word processor. For example with OpenOffice.org 1.1.0 you can drag the icon showing two triangles (shown in Figure 17) and thereby change the left margin directly.



*Figure 17:
OpenOffice.org 1.1.0
drag symbol.*

For more information about the history of computing see [12].

4 Design guidelines

The following generic design guidelines are equally applicable to any of the existing graphical user interface standards (like Microsoft Windows) and can also be taken for print design. Some of these guidelines even originate from print design because this is a much older research area.

The guidelines are intended to be used either before writing a program or to evaluate an existing user interface. They are written for the users' best interests but sometimes it may be necessary to break some of them because of existing restraints. Generally, you should always focus on the interests of the target users because they are the ones who really (have to) use the program. This means, if you get different results from user feedback, then you should of course do what works best in your situation.

I present the following information in guidelines, because I think this is the best way to ensure an easy appliance.

In the general section of this chapter, guidelines for the visual structure of the application are given. The next part is about text and how to format it, because most applications usually rely heavily on the written word to present information. Finally, I will present some useful rules for using graphics.

The text guidelines are mainly taken from [5] and the other parts are mainly based on [2] and [6].

4.1 General

The following guidelines are mainly about how to structure your content on the presenting area.

4.1.1 Use Gestalt laws for relationships

Max Westheimer, Kurt Koffka, and Wolfgang Kohler produced a set of Gestalt laws of pattern perception (original text in [59]). The word Gestalt means pattern in German. These seven rules describe the way we see patterns in visual displays (despite their age the laws are still valid!):

Proximity

Things that are close together are perceived as a group. This is the most powerful principle and the most useful for designers. It can be used for placing descriptions or grouping objects on the screen.

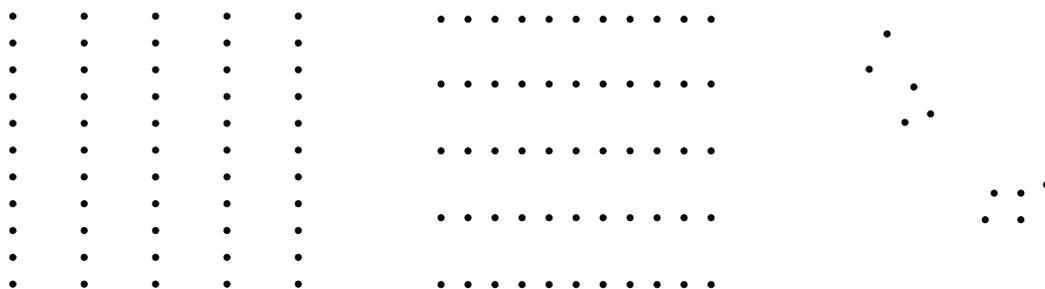


Figure 18: Proximity Gestalt law: The first array of dots is perceived as a set of rows. The middle array is perceived as a set of columns. The dots on the right side are perceived as two groups of dots instead of disjoint points.

An extension to the proximity law was proposed in [6] by Slocum. He proposed that we perceptually group regions of similar element density.

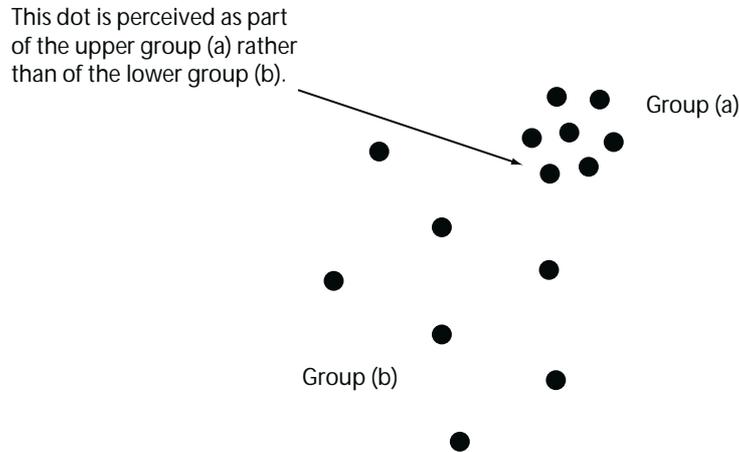


Figure 19: Example for the proximity law by Slocum.

Similarity

The human brain tends to perceive similar elements as grouped. This principle can be used for designing a table for example.

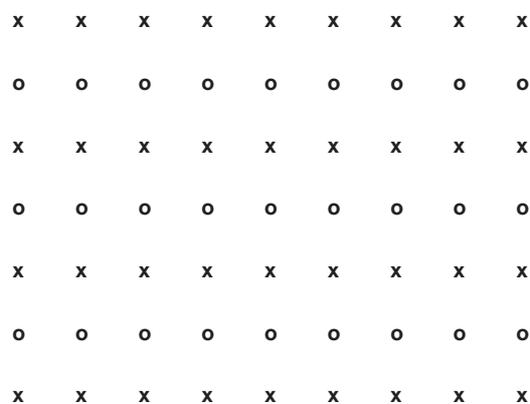


Figure 20: Because of the Gestalt law similarity, the elements above are perceived as rows.

Continuity

This principle states that smooth and continuous visual elements are more likely to be perceived as an entity than ones that contain abrupt changes in direction.

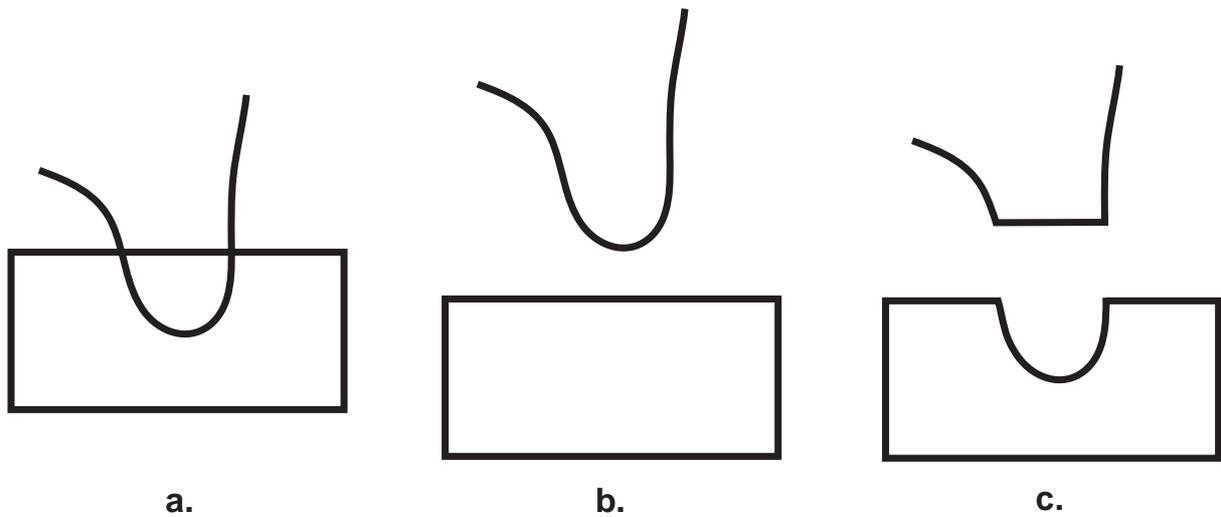


Figure 21: The figure on the left (a.) is perceived as a curved line overlapping a rectangle as seen in the middle figure (b.), rather than as the two components on the right side (c.).

This principle is especially important for drawing diagrams with nodes and links between them. Drawing the lines with smooth continuous lines makes them easier to follow than lines with abrupt changes.

Continuity assumes connectedness which is a fundamental organizing principle according to Palmer and Rock [61]. The demonstration in Figure 14 shows that connectedness is stronger than proximity and similarity.

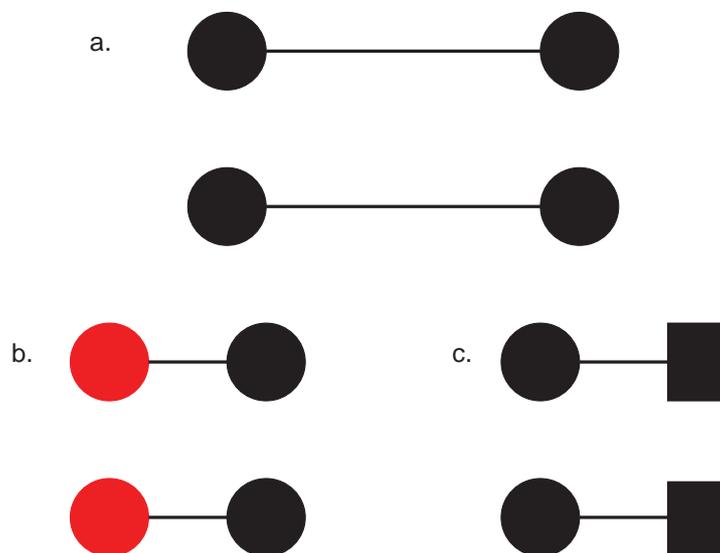


Figure 22: Connectedness is a more powerful grouping principle than proximity in seen in (a.), colour seen in (b.) and shape seen in (c.).

Symmetry

The human brain tries to group symmetrical figures. The left pattern in Figure 23 consists out of two parallel contours. The two patterns on the right deliver a much stronger sense of a holistic figure because they are composed in respect to the Gestalt law symmetry.

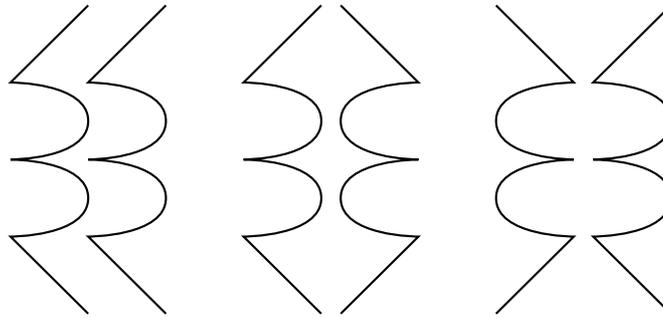


Figure 23: The pattern on the left consists of two identical parallel contours. The two patterns on the right make use out of the Gestalt law symmetry.

A possible application of symmetry is the analysis of two graphical datasets. It is easier to perceive similarities if the two series are arranged symmetrically. For example in Figure 24 the upper visualization can be perceived as nearly symmetrical where else the lower visualization can be clearly seen as unsymmetrical.

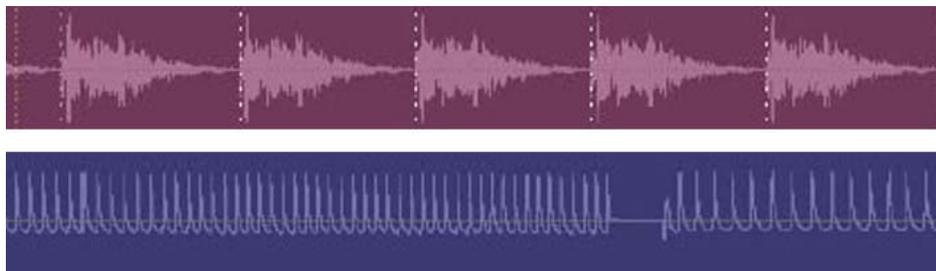


Figure 24: Screenshot of Adobe Audition that makes use of symmetrical display of sound data (left and right channel). The upper example can easily be perceived as symmetrical and the lower example as non-symmetrical (see [79]).

Closure

The law of closure says that the human brain tends to close contours that have gaps in them. Windows based interfaces make use of our ability to see closed contours as an object. We tend to judge each object within the frame relative to the enclosing frame.

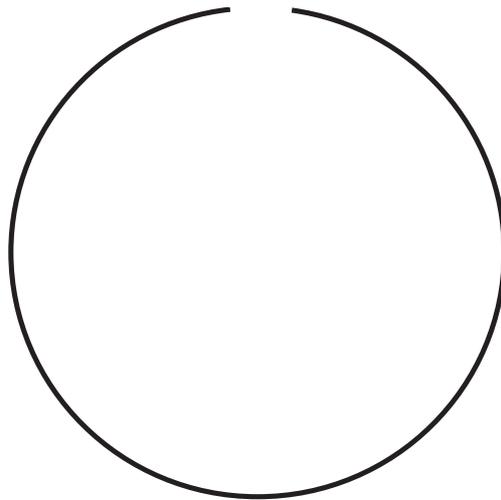


Figure 25: Because of the Gestalt law closure we tend to see a circle in the image above instead of a curve.

Relative Sizes

Smaller components of a pattern are perceived as objects whereas the bigger components are seen as background.

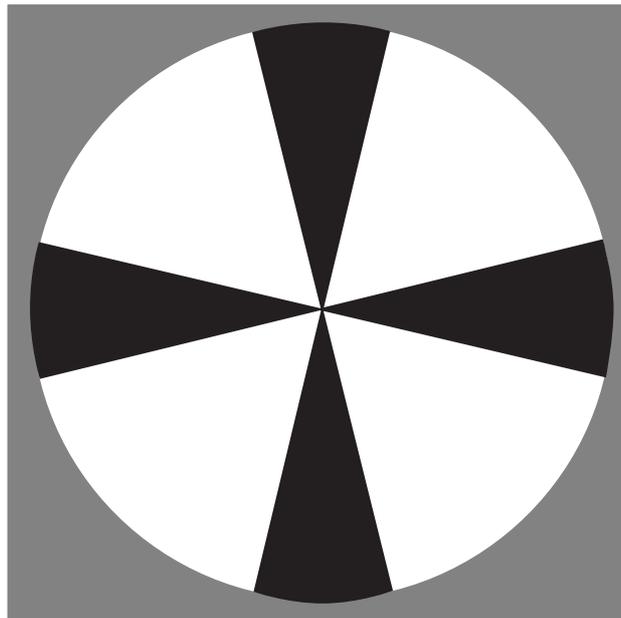


Figure 26: The black areas are perceived as an object because they are smaller than the white. It is also easier to perceive horizontal and vertical patterns as objects.

Figure and ground

A figure is a pattern that is perceived as an object that is being in the foreground. The ground is the space behind the figure. The human brain tends to pick out forms. In the example of Rubin's Vase (see Figure) it is possible to perceive either two faces, nose to nose in white on a black background, or a black vase on a white background. This identification process is

influenced by the context. When the viewer thinks about faces it is more likely that he or she will recognize the two faces instead of the vase.



Figure 27: Rubin's Vase. The cues for figure and ground are equally balanced. That is why you can see two faces or a vase.

4.1.2 Use a grid based structure for designing multiple pages

When a designer's product spans multiple pages or screens a grid-based design helps maintaining a coherent style. It can also greatly simplify and rationalize the design and production process. The advantage for the user is that he or she learns to predict where a particular information will be found.

A grid divides the screen into a small number of primitive units (usually rectangular) and exploits the Gestalt laws proximity, grouping, symmetry and alignment. Every piece of information is than placed in alignment to the grid.

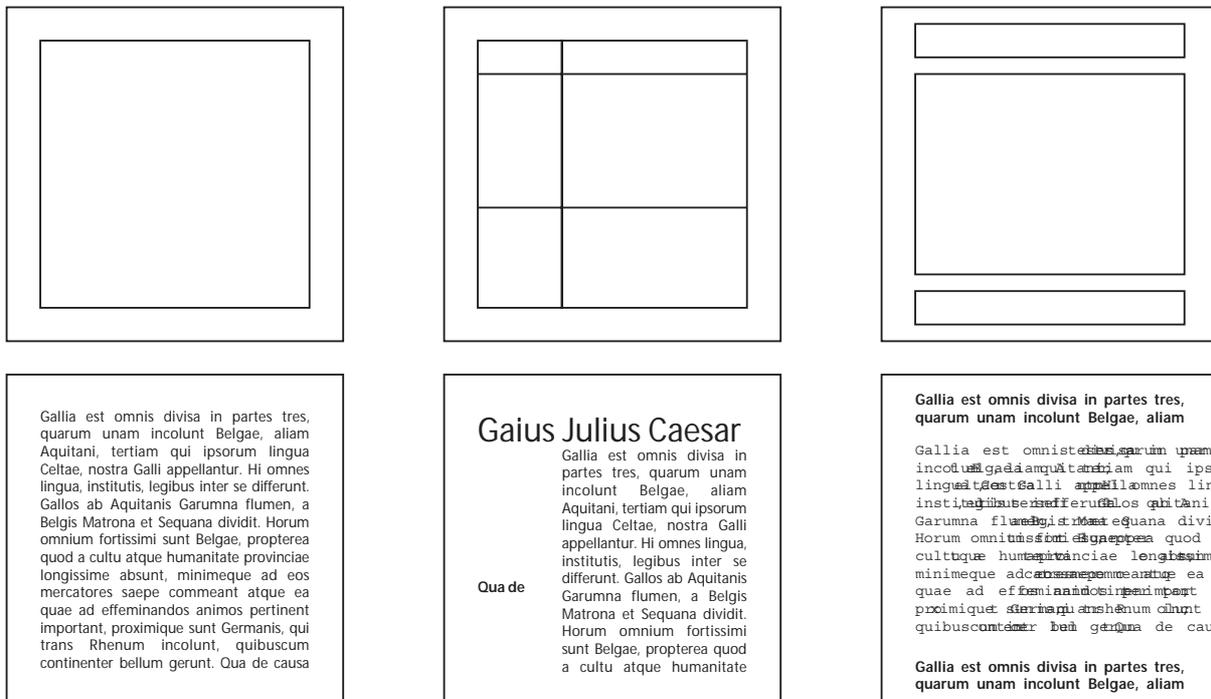


Figure 28: Three examples for grid based design. The upper image is the grid design, the lower images shows the resulting layout.

4.1.3 Highlight important elements

Scale and contrast can emphasize important elements on the screen. With this elements you can also move the viewers eye through the composition. Contrast is a visual difference between elements in a composition. This can be shape, size, colour, texture, position orientation or movement. Scale is the relative size of a given element in relationship to another. To simulate what elements draw attention to the viewer you can use the squint test (see [6] on Page 75). Close one eye completely and “squint” the other eye to reduce the light and disrupt the focus. Now you look on your creation and try to analyse the screen. Everything that does not draw your attention in the squint test, will not be apparent “at a glance” for the user.

A B C D E F A D L A S E G B D	A B C D E F A D L A S E G B D
G H J S E G J E D G J H R E K	G H J S E G J E D G J H R E K
J Z T B G F V H J M K D K D E	J Z T B G F V H J M K D K D E
S A L U R D C D L L D S H A C	S A L U R D C D L L D S H A C
D R D S R K L E V G H E F C A	D R D S R K L E V G H E F C A

Table 3: Try to find all the A in the left column and then in the right. As you can see it is significantly easier in the right column because the A's are emphasized in contrast (printed bold).

4.1.4 Use layering to display overlapping information

Scale and contrast can also be used to divide the display into specific regions (also called layers) that are processed selectively and coherently. To enable this the layers must be able to be viewed independently and without interference from other information in other layers. You can also code the importance of the layer by using stronger scale or contrast values (thus forming a perceptual hierarchy). For example a background logo on text makes use of layering. The logo is a separate layer and the text another one which can both be viewed independently.

This is a testtext written on a background logo. Both the logo and the text are in separate layers that can be read by the user on their own. They differentiate in hue, style and colour (also known as contrast differences).

Figure 29: In this example there are two layers. One with the logo that is in the background and the front layer with the text.

To verify that elements in the same layer group together as a unit, that the groups are separated from the other groups and that the layers form the desired perceptual hierarchy use

the squint test (for a description of the squint test see the guideline “Highlight important elements” above).

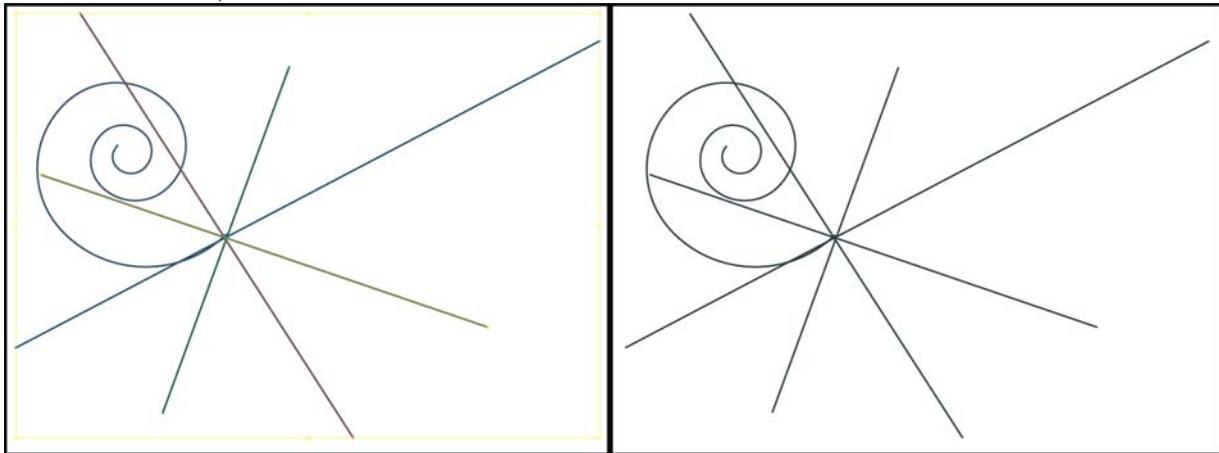


Figure 30: Adobe Illustrator 10 make intensive use of labelling. In the left screenshot the whole ensemble is marked. Every line is in another layer and is therefore coloured differently. In the right screenshot nothing is selected.

4.1.5 Grouping into functional areas

Group the screen into functional areas. Grouping can be done with graphical objects like boxes, lines, shading, colour, with white spaces, or by the Gestalt law proximity (see Gestalt Laws). No matter what style you use, the separation should be easily distinguishable (even by only scanning the page). Closely related items should be grouped together. For example in a bank form the account number and bank name should be grouped together. Otherwise the user would have to take out the banking informations twice while filling the form.

Different functional areas could be navigation, sub topic information (like status or page number), data, visualization, thematic groups or space for interaction functionality.

4.1.6 Keep controls in a separate area

Especially control buttons and options should be placed in a special area on the screen. On the web the most users expect a navigation bar for example on the left or top side of the screen. The main content is expected to be positioned in the centre of the screen. Furthermore it is very important to use always the same space for this controls (on every page / form).

4.1.7 Use indents to indicate hierarchies in your elements

Mark hierarchic elements in your presentation by using white spaces, lists, bullets numberings, paragraphs or text styles.

Example for a combination of bullets, paragraphs and text styles:

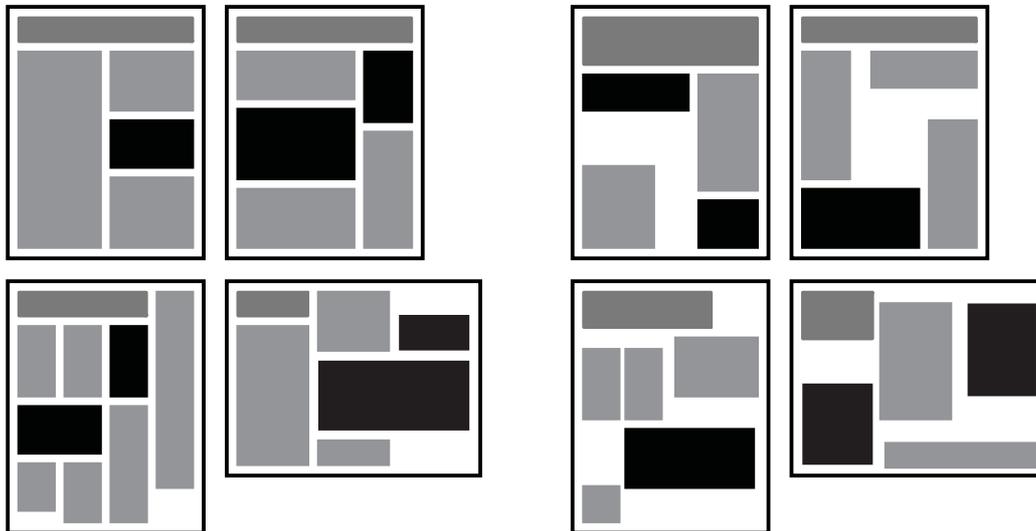
- **example 1**
 - *example 1.1*
 - *example 1.2*
 - *example 1.2.1*

4.1.8 Balance

To create a sense of balance you should distribute light and dark areas (or objects) evenly on the screen. You can use different colours or shades of grey to achieve the balancing. In

addition to this, you should also distribute the white space evenly and use consistent internal margins. Therefore, you should move larger white spaces to the end of the screen.

Another way to ensure balance is to use symmetry. The drawback of symmetry is that it can decrease the visual interest but for effective interface design it can be the perfect choice because it can present information efficiently and non-intrusively.



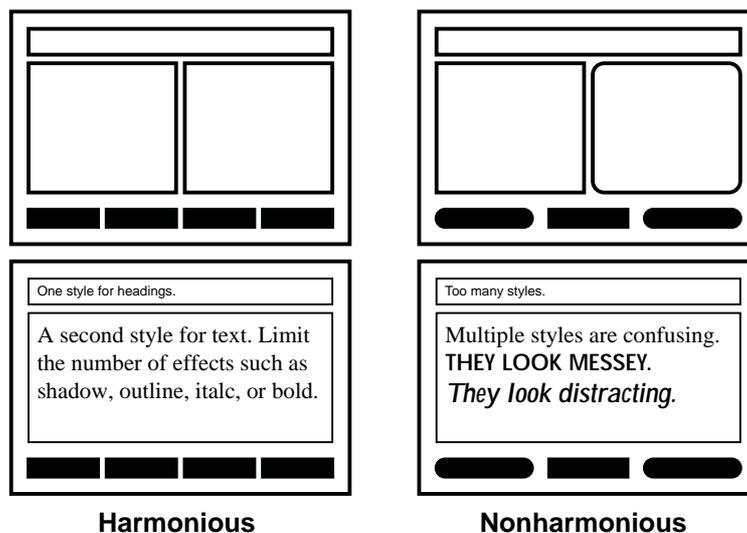
Example: White spaces are on the exterior and equal internal margins.

Nonexample: Unbalanced white space and inconsistent internal margins

Figure 31: Examples for good and bad balance.

4.1.9 Consistency in all object styles

Use consistent design styles in objects and appropriate timesteps in the whole application. This creates a sense of harmony. Do not use too many different styles. Focus on one style and draw with it a red line through your application. For example do not mix rectangular styles (like boxes) with round styles.



Harmonious

Nonharmonious

Figure 32: The left two examples are consistent, the two on the right side are not and therefore look non-harmonious.

4.1.10 Keep screens simple

Avoid too many interaction elements like buttons, graphics and text. Generally speaking, do not provide too much information per screen. Designers often start with a simple and well thought out concept, but end with a overcrowded design after adding “one extra feature” to that screen.

Generally, you should present on every screen a meaningful unit. Often this will be one idea per screen but large ideas may need to be separated into several screens.

A simple screen supports immediate use and invites to exploration. Furthermore simple designs can be recognized more easily. Finally, simplicity also enhances usability when unnecessary variations or details are eliminated.

Simplicity can be achieved by successive refinement of the user interface. To achieve an elegant design it must be reduced to its essential elements. Each element should be in its essential form. This is done by examining each element in the design and trying to remove or simplify it.

4.1.11 Avoid screens with text alone

Try to avoid screens with text alone because they look unorganized and uninteresting. That means it is harder to read for the user. But do not take senseless graphics. If you have no proper images at hand, take lines, boxes or other graphical elements to structure the text.

4.1.12 Use specific guidelines for the system you develop for

Always use the style guides for the system you develop for. For example if you are designing a user interface for a program running under Microsoft Windows use the Windows Interface Guidelines for Software Design [66].

