INFO GUIDE | 03

HALBMOND

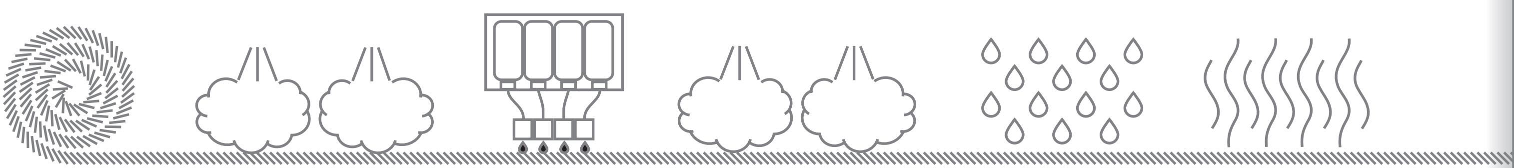
Colour & print EXPLANATION

Colour & print
EXPLANATION

en The infoguide ‘Colour & print EXPLANATION’ takes you from the process of colour vision through the world of colour systems to carpet printing at Halbmond. Your desired design usually begins on the PC and leads via a paper printout to the hand cut-off, after which the final carpet is definitively printed. But why do colours look different on the computer screen and on paper than on the final carpet and how can they be measured and reproduced exactly?
The infoguide ‘Colour & print EXPLANATION’ aims to answer these and other questions and also provide you with the right conditions and criteria for assessing print quality.

de Der Infoguide „Colour & print EXPLANATION“ führt Sie vom Prozess des Farbsehens durch die Welt der Farbsysteme hin zum Teppichdruck bei Halbmond.
Ihr Wunschdesign beginnt meist am PC und führt über einen Papierausdruck hin zum Handabschlag, nach dessen Freigabe schließlich der finale Teppich bedruckt wird. Warum jedoch wirken Farben am PC und auf dem Papier anders als auf dem finalen Teppich und wie können Sie gemessen und exakt reproduziert werden?
Diese und weitere Fragen möchte der Infoguide „Colour & print EXPLANATION“ beantworten und Ihnen außerdem die richtigen Bedingungen und Kriterien zur Beurteilung von Druckqualität an die Hand geben.

fr L’infoguide « Colour & print EXPLANATION » vous emmène du processus de vision des couleurs à l’impression de tapis chez Halbmond, en passant par le monde des systèmes de couleurs. Le dessin souhaité commence généralement sur l’ordinateur et passe par une impression sur papier jusqu’à la découpe manuelle, après quoi le tapis final est définitivement imprimé. Mais pourquoi les couleurs apparaissent-elles différemment sur l’ordinateur et sur le papier que sur le tapis final et comment peut-on les mesurer et les reproduire exactement ?
L’infoguide « Colour & print EXPLANATION » vise à répondre à ces questions et à d’autres, ainsi qu’à vous fournir les conditions et les critères adéquats pour évaluer la qualité de l’impression.



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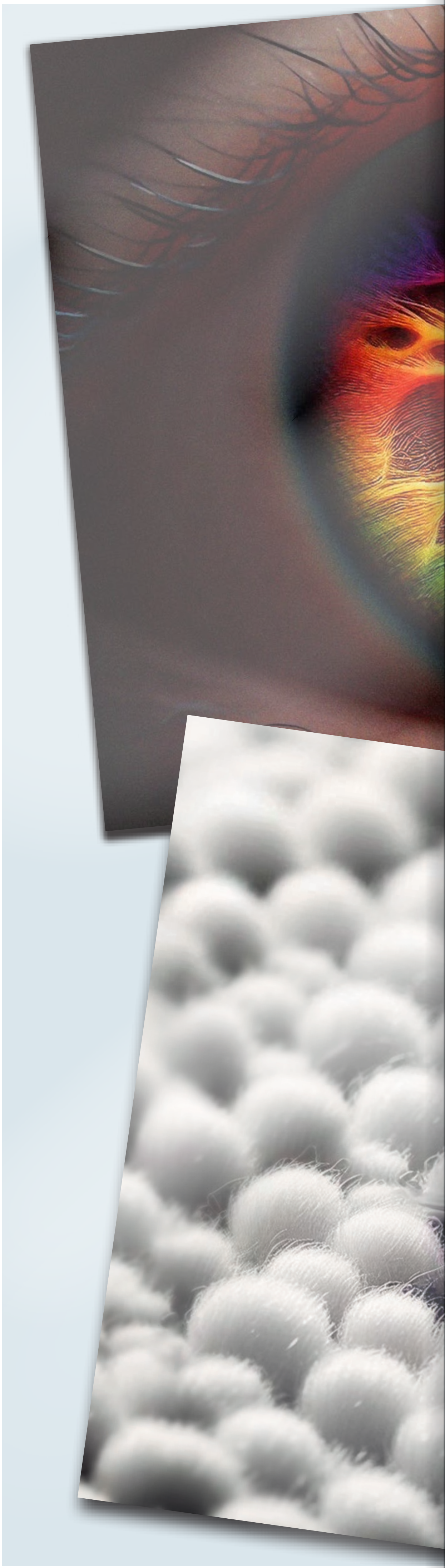