For more information about guidelines see [3] pages 91-93.

4.2 Text

Text guidelines are very important because most programs rely heavily on the written word to present information. It is very important to use text, because it can be perceived easily and quickly when presented correctly (see [2] pages 312-333). An essential guide for writers, editors, and publishers can be found in [65].

I also present writing for the web in a sub chapter, because of the growing importance of web pages.

4.2.1 Contrast

To ensure the best readability of text it should be printed with the highest possible contrast. Usually dark letters on light background are used but there is evidence that that light letters on a dark background are more readable for older or partially sighted people. But you should avoid small bright letters on a dark background because they are very hard to read.



Figure 33: The more contrast between text and background, the better the readability is.

4.2.2 Type colour

High contrasts are difficult to achieve with colour combinations other than black and white. That is why printed material is generally most readable in black and white. So you should use colour only for highlighting of regions or aesthetic reasons.

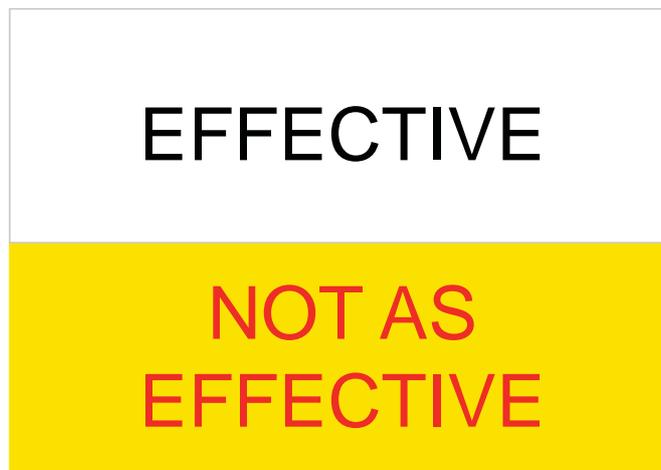


Figure 34: Black on white has the highest contrast value and is therefore better to read than colour-combinations.

4.2.3 Font family

Avoid complicated, decorative or cursive fonts and, when they must be used, reserve them for emphasis only. Standard serif or sans-serif fonts with familiar, easily recognizable characters are best. Also, there is some evidence that sans-serif fonts are more legible when character size is small relative to the reader's visual acuity.

4.2.4 Do not use too many different typestyles

Too many different typestyles destroy unity and result in a busy screen. As a rule of thumb you should take at most two different fonts. Typically, use one typeface for text and for

example a different, bigger one for headings. An exception of this rule would be to print source code in an article in a third font (for example Courier).

4.2.5 Use serif fonts for long texts.

Definition of serif by SIL International [26]:

A serif is a small line, curve, flourish, or embellishment projecting from the main stroke of a letter.

Serif fonts guide the reader's eye in a straight line, because they form a visible line on the bottom of the letters. So the reader will not lose track of the line that easily in text masses.

These letters have serifs on them. 

Figure 35: Text with serifs guide the reader's eye in a straight line.

Sans-serif fonts can be used for headings and captions or other short parts of text.

4.2.6 Use portable typestyles

Your used fonts may not be available on every computer the program is executed. Therefore, you should either deliver the fonts with the program or use standard fonts that are available on every computer. This problem is especially important in respect to web design. For example the font in a .css stylesheet should always be specified with alternatives.

The line “font-family: “Times New Roman”, Times, serif;” would be the appropriate when you want to show your text in “Times New Roman”. If this font is not installed on the target computer, the font “Times” is used and if this font also is not installed, the browser takes the preset serif font.

4.2.7 Typesize appropriate for the audience and amount of reading.

The right typesize depends on the distance of the user to the screen. It is also depending on the age and the state of health of the user. As a rule of thumb you should use about 12 to 14 point size for normal users with normal screens (17” crt display with 1024x768 pixels resolution).

In addition to this fact, the readers pick up cues from the size of the text. A large text will be seen as a heading.

If you use pixel sized fonts you have to consider that they have different sizes on displays with different resolutions.

Generally speaking, you should provide an option to resize all text (better the whole content). So the user can adapt the output to his or her needs.

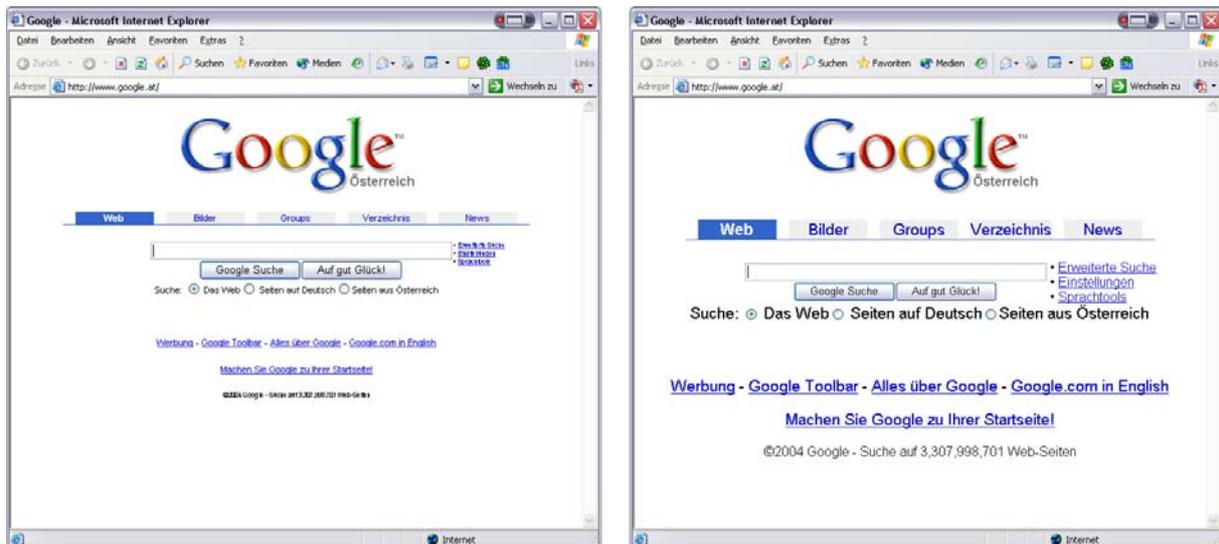


Figure 36: The left and right image show the Google start page (<http://www.google.com>) with small and large typesize adjusted.

4.2.8 Use both lower- and uppercase text.

It is easier to read a text if it is written in mixed case or lower case because lower case letters provide more cues about their uniqueness. Thus it is easier to recognize individual letters in lower case than in uppercase.

Writing all letters uppercase is appropriate for cuing an important part, like a heading or a word. But it is better to use bold or italic attributes to the letters in respect to the readability. In Figure 37 below you can see an example with the same text in mixed case and in uppercase.

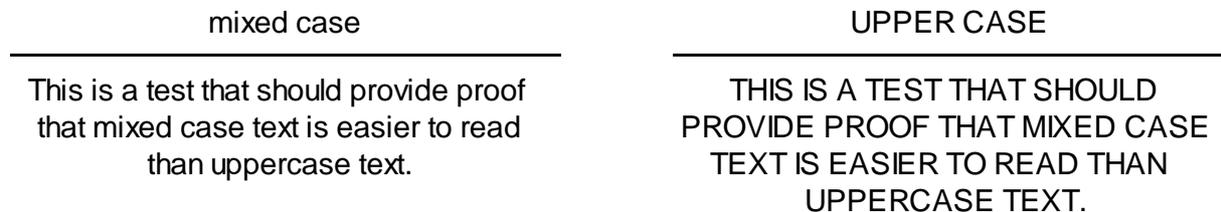


Figure 37: The text on the left in mixed mode is easier to read than the text on the right in uppercase mode.

4.2.9 Keep line lengths reasonable

Keep the line lengths between 8 to 10 words or 45 to 60 characters. This is a flexible recommendation. Long lines are difficult to follow across the screen for the reader. In addition to this, short lines permit more line breaks based on syntax.

4.2.10 Generally, use single spacing between lines of text

The space between two lines is called linespace or leading. Single spaced short lines are easier to perceive because they produce short blocks of text that appear like chunks of information. If you decide to use longer lines you also have to increase the spacing between the lines. This is needed to allow the reader not to lose track while reading.

4.2.11 Use of justification

Justification is the alignment of the text on the screen. There are three options for justification:

- Left justification: The text is aligned from left to right. That means that the right margin is ragged. This form has the best readability for people reading from left to right.
- Right justification: This text is aligned from right to the left. That means that the right margin is a straight line and the left margin is ragged.
- Centre justification: The text is aligned from the middle to the right and left margin.
- Full justification: There are even margins on both sides. Both margins form a straight line. It is achieved by adjusting the space between the words. This format is hard to read because with non proportional fonts and hyphenation, breaks of phrases and words happen.

Justification	Example
Left	This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification.
Right	This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification.
Centre	This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification.
Full	This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification. This is a test that should show you the difference between left, right, centre, and full justification.

Table 4: Examples for left, right, centre and full justification.

4.2.12 Font: wordspacing, letterspacing

Wordspacing is the space between words. If this value is too small the words are hard to isolate and thus the text is hard to read.

Thesewordshavenospacebetweenthem,makingthemhardtorecognizeandread.

Figure 38: Too small wordspacing makes text hard to read.

Letterspacing: Is the space between the letters of a word, called kerning. Text where the letters are too far apart or too close is hard to read. Especially partially sighted often have difficulties with close letter spacing (because of central visual field defects for example).

Some of these l e t t e r s a r e t o o f a r a p a r t , m a k i n g i t h a r d t o r e a d .

These text has a too small letterspacing and is thus hard to read.

Figure 39: If letterspacing is too small or too large the text is hard to read.

4.2.13 Use headings as organizers

Use headings to structure your text. Main headings can be placed anywhere appropriately. The typical example would be the centre of the top screen in big letters. Subheadings, that refer

directly to the information presentation should be placed within the text. Phrased headings (for example a question) can direct users attention.

4.2.14 Use paragraphs to organize the information in bite sizes

Use paragraphs to organize your text in chunks of information. So, the reader has a chance to reflect on what he or she read before continuing and can jump easily over a chunk (without over reading something) if he or she is not interested in the content.

4.2.15 Use directive cues to emphasize important terms or ideas

To move the attraction of the reader to certain words or phrases use directive cues like

- **bold** (best readability)
- *italic* (hard to read with long text)
- underlining (associated with hypertext links)
- **inverse**
- flashing
- colour
- size
- *shape*
- *direction*
- brightness
- UPPERCASE
- *outline*
- *embossed*

text. But you should use it sparingly because too much use will not move the attraction of the reader and can be extremely distracting. Especially, flashing is very distracting because of the very good movement detection in our eyes.

4.2.16 Set up comparison – contrast situations in a side-by-side columnar arrangement.

Side by side columnar arrangements are useful for both comparisons and contrasts because the viewer can easily compare the desired information. The optical distance allows to keep all items in view that are being compared.

4.2.17 Writing for the web

Principally all guidelines for text can be applied for writing for the web but some additional aspects should be considered. Writing for the web can be a bit different, because of the different user behaviour on the web.

In [25] John Morkes and Jakob Nielsen made studies on how users read on the web. They found out that 79 percent of the test users scanned any new page. Only 16 percent read word-by-word the whole page. The following guides are taken from the study [25].

Text should be scan-able

Because text is mostly scanned from users on the web you should write scan-able text. That means text should be short and concise. You should also provide manageable chunks of information. So the user can easier find the information he or she searches.

Users want to get their information quickly

John Morkes and Jakob Nielsen said

“Web users are under emotional and time constraints. The most important thing is to give them the information fast.”

That is why you should provide summaries of the information on the page. In addition to this, the inverted pyramid writing style is also a preferred style on the web. This means that you should bring the conclusion first in an abstract. Furthermore, simple and informal writing should be used.

Credibility is very important

Credibility on the web is a very important aspect for the users. Every user can publish informations as he or she likes. So the reader has to judge the credibility of the read text. To increase credibility you should always provide the sources of your information. Furthermore you should provide detailed information about the authors. Nielsen also found out that outbound links can increase credibility of the text. Finally, a tastefully and professional design is very important for the user.

Graphics and text should complement one another

Do not use graphics only as placeholders. Words and pictures that correlate can be a powerful combination to enforce understanding. In addition to this, you should always use captions for images on the page, so that a user, who only sees the image can easily see additional information (and has not to find them in the text).

Hypertext is liked

Make use of links in the text. This is the main advantage over normal text. Do not think of users who leave your site. Users will come back, if you provide good information and links.

4.3 Graphics

Modern user interfaces rely heavily on graphical representations. The following guidelines should give general hints about how to use graphical elements or images in an user interface. The chapter 7 *Icon design* on page 69 will present more additional information on graphical interface elements.

4.3.1 Use graphics for organization of functional areas

Use boxes, shading, colour, white space and texture to organize the functional areas and set them apart from each other.

4.3.2 Images versus words

Images are easier perceived than text for spatial structures, location, and detail, whereas words are better for representing procedural information, logical conditions, and abstract verbal concepts.

Colin Ware presented in [2] the following more detailed points:

- Images are best for showing structural relationships, like links between entities and groups of entities. Structural diagrams take advantage of this point.

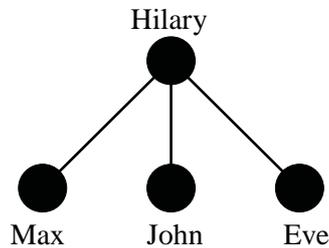


Figure 40: Hypothetical management hierarchy.

- Tasks involving localization information are better conveyed using images. A popular example for this point would be a city map.
- Visual information is generally remembered better than verbal information. The exception to this point are new, abstract images that are out of context.
- Images are best for providing detail and appearance. The amount of information should be related to the amount of time available to study it. A number of studies showed that we first look at the shape and overall structure of the object and later on the details. That is why simple line drawings are very effective for quick exposures.
- Text is better than images for conveying abstract concepts. For example the concepts freedom or efficiency are hard to visualize with images.
- Procedural information is best provided using text, spoken language, or text integrated with images. Static images are not effective in providing complex, non spatial instructions.
- Qualifying information that specifies conditions under which something should or should not be done is better provided using text of spoken language. An example for this would be instructions in case of a fire.

4.3.3 Use contrasts to differentiate elements

The human eye can detect contrast differences in a very early stage (see chapter 2.1.1 *Edge enhancement* on page 14). This mechanism is used to separate objects in the real world and should therefore also be used in the design process.

4.3.4 Visual integration requires equal scale and visual weight

To ensure the impression of a unified composition use equal scale, symmetry and visual weight in the design elements. Distributing light and dark areas equally or drawing everything in the same line length helps achieving visual integration. In Figure 39 the left symbol appears visually integrated because the dark and white areas are distributed equally and the same line weight is used for the “H” and the surrounding circle. The four examples on the right side break one of these principles and are thus appearing inhomogenous. This principle can also be applied to interface design. Here the distribution and scale of the interface objects (like buttons, text areas and so on) on the background have to be adjusted.

Note that symmetry is not always the best way to arrange a compilation. Asymmetrical compositions can produce tensions that can be exciting and interesting. For more information about how to integrate figures and ground look into chapter *Scale, Contrast, and Proportion* pages 84-87 from [6].

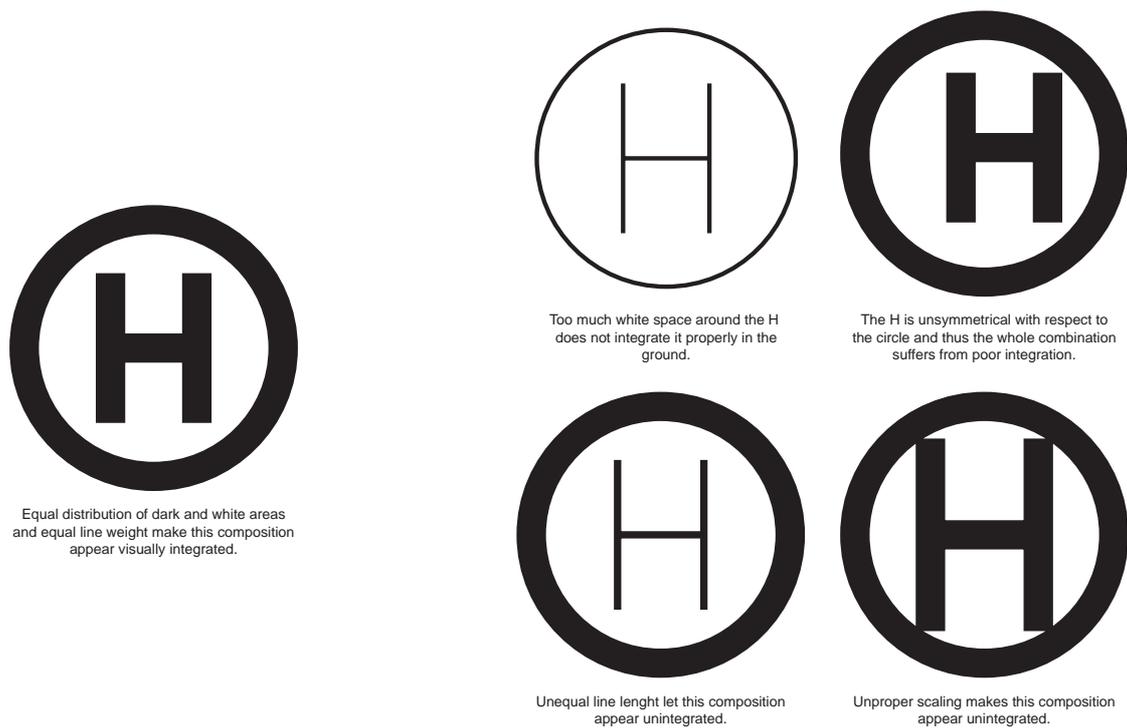


Figure 41: Example for a good and four bad visual integrations of a symbol.

4.3.5 Optical adjustments for human vision

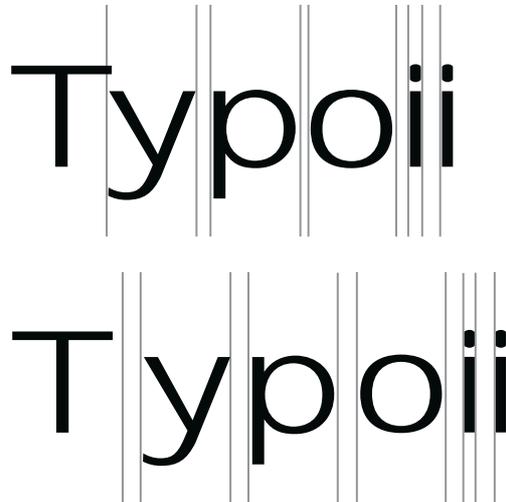
To compensate the peculiarities of human vision, visual design has to break some geometrical guides.

- Optical alignment: Curved and acute forms have to project farther beyond the margin than linear elements. Acute angles must project even further than curved ones to achieve the same effect. For example characters with curved bottoms must extend slightly below the baseline so that the baseline is perceived as straight. In Figure 42 you can see that the “o” extends slightly under the geometric baseline of the “n”.

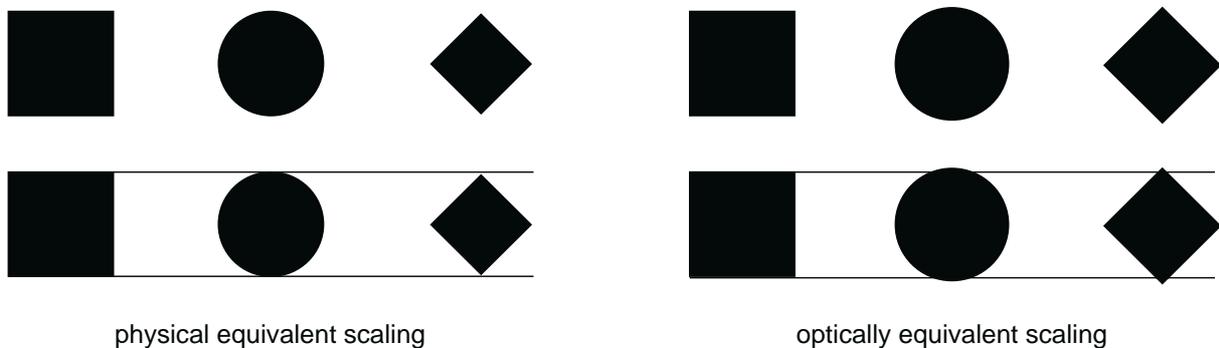


Figure 42: To align curvilinear elements properly with the baseline they have to project farther beyond the margin than linear elements (because of the human vision).

- Optical spacing: Equalize the area between the two elements rather than the distance between them. In Figure 43 the text above is positioned by equalizing the area between the letters and looks optically better spaced than the text below with equal distance between the characters.



- Optical scaling: To get optically equivalent scaling, round objects must be slightly larger than oblongs. Diamonds have to be even larger than round objects to be perceived equally scaled. In Figure 44 the left objects are scaled physically equivalent but each one looks smaller. On the right hand side the objects are each scaled a bit larger but they seem to be equivalent.



4.3.6 Use animations carefully

Moving pictures have a strong effect on the human peripheral vision. This was developed to see moving enemies in the peripheral vision. That is why it is hard to concentrate on something when we perceive movement in our periphery.

Jakob Nielsen stated in [62] that animation is good for:

- Showing continuity in transitions: Changes between two or more states are easier to understand when animated. Kaiser and Piffitt theorized in [27] that animations are perceived as “naive physics”. Thus certain kinds of mechanical logic will be readily interpreted. For example a sorting algorithm can be visualized by moving the values in the right position according to the sorting algorithm.

- Indicating dimensionality in transitions: Use animation to indicate movement back and forth along some navigational dimension. An animation that shows paging to the next page, when the user wants to read on, would be an example.
- Illustrating change over time: Animation provides a good one-to-one mapping for showing change over time. An example would be a progress bar.
- Multiplexing the display: Use animation for displaying multiple information in the same space. Blending between different text fields or by scrolling text on small displays (displays of audio players) would be examples for this.
- Enriching graphical representations: Some types of information are easier to visualize with movement. Baecker, Small, and Mander reported in an experiment in [63] that the comprehension of a set of icons increased from sixty two percent to one hundred percent by animating them. It is important that the icons are only animated when the user indicated a special interest in it (for example by placing the mouse over them).
- Visualizing three-dimensional structures: Animation can help to get the user the right three-dimensional impression on the two-dimensional screen. This can be done by moving or rotating the object slowly either automatically or under the user's control.
- Attracting attention: If you want to draw the users attention to a single element (for example to alert the user) animation is a good way to do this. But the animation should not go on if the user does not need to look at the animation or already looks at it. This can be done for example by playing the animation only a short time.

5 Colour

5.1 Computer colour

5.1.1 RGB

RGB stands for red, green and blue and is an additive colour system. In this additive system coloured light sources are superimposed to create all colours. If all three light sources are overlaid white light is produced.

This system is widely used in televisions and computer monitors. In a computer system every channel (light source) is stored with one byte (8 bits). That means that 256 different values for one channel are possible leading to 16.7 million different colours.

5.1.2 CMYK

CMYK stands for cyan, magenta, yellow and key (black) and is a subtractive colour system. Subtractive means that each pigment that is painted, absorbs light and therefore another colour is reflected. When pigments of all three primary colours (CMY) are painted theoretically black should appear. Because the colours do not have ideal reflectance properties a pure black can not be produced. Therefore, a fourth channel, the K in CMYK, with pure black pigments is used. The CMYK colour system is usually used for printers and has a smaller colour space than the RGB system. This means that some colours in the RGB colour space are not in the CMYK colour space and the designer has to consider this limitation.

5.1.3 CIE colour spaces

The International Commission on Illumination CIE (Commission Internationale de l'Eclairage) specified the three colour models CIE XYZ, CIE $L^*a^*b^*$ and CIE $L^*u^*v^*$.

These are three device-independent colour models based on the human perception. For more information see [57].

5.2 Colour guidelines

5.2.1 Use colour contrasts to separate

Contrasts are very effective because the human eye has an edge enhancement mechanism (see chapter 2.1.1 *Edge enhancement* on page 14). They can arise interest, be a stylistic device in painting or point to important information. Johannes Itten, painter and colour theoretician, described seven colour contrasts in [50]:

Pure colour contrast

A strong contrast can be achieved by using the primary colours red, yellow and blue. The intensity gets weaker when you use secondary mixed colours like green, orange or violet.

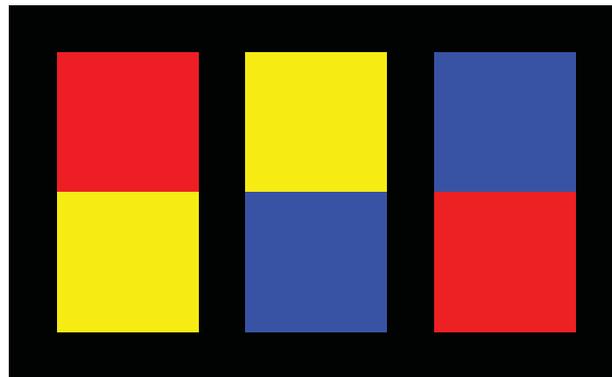


Figure 45: Primary colour contrasts

Brightness contrast

Here two colours with different brightness values are opposed. The greater the difference, the better the contrast. The highest contrast is reached with the achromatic colours black and white.

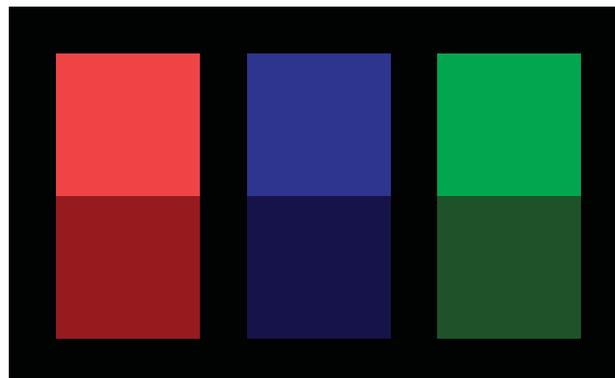


Figure 46: Brightness contrasts

Warm-cold contrast

Warm colours like yellow, orange, magenta, and red are opposed to cold colours like cyan, green, and blue. With these contrasts ambiances are presentable like “sun and shadow” or “near and far”. The classification of cold and warm colours is only a social convention (in the Middle Ages blue was considered as a warm colour for example) and may originate from the associations with fire, water and ice.

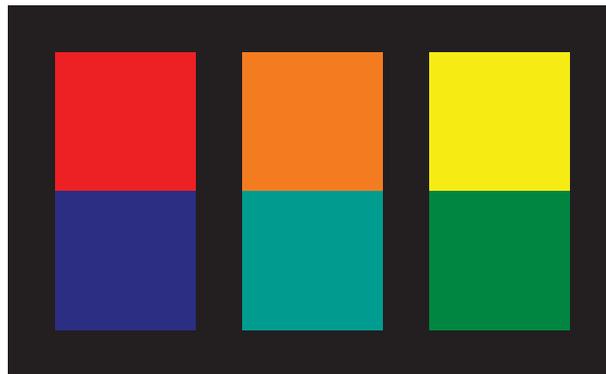


Figure 47: Warm to cold colour contrast (warm above)

Simultaneous contrast

Adjacent colour areas that are not exactly complementary influence each other so that one colour seems to be shifted. They repel one another and vibrate as the eye tries to bring them closer to their precise complementary colour. This effect occurs because the human brain tries to view the complementary colour next to every colour seen. The use of such contrasts makes chromatic compositions more interesting and livelier. For example a grey square that is surrounded by a red area looks like it has a green tone because green is the complementary colour of red.