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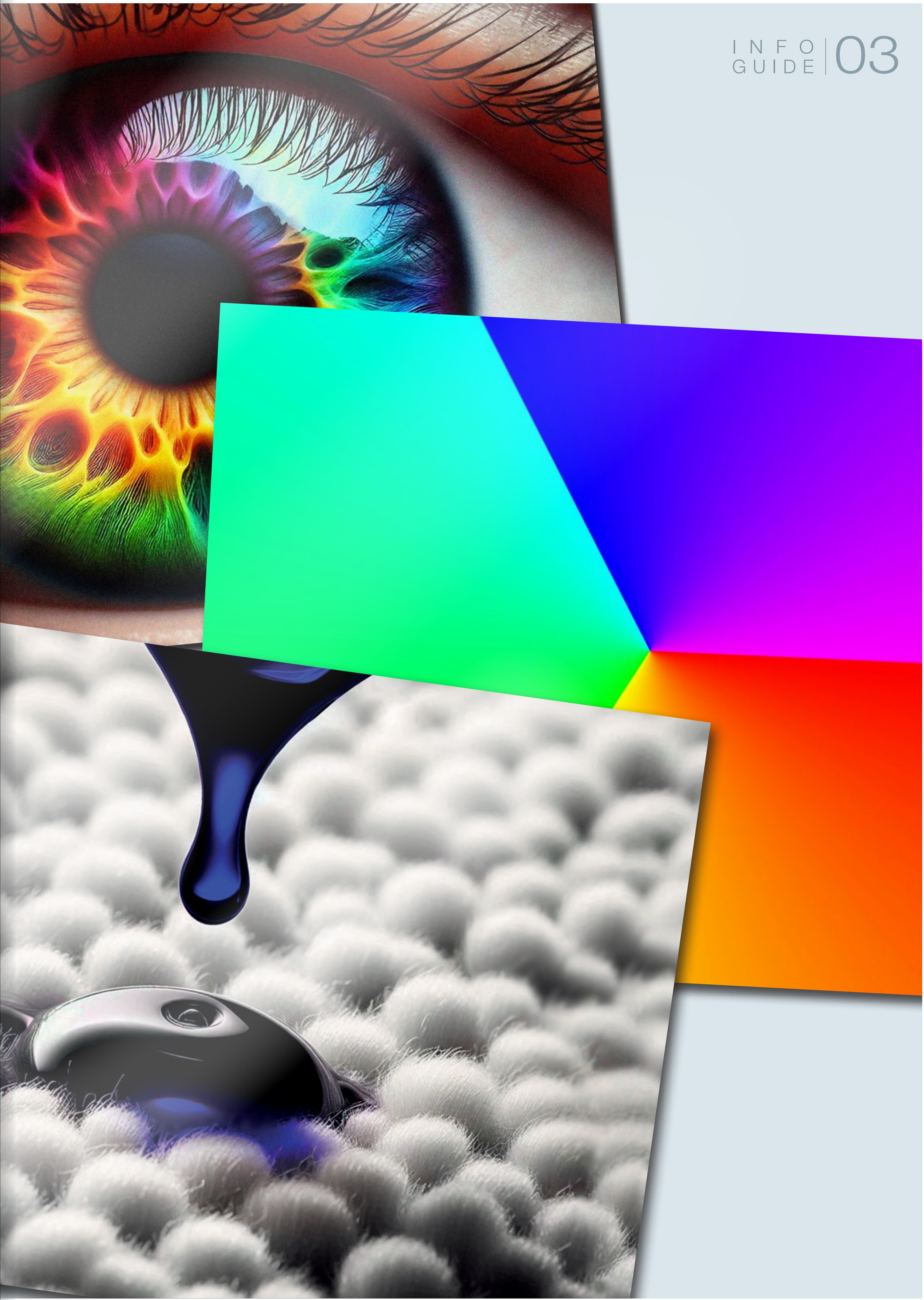


INFO GUIDE 03

COLOUR VISION

The phenomenon of

How many colours can we differentiate?

A trained person can differentiate up to **200 colour tones**, around **20-25 saturation levels** and **500 lightness levels** - that‘s up to **2.3 million colours**! In comparison, a monitor with 8bit can display 16.8 million colours.

Do all people name colours the same way?

No. The number of existing colour names varies greatly in different cultures and so the possibility of naming intermediate shades is sometimes very limited. Numerous tropical peoples, for example in South Africa or Papua New Guinea, use one and the same word for green and blue shades, but are able to distinguish these colours visually. It is assumed that the name is inspired by the sky or water, which change colour depending on the situation (environment/weather/season).

Do older people see colours less well?

Mostly yes, for three reasons:

1. Due to the increasing **yellowing of the lens** with age, colours appear duller, hues such as blue, turquoise and violet are harder to distinguish from each other.
2. **Cataracts** (affecting ~75% of people over 65) cause the lens of the eye to become cloudy, making the surroundings appear dull in contrast and colour, as if through frosted glass.
3. In addition, **the pupil diameter decreases** by ~60% between the ages of 30 and 60, and the need for light increases threefold. If too little light falls on the retina, colours appear duller or darker.

Fig. 1: colour tones, saturation, lightness

COLOUR

Colour tone

Synonymous: hue

The colour tones (also called 'hues') are what we call by general names and arrange in simple colour circles. The colour tone is usually what is at the core of a colour consideration, where it begins: 'I want my wall to be purple!'. However, this now includes a multitude of possible purple versions. The colour tone is therefore specified more precisely via the properties of lightness (also known as 'brightness') and saturation in order to arrive at the final colour. This can then be specified precisely in a colour model using the three values 'hue/ saturation/ brightness'.

Saturation

Synonymous: intensity

Saturation describes the intensity of a colour, i.e. how strongly it shines or instead falls into colourlessness, towards a pure grey value. To reduce saturation, either grey or the complementary colour is added, which leads to greying or clouding. As the saturation of colours increases, so does their contrast with each other.

Lightness

Synonymous: brightness

The lightness describes how light or dark a colour tone is, how strongly it is illuminated or shaded, i.e. how much white or black is added without clouding the colour into grey. It does not become 'dirtier', so the saturation is retained.