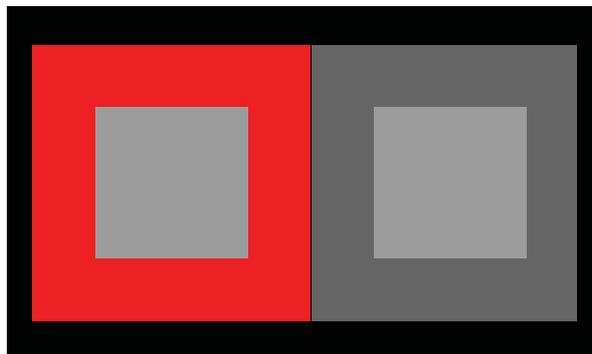


Figure 48: Concurrent contrast: left grey square appears greenish

Complementary contrast

These contrasts are perceived harmonically and with a high difference. The complementary colours can be found as the opposite colour on the colour wheel in Figure 49 or on the online colour wheel from Hewlett Packard in [52].

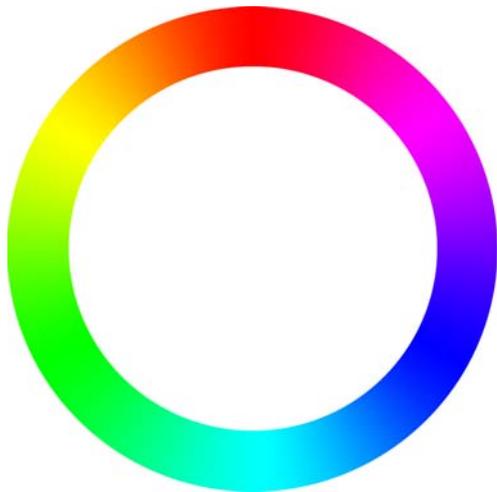


Figure 49: Complementary colour wheel

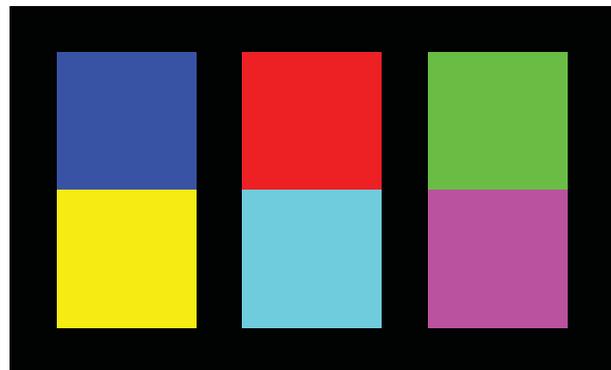


Figure 50: Complementary colour contrasts

Quality contrast

The juxtaposition of saturated and unsaturated colours, or bright and a grey-tinted colours results in quality contrasts. This contrast only exists if the unsaturated colours are dominant.

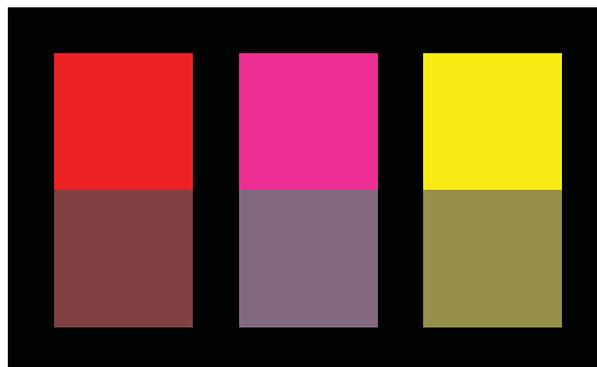


Figure 51: Quality contrast

Quantity contrast

Quantity contrast uses the effect of different sized colour areas. The surface devoted to each colour influences their impact on the composition. The more saturated or brighter a colour is, the greater is its impact on the composition leading to a lower need for space. In [51] Johann Wolfgang von Goethe gave the following values: yellow: 9, orange: 8, red: 6, violet: 3, blue: 4, green: 6. If you want to use red (6) and violet (3) you have to use 6:3 parts red:violet, that means the red surface has to be twice as big to perceived harmonically.

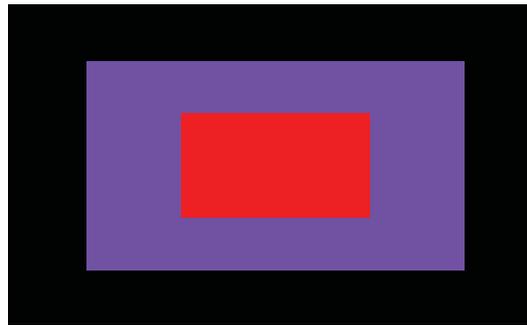


Figure 52: *Quantity contrast:*
violet (2) : red (1)

5.2.2 Consider colour blind people

About ten percent of the male population and about one percent of the female population suffer from some form of colour blindness. These deficiencies are the lack of one colour pigment. The most common form is the red-green blindness, where either the red (called pronopia) or the green (called deuteranopia) pigments are missing. People having this deficiency are unable to distinguish red and green. Blue-yellow blindness (called tritanope) is much rarer and equally distributed among males and females. People suffering under tritanope have no blue pigments. Complete blindness would be the complete absence of spectrally selective opsins and is very rare.

To test colour blindness test plates like in Figure 53 and 54 are used.

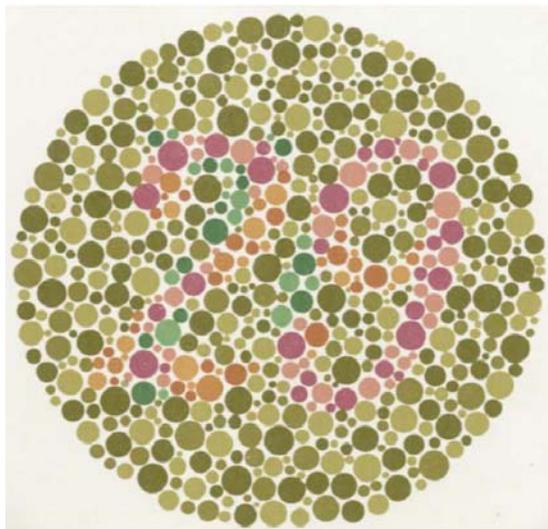


Figure 53: *Test plate for colour blindness [7].*

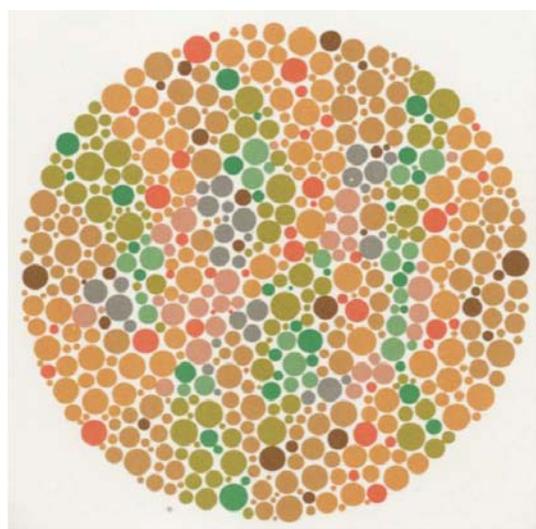


Figure 54: *Test plate for colour blindness [7].*

That is why you should not show differences only by colouring them differently.

5.2.3 Do not display fine detail only with chromatic differences

In [53] Mullen found out that the red-green and yellow-blue chromatic channels from the eye to the brain are each only capable of carrying about one-third the amount of detail carried by the black-white (luminance) channel (see chapter 2.1.1 *Colour separation* on page 15 for more detail about the preprocessing of visual information in the eye). That is why you should

not code fine detailed information like text only by chromatic differences and the same luminance.

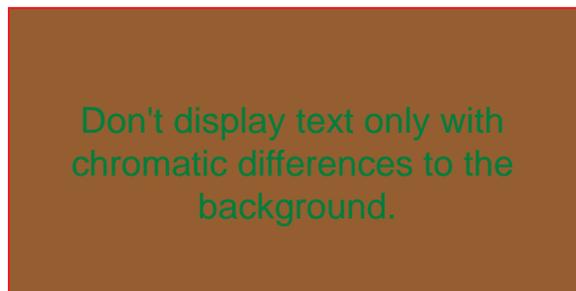


Figure 55: Text and background only with chromatic difference.

5.2.4 Do not display motion only with chromatic differences

Antis and Cavanaugh found out in [54] that a pattern that is equiluminous with its background and only contains chromatic differences appears to move slower than the same pattern coded with black and white moving at the same speed. Therefore, motion perception is primarily based on information from the luminance channel.

5.2.5 Do not display an object's shape only with chromatic differences

If an object is only shaded by a purely chromatic gradient and not the usual luminance gradient, the impression of the shape of the surface is much reduced. That means that the perception of shape also appears to be processed mainly through the luminance channel (see [55]).

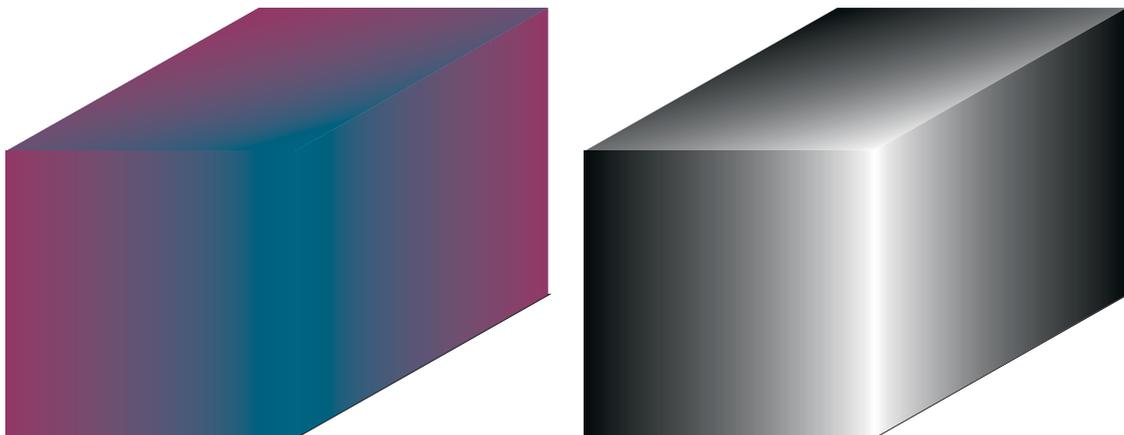


Figure 56: Shading with chromatic gradient versus luminance gradient

5.2.6 Consider brightness contrast

The impression of a colour is always influenced by the background colour. A grey patch on a dark background looks lighter than the same grey patch on a light background for example. This effect is known as “simultaneous brightness contrast” and occurs because of the lateral inhibition in the eye (see chapter 2.1.1 *Edge enhancement* on page 14).

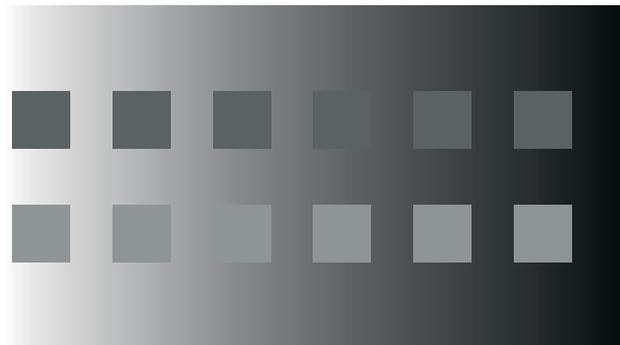


Figure 57: Brightness contrast example: The upper row of rectangles are an identical grey. The lower rectangles are a lighter gray, but are also identical.

5.2.7 Use distinct colours for labelling

The following list of twelve colours are recommended for use in coding:

red, green, yellow, blue, black, white, pink, cyan, grey, orange, brown, purple (see Figure 58)

These colours are reasonably far apart in the colour space and have widely agreed-upon category names. The first six colours are the end-colours of the three channels, in which the human brain gets the visual information (red-green channel, yellow-blue channel, black-white channel).

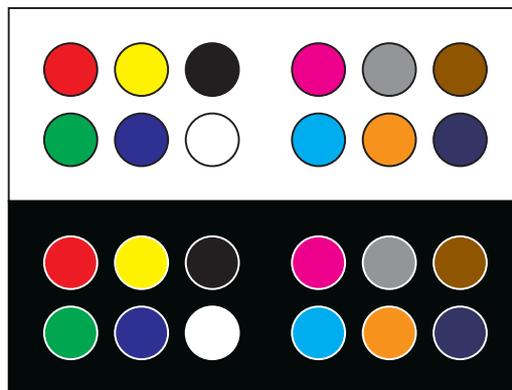


Figure 58: Twelve distinct colours for use in labelling. The same colours are shown on a white and a black background.

5.2.8 Do not use red text on blue background and vice versa.

Different wavelengths of light are focused at different distances in the human eye because it is not corrected for chromatic aberration (see chapter 2.1.1 *Transmission / Refraction* on page 6). Short wave-lengthened blue light is refracted more than long wave-lengthened red light. This means that both colours can not be focused simultaneously. Thus red text on a blue background is very hard to read and vice versa. In addition to this, red and blue can give a strong illusory depth effect.

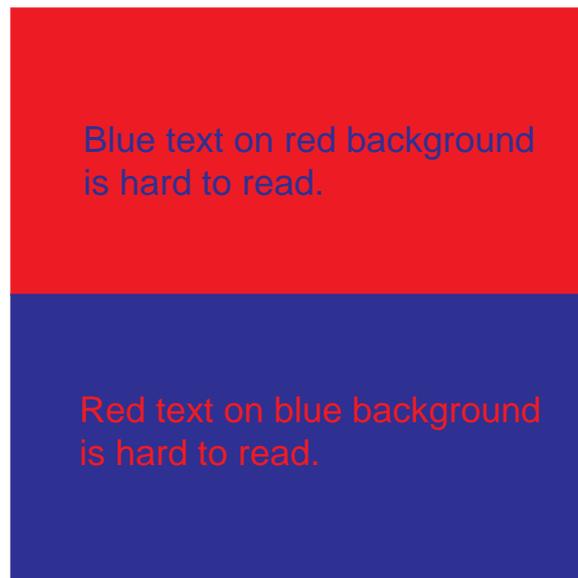


Figure 59: Red text on blue background is hard to read (and vice versa)

5.2.9 Colours have a stronger effect on a dark background

Colours look more vibrating and gaudy when they are in front of a black background.



Figure 60: Colour on black in comparison to colour on white

5.2.10 Do not use blue for fine details

Because of the chromatic aberration of the eye there are less S-cones (sensitive for blue light) and therefore the resolution of blue is very low. So you should not use the colour blue for fine details.

5.2.11 Colour sequences for maps

- Black to white, red to green, yellow to blue or saturation sequence should be used if the sequence should be perceptually orderable.
- If you want to display data with a high level of detail you should use a colour sequence based mostly on luminance (because the luminance channel can carry more detail).
- When identifying values of a map using a colour key is required, use many different colours, so that contrast effects do not alter the recognition.

5.2.12 Colour affections

Consider that different people like different colours. The conclusion of a German survey (see [13] page 55) was that blue, red and green are the preferred colours of most people. Brown, orange and purple are the most disliked colours. Differently aged people have different preferences. For example 75 percent of all school kids liked purple the best. That changed as they grew older (to orange, green and then blue).

5.2.13 Use red light to preserve dark adoption

Red light does not prevent the eye to adapt to the dark because rods do not respond to red. So you should use red light for instruments or information that are viewed at night and should not spoil the dark-adoption. For example ship instruments usually glow in red to assure that the captain can gain full dark-adapted vision.(see [56])



Figure 61: Red illumination of a Seat Leon.

5.3 Psychology of colour

From the early past up to now colour had a great importance in human psychology. The observer links colours to determined feelings and properties. Many scientists think that this links are collective patterns in all humans. Furthermore colour therapists claim that colour has different effects on the physical and mental health. In a German study from [13] the top three colours of seventy percent of all asked were blue, red and green (in this order). The most disliked colours were brown, with twenty seven percent, orange, with eleven percent, and violet also with eleven percent. Interestingly there were only differences in age. Seventy five percent of all asked children liked violet the most.

5.3.1 Red

<p>Second most liked colour</p> <p>700 nm: purest red seen Range: 620-780 nm 580 nm absorption maximum of the L-cones</p> <p>Range: from orange (585 nm) again to orange-red (780 nm)</p> <p>RGB 255, 0, 0</p> <p>CMYK 0%, 100%, 100%, 0% Magenta absorbs the green light and yellow the blue light. Only the red light is reflected.</p> <p>Associations: love, hate, anger, heat, fire, warm, lips, rose, mouth, cherry, red wine, heart, danger, Ferrari, tomato, blood, hell, war, aggression, strength, courage, fertility, urgency</p>	
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There are two fundamental associations with the colour red: As fire it is connected with light and heat and as the colour of the blood it is connected with life and sacrifice. It is associated positively with strength, love, courage and fertility. Hate, anger, war, aggression and blood spilling is linked negatively with red.

Today red is a sign for stopping and a warning colour. It is used in ads because it is fast recognizable and distinguishable. In the medicine red is known to increase the appetite, the blood supply and aggressions.

In China red is linked with luck and wealth.

5.3.2 Green

<p>Third most liked colour</p> <p>546 nm Range: 497-530 nm 545 nm: absorption maximum of the M-cones</p> <p>Range: from blue-green (492 nm) to green-yellow (575 nm)</p> <p>RGB 0, 255, 0</p> <p>CMYK 100%, 0%, 100%, 0% Cyan absorbs the red light and yellow the blue light. Only the green light is reflected.</p> <p>Associations: nature, health, poison, grass, leaves, forest, recreation, hope, youth, garden, summer, calming, generosity, confidence, freshness, unripe, stagnation, envy</p>	
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The fundamental association of green is nature because it is the dominant colour of the vegetation. Generally, people associate green positively with youth, generosity, confidence, freshness and nature, and negatively with unripe, poison, stagnation, envy and careless. Most of this associations can be derived from the green nature.

5.3.3 Blue

<p>Most liked colour</p> <p>435 nm Range 450-497 nm 440 nm absorption maximum of the S-cones</p> <p>Range: from green-blue (497 nm) to crimson blue (450 nm)</p> <p>RGB 0, 0, 255</p> <p>CMYK 100%, 100%, 0%, 0% Cyan absorbs the red light and red absorbs the green light. Only the blue light is reflected.</p> <p>Associations: distance, trust, cleanness, cold, sky, water, harmony, relaxation, sportiveness, ink, infinity</p>	
--	--

Blue is one of the oldest colours used by humans and was one of the most expensive up to the development of synthetic colours. That is why blue was the colour of kings and gods.

It is the colour of the sky and of water because of refraction. Because of this refraction mountains look blueish in the distance.

In arts blue stands for the distance, the religious, and divinity.

In the psychology blue is known to have the exact opposite effect than red. This means it relaxes and calms down. Furthermore blue is the colour of dreaming, longing, the unconscious, the dreaming, depth, truth and faithfulness. Negative associations with blue are the cold, lies, and alcoholism.

Blue is very often used in the fashion industry.

Ads also use blue very often because it is a friendly and gentle colour.

5.3.4 Yellow

<p>580 nm Range 575-580 nm</p> <p>Surrounding: from green-yellow (530 nm) to yellow-orange(585 nm)</p> <p>RGB 255, 255, 0</p> <p>CMYK 0%, 0%, 100%, 0% The blue parts of the yellow light are absorbed and red and green is reflected.</p> <p>Associations: sun, sunflowers, summer, moon, gold, post, grain</p>	
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Yellow is the brightest of all colours and is a mixture of red and green light. However, a human observer sees it as a pure and unmixed colour. This is because of the colour separation (see chapter 2.1.1 *Colour separation* on page 15) in the human retina.

In the Asian culture yellow stands for happiness and wisdom. Positive properties associated with yellow are fun, friendliness and optimism. On the other hand, negative properties are envy, egoism, jealousy, stinginess and untruthfulness.

Yellow is the most important colour for colour therapists. Especially in the dark winter time it should have healing capabilities.

In the nature yellow is the colour of ripe fruits and of the autumn. Gold is just a yellow material with metal reflections.

5.3.5 Cyan

<p>490 nm, Range 487-492 nm</p> <p>Surrounding: from blue (482 nm) to green (530 nm)</p> <p>RGB 0, 255, 255</p> <p>CMYK 100%, 0%, 0%, 0%</p> <p>Red light is absorbed by the cyan colour. Blue and green light is reflected to the eye.</p> <p>Associations: sky, sea, swimming pool, cold, hygiene, clean</p>	
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Cyan is very important for printing because it is one of the four components in the CMYK colour scheme, which is used mainly with printers (the C in CMYK). It is exactly in the middle between blue and green and people see it as a hygienic and clean colour. Furthermore most people sense cyan as the coldest colour of them all.

5.3.6 Magenta

<p>Mixture of blue (450 – 482 nm) and red (620 – 780 nm)</p> <p>RGB 255, 0, 255</p> <p>CMYK 0%, 100%, 0%, 0%</p> <p>Green light is absorbed by magenta pigments and red and blue light is reflected to the eye.</p> <p>Association: red, blue</p>	
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Magenta is also important for printing because it is part of the CMYK process. It is also called cold red and there is no single wavelength that can be perceived magenta. That is why no magenta coloured laser can be produced.

5.3.7 Orange

<p>590 nm</p> <p>Surrounding: yellow-orange (580 nm) to orange-red (620 nm)</p> <p>RGB 255, 127, 0</p> <p>CMYK 0%, 50%, 100%, 0%</p> <p>Blue light is absorbed and the half of green light is absorbed. The rest of the green light and the red light is reflected</p> <p>Association: orange, fire, carrot, autumn leaves</p>	
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With brown, orange is the most disliked colour in Germany. It has got its name from the same named tropical fruit. Positive associations with orange are activity, energy, chumminess, high spirits, sociableness, change, youth and autumn. Negatively associated are importunity, nonseriosity and easygoing. Substandard impression from orange objects are because of the cheap orange plastic products in the last decades.

Orange is the colour of the royal Dutch coat of arms and was the the colour of the sexual revolution.

In other cultures orange has a different meaning. Indians for example are proud on their skin colour, which they call orange and in the Buddhism orange stands for the highest human enlightenment.

Because of its luminosity orange is used as a warning colour for clothes of road men and dustmen or for security markings

5.3.8 Brown

590 nm like orange but less intensity	
RGB 127, 51, 0	
CMYK 0%, 60%, 100%, 50%	
Red light is reflected and blue absorbed. Some of the green light is reflected, some is absorbed.	
Association: coffee, chocolate, earth, skin, leather, wood, clay, dirt, swamp, shit	

Brown is only a dark orange and has therefore the same wavelength of 590 nm. That is why it can only be mapped to three dimensional colour models and not two dimensional.

It can often be seen in nature in rotting plants like dead leafs or wood. Light brown can be seen on roasted meat. Dark brown can be seen in chocolate, tea, coffee, hot chocolate, and old apples.

It is one of the most disliked colours in Germany (twenty seven percent) and negatively associated with accommodativeness, laziness and petty bourgeoisie. On the other hand, it is connected with rootedness, duteousness, cosiness, sensuality and security. Furthermore tanned brown skin is seen as sportive and good looking on white people in spite of the risk of skin cancer.

5.3.9 Black

Pure black is no colour but the absorption of all colours.	
RGB 0, 0, 0	
CMYK 0%, 0%, 0%, 100%	
CMY 100%, 100%, 100% looks in reality brown-green because the absorptions spectra of the used colours are not ideal.	
All light is absorbed and none reflected.	
Association: cosmos, night, soot, coal, coffee, elegant, black hole	

Black is an achromatic colour. Physically it is the absence of all colours. That means if no light hits our retina we perceive a pure black. The normal black we see in our environment (black objects) is a very dark white.

Stands for finality, unaccommodating, cold bloodedness, severity, strictness, negative, evil and nothing. Black is often used in figure of speeches in a negative way (for example black sheep, black Friday or black magic). Black animals are believed to bring no luck or death (black crow, black cat)

On the positive side black is seen as an very elegant colour and in Africa black is seen as the most beautiful colour of them all.

For designers black is very important because it shows the highest contrast with white and is therefore used as a text colour on white paper for best readability.

5.3.10 White

<p>All wavelengths from 380 to 800 nm</p> <p>RGB 255, 255, 255</p> <p>CMYK 0%, 0%, 0%, 0%</p> <p>All colours (red, green and blue) are reflected, none is absorbed.</p> <p>Association: snow, cold, paper, sail, marriage, sail, laundry, moon, salt</p>	
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White is also an achromatic colour (with black and all grey shades) and is seen when all three cones on the retina are evenly stimulated. It stands for wisdom (white haired old people), peace (white dove), purity, innocence, cleanliness (doctors wear white), maidenliness and capitulation (white flag). On the other hand, it symbolizes aggression and killing (white whale from Moby Dick or white shark).

White is seen as the counterpart of black and the two are associated with “good and evil” or “yin and yang” and so on.

5.3.11 Grey

<p>from 400 to 740 nm</p> <p>RGB 127, 127, 127</p> <p>CMYK 0%, 0%, 0%, 50%</p> <p>All colours are reflected.</p> <p>Association: fog, mice, elephant, wolf, rain weather, old people</p>	
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Grey is also an achromatic colour and the link between black and white. Therefore, it is also absent in all two dimensional colour models. Furthermore it has no complementary colour.

In the psychology it mostly stands for negative things like desolation, uniformity, abject, iciness of the heart and monotone (grey routine). Grey, foggy, rainy days are seen annoying and bring in a bad mood. On the other hand, grey is connected with soberness, meditateness and practicality.

6 Usability

This chapter is mainly based on the book “Usability Engineering” from Jakob Nielsen (see [3]).

6.1 What is usability?

System acceptability is the overall value if a system is good enough to satisfy all the needs and requirements of the users and other potential stakeholders. It consists out of social and practical acceptability. Practical acceptability can be described by the costs, the compability with existing systems, the reliability, the support and the usefulness. The usefulness can be again broken into the utility and the usability. Utility is the measurement of the system's functionality. In other words, can the system do, what it is expected to do?

Usability includes all aspects of a system with which a human might interact. This includes the everyday user, the administrators, the maintenance personal and also the developers.

Usability can also be described by the terms:

- user friendly
- CHI: computer-human interaction
- HCI: human-computer interaction, here the “human stands in first place”
- UCD: user-centred design
- MMI: man-machine interface
- HMI: human-machine interface
- OMI: operator-machine interface
- UID: user interface design
- HF: human factors
- ergonomics

6.1.1 Definition of usability

Usability is usually associated with these five usability attributes (see [3]):

- Learnability
- Efficiency
- Memorability
- Errors
- Satisfaction

By defining these five components usability can be systematically evaluated and improved.

In Figure 62 the hierarchical structure of system acceptability is shown. Usability, and therefore also the five usability attributes, is part of practical acceptability which forms together with social acceptability the system acceptability.

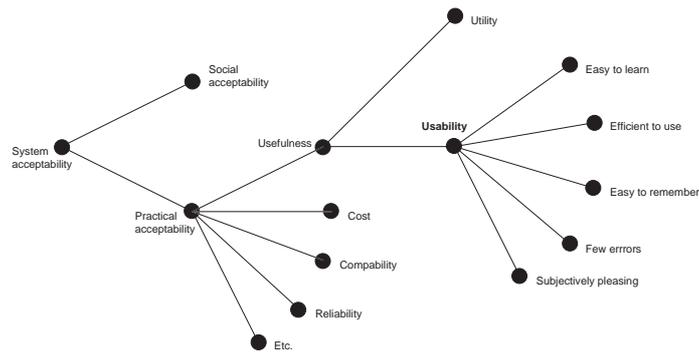


Figure 62: Model of System acceptability. Usability is only a part of system acceptability and can be split up into the five sub components learnability, efficiency, memorability, errors, and satisfaction.