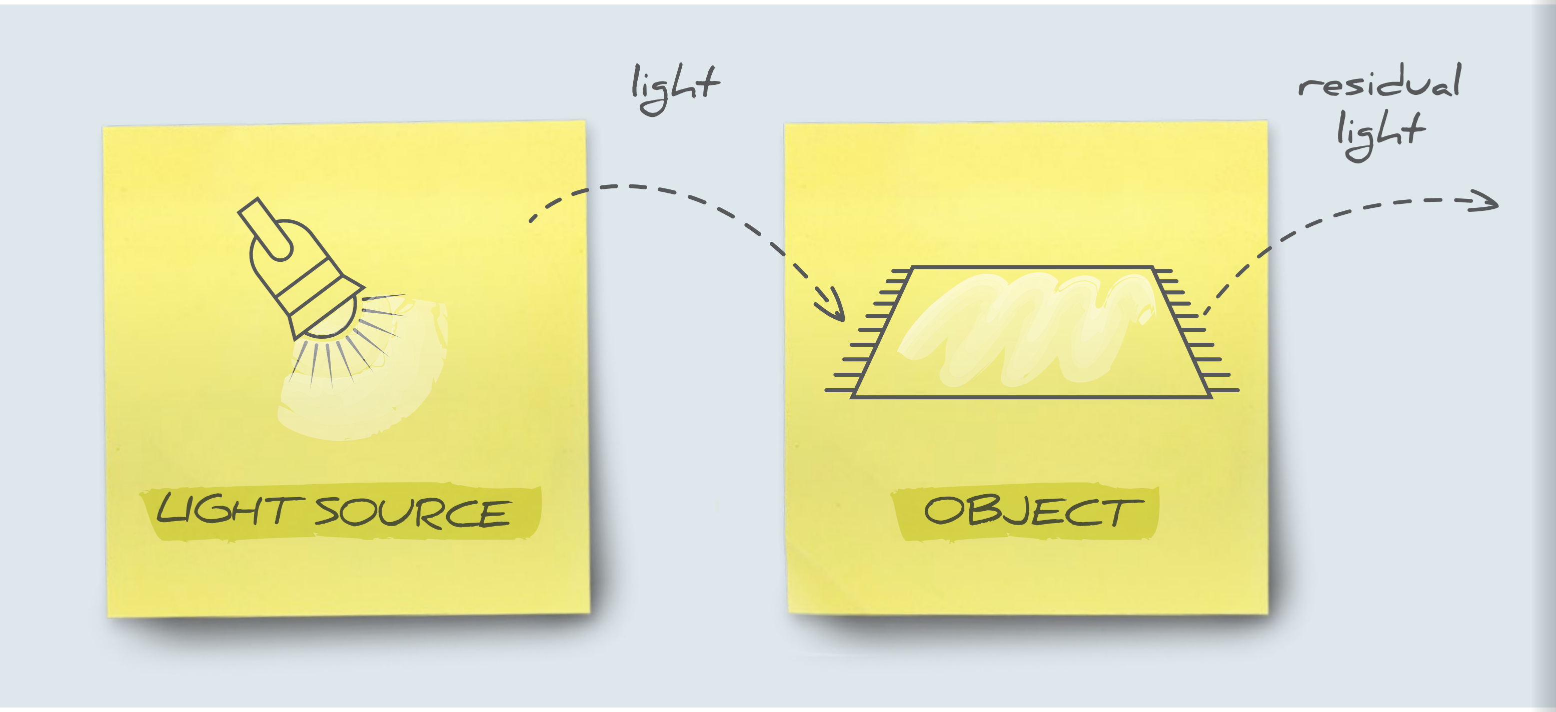
Test your colour IQ playfully online:

Click here for the Farnsworth-Munsell 100 Hue test: https://www.xrite.com/en/hue-test

Fig. 2: Farnsworth-Munsell-100-hue-test

The process

The following diagram shows colour vision as a combination of four main influencing factors: Light (source), object, eye and brain. Each component has a very significant influence on the perception of colour, and any change in one factor influences the result.
The 'colour' is created first and only in the brain.



1. The light

Human vision needs light. Light is energy radiation. If it is in the wavelength range between around 380 and 780 nanometres, it is visible to us. A light source - whether sun, candle or lamp - illuminates the object by emitting light waves and thus enables us to perceive it visually.
How detailed and in what colours we see the illuminated surroundings depends very much on the light source. The object can only reflect what was previously contained in the light falling on it.

2. The object

The light hits the surface of the object. Depending on the molecular structure of the object, some of the light is absorbed and converted into heat. The remaining light is reflected. We see this part as the object colour. Each object generates its own individual residual light mixture. It is a subset of the original light and is therefore highly dependent on the light source. To change the colour of an object, its surface can be painted, for example. A different residual light mixture is then reflected and seen as a new colour.

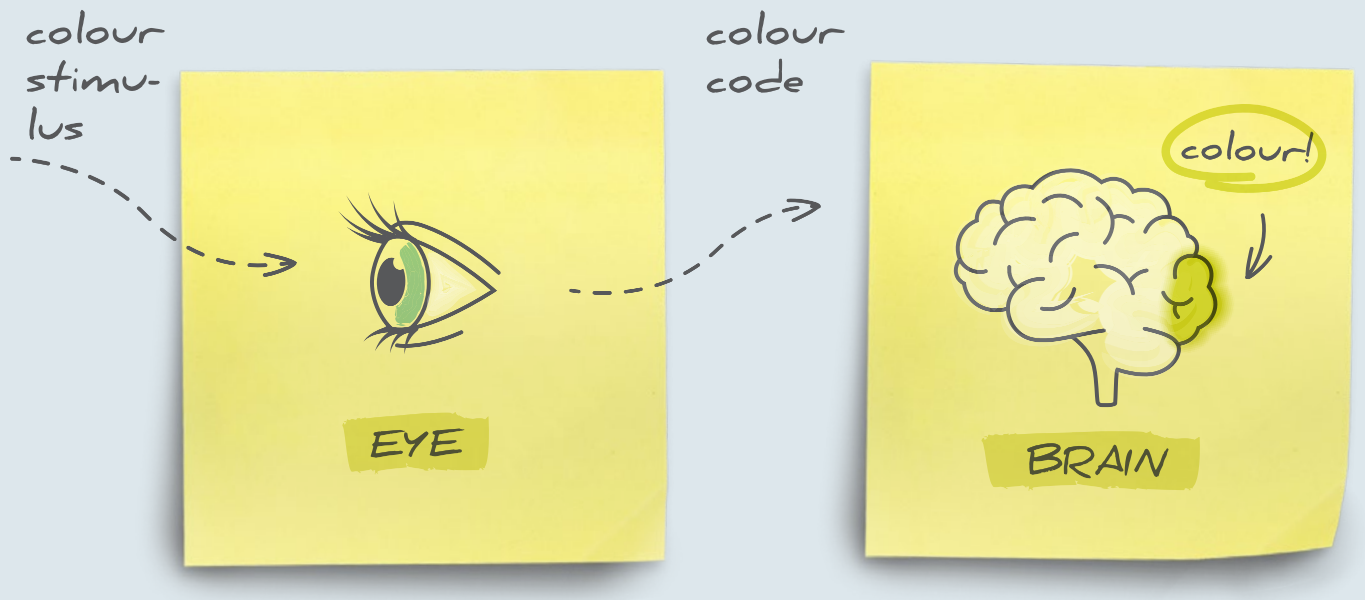


Fig. 3: Colour vision - the process

3. The eye

If the light reflected by the object falls into our eye, it represents a colour stimulus for it, which is perceived by the retina. Here, a conversion into a colour code - similar to a barcode in 'brain language' - takes place, which is sent to the brain via the optic nerve.
However, there is still no colour impression. This only arises at the very end when the colour code is read by the correct brain regions and converted into a colour impression.

4. The brain

The colour code is transmitted via the optic nerve to the occipital lobe of the brain. This is where the visual cortex - the area of the brain responsible for vision - is located. The incoming stimuli are then translated into a colour sensation.

We only see a red carpet in this colour because our eyes and brain interpret the wavelengths it reflects as 'red'. The perceived colour varies from person to person and only applies to the respective light situation and time.

1. The light and the light

Wavelength - light. The wavelength is given in **nanometres (nm).** Humans can only see a small wavelength range of the electromagnetic spectrum, namely that between ~380 and ~780nm - the 'light'. Both UV (<380nm) and IR radiation (>780nm) are invisible to us. However, we perceive the infrared wavelengths as heat.

Time of day - light spectrum. The composition of sunlight varies from place to place, day to day, with the weather and at different times of the year. This means that every moment has a unique wavelength profile.

Light spectrum - light colour. The light colour is specified in **Kelvin (K)**. Each colour of the light spectrum has a specific wavelength. However, it is also possible to add wavelengths to form a wavelength mixture with the same light colour. This means that **completely different wavelength proportions** can be behind **the same light colour**. The light colour 'warm white with 3000K' therefore does not indicate the underlying wa-