Learnability

Learnability means that it should be easy to learn how to use the system. So the user can rapidly start to use the system productively. It is one of the most important usability attribute, because most systems need to be easy to learn. In addition to this, the first contact with the system is very important for the user's opinion about it.

The learnability of a system can be mapped to a so called learning curve. Therefore, the efficiency is mapped to the y-axis and the time on the x-axis. The gradient of the curve is the indicator of the learnability at this time. If it is positive the learnability is high. Usually the curve has only a positive gradient, a negative gradient would mean that a user is forgetting functions. Another example for a negative part in the learning curve would be the switching from an novice interface to an expert mode, where more options and other interaction styles are available. At the time of the switching the user may be able to do less things with the program because the options are different to activate. The learning curve could also be seen as the transition from a novice user to an expert user. Practically, all user interfaces have a learning curve starting at zero efficiency at time zero. That means that the users are able to do nothing when they first use the system. Exceptions are so called “walk up and use” systems. These systems are intended to be used only once and therefore need a zero learning time. An example for such a system would be an information system in a museum or a ticket system. Another exception are users with skills from previous systems. For example if a new version of a word processor is introduced and the user interface hasn't changed too much, the users of the previous version start a fair bit up on the learning curve for the new system. In Figure 63 you can see learning curves for three hypothetical systems. The first focuses on novice users. This means it is easy to learn but less efficient to use. The second system focuses on expert users and is hard to learn but highly efficient to use. The third system supports immediate use (for example a ticket system at a train station) but is the least efficient to use.

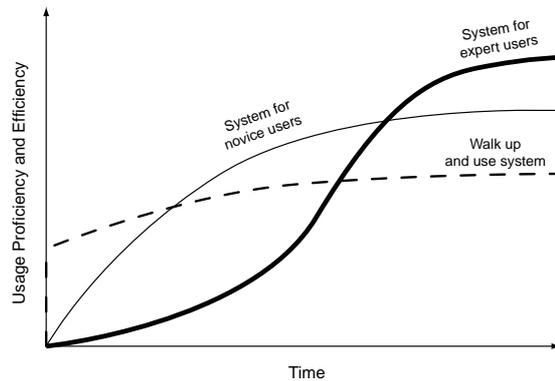


Figure 63: Learning curves for a system for novice users, for expert users, and for immediate use.

Learnability is relatively easy to measure. You just have to pick some users, who have no experience with the system, and measure the time it takes them to reach some specified goals. The test users should be representatives of the intended usergroup. You should also consider users who have no experience with computers.

A survey of business professionals who were experienced personal computer users found out these top four highest-rated usability characteristics (see [32]):

- easy to understand error messages
- possibility to do useful work with the program before having learned all of it
- availability of undo
- confirming questions before execution of risky commands

Especially the availability of undo and the confirming dialogues give the user a safe feeling to try out new options and thoughts.

Efficiency of use

The efficiency measures the level of productivity once the system has been learned. This steady state of performance is reached when the learning curve flattens out. This level must not be reached by the users any time soon. Complex systems may take several years to reach expert level performance. Most users will not learn the whole functionality but plateau once they have learned “enough” for their purposes.

To measure efficiency of use you need experienced users that have been using the system for quite a while. This can be difficult if you are measuring a brand new system. In addition to this, it is difficult to measure the experience level of a user. Users can be considered as experienced if they have spent a certain amount of time using the system, when their performance has not increased for some time, or when an expert decides by watching the user.

Memorability

Memorability measures how easy it is to remember the usage of the system. This is the case with normal users. These users use the system only intermittently and are the third major category of users besides expert and novice users. Casual use is typical for utility programs, supplementary applications, and programs that are used only at long intervals (like report programs that are used once a year). Furthermore, users that were on vacation, were sick, or for some other reason have not used the program over some time have an advantage using user interfaces that are easy to remember. A good learnability often also makes an interface

easier to remember but generally remembering is different from exploring. Graphical interfaces have a better memorability value, because humans are better in recognizing than remembering graphical objects. That is why you should use icons because they are better recognizable than text alone.

There are two ways of testing memorability. The first is to test casual users with a standard test (test the amount of time they need for performing some typical tasks). The problem with this test is how to get a casual user (especially if you want to test a new program). The second way of testing memorability is to conduct a memory test after they finished a test session (explain or name commands for example). This test may be easier to carry out but graphical interfaces make as much as possible visible to the user, so he or she does only has to recognize and not remember. This is proofed by the study of Mayes in [33] . There, users of a graphical interface were unable to remember the contents of menus although they were able to use the same menus with no problems when sitting again in front of the computer.

Errors

Jakob Nielsen defines an error in [3] as:

“.. any action that does not accomplish the desired goal”

Errors can have a highly varying impact on the work flow. Some may have no other effect than slowing the user down (choosing the wrong top menu entry for example), others may be more catastrophic in nature. These catastrophic errors may destroy the users work (ending a program instead of saving the work for example) or lead to a faulty work (for example ordering a wrong number of desired articles in a shop system).

Errors can be measured by counting them in usability tests. The slowdown effect of non catastrophic errors is also included in the efficiency measurement.

Subjective satisfaction

Subjective satisfaction measures how pleasing it is to use the system. This is especially important for non-work applications whose main purpose is entertainment. Subjective satisfaction can also be seen as a component of the social acceptability of computers rather than their usability. LaLomia and Sidowski, for example, made a survey of such computer attitude studies in 1991 (see [34]).

R. H. Kay found out in 1989 that users who perceive that they have a high degree of control over the computers also have positive attitudes toward computers.

Subjective satisfaction can be measured either by simply asking the user or by taking psychophysiological measures, such as EEG, pupil dilation, heart rate, skin conductivity, blood pressure, or adrenaline level during the test.

6.1.2 Usability trade-offs

Trade-offs are inherent in every design process including user interface design. Attempts should be made to archive a satisfying solution for both requirements. If this is not possible the decisions should be based on the project's most important usability attributes.

One usability trade-off is for example the learnability for novice users versus the efficiency of use for expert users. A system that is easy to learn may be inefficient to use for expert users.

This problem can be solved with dual interfaces. One interface is for the novice user and for expert users the interface can be switched to provide more options or faster interaction styles.

Another approach would be to implement multiple interaction styles. The user starts with a interaction style that is easy to learn and later changes to the other one that is efficient to use.

Typically this is achieved by using accelerators in the user interface. Accelerators are user interface elements that allow the users to perform frequent tasks quickly. One example would be in Openoffice.org 1.1.0 that the “Save” command can be used by menu or by pressing “Ctrl” and “S” together. This shortcut is used by the most Microsoft Windows application. Another example would be the completion of commands by pressing the tabulator key in the Linux shell.

Good descriptions of user interface elements can help the novice but do not hurt the expert. One example would be to write out abbreviations of dialogue box descriptions.

Useful default values can help both user groups. Experts do not have to fill in the values that often and novices can leave the default values, if they do not understand the meaning of the value.

Another usability trade-off would be security versus usability. Access controls are considered to be not user friendly. They should not give useful error messages to make it more difficult to get unauthorized access (for example when a wrong password was entered). In addition to this, the logging in costs time especially when long and secure passwords are used. This decreases the efficiency of the system.

6.1.3 Categories of users

Jakob Nielsen found out that the top 3 usability differences in the usability of hypertext systems were due to individual differences between users (see [40]). In this example you can see how important it is to consider the user when engineering software.

Classifying the user's experience may help in the usability design process. This can be done with the “user cube” which Jakob Nielsen introduced in [3] page 43. The three main dimensions along which users' experience differs are :

- experience with the system: The users can be either novices, experts, or somewhere in-between. This attribute is also considered in the learnability of the system.
- experience with computers in general: This axis is influenced by the time the user spent working with computers and what he or she is able to do with computers. Also experience with similar applications can be taken into account. For example an utility for novice users has to have a more descriptive user interface than the same utility for administrators.
- experience with the task domain: How good is the knowledge of the task domain addressed by the system. If the user is experienced with the task domain the interface can use specialized terminology, abbreviations, and a high density of information. In the other case that the user has little knowledge about the task domain, the interface should explain each option and function and the terminology should not be abbreviated and dense. For example a financial program for novices should have an other interface than one for experts. Especially the user interface for novices should be very explanatory so that the user knows what goes on. The designer can assume that the expert does not need so much additional information about what each function does.

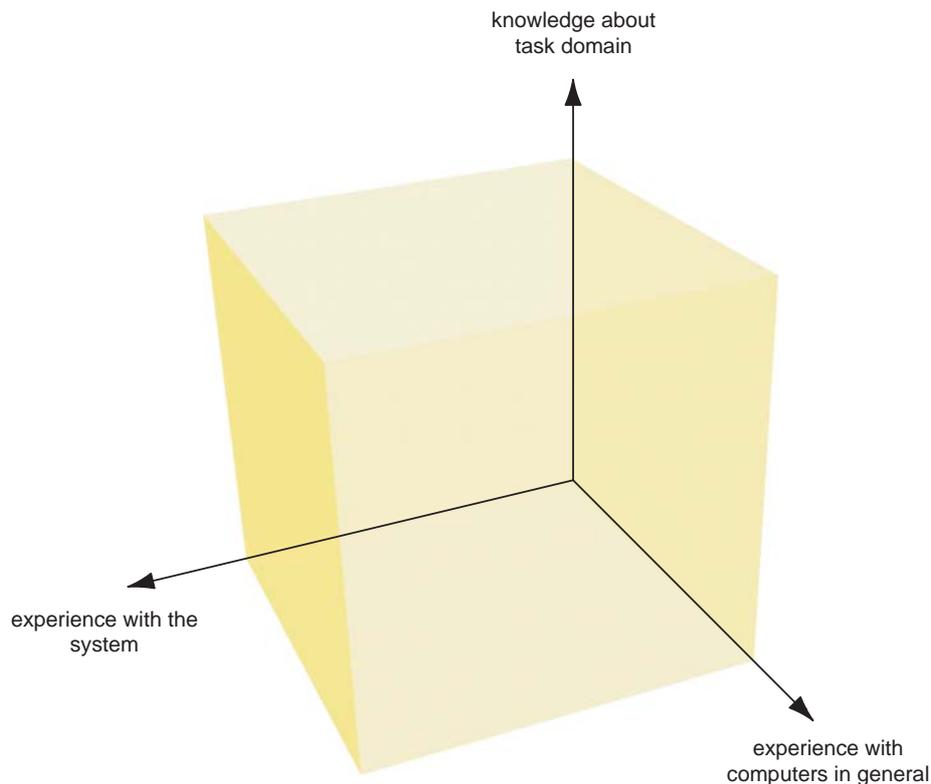


Figure 64: User cube for specifying user differences

User's also differ in other ways than experience, like

- age: Older people for example can have decreased abilities with seeing, hearing and memory. See [41] for more information.
- gender: See [42] and [43] for more information.
- differences in spatial memory and reasoning abilities: See [44] for additional information.
- programming abilities: Is the user able to use and learn a programming language? This question can be vital if the designers choose to implement a macro language in the product.
- preferred learning style: See [45] for more details.
- attitude towards computers: There are people who love to use the computer and will go to extreme efforts to learn all about their system and other people who only see the computer as a tool to get the work done. The users of the first group are also called super-users, power-users or gurus. They like to try new computer developments and help novice users with their knowledge.

6.2 Usability engineering lifecycle

Usability engineering is a set of activities that take place throughout the lifecycle of the product. The lifecycle can be divided into the three categories: before the design phase, during the design phase, and after the production of the software.

6.2.1 Before the design phase

- Know the user: Study the intended users and use of the product. This can be done by visiting the customer site for example or studying existing solutions. Consider that a user is everybody whose work is affected by the product in some way.

- Competitive analysis: Competing products can be the best prototypes for the own product. Analyse and compare several of them to find out good and bad properties.
- Set up usability goals: Because the usability goals for your project can stay in conflict with each other (see chapter 6.1.2 *Usability trade-offs* on page 58), the designers should weight the usability goals.

6.2.2 During the design phase

- Parallel design: Several different and independent designers work out preliminary designs. With this approach you can explore different design alternatives before settling to a single approach.
- Participatory design: A pool of representative users should be embedded in the design phase. These users can give hints and answer important questions during the design of the program but remember that users are not designers.
- Coordinate the total interface: This assures consistency across the product or even product families.
- Use guidelines: If there are guidelines for the operating system or product line you should use them to assure maximum consistency.
- Prototyping: Early usability evaluation is based on prototypes. There are two types of prototyping, horizontal and vertical prototyping. Horizontal prototyping keeps the features but eliminates depth of functionality. An example would be a menu bar with all options displayed but none is working. Vertical prototyping gives full functionality for a few features. An example for this would be an menu bar where only one entry is selectable, but fully functional.
- Interface Evaluation: The evaluation of the interface can be done by prototyping during the design or at the end with the working product.
- Iterative Design: Usability problems and opportunities that were found in the interface evaluation process lead to new versions of the interface. These new versions are again tested and improved afterwards.

6.2.3 After the design phase

Follow-up studies of installed systems: By testing the end version of the product at the customer, you may gather usability data for next versions. The end-version of the product can therefore be seen as a prototype for future products.

6.3 Usability guidelines

This chapter presents some basic guidelines for good user interfaces. The principles apply to practically any type of user interface.

6.3.1 Simple and natural dialogue

User interfaces should be as simple as possible. So the learnability and the ability to find something is improved. Too much information (or options) can distract the user from the primary information (or options). For example do not use too much space for the name of the program, the vendor's logo, or the version number. This information takes up much place without being needed all the time.

Furthermore, the interface should match the user's task in a natural way. This means that the user's concepts of the task and the user interface concepts should be as similar as possible. In addition to this, the amount of navigation in the interface should be minimized.

In other words information that will be used together should be displayed in relation (see the Gestalt rules for human perception). Information objects and operations should be ordered in the sequence the user will most effectively and productively use them.

6.3.2 Speak the user's language

- As far as possible present the information in the user's native language. You also have to translate non verbal elements like icons (see chapter 7.6 *Internationalization of icons* on page 73).
- At least the terminology in the user interface should be based on the user's language. For example a program that presents amounts of money should be customizable to show the amounts in the currency of the current user.
- Furthermore, you should not use words in non-standard meanings. Some users might not know all meanings of a word (especially if the used language is a foreign language for them).
- If the program is for a special user group, use the specialized terminology for their domain. For example a chat program should provide “emoticons” for the user to communicate (“emoticons” are icons that express the users feelings, like smilies).
- View interactions from the user's perspective. For example “You have turned off the virus protection” instead of “The override mode for the protection engine is now on” because in the latter example the user might be unsure if he or she turned off the protection or on.
- Do not force naming conventions or restrictions on objects named by the user. If this is not possible because of technical limitations provide constructive error messages and possible examples.
- Use mappings between the computer's display of information and the user's conceptual model of the information. For this task it is very important to know the user (see in this chapter before design phase – know the user). One way of achieving mappings are metaphors. For example use the metaphor of a book to present an online help. Another example is a trash bin for the operation “delete”.



Figure 65: Icon for the delete operation in Microsoft Windows XP

6.3.3 Minimize memory load

The human brain is better in recognizing something than recalling the same information from memory without help. That is because the human brain can be seen as a network of linked concepts (see chapter 2.2 *Cognition* on page 16 for more details). This phenomenon can also be seen by learning a foreign language. The passive vocabulary is always much larger than the active vocabulary. As a matter of fact we can think of the computer speaking a foreign language to us.

To minimize the memory load the computer should display dialogue elements. This can be done by using menus instead of a command line, by displaying default and example values for edit fields or by displaying the data format of input fields.

Generic commands can also minimize memory load. These commands make similar things happen in different circumstances and programs. So the user only has to learn a few commands and can use this knowledge with different data and different software. So the user can transfer his or her learned experience from one program to another. A typical example would be the copy and paste function in Microsoft Windows. This function can copy all kinds of objects (text, graphics,...) into a memory space called clipboard and later paste it into any application that supports copy and paste. So the learned copy and paste procedure with text from a word processor can be transferred to an imaging program for use with bitmaps for example.

6.3.4 Consistency

Users that know that the same command or the same action will always have the same effect, feel more confident in using the system. It encourages them to try out and explore new parts of the system.

The same information should be displayed in the same location on all screens and should be formatted equally. dialogue boxes should look the same and pop up in the same screen space.

Consistency becomes easier to achieve by following user interface standards. But following a standard is not sufficient to ensure consistency.

Furthermore, consistency is not only a question of screen design, but should also be considered for the task and the functional structure of the system.

6.3.5 Feedback

Always inform the user what is going on. The system should not only provide negative feedback (error messages) but also positive feedback. In addition to this, you should also provide partial feedback. This means that you should show information about the progress or in other words the current state. Another very important aspect is that the feedback should always be actual. For example do not leave the warning message "Printer out of paper" on the screen after the problem has been fixed.

Also try to give informative feedback in case of system failure. Many systems just stop to response or give out cryptic error messages with hex addresses of the memory location where the error occurred.

Generally speaking, try to give messages that inform the user what to do and what goes on. For example you should confirm a shortened input with the written out command (input of "dir" should be confirmed with something like "directory of c:\").

Response time limits

Feedback is very important if the system has a long response time for a certain operation. Miller in [46] and Card in [47] proposed the following advice regarding response time upper limits:

- 0.1 second limit: User feels that the system is reacting instantaneous. No feedback is required.
- 1.0 second limit: User will notice a delay but will not lose attention. he or she loses the feeling of operating directly on the data. Normally no feedback is required up to 1.0 second.
- 10 seconds limit: This is the limit for a user to keep focused on a dialogue. Feedback is required for operations in this period. For example some programs use the Microsoft Windows cursor of a sand watch to symbolize a working operation (see Figure 66).



Figure 66: Microsoft Windows sand watch icon

- longer than 10 seconds: User loses focus on the operation and wants to perform other tasks while waiting. The feedback should indicate when the operation is finished. If the operation is highly variable you should give detailed feedback what is going on and what is still to come. Microsoft Windows uses the bar in Figure 67 to give feedback about file operations going on.



Figure 67: Microsoft Windows copy feedback

6.3.6 Exits and undo

Always give the user easy to see and use exits out of every dialogue and the whole program. Furthermore, you should implement a generic undo command that can be used with all functions of the system. So the user can safely try out and explore new functions. This increases the learnability of the program and gives the user a feeling of being in control.

6.3.7 Shortcuts

Implement shortcuts for frequently used operations to speed up performance. Command keys, function keys, key combinations, or gestures with a mouse or pen can be used as an input for

accelerators. For example a word processor can speed up work immensely if the important functions can be accessed by key combinations. So the user does not have to put his or her hands from the keyboard to access the desired functions in the menu.

6.3.8 Use good error messages

Shneiderman put up four simple rules error messages should follow in [8]:

1. Use a clear language and avoid obscure codes in the error messages. The user should understand what went wrong. Keep the user group of the program in mind, because you have to write different error messages for different user groups. One example would be to display an easy understandable error message first (for novice users) and underneath include code for system managers.
2. Write the messages precise rather than vague or general. For example do not display “Can not open this document”, instead write “Can not open document1.txt. File not found in c:\docs.”
3. Constructively help the user to solve the problem. Give tips what the user has to do to correct the error. One useful way of constructive help is to guess what the user really meant and offer this as an option in the error message. For example spell-correction methods can be used when a textual input produced an error. Another example would be to change the input to fit the constraint of the input. When a name can only be seven characters long, offer the user the first seven input characters to use for example.
4. Be polite and do not blame the user for the error in the messages. Do not use uppercase letters because this looks like screaming to the user and avoid abusive terms like fatal, illegal, and so on.

Another important factor for usability is a good error recovery. For example when an error occurs in a long form all inputted data up to the error should not be lost.

Furthermore, error messages should be consistent. Always position the confirmation buttons on the same place and in the same order.

Use multilevel messages if you want to display much information. Short messages are fast to read and can be easily recognized. So you should provide two levels of information. One with the short information and the other level with the detailed information. The second level can for example be reached by a button with the text “more” on it.

The error message in Figure 68 is bad because it does not tell the user what went wrong and gives no hint how to prevent the error.



Figure 68: Example of a bad error message of Outlook Express.

6.3.9 Prevent errors

Even more desirable than good error messages is to avoid the error situations themselves.

- Selecting an option is always less error sensitive than typing in the desired value.
- Confirmation dialogues for critical function can reduce errors that make serious changes.
- Do not use confirmation dialogues too often because sequence errors can occur. This means that the user gets used to the dialogues and clicks them away without reading them. So a critical dialogue will not be read.
- Avoid different modes (different actions are available at different times) because they are a frequent source of error. If you have to use modes (because of too much complexity) show the current state clearly and distinctly to the user.
- Avoid too similar commands like similar looking icons or commands. Also think about lower and uppercase writing of commands. The best solution is not to use a case sensitive input or to check the “caps lock” key, if it is activated.
- Only show options that are available. For example “grey out” options that can not be used because some sort of data should be selected, so that the option can be performed on the selected data. To enhance learnability you could also give the user the information why the option is not usable (for example in a status text on the bottom of the screen). IBM's Aptiva Communication Center software brings up the error message in Figure 69 on selecting an empty dataset and pressing the “change” button. This error message could be prevented if the change button would not be showed (or would not be click-able) when an empty dataset is selected.



Figure 69: Error message of IBM's Aptiva Communication Center on selecting an empty dataset and pressing the “change” button.

6.3.10 Help and documentation

Help and documentation should not be needed to use the program but should supplement the user interface. It has two main purposes. To enable the user to acquire higher levels of expertise and to look up when they need help. That is why the text should be scan-able (see chapter 4.2 *Text* on page 30) and provide other means (like a good search in the online help or a glossary in the documentation) to enable a fast search.

6.4 Usability testing

6.4.1 Heuristic evaluation

Heuristic evaluation is examining an interface and judging its compliance with recognized usability principles (guidelines). Usually it is best to take a small set of expert evaluators. Nielsen stated in [3] on page 156 that about three to five evaluators seem reasonable. It is important that each evaluator inspects the interface alone and afterwards communicates with

the others. During the sessions they check the various dialogues and compare them with the list of usability guidelines. Since the testers are not using the system it is possible to perform a heuristic evaluation on a prototype of the system (also on paper based prototypes).

It is important to note that heuristic evaluation only points out the usability problems (that were found) and does not provides a systematic way to generate fixes.

All in all the research of Jeffries in [48] and Nielsen in [49] has confirmed that heuristic evaluations is a very efficient usability engineering method and has a good benefit-cost ratio.

6.4.2 Testing with users

Testing with real users is the most important usability method because it provides direct information on how the users use computers (often they are used in an other way than the designers planned) and what the exact problems are.

Reliability is one problem of user tests because of the individual differences of the test users. That is why you need more than ten test users to acquire good results (see Nielsen in [3] pages 166-169).

Validity is the second major problem of user tests. Validity means that the user test measures something of relevance to usability of real products in real use. Typical validity problems are wrong users or giving them the wrong tasks or not including time constraints and social influences.

Test goals and test plans

Before you start testing the product, you should clarify the purpose of the test and think about the following issues:

- What are the goals of the test?
- Where and when will the test take place?
- How long will each test session take?
- What hardware do I need for the test?
- What software is needed for the test?
- How should the state of the system look like at the beginning of the test?
- Who will be the experimenters?
- Who will be the test users?
- How many test users are needed?
- What test tasks will the user perform?
- What criteria signalizes the end of a user test?
- What user aids like a manual will be given to the user?
- To what extent will the users get help during the test?
- What data is going to be collected?
- How much test budget do I have?

When all this questions are answered you should perform pilot tests before starting the real usability tests. These pilot tests show severe problems in the test plan (like hardware problems, or wrong software versions,...).

Getting test users

The test users should be as representative as possible. Always consider all possible user groups (users age, education level,...).

In addition to this, there are two groups of users, the novice and the experts. To get expert users of a new system you have to train them before starting the test.

Choosing experimenters

As important as good test users are good experimenters with previous experience. An experimenter is the person who is in charge of running the usability test. Good experimenters find much more usability problems of the test users. In addition to the experience of the experimenters, they should have extensive knowledge of the application.

Test methods

- Thinking aloud: A test user in a user test uses the system while continuously thinking out loudly.
- Observations: Visit the users to observe them during their work with the system.
- Questionnaires and interviews: Ask the user how they use the system and what they like and dislike.
- Focus groups: About six to nine users are brought together to discuss new concepts and identify issues before the interface is designed.
- Logging: The computer automatically collects statistics about the use of the system. It can be used during user tests or after the system release.
- User feedback: The users give feedback on their problems on the installed system.
- Performance measurement: Group of test users perform a predefined set of tasks while collecting time and error rate.

Stages of testing

1. Preparation: Prepare the test room and equipment.
2. Introduction: Welcome the user and give a brief explanation.
3. The test itself.
4. Debriefing: Debrief and thank the user. User may fill in a satisfaction questionnaire.

7 Icon design

This chapter is about icon design. I will first introduce what an icon is and why to use icons. After this comes a small history of icon design. The remaining sub chapters are about how to design good icons.

The content of this chapter is based on [1] pages 125 – 127, [11], [9] page 46 and page 50, [2] pages 37 – 40 and pages 239 – 241, [4] page 270, [16], and [20].

7.1 What is an icon?

An icon is a symbolically coded visual element for understanding complex processes. It's content should be a meaningful symbol for as many users as possible. In other words icons are visual signs.

Another definition by S. Lee would be:

“a visual representation that looks like what it is”

The most popular icons are on-screen drawings representing folders, documents, a trash can, programs, and program functions.

There are various interaction techniques that can be applied on icons. Usually the main function of the icon (like starting a program) can be activated by clicking on it (for example per mouse on a computer). Sometimes the position of the icons can be changed. Sometimes the icons also support drag and drop operations. For example in Microsoft Windows the icons standing for files can be dragged to different folder icons. So the files represented by the icons are copied to the folder represented by the folder icon.

Designing a good icon takes more than a few minutes. For example Aaron Marcus, President of Aaron Marcus and Associates, Inc. (AM+A) wrote in [11]:

“In general, we calculated that it would take three to eight hours to design a single sign, depending upon its semiotic complexity. ... In fact, I recall that Digital Equipment Corporation did an in-house study of how much it costs to develop one sign in the late 1980s and found that reasonable costs, including all those involved in planning, analysing, designing, evaluating, and implementing, was \$2,000 per sign.”

Jakob Nielsen classified icons into three categories according to their graphic design ([2] page 239):

1. *“Resemblance icons: Depicting a physical object which the icon is intended to represent. Using a picture of an envelope to represent a file of electronic mail would be a resemblance icon.”*
2. *“Reference icons: Depicting some object which by reference or analogy might represent the concept the icon is intended to represent. For example, using a picture of a clamp to represent a file-compression utility (because it squeezes) would be a reference icon. It would be hard to come up with a good resemblance icon for compression except through use of a before-after combination of a large and a small document, but icons showing state changes are notoriously hard to understand. Reference icons are sometimes also called symbolic icons or index icons.”*
3. *“Arbitrary icons: Arbitrary shapes that only have meaning by convention. Traffic signs are often arbitrary icons and may form a good source of computer icons because of their fairly standardized international use. For*

example, a warning triangle might be used as the icon for a warning message. Obviously, arbitrary icons are the hardest for users to learn, unless they are so widely used that the convention becomes second nature. For example, it is doubtful that many people worry that the shape “?” is completely arbitrary as an indicator of a question.”

Another notation for these three categories would be iconic for resemblance icons, indexing for reference icons and symbolic for arbitrary icons.

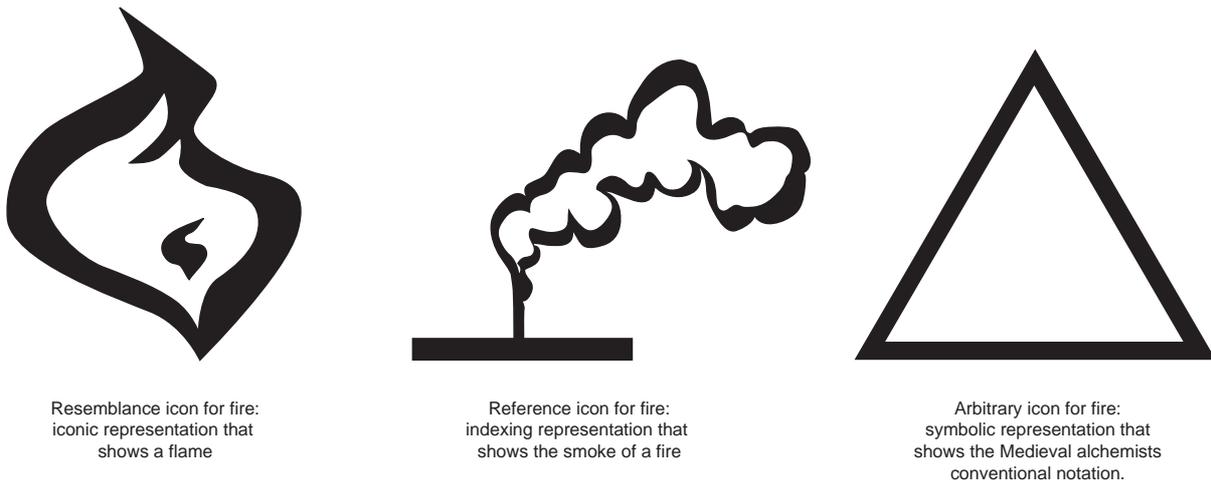


Figure 70: Three icons symbolizing fire (iconic, indexing and symbolic).

For best results, the same category should be used throughout an image set.

7.2 Why use icons?

An icon can be used everywhere a word label is used:

to activate menu, to perform actions, to select tools, to toggle between modes, to manipulate windows, to change states, to start programs, to represent files and directories and so on.

The use of icons has the following advantages:

- Fast recognition of the Icons: Images can be perceived faster than text. If the icons are adequately distinguishable, the search for a certain icon is very fast.
- Small spaced: The graphical representations can be much smaller than the adequate describing text.

Icon	Equivalent word label
	Scroll Page up
	Quit Program

Table 5: Icons taken from Microsoft Windows XP.

- Multilingual icons are possible: As long as no text is used and the image is meaningful to all users (consider cultural differences) the graphical icons can be multilingual. This means they can be used for different users from different countries without adapting them.
- No reading necessary

7.3 History of the icon

The first icons were on the sketchpad in 1962. These on-screen graphic objects represented constraints for the geometrical objects. Next followed the Flex machine built in 1967 at the University of Utah, that had squares representing programs and data. This was analog to today's folder icons. In 1974 the Xerox Alto had the first iconic representations and in 1981 the Xerox Star, the first personal computer with a real graphical user interface was sold. In 1983 Apple copied the ideas and brought the innovative Lisa (with the first movable icons) and later in 1984 the Apple Macintosh. With this computer the graphical user interfaces and icons got popular. In 1987 the Macintosh II presented colourful icons and in 1990 Microsoft's Windows 3.0 showed icons plastically. In 2001 Apple introduced photorealistic icons with Mac Os X. In the future, vector icons will be introduced (like proposed for the next generation of Windows, codenamed Longhorn). Table 6 shows a tabular summary of the most important user interfaces that make use of icons.

1945	Vannevar BUSH – “Hypertext”
1962	Douglas ENGELBART – “X-Y position Indicator”
1963	Ivan SUTHERLAND – “Sketchpad”, First graphical user interface (GUI)
1974	PARC – “Xerox Alto”, Iconic representation, [17]
1981	PARC – “Xerox Star”, First computer with real GUI (WIMP), [18]
1983	Apple – “LISA”, Introduced moveable icons, [19]
1984	Apple – “Macintosh”, GUI gets popular
1984	MIT – “X” (“X Windows”), UNIX GUI
1985	Microsoft – “Windows 1.0” (“Interface Manager”)
1987	Apple – “Macintosh II”, GUI gets coloured
1990	Microsoft – “Windows 3.0”, Graphic and vivid icons introduced
2001	Apple – “Mac Os X”, Photo realistic icons
2005	Microsoft - “Windows Codename Longhorn”, Vector based user interface

Table 6: Time line of user interfaces.

7.4 How to represent ideas graphically

Human beings are communicating through symbols. An example for a symbol would be the word “table”. We all know what is meant when we talk about a table but the physical objects referenced by the word table can be very different.

To communicate the meaning of an icon you have to use symbols. This symbols can be directly recognized as a real world object (resemblance icons). To visualize a complex meaning you have to use a collection of symbols to evoke the desired meaning in the viewers

thought. It is very important that every symbol has its strong and direct association with the desired meaning in the mind of the viewer.

To find the right symbols always think about the way the icon is seen. As seen in Figure 71 the user can recognize a real world object and then deduce its function or can directly associate the function with the icon. In addition to this, the experience of the user, the application, the context, and the known metaphors always contribute to the meaning of an icon. Because of these factors, the recognition is different with different users.

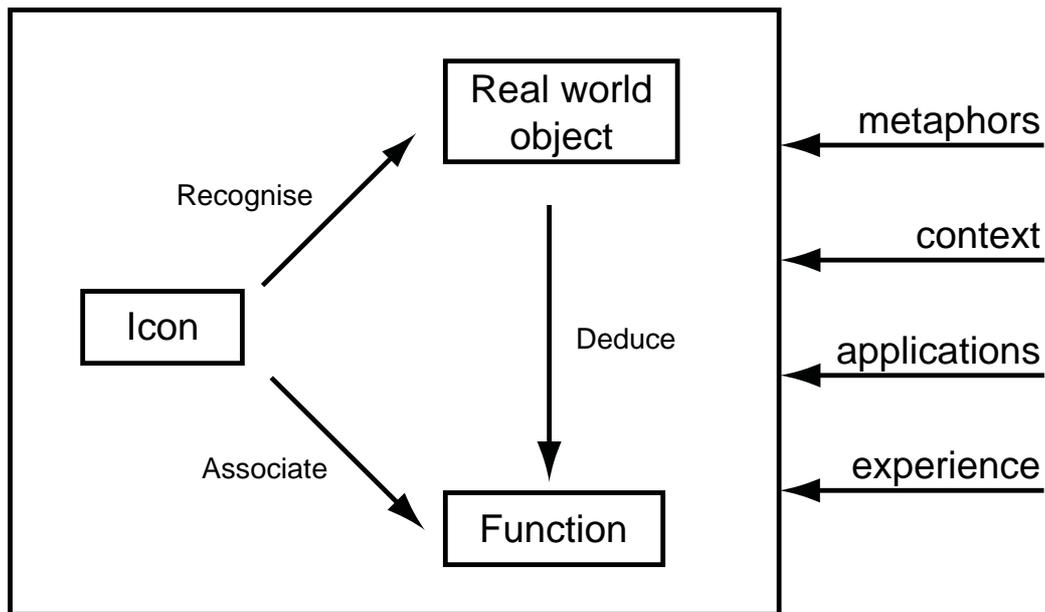


Figure 71: Cognition of an icon

7.5 Schematic versus precise

After you decided what the icon should represent, you must decide how to draw them. How detailed should the objects be represented? Appropriate details are important to recognize the object but detail can also distract and clutter. So how much detail is needed?

Include that much details necessary for the icon to be recognized easily. Every detail too much can make the image harder to recognize.

The structural theories of perception (see [2] Chapter 7 Pages 249 to 252) state that simplified views are easier to read. Other studies show that time is required for detailed information to be perceived. So, simplified line drawings are most appropriate only where rapid responses are required. Furthermore, schematic representations are better in representing a broader class of objects instead of one of its instances. The problem with too simple representations is that they can be mistaken. On the other hand, the problem with too detailed images is that they can be identified as the object itself and not as the representamen. In Figure 72 you can see five icons representing a tool. The images vary from a precise photorealistic image to a schematic silhouette.

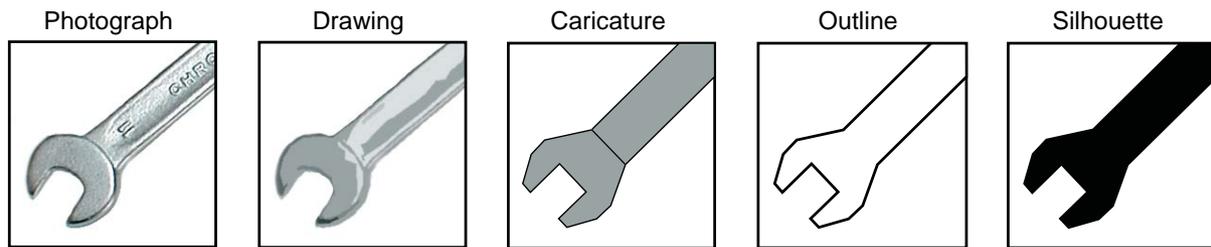


Figure 72: Above you can see various icons representing a tool (precise to schematic from left to right).

7.6 Internationalization of icons

At first sight the use of icons seems to solve the problem of internationalization. This is not so because icons and colour connotations are not necessarily universal. For example the colour red stands in China for luck and in European countries for attention. Another example would be a mailbox icon in an electronic mail application. Actually mailboxes look very different in different countries and that is why an icon showing an American mailbox can be hard to recognize for European users. As we can see physical objects often have different designs over the globe. So resemblance icons can be difficult to recognize in many countries. Reference and arbitrary icons are even worse in internationalization. For example the Red Cross logo (Figure 73) was recognized by only thirteen percent in Japan(see [21]). So the designer should think about the target users before designing the icon.

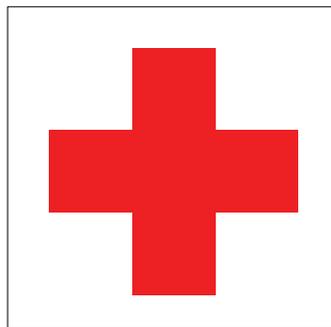


Figure 73: Red Cross logo standing for first aid..

If text is used in the icon the designers should leave enough space for longer translations. Not only the horizontal space but also the vertical space should be considered because for example Chinese signs need to be higher to be recognized clearly. See [2] Chapter 9.3 Page 247 for a complete set of guidelines for internationalization.

Generally speaking, the designer should always choose the lowest common denominator in respect to internalization.

7.7 Creating icons

In this section I will give some instructions, how to design an icon based on the Microsoft Style Guide [15].

7.7.1 Conceptualize

Choose the symbols you want to use. Use established concepts from similar programs or the operating system. Use no more than two objects and a relation between them. Otherwise it would be too hard and time consuming to recognize. Think about usability aspects like how will the icon change when clicked (if the operating system isn't doing this for you). Decide the right angle and grouping of the objects shown in the icon. In Figure 74 you can see a perspective grid that is used for the default icons of Windows XP. You can also make an animated icon but consider that animations catch the users attention even if he or she does not want to and this can be annoying (animated icons are widely used on the web).

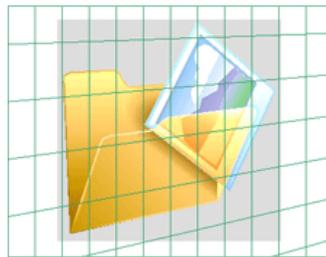


Figure 74: Perspective grid for Windows XP icons. Image taken from [15].

Finally, you should refine the image through progressive abstraction until your icon is easily and quickly recognizable. This can be done by simplifying, removing extraneous detail, and regularizing irregular elements. For a more complete guidance how to improve the quality of your images see [6] pages 199-212.

7.7.2 Illustrate

Now illustrate the image using a vector painting program. Export the icon in the needed sizes (Microsoft Windows XP for example supports 48×48 , 32×32 , 24×24 , and 16×16 pixels). Now add pixel effects (like drop shadow) with a pixel based painting program. You can also change the size after the application of the pixel effects. Finally, reduce the colour depth if necessary.

7.7.3 Create the icon file

Every operating system has its own specification for icon files. Microsoft Windows for example uses .ico files, Mac OS X .icns files and KDE/Gnome takes .png files.

7.8 Usability testing of icons

A classical study of icon usability is described in [14]. In this test four different sets of icons were designed for the graphical user interface of the Xerox Star. All icons were tested for

- Intuitiveness: Show every icon to the user and ask them about their opinion.
- Understandability of sets of icons: The users were shown a set of icons and a table of descriptions of program-functions. Then the users had to find the best match for each description. The amount of correctly described icons was noted.
- Efficiency: The time it takes for a user to find the correct icon to a given description.
- Subjective satisfaction: Users had to rate each icon or choose their favourite out of a given set.

Furthermore, the icons should be tested for usability. Is there an optical or acoustical response on clicking or dragging the icon? How can I activate the icons purpose?
For more information about usability testing see [3].

8 Menu Design

This chapter is mainly based on [1], [4] pages 268-269 and [9].

8.1 What is a menu?

A menu is a displayed list of options, which a user can select to enable actions. In comparison to command driven systems, menu systems are better because they reduce memorization of commands, reduce training and structure the user's decision making.

Usually the options in the menus are labelled by text or icons. There is also the possibility to use icons and text in the menu. If more than a few options are used, the menu has to be organized hierarchically. The sub structures are usually organized in a list form. Another way of organizing the options is the pie form. See Figure 75 for an example of a pie form menu.

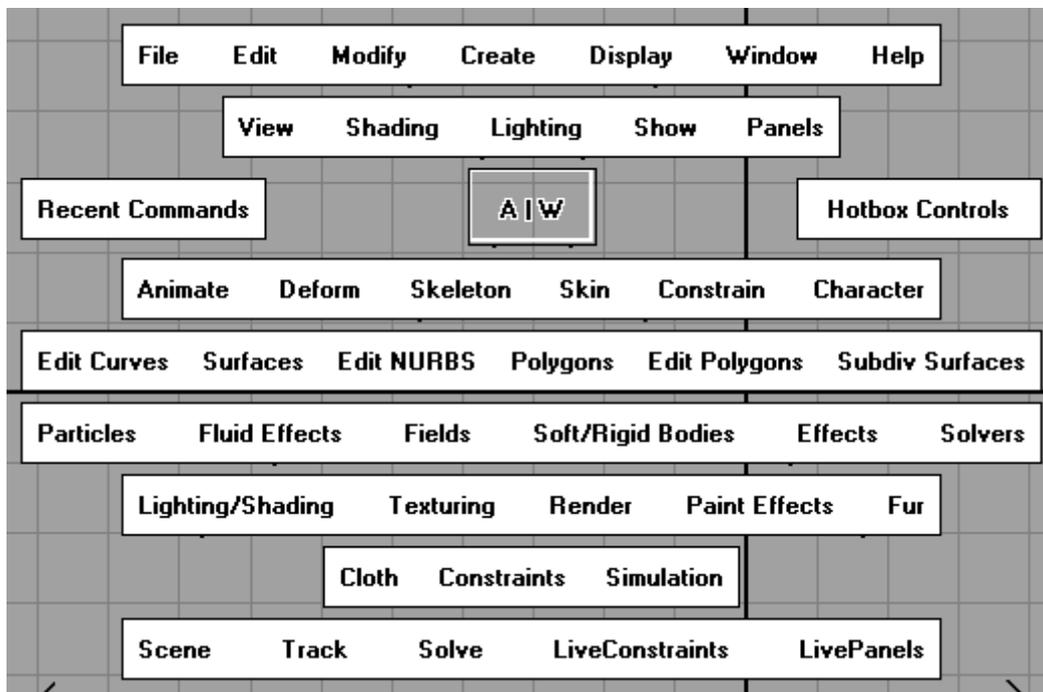


Figure 75: Pie form menu in Maya from AliasWavefront.

In [23] pie form menus are compared against with linear menus.

For expert users the most menus can be accessed by shortcuts. For example the user can save the document in OpenOffice.org 1.1.0 by pressing “Ctrl” and “s” instead of using the menu item “File” and then “Save”.

8.2 Why use menus?

In addition to the advantages of menus over command driven systems, menus have the following qualities:

- Structuring of options: If the options are structured logically, the user is able to find the wanted entry much faster.
- Space saving: Hierarchical menus save space in comparison to all the options displayed on the screen.

8.3 Interactions with menus

In a usual WIMP (Windows Icons Menu Pointer) system the menus are used by pointing device (usually the mouse). The primary activation leads to the invocation of the assigned program function or in hierarchical menus the displaying of the sub menu. In some programs like Microsoft Office 2000 the menu entries can be fully customized (ordered, deleted and added). The drawbacks of this feature are:

- Novice users may reorder or even delete the menu entries unintentional. This can lead to the problem, that they may not be able to find the option again.
- Advanced users know exactly where to find often used program options in the menu. So reordering would destroy their mind map of the menu structure.
- With each new version of the used software the menu would have to be customized again.

8.4 History of the menus

The first menus were introduced on line-oriented interfaces. The user could choose from a menu by typing an indication of the desired option on the command line. This can be comparable to the interaction of systems navigated by a telephone keyboard (like a mailbox). With the introduction of full-screen systems the menus were widely used. In nowadays WIMP (Windows Icons Menu Pointer) systems nearly every program makes extensive use of menus.

8.5 Creating menus

1. Write down all the options you need.
2. Think about good names for the options and(or) if you want to use icons draw the proper images.
3. Now form a hierarchical tree where the leave nodes are the options. It is better to overload a level slightly than to split it up. That means the less deep the tree gets the better it is.
4. For the most used options create shortcuts that can be accessed by keyboard commands.

9 Evaluating three user interfaces with the guidelines

9.1 Evaluating the website of IDEO

In the following chapter I will analyse the website of IDEO (www.ideo.com) [68] with the guidelines presented so far. The evaluation was done by conducting a heuristic evaluation (see chapter 6.4.1 *Heuristic evaluation* on page 66).

9.1.1 What is IDEO?

IDEO is a company that designs products, services, environments, and digital experiences. Their webpage gives information about what IDEO is and shows profiles of its work.

9.1.2 Why IDEO?

I chose the webpage from IDEO because I find it optically appealing and it won the Webby Business Award 2003 (see [67]) in the category creative services. The Webby Awards are presented by The International Academy of Digital Arts and Sciences.

The judges statement, why the site won, was:

The IDEO site achieves two things with great effect: One, excellent branding presence – effectively communicating what IDEO is about as a group of highly creative thinkers and pragmatic problem solvers; Two, offering in-depth profiles of its work in one of the most extensive online portfolios in the industry, enabling visitors and/or prospects to drill deep into the achievements of this organization. The new site benefits the company as a business development tool, a media center and a reference guide. By providing printer-friendly access to the company's work and press, including full-color PDF files, the company is now able to provide high-quality information to distant people quickly and easily, decreasing its expenses on reprint charges and postage.

9.1.3 Evaluation

I started the heuristic evaluation by visiting all pages of the website. During this, I searched for errors and good solutions. This took about an hour. After this, I took some representative screenshots and analysed them for a grid structure. Finally, I took each guideline and tried to find out if the guideline was fulfilled or not. All in all, the analysis took about three hours.

In the following section I will present the results of the analysis with the guidelines.

General design guidelines

Use Gestalt laws for relationships

The Gestalt law proximity is used in various ways on the pages of IDEO. For example on the starting page (see Figure 76) it is used for connecting the images. Although there are four different photos, they are perceived as one central bar. Another example is the headline “Teams” on the “About Us” page (Figure 77). There is only a small distance to the menu and therefore it is perceived as belonging to it.

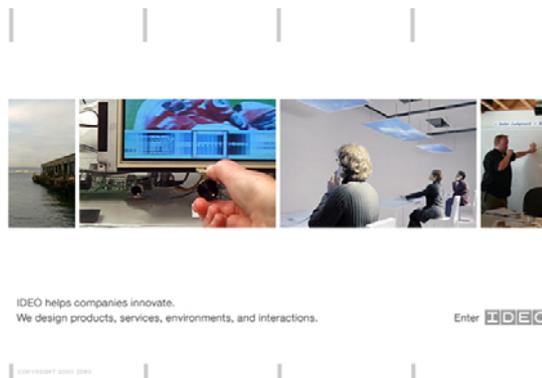


Figure 76: Starting page of IDEO.



Figure 77: Sub menu on "About Us" page.

The Gestalt law symmetry is used to connect the top and bottom navigation areas. Small grey vertical lines are positioned symmetrically on the top and on the bottom area. They part the white space and are used for links (except on the starting page).

Some pages like "Contact Us" (Figure 78) make use of the Gestalt law relative sizes. The small sized text areas are perceived as objects whereas the background picture is seen as background.

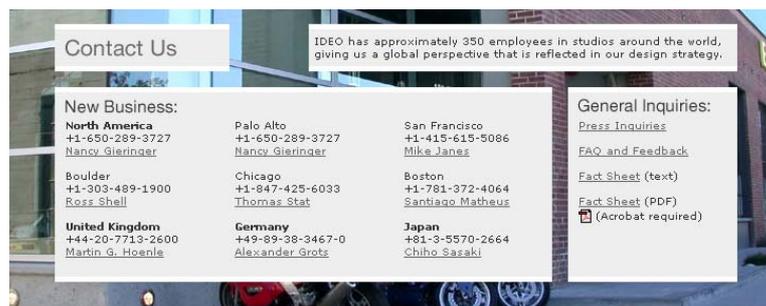


Figure 78: The small sized text areas are accentuated in respect to the background figure.

Use a grid based structure for designing multiple pages

When analysing the structure of the web pages, it is clear that some kind of grid was used to maintain a coherent style. But it is remarkable that on some pages some elements are not aligned the same way. For example on the "Culture" page shown in Figure 79 the lower grey navigation bars are not aligned with the upper ones (although they are on some other pages). Another example would be the headline (shown in Figure 77 on top of the menu) that is sometimes positioned a bit higher in the content area. This abnormalities could be corrected to achieve a better balance of the figure.

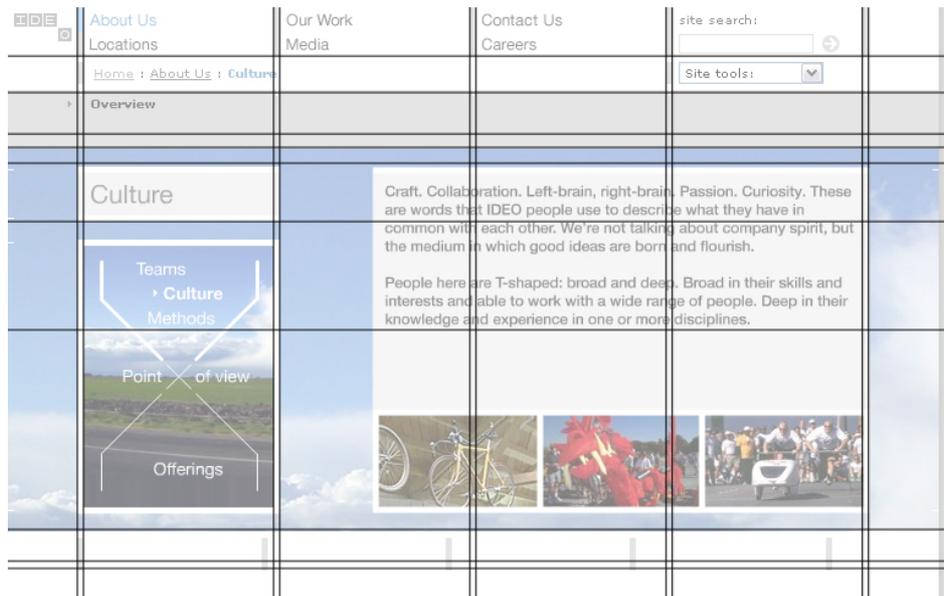


Figure 79: Superimposing this grid over all pages, shows that there are some minor deviants. In this picture we can see, that the lower grey navigation bars are not aligned with the upper ones (although they are on some other pages).

Highlight important elements

In the navigation area, on top of the screen, the currently shown site is highlighted in blue. Furthermore, when navigating with the mouse over a menu entry, the corresponding name is also highlighted in the same blue colour. Figure 80 shows the navigating area on the “Media” page (note the blue text “Media” in the second row).



Figure 80: Selected and hovered menu items are highlighted in blue.

Use layering to display overlapping information

Layering is used in various ways across the site of IDEO. For example on the main screen, layering is used to label a link on a background image with text on it (Figure 81). Another example is on the locations screen. City names where an office is located, are superimposed on the image of a world map (Figure 82). This way the user can easily find an office near him or her, without going through a list of all office addresses.



Figure 81: On the main screen, layering is used for button labelling on an image with text on it.



Figure 82: On the locations screen, layering is used to show the positions of each office.

Grouping into functional areas

Every page, except the starting page, is structured into a menu bar on top. The area with the information is located in the middle. The label of each page is located in the upper left area of the information area. Finally, another navigation area is located on the bottom of the screen. Each section can be easily distinguished by different background colours or structuring.

Keep controls in a separate area

There are three areas on the IDEO website that are used for navigation (except on the starting page). On top is the main navigation area (shown in Figure 83) with the links to the homepage (the icon), to “About Us”, to “Locations”, to “Our Work”, to “Media”, to “Contact Us”, to “Careers”, to the search, and to the site tools.



Figure 83: Top navigation area.

In this area is also a hierarchical representation that shows the current location and links to all pages that lie in the upper hierarchical levels. In Figure 84 this hierarchy is shown for the page “Prototyping”. It can be reached by navigating from the homepage to “About Us”, then to “Methods”, and finally to the “Prototyping” page. The links are visually separated by colons.



Figure 84: Hierarchical representation of the current location.

The second area, that is used for navigation on the pages about IDEOs work, is located on the bottom. The links are placed between the vertical lines that are always shown (Figure 85).



Figure 85: Bottom navigation area on “Our Work” pages.

Use indents to indicate hierarchies in your elements

Indents are used in the hierarchical representation in the top navigation area. The whole site can be seen as a tree where every node is a page. The hierarchical representation shows links to every node from the shown page to the root node.

Balance

Light and dark areas are distributed evenly across every screen. Furthermore, the site uses consistent internal margins to create a sense of balance. Figure 86 shows a schematic representation of the light and dark areas on the main page.

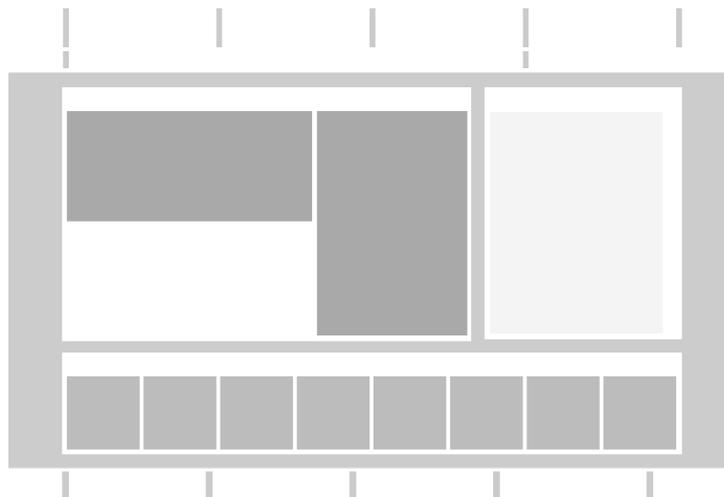


Figure 86: Light and dark areas are distributed evenly across the screen on the main page.

Consistency in all object styles

Consistency is achieved by using only rectangular object shapes. Figure 86 shows schematic representation of the main page. There you can see that each element has a rectangular shape.

Keep screens simple

By dividing the screen into the navigation area on top and the content under it, a simple structure is achieved. On every screen only one topic is presented. In my opinion the site supports immediate use.

Avoid screens with text alone

There are no screens with text alone and therefore this guideline is fully fulfilled.

Use specific guidelines for the system you develop for

This guideline is hard to verify by only analysing the finished product. As the IDEO site is implemented in HTML and Flash, specific Web Guidelines should have been considered in the development.

Text guidelines

Contrast

Long text pieces are always printed in black on white background ensuring maximum contrast. Links and headings are shown in blue, orange, and grey on white or grey background. Although even grey text on grey background is used, the contrast is adequate in every combination. Figure 87 shows a text segment from the website of IDEO.

PopShots for Polaroid

Disposable instant camera

 [Printer-friendly version](#)

With PopShots, Polaroid offers the first single-use instant camera. PopShots combines the immediate satisfaction of instant photography with the ease of single-use cameras. The package encourages the user to return the camera for recycling by including a postage-paid return envelope, a cash refund, and a chance to win larger prizes.

IDEO's multidisciplinary team of industrial designers, mechanical engineers, and human factors specialists adopted an upside-down internal architecture that creates a perception of small size, and developed the 1-2-3 operational graphics and color-coded interface features to walk the user through the picture-taking process. In addition, the form reflects a qualitative study IDEO performed to understand how users in the target segment defined "cool."

Figure 87: Text segment taken from the IDEO page presenting one of their work.

Type colour

Colour is only used for highlighting a link and therefore text was designed in respect to this guideline.

Font family

All text implemented in HTML is displayed in the font family Verdana. Displaying the page for example with the Microsoft Internet Explorer under Microsoft Windows XP shows the text using the True Type font Arial. Furthermore, headings and the top links are shown as antialiased images in a very similar font to Arial. Both fonts are easily recognizable and familiar to the users.

Do not use too many different tpestyles

The font family Verdana is the only one used to display text. The headings and links are displayed as a graphic in a similar font. Both fonts look very similar and match each other.

Use serif fonts for long texts

All texts are written in the font family Verdana, a sans-serif font. As only relative small text segments are displayed, the sans-serif font has no drawback to serif fonts.

Use portable tpestyles

The fonts are either images or defined in the stylesheet as font family Verdana, leading to very portable tpestyles.

Typesize appropriate for the audience and amount of reading

The typesize on the whole site is rather small but still adequately legible. A small typesize looks aesthetically more pleasing because the text lines look more like a whole structure leading to more balance. Sadly, the site does not support the change of the text size (for example per browser).

Use both lower- and uppercase text

The text is written in mixed case providing a good readability.

Keep line lengths reasonable

All line lengths are adapted to the amount of text. If more text is displayed the line length is much larger than when only displaying short sentences.

Generally, use single spacing between lines of text

The whole site uses single spacing between the lines of text.

Use of justification

All text is displayed in left justification, leading to good readability.

Font: wordspacing, letterspacing

Wordspacing and letterspacing is not changed from the standard and therefore ensures a good readability.

Use headings as organizers

Headings are only used at the beginning of a new topic, but not as organizers.

Use paragraphs to organize the information in bite sizes

Paragraphs are used to organize the information in long texts. This makes it easier to scan over the information and jump over junks of information that are not interesting for the reader.

Use directive cues to emphasize important terms or ideas

Directive cues are not used but could help in making the text more scan-able and to emphasize important terms or ideas.

Set up comparison – contrast situations in a side-by-side columnar arrangement

On the first page where the work of IDEO is shown (labelled “Our Work”), images of their best work is placed next to each other. Tables to compare information are not used by IDEO.

Writing for the web

As I analyse the website from IDEO, the following guidelines about writing on the web can be used for this analysis.

Text should be scan-able

Small portions of text are used on the IDEO webpages. This leads to a scan-able text. To improve this scan-ability more headings and directive cues could be inserted in long text passages.

Users want to get their information quickly

The inverted pyramid style is not used in larger text pieces. But the text pieces are rather short and well structured, so that getting the right information is no problem.

Credibility is very important

The tasteful and professional design adds much to the credibility of the site. Furthermore, IDEO is a well known design company and therefore the credibility is also high. The site also makes use of external links (for example to each product they designed) which increases the credibility some more.

Graphics and text should complement one another

All graphics used on the website of IDEO are in some way or another related to the text they are next to. For example on the portfolio pages the top graphic always shows a product photo that is linked to the description of the product.

Hypertext is liked

Links are used throughout the pages of IDEO and therefore this guideline is fully fulfilled.

Guidelines for graphics

Use graphics for organization of functional areas

Boxes and borders are used to separate different areas on the screen.

Images versus words

On the page where the location of each office is presented, IDEO makes use from the fact that localization information is better conveyed using images. This is done by positioning the names of the offices on their geographic position on a world map.

Use contrasts to differentiate elements

The sub menu is differentiated from the main menu above by using another background colour (white versus grey).

Visual integration requires equal scale and visual weight

The IDEO logo (one variant is shown in Figure 88) appears as a unified composition because it uses equal scale, symmetry and visual weight in the design elements.



Figure 88: One variant of the IDEO logo.

Optical adjustments for human vision

The fonts used by the different browsers are optically adjusted. So this guideline is automatically fulfilled by using standard fonts.

Use animations carefully

The only animation, that is used on the IDEO website, is the logo in the left upper corner of every page (except the starting page). The animation is slow enough that it does not distract too much.

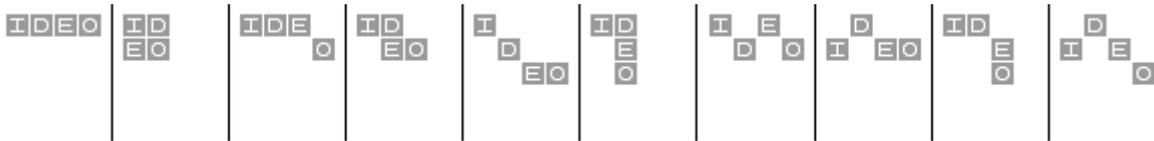


Figure 89: Some frames of the animation that switches between different variants of the IDEO logo.

Consider colour blind people

The site does not show differences only by colouring them differently. Figure 90 shows a black and white image of the main page and, as you can see, every object can be clearly differentiated.

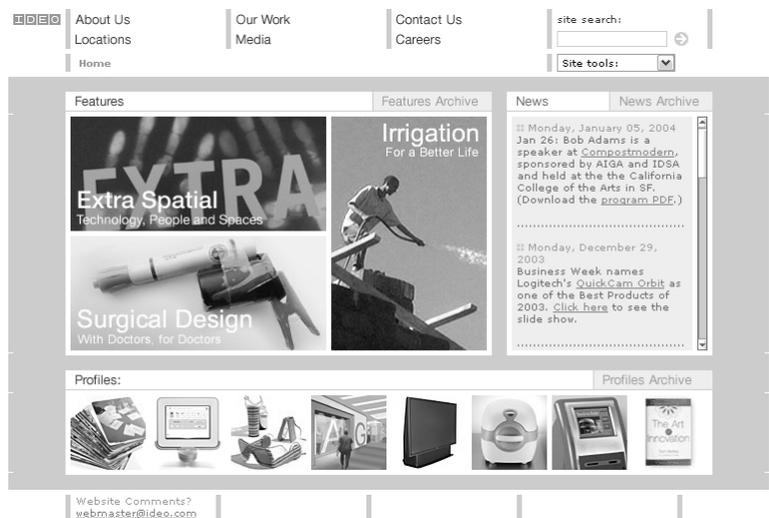


Figure 90: Greyscale image of the main page.

Do not display fine detail only with chromatic differences

See “Consider colour blind people” above.

Do not display motion only with chromatic differences

No animation that uses motion is used on the website of IDEO.

Do not display an objects shape only with chromatic differences

No three dimensional object is shaded by a purely chromatic gradient.

Consider brightness contrast

The website does not make use from the identification of a colour and therefore this guideline does not apply.

Use distinct colours for labelling

No colour labelling is used on the website.

Do not use red text on blue background and vice versa

This colour combination is not used on the website.

Colours have a stronger effect on a dark background

This guideline was not applied on this website

Do not use blue for fine details

Blue is used to highlight the menu items. It could be argued that the font is large enough not to rely on identifying fine detail for recognizing the letters.

Colour sequences for maps

No maps are used on the website of IDEO.

Colour affections

Grey is the dominant colour that is used across the web pages.

Use red light to preserve dark adoption

Dark adoption is not needed for websites and therefore this guideline does not apply here.

Psychology of Colour

This guideline should help on which colours to use during the design phase.

Usability guidelines

Simple and natural dialogue

The user interface is relative simple because of the central navigation area. The structure of the site is relatively intuitive and minimizes the amount of navigation. Furthermore, the IDEO logo does not take too much space.

Speak the user's language

The telephone numbers are printed including the appropriate area code thus making it easier to reach each office from any country around the world. Currencies or length measurements are not used on the website thus making it unnecessary to implement some sort of conversion.

Minimize memory load

The website is designed in such a way, that it is not necessary to remember some things.

Consistency

The controls and the content are always in the same area which is positive in respect to consistency. One thing that is not consistent across the screen is that some links are not underlined (in the bottom navigation area for example) and some are.

Feedback

Feedback is provided on the website in two ways. When moving the cursor over a link it changes its appearance. In the main navigation area, the text turns its colour to blue and other links are either underlined or change its colour.

During a flash animation is loaded the information "loading..." is printed on the screen.

Response time limits

The IDEO webpage is located on a fast server and therefore the response times are very good.

Exits and undo

As every browser has the option to go to the last visited page and quit the browser at any time, this guideline is fulfilled automatically.

Shortcuts

Shortcuts are also implemented in the browser software.

Use Good Error Messages

The first sort of error messages I have found was the 404 web error (Figure 91). This means that a file on the server was requested but could not be found. The site explains each error message but does not give hints how to reach the requested site. The menu structure is displayed (including the search button) so that the navigation can continue from this error page on. A possible improvement would be to spell check the input of the name of the page and give links to similar pages.

In the email dialogue page the second type of error messages are provided. If no recipient or sender was typed in, an error message appears (Figure 92). These error messages are a bit short but they move the cursor to the appropriate field to remedy the error.

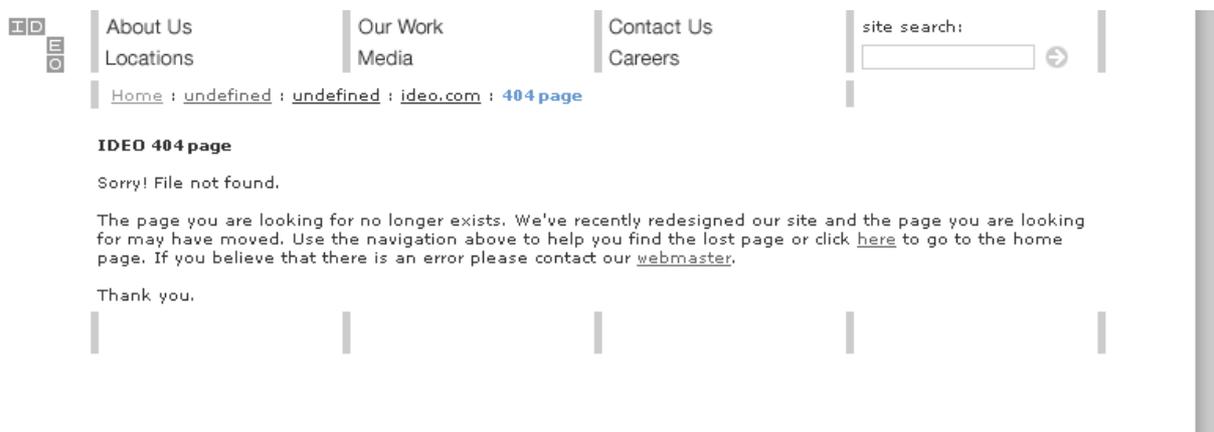


Figure 91: Error message of ideo.com

Prevent errors

The website does not try to prevent errors. The script, for example, does not check if the email address is correct but just checks if something was entered in the appropriate field.

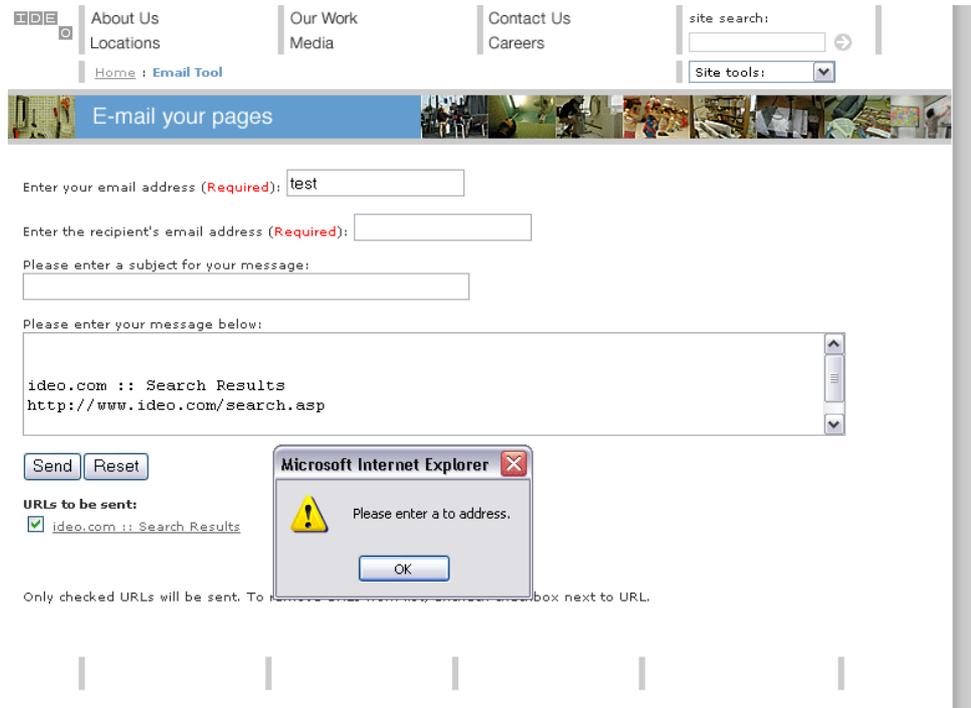


Figure 92: Error message on entering no recipient in the email page.

Help and Documentation

No help is available on the use of the webpage. A frequently asked question section is available on the homepage but it does not give help on how to use the homepage.

9.1.4 Summary

Finally, I think the website of IDEO is optically very pleasing and good to use. The navigation and the grid based structuring is well done. Furthermore, the information is presented in a optical pleasing and easy to read style.

The page fulfils nearly all guidelines I presented in this thesis. There are only some small improvements that could be made:

- The readability of the pages could be improved by using directive cues and more headlines in the long text sections. Furthermore, the inverted pyramid writing style could be used to improve the readability.
- A black background could be used, for making the colours appear more vibrating and gaudy. The drawback would be the change in the balance of the screen, and therefore the need for a complete redesign.
- The blue highlight of the text in the main menu could be changed to another colour (for example green or red), because blue is badly resolved in the human eye.
- Not every link is underlined. Web pages should generally underline all links, because this is an original HTML feature. Therefore, underlined links can be easier identified. At least all links should be formatted equally to ensure consistency. I think this is the most important improvement.
- To improve the error behaviour of the site the following improvements could be made. If a page was accessed, that does not exist (normally due to an old link or because the name of

the page was misspelled), the error page should guess what page was meant (for example by spellchecking). This guesses could be shown as a list of links. Furthermore, the error handling on the email form could be improved by checking if the mail address of the receiver and the sender are existing.

9.2 Evaluating the website of “Gasthof Ramingsteinerhof-Durigon”

The second website I will analyse is from the hotel “Gasthof Ramingsteinerhof-Durigon” [70]. The evaluation was done by conducting a heuristic evaluation (see chapter 6.4.1 *Heuristic evaluation* on page 66).

9.2.1 What is “Gasthof Ramingsteinerhof-Durigon”?

This hotel is located in Ramingstein, Salzburg, Austria. The homepage should present the hotel, its location, and how to get there. Furthermore, they have two pages with special offers. Figure 93 shows the four main pages from the website.

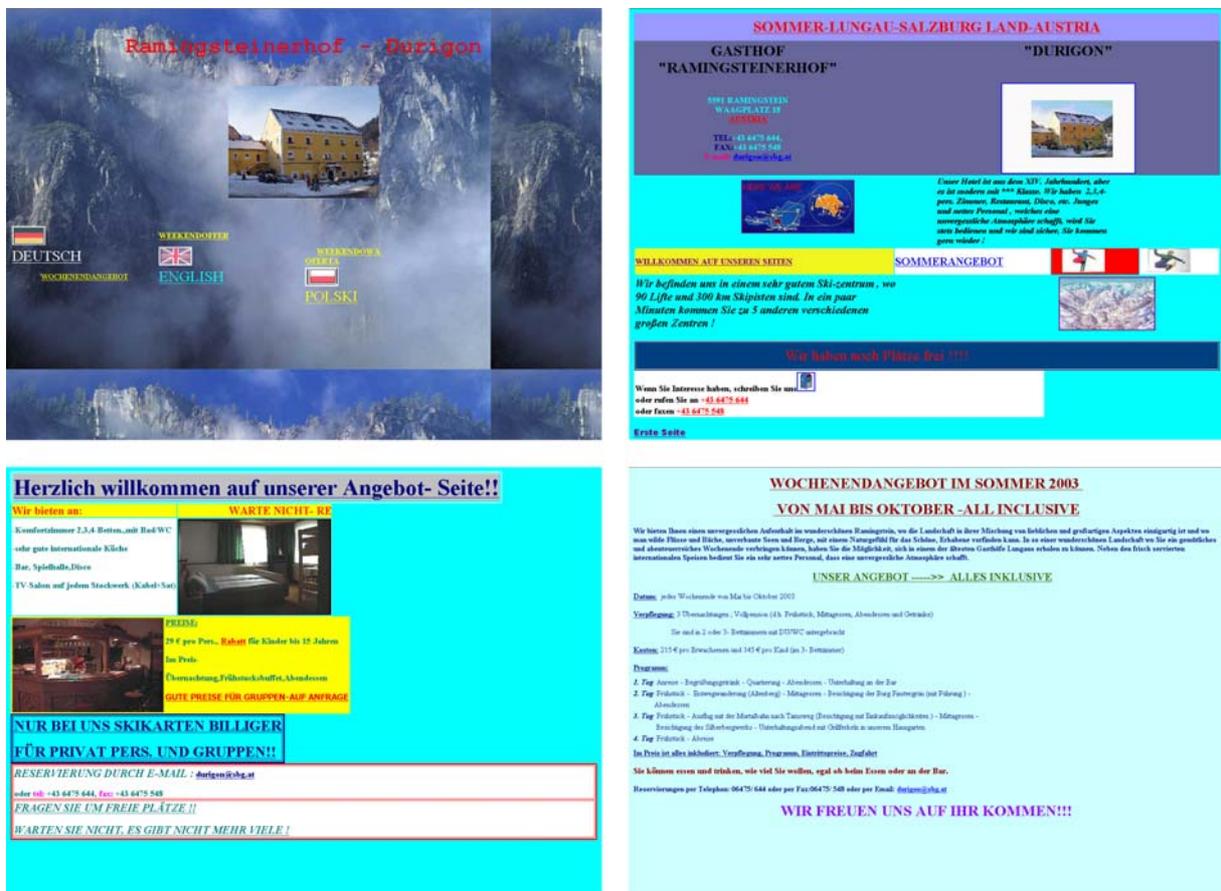


Figure 93: The four main pages from the website of "Gasthof Ramingsteinerhof".

9.2.2 Why “Gasthof Ramingsteinerhof-Durigon”?

I chose the website from the hotel “Gasthof Ramingsteinerhof” because it was listed on the webpage www.muellseite.de [69] for having a very bad design.

My opinion about the site is, that the pages are hard to read and hard to use. Furthermore, they are not visually pleasing.

9.2.3 Evaluation

I started the heuristic evaluation by visiting all pages of the website. During this, I searched for errors and good solutions. After this, I took some representative screenshots and analysed them for a grid structure. Then, I took each guideline and tried to find out if the guideline was fulfilled or not. All in all, the analysis took about three hours.

In the following section I will present the results of the analysis with the guidelines.

General design guidelines

Use Gestalt laws for relationships

The Gestalt law proximity is used to link the flags with the two links on the starting page (Figure 94).



Figure 94: In this dialogue the user can choose the appropriate language for the main pages.

On the other hand, on the main page the elements are often only linked by their semantic coherence. This is because the design is not fixed in the breadth and adapts to the browser window. In Figure 96 the images are next to the corresponding text because the browser was adjusted to a small breadth. In Figure 95 the width of the browser window was kept at a standard value, leading to too much space between text and figures (and thus breaking the Gestalt law proximity).



Figure 95: Main page where text and pictures are too far apart.



Figure 96: Main page with text and pictures next to each other.

Use a grid based structure for designing multiple pages

No grid was used to design the different pages because each page has a different layout. That's why the user has to analyse each page.

Highlight important elements

Too much is highlighted with different styles. This leads to visual clutter. For example on the main page (Figure 95) five different colours, uppercase mode, and different sizes are used for the text elements.

Use layering to display overlapping information

Layering is used on the ski-map (see Figure 97) to show the different ski tracks and the position of the hotel on the map.

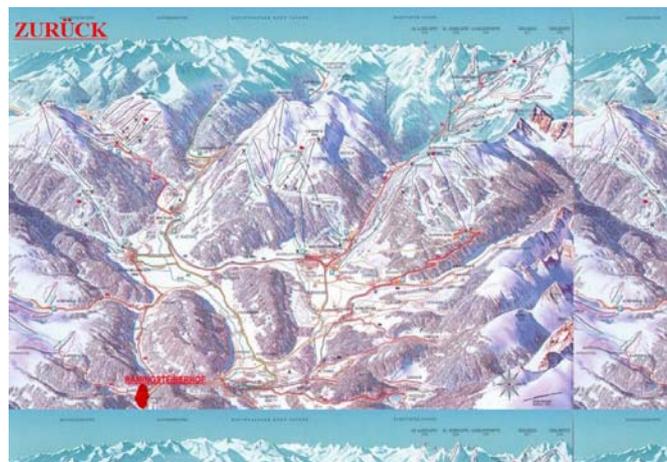


Figure 97: Ski map where the location of the hotel is shown by using layering.

Grouping into functional areas

No grouping can be perceived on the different pages.

Keep controls in a separate area

The controls (links in this case) are distributed across the screen.

Use indents to indicate hierarchies in your elements

No hierarchies are used on the pages and therefore this rule does not apply.

Balance

Colours and light and dark areas are not distributed evenly on the screen. Furthermore, the internal margins are not equal.



Figure 98: Schematic image, showing the distribution of bright and dark areas on the main screen.

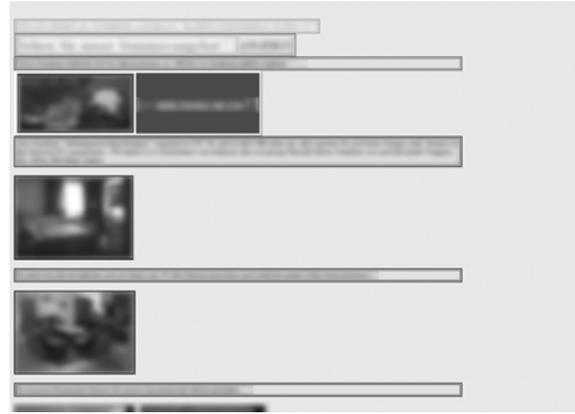


Figure 99: Schematic image, showing the distribution of bright and dark areas on a sub page.

Consistency in all object styles

Only rectangular shapes are used on the different pages.

Keep screens simple

The different pages of the hotel are overloaded and use too much visual elements like borders and different colours. This leads to the distraction of the reader.

Avoid screens with text alone

There are no screens with text alone and therefore this guideline is fully fulfilled.

Use specific guidelines for the system you develop for

This guideline is hard to verify by only analysing the finished product. As the website is implemented in HTML, specific Web Guidelines should have been considered in the development.

Text guidelines

Contrast

Although various colour combinations are used for text, the contrast is always sufficient.

Type colour

Various colour combinations are used for text and background, limiting the maximum contrast and leading to visual clutter and bad readability.

Font family

Two fonts are used, “Old English Text MT” and “Times New Roman”. Both deliver a good type face but the main part is written in italic and is therefore harder to read.

Do not use too many different tpestyles

Only two different fonts are used but differently coloured and sized.

Use serif fonts for long texts

The serif font “Times New Roman” is used for long texts.

Use portable typestyles

The font used for the header on the starting page (Old English Text MT) may not be installed at all operating systems.

Typesize appropriate for the audience and amount of reading

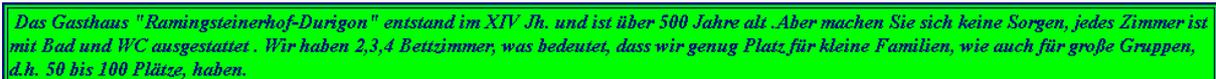
The typesize is large enough for the audience and even sufficient for older people. The typesize can be changed in the browser for individual adjustment.

Use both lower- and uppercase text

Uppercase text is used to emphasize important text parts. Sometimes longer sentences are also written in uppercase letters and therefore hard to read.

Keep line lengths reasonable

Some text sections have a long line lengths and this makes them hard to read. For example in Figure 100 a text section from a sub page is displayed. The line lengths is too long making it easy to loose track during reading the text.



Das Gasthaus "Ramingerhof-Durigon" entstand im XIV Jh. und ist über 500 Jahre alt. Aber machen Sie sich keine Sorgen, jedes Zimmer ist mit Bad und WC ausgestattet. Wir haben 2,3,4 Bettzimmer, was bedeutet, dass wir genug Platz für kleine Familien, wie auch für große Gruppen, d.h. 50 bis 100 Plätze, haben.

Figure 100: Text section from a sub page of the web site.

Generally, use single spacing between lines of text

The whole site uses single spacing between the lines of text.

Use of justification

All text is displayed in left justification

Font: wordspacing, letterspacing

Wordspacing and letterspacing is not changed from the standard.

Use headings as organizers

Headings are not used as organizers because no long text chunks are used.

Use paragraphs to organize the information in bite sizes

The text is parted into paragraphs. Figure 100 shows one paragraph from a sub screen of the website.

Use directive cues to emphasize important terms or ideas

Directive cues are not used to emphasize important terms or ideas.

Set up comparison – contrast situations in a side-by-side columnar arrangement

No comparison is presented and therefore this guideline does not apply.

Writing for the web

Text should be scan-able

Because of the different colours, differently looking headings and the asymmetric positioning of the elements the text is not scan-able.

Users want to get their information quickly

The text is not structured very well and also not scan-able. The consequence of this is, that sought information can not be found very quickly.

Credibility is very important

No external links and anaesthetic design leads to a bad credibility of the webpage.

Graphics and text should complement one another

Words and pictures correlate on all pages. In Figure 101 the text above describes the television room in every floor. Beneath is a photo of one television room, so that the viewer gets an idea how they look like.

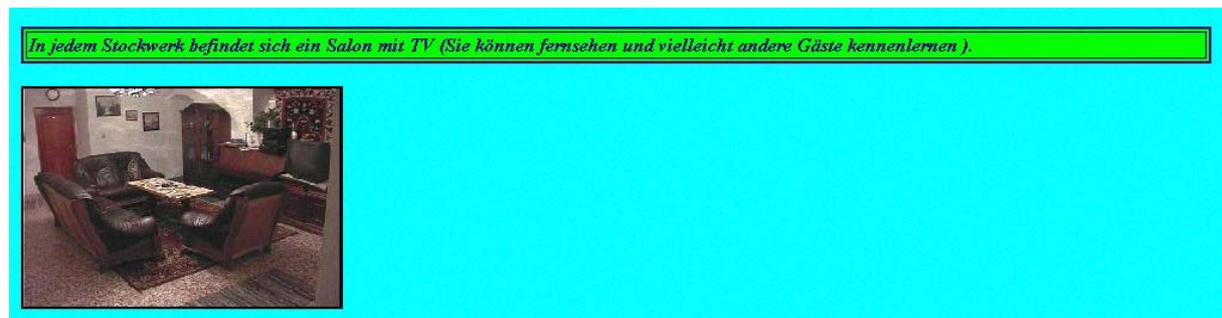


Figure 101: Text and image complement one another.

Hypertext is liked

The whole information is structured into multiple pages and linked with hypertext links.

Graphics guidelines

Use graphics for organization of functional areas

In principle the designer has followed this guideline, but he used too many borders and boxes which produced visual clutter.

Images versus words

The skiing area and the information where the hotel is localized is displayed as a map and therefore makes use from the fact that localization information is better conveyed using images.

Use contrasts to differentiate elements

High colour contrasts are used to differentiate different areas.

Visual integration requires equal scale and visual weight

Equal scale, symmetry and visual weight is not given and therefore the pages do not give an impression as a unified composition.

Optical adjustments for human vision

The fonts used by the different browsers use fonts, which are optically adjusted. So this guideline is automatically fulfilled by using standard fonts.

Use animations carefully

On the welcome screen the hotel name is blinking which is very distracting and on the sub pages automatically scrolling text is used. This scrolling text is not only very distracting but someone who wants to read it has to wait until the whole text scrolled in.

Consider colour blind people

As text and background is coloured in different colours, colour blind people may have difficulties reading all of the text.

Do not display fine detail only with chromatic differences

The header on the starting page has nearly the same hue as the background. In Figure 102 you can see that the header can hardly be distinguished from the background when only the brightness differences are displayed.



Figure 102: Grayscale image of the header on the starting page.

Do not display motion only with chromatic differences

No animation that uses motion is used on the website.

Do not display an objects shape only with chromatic differences

No three dimensional object is shaded by a purely chromatic gradient.

Consider brightness contrast

The website does not make use from the identification of a colour and therefore this guideline does not apply.

Use distinct colours for labelling

No colour labelling is used on the website.

Do not use red text on blue background and vice versa

Red text on blue background is used on the homepage. One example is shown in Figure 103.



Figure 103: Red text on blue background is hard to read.

Colours have a stronger effect on a dark background

This guideline was not applied on this website

Do not use blue for fine details

Blue is often used for colouring text and therefore this is hard to read.

Colour sequences for maps

No coloured maps are used on the website.

Colour affections

This guideline should help on which colours to use during the design phase and is hard to use for analysing the page.

Use red light to preserve dark adoption

Dark adoption is not needed for websites and therefore this guideline does not apply here.

Psychology of Colour

This guideline should help on which colours to use during the design phase and is hard to use for analysing the page.

Usability guidelines

Simple and natural dialogue

As the links are placed all over the page, the whole site is hard to use.

Speak the user's language

The telephone numbers are printed including the appropriate area code except on the page where special weekend offers are proposed. Currencies are printed only in Euro and no conversion is provided.

Minimize memory load

Because of the lack of a determined navigation area, the user has to remind where each link is located making it harder to use the site efficiently.

Consistency

Every page has a different layout and uses different typesizes and colours. Furthermore, links are not printed homogeneously. Some headlines even look the same way as links. Therefore, the user has to move the cursor over a link and see if the cursor changes to identify links. For example, Figure 104 shows a link named “ZURÜCK” and Figure 105 shows a headline named “SOMMER-LUNGAU-SALZBURG LAND-AUSTRIA”.



Figure 104: Link on the map page.

SOMMER-LUNGAU-SALZBURG LAND-AUSTRIA

Figure 105: Headline on the main page.

Feedback

No feedback is given from the webpage itself. Only the web browser changes how the cursor looks like when moving over a link (otherwise some links would not be identifiable).

Response time limits

The webpage is located on a fast server and therefore the response times are very good. But for people with a slow internet connection the loading of the big background picture on the starting page may take too long.

Exits and undo

As every browser has the option to go to the last visited page and quit the browser at any time, this guideline is fulfilled automatically.

Shortcuts

Shortcuts are also implemented in the browser software.

Use Good Error Messages

When a page is accessed that is wrongly spelled, the error message in Figure 106 appears. This error message gives no hint what to do and not even a link to the main page.

Not Found

The requested URL /ramingsteinerhof-durigon/x.html was not found on this server.

Apache/1.3.28 Server at www.sbg.at Port 80

Figure 106: Error message from the website.

Prevent errors

Nothing is done on the page to prevent errors.

Help and Documentation

Help and documentation is not available for the end user on this website.

9.2.4 Summary

In my opinion the website from the hotel Gasthof Ramingsteinerhof-Durigon is designed weakly. It has a bad usability because it is hard to read and to use.

To improve the site, a complete redesign would be necessary. The most important changes would be:

- A grid like structure should be applied to all pages including a navigation area.

- The number of colours should be reduced to only a few and the text should be printed in black on white or a very bright background.
- Only one font should be used and the portability of this font should be ensured. Only a few font sizes should be used, like a bigger size for headings and a smaller one for the remaining text. Furthermore, headlines and directive cues should be used to make the text more scan-able.
- The blinking and scrolling sentences should be removed.
- The images should be recoded, because they have a very bad quality.

9.3 Evaluating iTunes for Windows

The last practical analysis will be about Apple's iTunes music store. The evaluation was done by conducting a heuristic evaluation (see chapter 6.4.1 *Heuristic evaluation* on page 66) with the version 4.2.0.72 for Microsoft Windows.

9.3.1 What is the iTunes music store?

iTunes is a music software that lets you organize and listen to digital audio on your computer. You can listen to digital music (including audio CDs), import the songs on audio CDs (and recode them), burn songs to CDs or DVDs, buy individual songs or albums over the internet, listen to internet radio stations, create lists of you favourite songs, and share your music library across computers.



Figure 107: Main shopping page from iTunes for Windows.

9.3.2 Why iTunes music store?

I choose iTunes because it was the first commercial successful program where you could legally buy music over the internet to a moderate price (0.99 cent, 2. February 2004). Furthermore, the TIME Magazine choose iTunes as the coolest invention of the year 2003 (see [71]) and stated:

It's a disarmingly simple concept: sell songs in digital format for less than a buck and let buyers play them whenever and wherever they like—as long as it's on an Apple iPod.

...

But for finally finding a middle ground between the foot-dragging record labels and the free-for-all digital pirates and for creating a bandwagon onto which its competitors immediately jumped, Apple's iTunes Music Store is TIME's Coolest Invention of 2003.

9.3.3 Evaluation

I started the heuristic evaluation by installing the software. Next, I started the software and tried to find all options of iTunes. Then I searched for positive and negative things on each screen. At first, I analysed the off-line functions like importing music from the hard disk, organizing the music in playlists, and playing back music. Next, I tested the online features of the “Music Store” area. After this I took some screenshots, to analyse them for a grid based structure. Then I took each guideline and tried to find out if the guideline was fulfilled or not. For the whole analysis I needed about four hours. One hour for testing the software and three hours for applying the guidelines to the interface.

The next section will present the results of this evaluation with the guidelines.

General design guidelines

Use Gestalt laws for relationships

The Gestalt law proximity is used to connect various elements on the user interface. For example the interaction elements in Figure 108 are perceived as a unity because they are placed near each other. The playlist buttons shown in Figure 109 belong together because of proximity and similarity.



Figure 108: Music controls in iTunes.



Figure 109: Playlist control buttons are perceived as belonging together because of proximity and similarity.

Furthermore, similarity is used to connect the whole control bar (seen in Figure 110). This is done by designing all elements with rounded corners.



Figure 110: Top control area from iTunes.

Connectedness, for example, is used to connect the two speaker icons and compose a controller element for changing the volume of the played music.



Figure 111: The two speaker symbols are connected by the Gestalt law of connectedness.

Use a grid based structure for designing multiple pages

A grid was used for the top navigation area and the surrounding border. On every page these graphical elements remain at the same position. On the other hand, the position of the content is customizable. This means that the user can change the size of the different content areas.

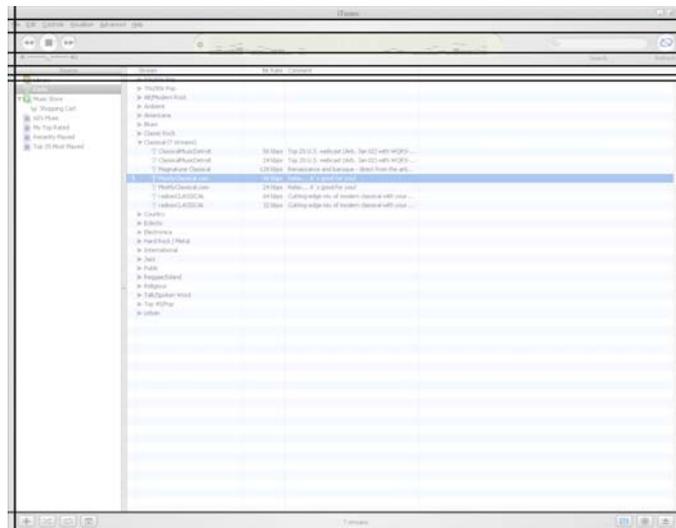


Figure 112: Grid structure of iTunes.

Highlight important elements

Bold text is used to highlight important things, like song titles. In Figure 113 the top ten songs are shown where each song title is emphasized by a bold formatting.

1. **Toxic**
Britney Spears
2. **Someday**
Nickelback
3. **This Love**
Maroon 5
4. **Hey Ya!**
OutKast
5. **Seven Nation Army**
The White Stripes
6. **The Way You Move**

Figure 113: Top sold songs in Apple's iTunes. The song title is highlighted by using bold text.

Use layering to display overlapping information

The software itself does not make use of layering.

Grouping into functional areas

The fundamental grouping is done by metallic looking borders (see Figure 115 for an image of the top control bar in this metallic look). In the music store area the sub areas are grouped by little windows (see Figure 114 for a example window). These small windows can not be dragged or closed by the user and their only use is to separate the content from the remaining one.

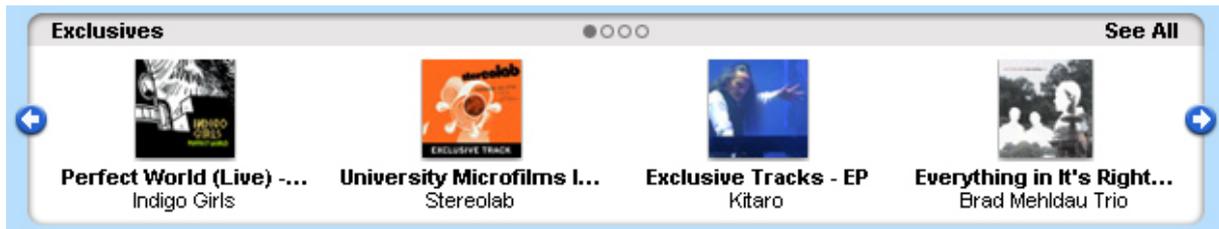


Figure 114: Grouped information in a window-like style.

Keep controls in a separate area

The main controls are always on top of the application. Figure 115 shows the top navigation area.



Figure 115: Top control area.

Use indents to indicate hierarchies in your elements

Indents are used to visualize hierarchies in the source window and in the window showing the available internet radio stations. For example the shopping cart on the left side of Figure 116 is indented and therefore it is clear that it is part of the music store. On the right side of Figure 116 you can see another example of hierarchies in Apple's iTunes. The radio stations playing ambient music are printed indented relativeto the heading.

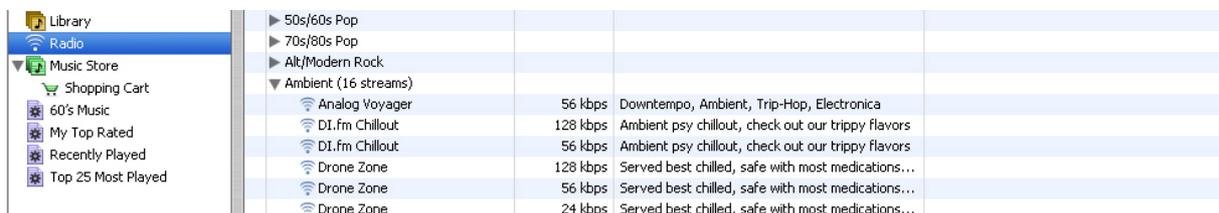


Figure 116: Hierarchies are used to show that the shopping cart is part of the music store and the radio stations playing ambient music.

Balance

White and dark areas are distributed evenly across the screen. Only in the screen of the music store the distribution is sometimes a bit uneven, because of the changing CD cover images. Figure 117 shows a schematic image of the main view of the music store window. As you can

see the whitespaces are distributed evenly but the hue and colour of the cover images are displayed randomly.



Figure 117: Schematic view of the main view to see balance between black and white areas.

Consistency in all object styles

Rectangular objects with mostly rounded corners are used. As the most objects use rounded corners the consistency is given.

Keep screens simple

All screens except the main screen of the music store are kept simple. This main screen is a bit overcrowded, because it has to present much information. Nevertheless, every screen represents a meaningful unit.

Avoid screens with text alone

There are no screens with a long text that should be enhanced by an image.

Use specific guidelines for the system you develop for

iTunes was first developed for MacOS X and therefore the userinterface was adjusted for this operating system. After porting the product to Windows some essential user interface elements from windows were implemented to enhance learnability. For example the three buttons to minimize, maximize, and close the application (see Figure 118) were included because they are typical for Windows applications.



Figure 118: Standard Windows Buttons to minimize, maximize and close the window.

The other user interface elements are still looking like the standard elements from MacOS X. In Figure 119 the horizontal scrollbar in MacOS X style is shown.



Figure 119: MacOSX style navigation elements.

Text guidelines

Contrast

All text is printed either in black on white or light blue background or in white on dark colours. Longer text is always printed in black on white / blue.

Cutting-edge mix of modern classical with your ...

Cutting-edge mix of modern classical with your ...

Figure 120: iTunes presents text mostly in black on a bright background.

Type colour

Only black or white is used for text.

Font family

Only one standard font is used throughout the program.

Do not use too many different tpestyles

Only bold variation of standard font is used to highlight important terms.

Use serif fonts for long texts

Only short text segments are used and therefore the used sans-serif font is appropriate.

Use portable tpestyles

Only a standard windows font is used that is installed on all windows versions. Therefore, the portability of the tpestyle is ensured.

Typesize appropriate for the audience and amount of reading

The typesize used throughout the application is a bit small, when using a high resolution display but still appropriate for the audience (mostly younger people).

Use both lower- and uppercase text

Mixed case text is used and thus this guideline is fulfilled.

Keep line lengths reasonable

No long text sections are used in the program, thus the line length is not that important.

Generally, use single spacing between lines of text

The whole site uses single spacing between the lines of text.

Use of justification

All text is displayed in left justification

Font: wordspacing, letterspacing

Wordspacing and letterspacing is not changed from the standard.

Use headings as organizers

Headings are not used as organizers, because no long text chunks are used.

Use paragraphs to organize the information in bite sizes

No paragraphs are used, because no long text is displayed.

Use directive cues to emphasize important terms or ideas

Important words are printed bold.

Set up comparison – contrast situations in a side-by-side columnar arrangement

A tabular view is used to display the personal music library. This leads to a very good ability to compare different music titles. In Figure 121 the personal music library is shown.

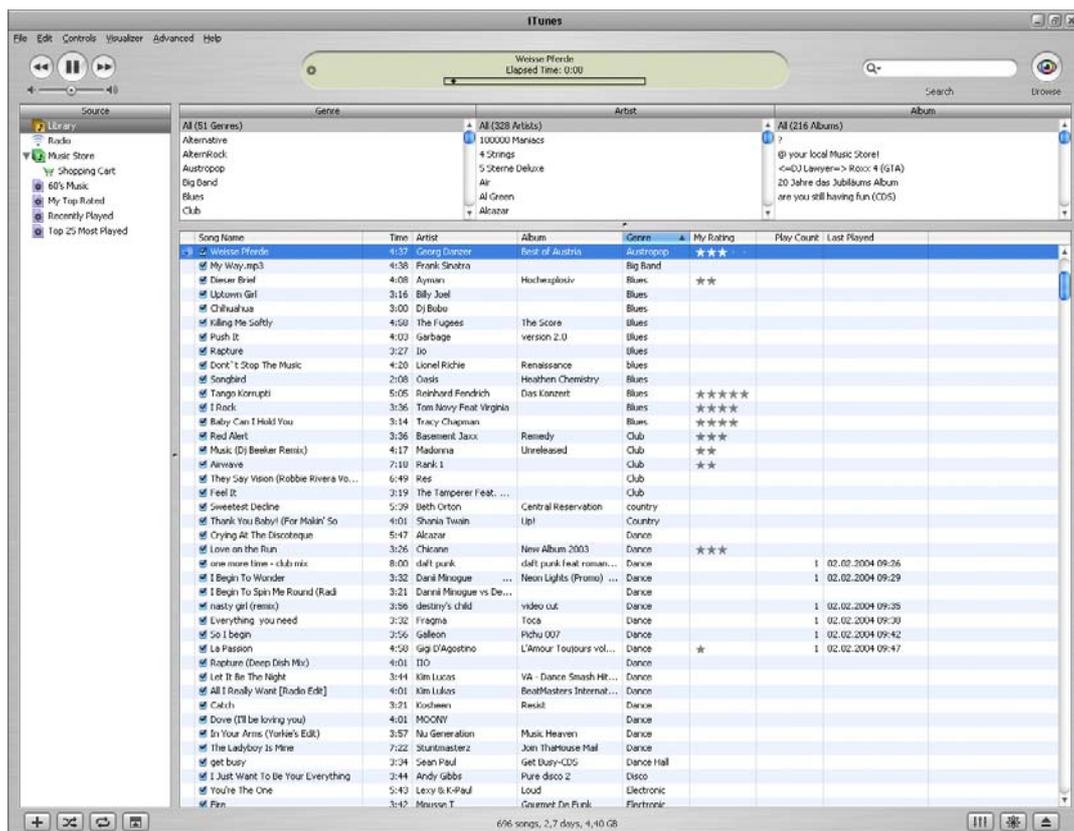


Figure 121: Tabular view of the personal music library.

Writing for the web

iTunes is an application and therefore it makes no sense to apply the web guidelines to this program.

Graphics guidelines

Use graphics for organization of functional areas

Metallic looking borders are used to separate the functional areas.

Images versus words

This guideline does not apply to this category of programs.

Use contrasts to differentiate elements

The rows in the tabular view are differentiated by the colour contrast white and blue. Furthermore, the highlighted row is marked in blue in contrast to the light blue or white background of non-marked rows. Figure 121 shows the tabular view of the personal music library.

Visual integration requires equal scale and visual weight

The objects are equally scaled and distributed. Furthermore, all elements are spaced evenly.

Optical adjustments for human vision

The font used in iTunes is a standard Windows font, that uses optical adjustments.

Use animations carefully

There are different sort of animations used in iTunes. On the main screen of the music store the three banners use an animation. They use blending to change the content slowly. This animations turn the attention of the user to the new content without being annoying. Jakob Nielsen called this kind of animation multiplexing. Furthermore, some interface elements are animated when activated as some sort of feedback.

Finally, the music can be viewed as a animation but this is only used for entertainment.

Consider colour blind people

No colour coding is used in iTunes.

Do not display fine detail only with chromatic differences

As you can see in the greyscale image in Figure 122 all elements are clearly visible. This means that no fine detail is displayed only with chromatic differences.



Figure 122: Greyscale image of the main page of the music store.

Do not display motion only with chromatic differences

No detail is coded only with chromatic differences and therefore this guideline is fulfilled.

Do not display an objects shape only with chromatic differences

No three dimensional object is shaded by a purely chromatic gradient.

Consider brightness contrast

The application does not make use from the identification of a colour and therefore this guideline does not apply.

Use distinct colours for labelling

No colour labelling is used on the website.

Do not use red text on blue background and vice versa

No red text is used in iTunes.

Colours have a stronger effect on a dark background

This guideline was not applied on this application.

Do not use blue for fine details

Blue is not used for fine detail but only as a background colour.

Colour sequences for maps

No coloured maps are used in iTunes.

Colour affections

This guideline should help on which colours to use during the design phase and is hard to use for analysing the page.

Use red light to preserve dark adoption

Dark adoption is not needed for this kind of application and therefore this guideline does not apply here.

Psychology of Colour

This guideline should help on which colours to use during the design phase and is hard to use for analysing the page.

Usability guidelines

Simple and natural dialogue

The program was easy to use for me and it is easy to keep track of the options because they are easy to find and not too much of them are available. Furthermore, the name of the program and the logo do not use too much space.

Speak the user's language

iTunes is available in Chinese (Simplified), Chinese (Traditional), Danish, Dutch, Finnish, French, German, Korean, Italian, Japanese, Norwegian, Spanish, and Swedish. Sadly the music store area is only available in English (at least in the German version I tested). Furthermore, the prices of the songs are also only viewed in US Dollars.

Minimize memory load

iTunes uses a graphical user interface that helps minimize memory load. That means that no input has to be made from memory. Support for copy and paste is also a positive point to mention and when naming files or playlists, a default name (or the old name) is displayed.

Consistency

Dedicated navigation and content areas are implemented in the software and all dialogue boxes always pop up at the same location. Figure 123 for example shows a information window, that shows information about the current processes.



Figure 123: Information window showing loading bar.

Feedback

The system provides negative feedback with error messages and positive feedback like the progress bar in Figure 123.

Response time limits

The average response times are fast enough that a user feels that the system is reacting instantaneous. If the system takes longer, feedback is shown in the information area (Figure 123).

Exits and undo

In the music store a back and forward button is available that works like the buttons in a webbrowser. Furthermore, an undo option is implemented.

Shortcuts

Shortcuts are implemented for the most used options.

Use Good Error Messages

Clear error messages are given when an error occurs. However, I found the error message in Figure 124 that gives no hint how to correct the error (iTunes takes the internet connection settings from the windows system and therefore the proxy server has to be disabled).

No multilevel error messages are used.



Figure 124: iTunes error message.

Prevent errors

The bad thing is, that no confirmation dialogue is showed on closing the application. To prevent errors the program has good differentiable icons. In addition to this, options that can't be used are greyed out.

Help and Documentation

A well written online help with a search option is available (Figure 125).

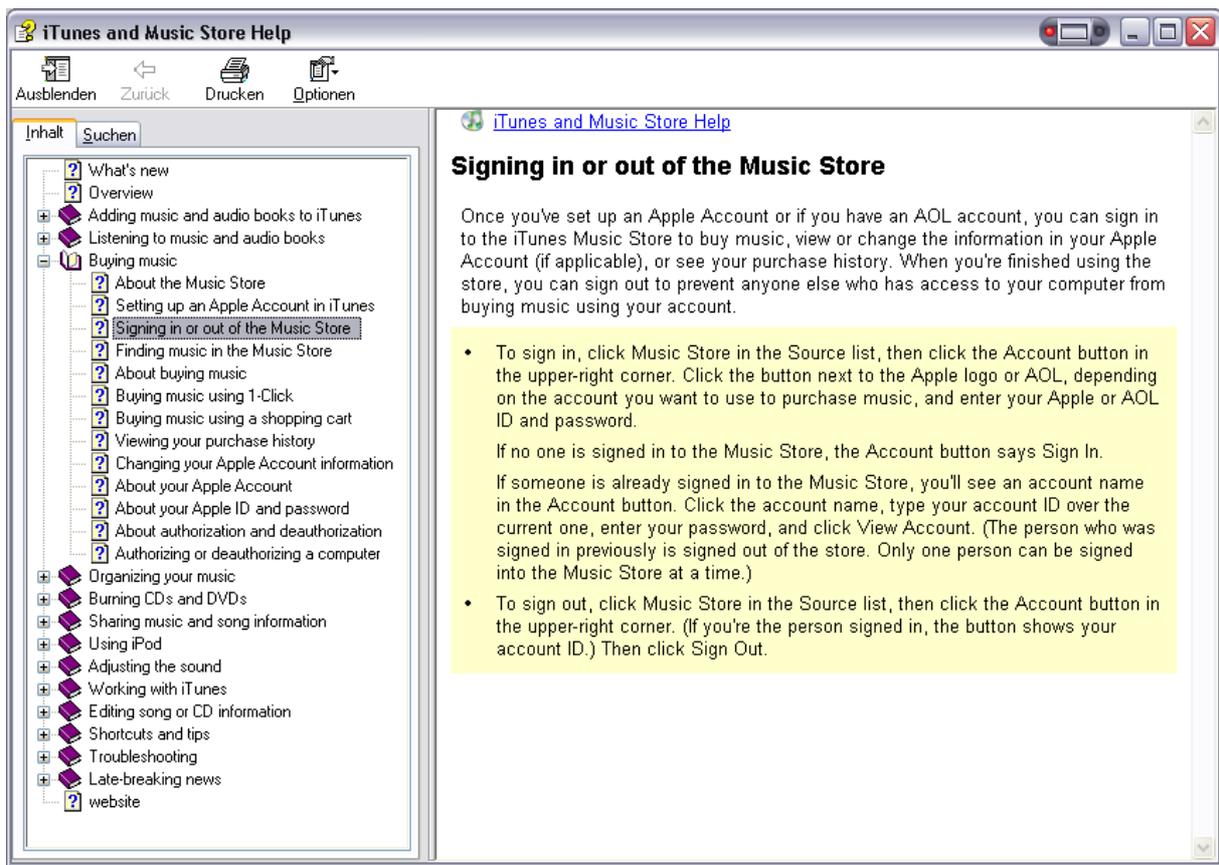


Figure 125: Help screen from iTunes.

Furthermore, an online tutorial is available on Apples homepage. (see Figure 126 and [72])

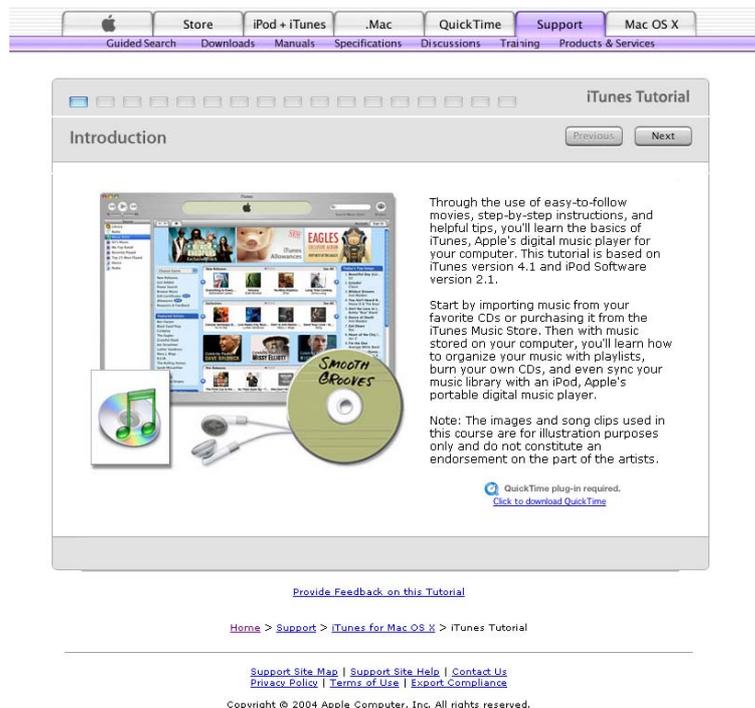


Figure 126: iTunes online Tutorial.

9.3.4 Summary

In my opinion iTunes is a very good program which is easy to use and looks aesthetically pleasing. The navigation is solved very good and the tabular view of the songs helps finding and sorting songs. Furthermore, the handling of the program is very easy and intuitive.

There are only a few small point that could be improved:

- The music store should be implemented in other languages or at least there should be an option to display the price tag in the appropriate currency.
- The error message, that SOCKS firewall are not supported, should be improved. Tips should be given how to correct this error.
- Standard windows interaction elements could be implemented instead of the Apple style ones. Examples for this would be the scrollbars and buttons.
- A better balance of the music store page could be achieved by altering the position of the CD cover images or showing them only in greyscale for example.

9.4 Evaluating LinkVis

LinkVis is a visualization program to explore highly structured data. The program was still in implementation stage when I analysed it. The analysis of the program was done by conducting a heuristic evaluation (see chapter 6.4.1 *Heuristic evaluation* on page 66) with the version from 2004-02-02. I tested the program with some example data from the author and also got a short introduction on how to use the system from him.

9.4.1 What is LinkVis?

LinkVis is a visualization program for highly structured data developed by Herbert Herzog. It can be used to visualize and evaluate psychotherapeutic processes. The user gets new insight into the data due to the combination of three different visualization techniques: scatterplots, Chernoff-Faces, and parallel coordinates (planned). The selection of desired dataset is done in a hyperbolic tree (see [73] for more information about hyperbolic trees). For more information about LinkVis see [74].

In Figure 127 you can see a typical dataset displayed with Chernoff-Faces and three scatterplots. The dataset was chosen from the hyperbolic tree on the right of Figure 127.

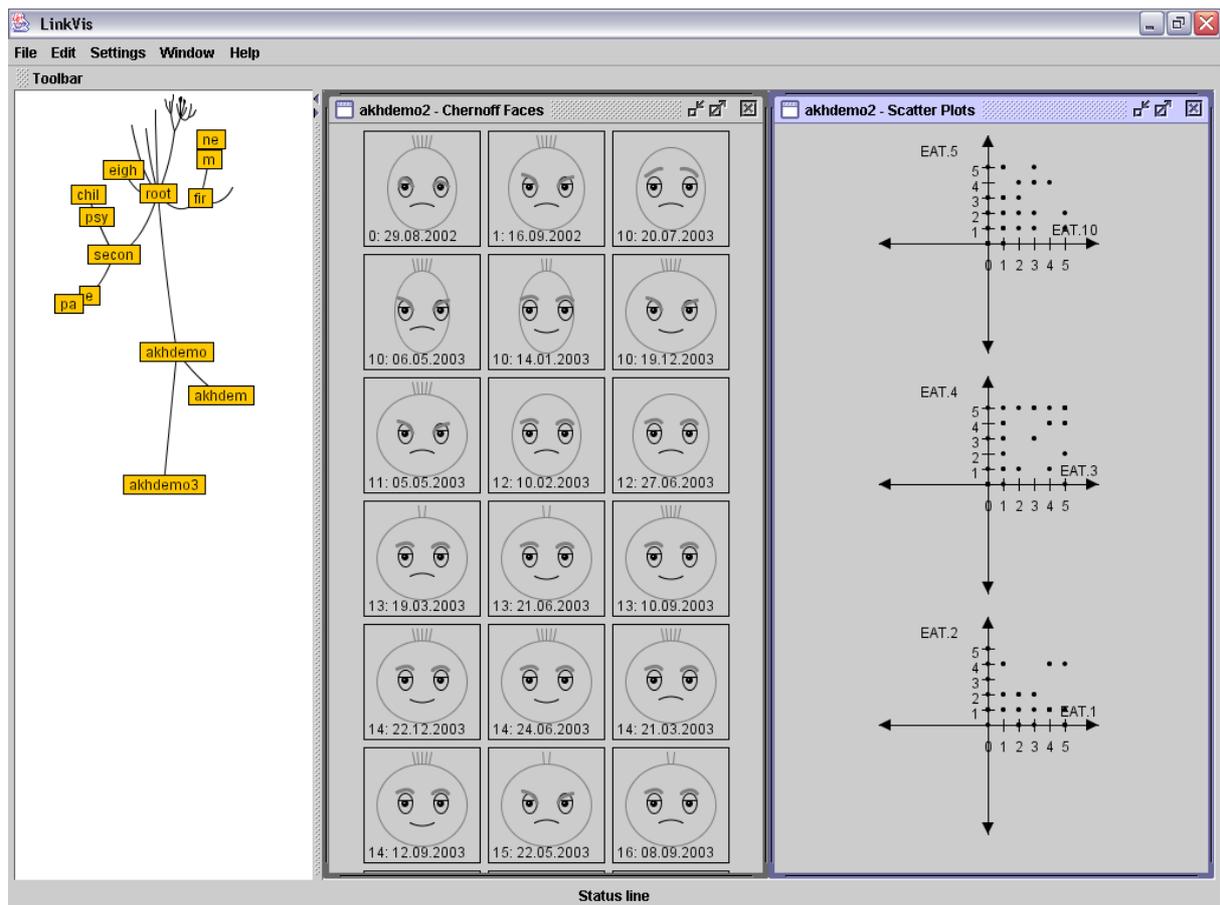


Figure 127: Main application window of LinkVis.

In Figure 130 the spacing was corrected, leading to a correct visual grouping of the labels with the input boxes.



Figure 130: Corrected top bar of the properties window.

Use a grid based structure for designing multiple pages

The menu, the toolbar, and the status bar always remain at the same position. The three content areas are customizable. The area where the hyperbolic tree is displayed can be found on the left hand side and its width is changeable. In the remaining area the window with the Chernoff-Faces in it and the window with the scatterplot in it can be positioned and sized by the user. Figure 131 shows a grid that can be applied on LinkVis.

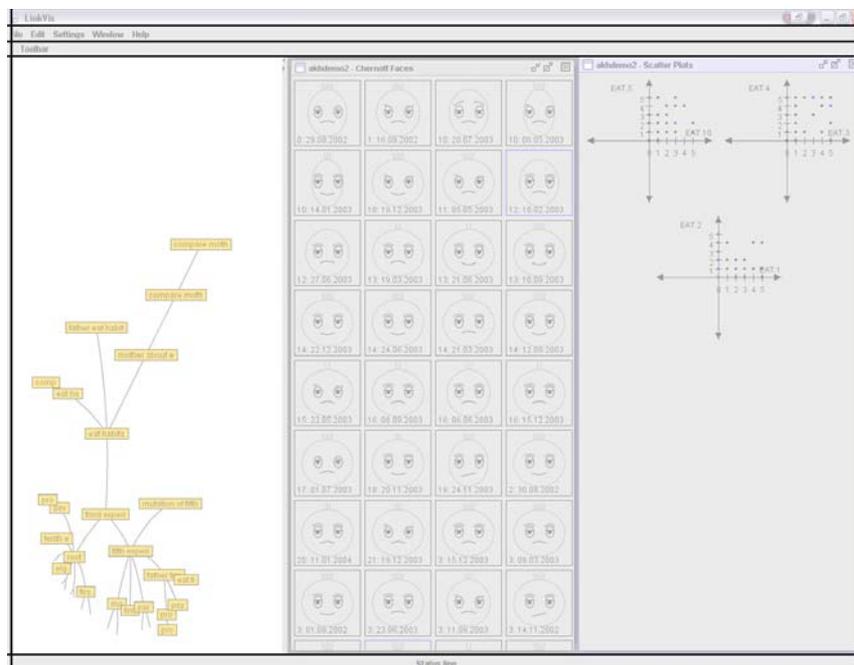


Figure 131: In this figure you can see the grid, that was used to design the user interface of LinkVis.

A grid based structure should be used for positioning the elements in the properties window. Figure 132 shows an example grid that could be used to position the elements in the main area of the properties window. Furthermore, a grid should also be used for the preferences window.

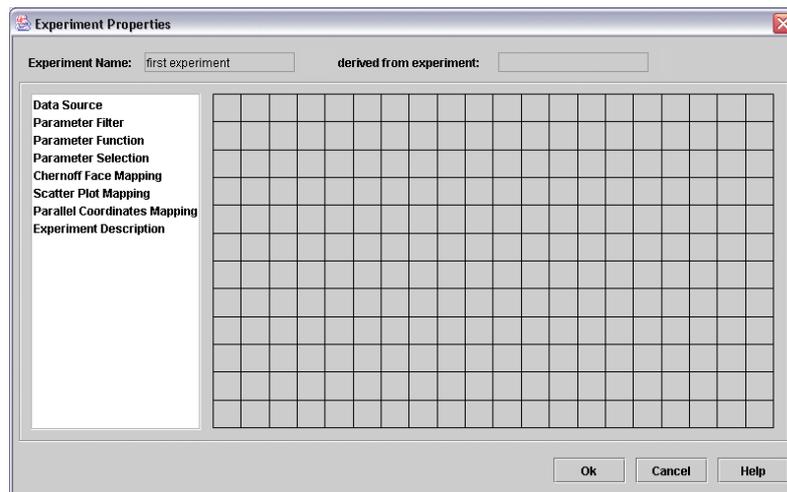


Figure 132: Example grid for the main area of the properties window.

Highlight important elements

Selected data is highlighted with blue colour in the Chernoff-Faces and in the scatterplot visualization.

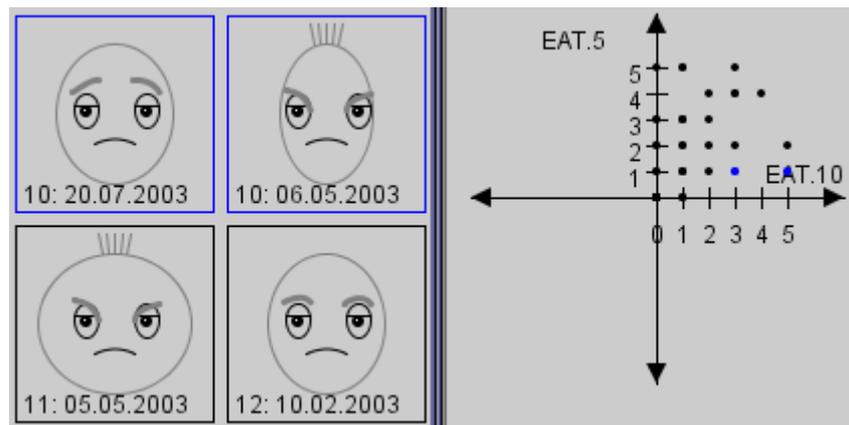


Figure 133: Highlighting selected data in LinkVis.

In the properties and preferences window nearly all text is printed bold. A more selective highlighting (for example only the headlines) should be used.

Use layering to display overlapping information

The software itself does not make use of layering.

Grouping into functional areas

The application is subdivided into six functional areas. On top the menu and the toolbar is located. The content area with the hyperbolic tree and the windows for the Chernoff-Faces and the scatterplot are located in the centre. On the bottom there is the status line. Each area can be easily distinguished and the grouping is well done.

Although the dialogue windows are also grouped into functional areas, the grouping is not always clear on the first sight. Some areas are grouped with boxes. This groupings are not necessary and could also be achieved by indents and spacings.

Keep controls in a separate area

The menu is always on top of the application window. The toolbar is also located at the top but can be dragged everywhere on the screen. In the dialogue windows the navigation is always position at the left side of the window.

Use indents to indicate hierarchies in your elements

Indents are used to indicate the hierarchies in the menu of LinkVis. For example in Figure 134 the options for akhdemo2 are displayed indented.

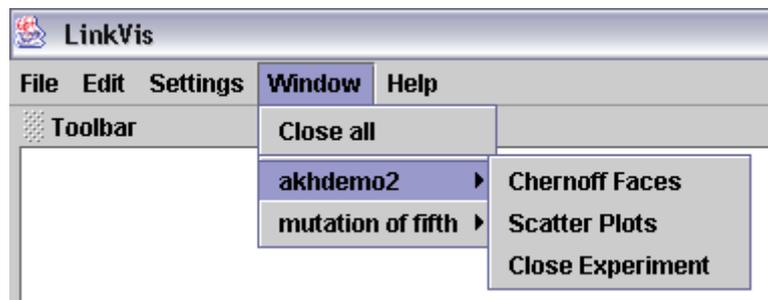


Figure 134: Indents are used to indicate hierarchies in the menu.

In the properties window under “Data Source” the indent to the input field for the data storage is too big. Therefore the coupling to the heading is lost (see Figure 135). Not all elements on the preferences and properties page use indents to indicate hierarchies.

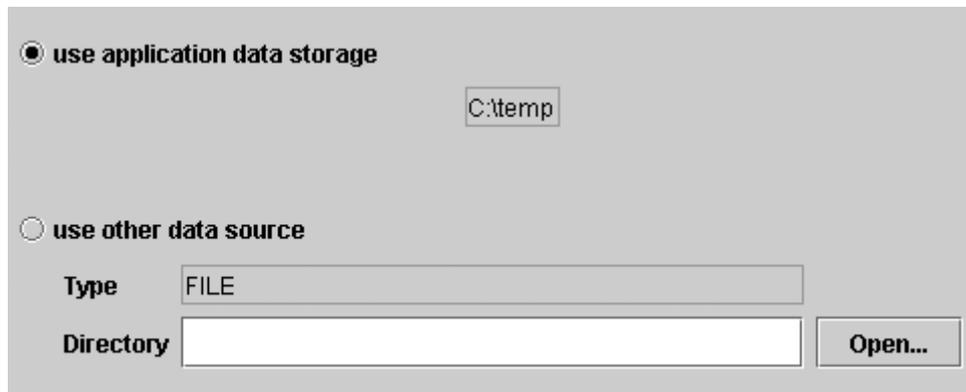


Figure 135: The input field

Balance

The white background of the hyperbolic tree is too dominant in comparison to the grey and blue background of the other elements (see Figure 136 for this effect). Furthermore, the blue background of the window area is also too dominant.

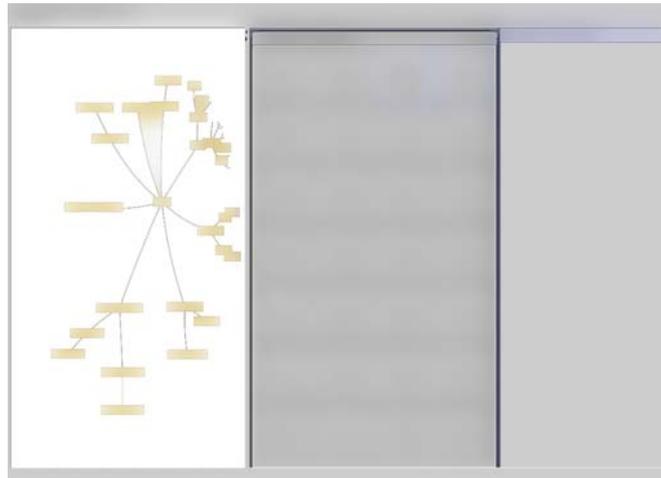


Figure 136: Schematic image of a typical working screen.

The whitespaces are distributed evenly on the screen.

In the properties window some sub-pages are unbalanced because they have a unequal distribution of the whitespaces. For example the screen in Figure 137 gives an unbalanced impression, because the objects are not distributed evenly. Furthermore, the “Ok”, “Cancel”, and “Help” buttons should be aligned to the right border. This means the buttons haft to be shifted slightly to the right in the properties window and to the left in the preferences window.

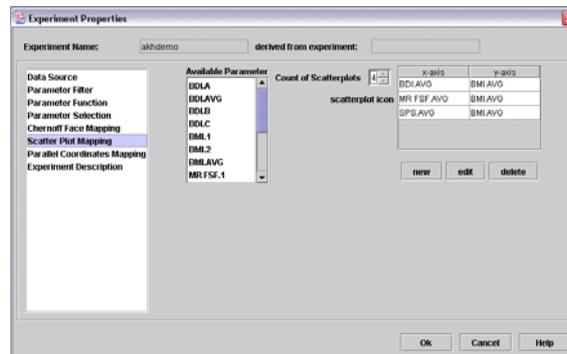


Figure 137: Unbalanced dialogue in LinkVis.

Consistency in all object styles

LinkVis only uses rectangular objects which leads to a consistent design.

Keep screens simple

Every screen represents a meaningful unit and is kept simple.

Avoid screens with text alone

There are no screens with a long text that should be enhanced by an image.

Use specific guidelines for the system you develop for

LinkVis was developed in Java for use on multiple platforms. Therefore this guideline is hard to follow because it would mean a platform dependent programming.

Text guidelines

Contrast

Text is always printed in black on either grey or yellow background. The contrast is not ideal but still the letters are easy to identify.

Type colour

All text is printed in black.

Font family

Only one standard font is used throughout the program.

Do not use too many different timesteps

Only a bold variation of the standard font is used for the menu and windows headlines.

Use serif fonts for long texts

Only short text segments are used and therefore the used sans-serif font is appropriate.

Use portable timesteps

Only a standard font is used that is installed on all Windows and Linux versions. Therefore the portability of the timestep is ensured.

Typesize appropriate for the audience and amount of reading

The typesize is appropriate for the audience.

Use both lower- and uppercase text

Mixed case text is used and thus this guideline is fulfilled.

Keep line lengths reasonable

No long text sections are used in the program, thus the line length is not that important.

Generally, use single spacing between lines of text

The whole site uses single spacing between the lines of text.

Use of justification

No long text sections are used throughout the program.

Font: wordspacing, letterspacing

Wordspacing and letterspacing is not changed from the standard.

Use headings as organizers

Headings are not used as organizers, because no long text chunks are used.

Use paragraphs to organize the information in bite sizes

No paragraphs are used, because no long text is displayed.

Use directive cues to emphasize important terms or ideas

Nearly all text is printed in bold. Important terms are not emphasized.

Set up comparison – contrast situations in a side-by-side columnar arrangement

The Chernoff-Faces are arranged in a table. This makes it easy to compare them and identify differences between them.

Writing for the web

LinkVis is an application and therefore it makes no sense to apply the web guidelines to this program.

Graphics guidelines

Use graphics for organization of functional areas

Grey borders are used to separate the functional areas. In the dialogue windows, embossed borders are used to separate different functional areas.

Images versus words

This visualization program makes intensive use of images to represent information. Colin Ware presented in [2] that images are best for structural relationships. The hyperbolic tree takes advantage of this fact. Furthermore, the Chernoff-Faces and the scatterplot make use of the advantages of images over words.

Use contrasts to differentiate elements

Colour contrasts are not used to differentiate elements.

Visual integration requires equal scale and visual weight

The Chernoff-Faces are not integrated perfectly in the surrounding box because the lettering has no spacing to the face themselves. Furthermore, the light and dark areas are distributed unevenly. In Figure 138 you can see a Chernoff-Face from LinkVis.



*Figure 138:
Chernoff-Face from
LinkVis.*

Optical adjustments for human vision

The font used in LinkVis is a standard font, that uses optical adjustments.

Use animations carefully

When moving a node of the hyperbolic tree to the centre (by clicking on it) an animation is displayed. This animation shows the continuity in transitions (as Nielsen called it in [62]).

Consider colour blind people

Only one colour is used in the program and it is not important to identify this colour. Therefore this guideline is fulfilled.

Do not display fine detail only with chromatic differences

As you can see in the greyscale image in Figure 139 all elements are clearly visible. This means that no fine detail is displayed only with chromatic differences.

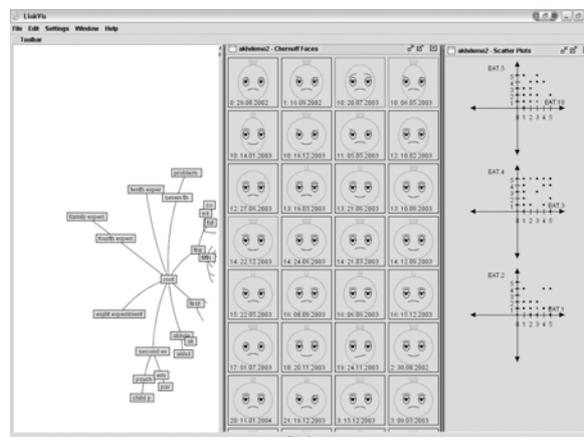


Figure 139: Greyscale image of the main screen.

Do not display motion only with chromatic differences

No detail is coded only with chromatic differences and therefore this guideline is fulfilled.

Do not display an objects shape only with chromatic differences

No three dimensional object is shaded by a purely chromatic gradient.

Consider brightness contrast

The application does not make use from the identification of a colour and therefore this guideline does not apply.

Use distinct colours for labelling

No colour labelling is used on the website.

Do not use red text on blue background and vice versa

No red text is used in LinkVis.

Colours have a stronger effect on a dark background

This guideline was not applied on this application.

Do not use blue for fine details

Blue is used to highlight selected information in the Chernoff-Faces and the scatterplot.

Colour sequences for maps

No coloured maps are used in LinkVis.

Colour affections

This guideline should help on which colours to use during the design phase and is hard to use for analysing the page.

Use red light to preserve dark adoption

Dark adoption is not needed for this kind of application and therefore this guideline does not apply here.

Psychology of Colour

This guideline should help on which colours to use during the design phase and is hard to use for analysing the page.

Usability guidelines

Simple and natural dialogue

The user interface is simple enough for finding wanted options. The right click options in the hyperbolic tree are not found easily and should be made available in the toolbar. Furthermore, an automatic alignment option for the Chernoff-Faces and scatterplot windows would be helpful.

Speak the user's language

LinkVis will be available in English and German. Dates are currently displayed only in the German format (Day.Month.Year).

Minimize memory load

No input has to be made from memory. File names can be chosen from a file tree dialogue. Some default values are used for new fields and a calendar can be used to choose a date.

Consistency

Size of preferences window is not consistent. Every sub-section has a different width. Property and preferences window pop up in the upper left side of the monitor. Error messages in the middle of the screen. A dedicated navigation and content area is implemented in the dialogue windows (properties and preferences).

Feedback

No feedback is being given so far, when an operation takes longer than one second. For example loading a view of a selected dataset can take up to a few seconds. Negative feedback is delivered in form of error messages. A status line is implemented in the design but is not used in this program version.

Response time limits

Some response times take too long without displaying feedback. For example loading of the properties window can take up to a few seconds without showing any feedback.

Exits and undo

A clearly marked exit is provided. There is no undo option in this version of the program.

Shortcuts

No shortcuts are implemented so far.

Use Good Error Messages

The only error message I have found is displayed in Figure 140. It was displayed after trying to view the Chernoff-Faces and scatterplot of the root node. The error message does not help the user on fixing the error.



Figure 140: Error message of LinkVis.

Prevent errors

To prevent errors, options that can not be selected at that time, should be greyed out. This way the error message in Figure 140 could have been prevented.

Help and Documentation

Help and documentation was not available in this version.

9.4.4 Summary

In my opinion LinkVis is a very good tool and despite its early development stage it is good to use. The hyperbolic tree works very well, is easy to use, and looks good. Centring a note with one mouse click is a very convenient feature. The parted main screen is a very good concept and the menu structure is easy to perceive.

Still there are some things that have to be implemented or improved:

- The user has to click on the right mouse button to see what options can be activated for a node in the hyperbolic tree. It would be better to move this options to the toolbar.
- If an option is not available it should be greyed out instead of bringing an error message.
- Layering could be used to display the overlapping nodes at the edges (for example with transparency).
- The background colour of the windows area should be changed to a more decent colour. For example colour affections of the user group could be used to choose this colour.
- To improve the contrast of the text the background colours could be lightened. For example a lighter grey (like the one used by Microsoft Windows) could be used.
- To ensure a better visual integration of the Chernoff-Faces, the spacing to the lettering should be increased and the distribution of the light and dark areas should be equalized.
- Another colour for highlighting menu points and data entries should be used because blue is resolved badly in the human eye. Green or red would be better.
- Important terms and headlines should be emphasized with bold text and the remaining text should be left in plain format.

- Indents and headings should be used consistently on the properties and preferences page to group the content into meaningful units. Furthermore, too many borders to separate objects should be avoided (it is better to separate them with spacings).
- The preferences window should maintain its size on viewing the sub-options.
- The error messages should be improved and tips should be given on how to prevent the error next time (or fix the error). Multilevel error messages could help novice and expert users.
- A grid should be used to align the elements on the main screen and in the different windows.
- New windows, like error messages, should all pop up at the centre of the screen (or at least at the same location).
- An option to automatically align all windows (except error and preferences windows) on the screen should be implemented.
- Shortcuts for the most used options should be implemented. For example “Strg” + “s” could be used to save the data.
- If any operation takes longer than one second, feedback should be displayed. If the operation takes longer than ten seconds, a progress bar should be implemented.
- The date format should be displayed in the appropriate format for the user. At least a description of the used format should be displayed.

10 Summary

Good graphical user interface design is a difficult task. The interface should be easy and efficient to use. Furthermore, it should be easy to learn and aesthetically pleasing. Maximizing these properties may be impossible for a given task. Especially the aesthetic quality of an interface can not be just achieved by following guidelines. Much practice, knowledge about users, and perhaps even talent is needed to accomplish this task. However, guidelines can help to create a good user interface significantly by avoiding common errors. They can also be used to improve or analyse an existing user interface.

The presented guidelines and methods are far from being complete but they are a summary of the best bibliography I found. Guidelines for icon and menu design could be developed furthermore.

Beside using the guidelines, user testing has to be conducted to find further problems. The result of the user testing may even lead to break some guidelines. This should always be considered because the user stands in the first place.

The evaluation of the website of IDEO proved that good web design is characterised by the fulfilment of all guidelines. Still some suggestions for improvements could be found through analysing the website.

On the contrary, the analysis of the webpage of “Gasthof Ramingsteinerhof-Durigon” showed that a bad design that is also hard to use fulfils only a few guidelines. The analysis showed so many issues that a redesign is the only solution.

iTunes for Windows was analysed to verify if the guidelines can also be used to rate a windows program. iTunes fulfilled nearly all guidelines. This confirms that the award winning user interface is a good one.

Finally, the evaluation of LinkVis proofed that the guidelines can also be used to help with the development of an interface. This can prevent errors in the final product and can lead to a better interface. LinkVis' main problem was the visual structure of the properties and settings dialogue. Furthermore, the colouring should be improved. To summarize, LinkVis is on a good way to a good user interface.

For me this thesis helped, recognizing and analysing user interface errors. Before writing this thesis I was only able to decide if I liked a user interface or not but I was not able to clearly state why something was hard to use or aesthetically unpleasing.

10.1 Outlook

As mentioned in chapter 3 *History of interface design* on page 18 future user interfaces will possibly integrate a vector engine. This enables a better visual scalability for high resolution displays. Therefore, the way icons and interface elements are designed, may change. Vectorized images can be scaled up and down without any quality loss because they do not store each pixel colour but where an object is located with which properties. Objects can be lines, circles, polygons, or text for example with properties like colour, or texture. conversion to pixel format can be omitted. The methods to create an icon presented in 7.7 *Creating icons* on page 73 can also be applied for vector icons. The only difference is that the image does not has to be rasterized (converted into a pixel format).

Furthermore, three dimensional user interfaces may become available for the masses.

Therefore, new guidelines concerning three dimensional perception and interaction have to be developed. For example the visibility of objects has to be considered. Sun Microsystems are currently developing a three dimensional desktop based on Java technology. It provides translucent, three dimensional windows for Solaris and Linux desktop environments. For more information about the project Looking Glass see [78].

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