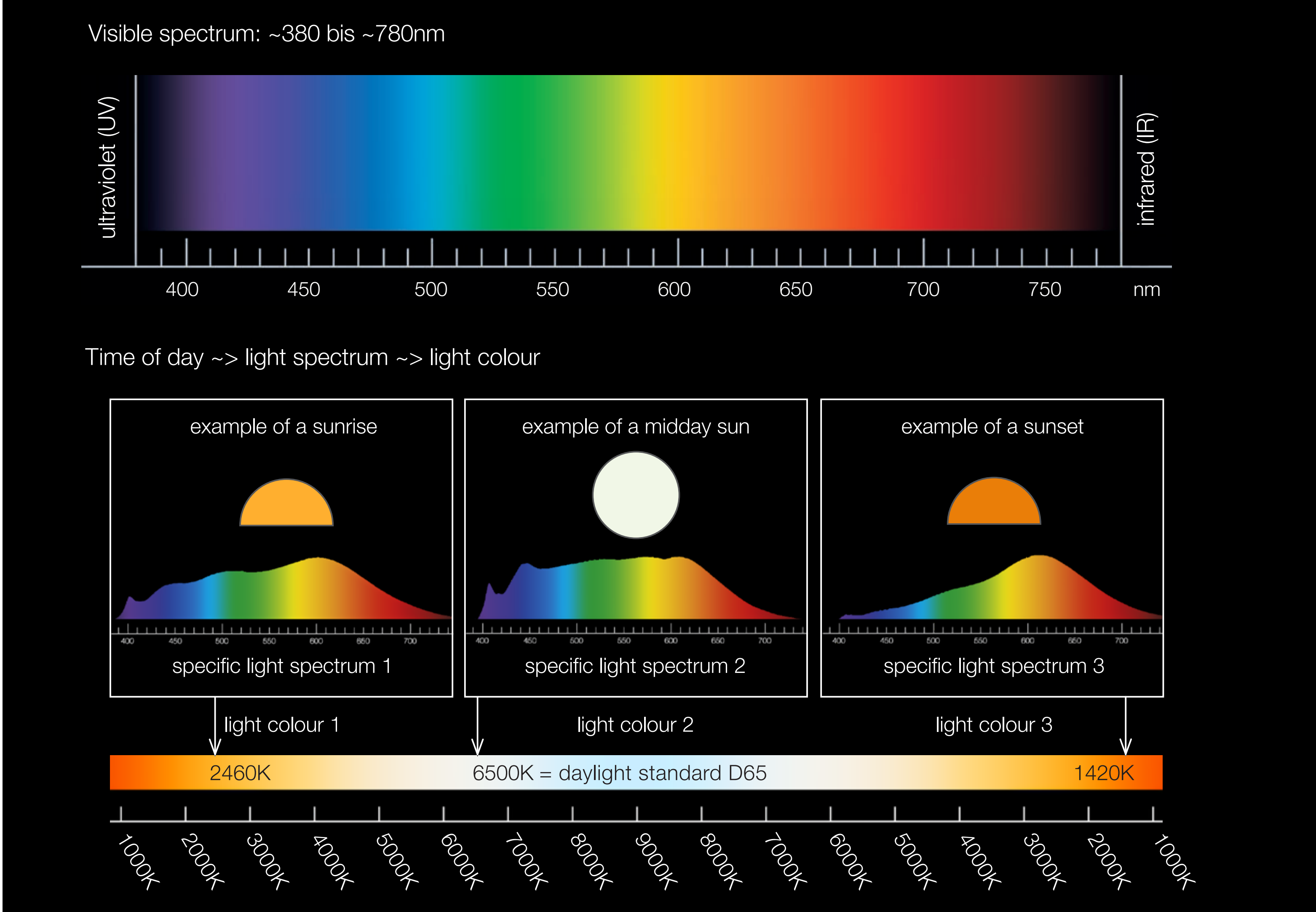


Fig. 4: time of day - light spectrum - light colour

source

velength profile! This can be particularly important when using artificial light to illuminate an object such as a carpet.

Light colour - body colour. Body colours are always dependent on the light that falls on the body. The wavelength mix behind the light colour is important here, as the final body colour is ‘mixed’ from this spectral range by reflection. This means that light sources with the same light colour but varying wavelength profiles produce different colour impressions on the illuminated object. It not only appears to us as if the carpet in the shop had a different colour than in the hallway at home or in the living room flooded with sunlight - it is actually the case! If two carpets have the same color under one light source but different colors under another, they are called “conditionally identical” or “metameric.” This phenomenon is generally called “illumination metamerism.” Halbmond generally uses **standardized daylight D65** with a wavelength of 6500 K.

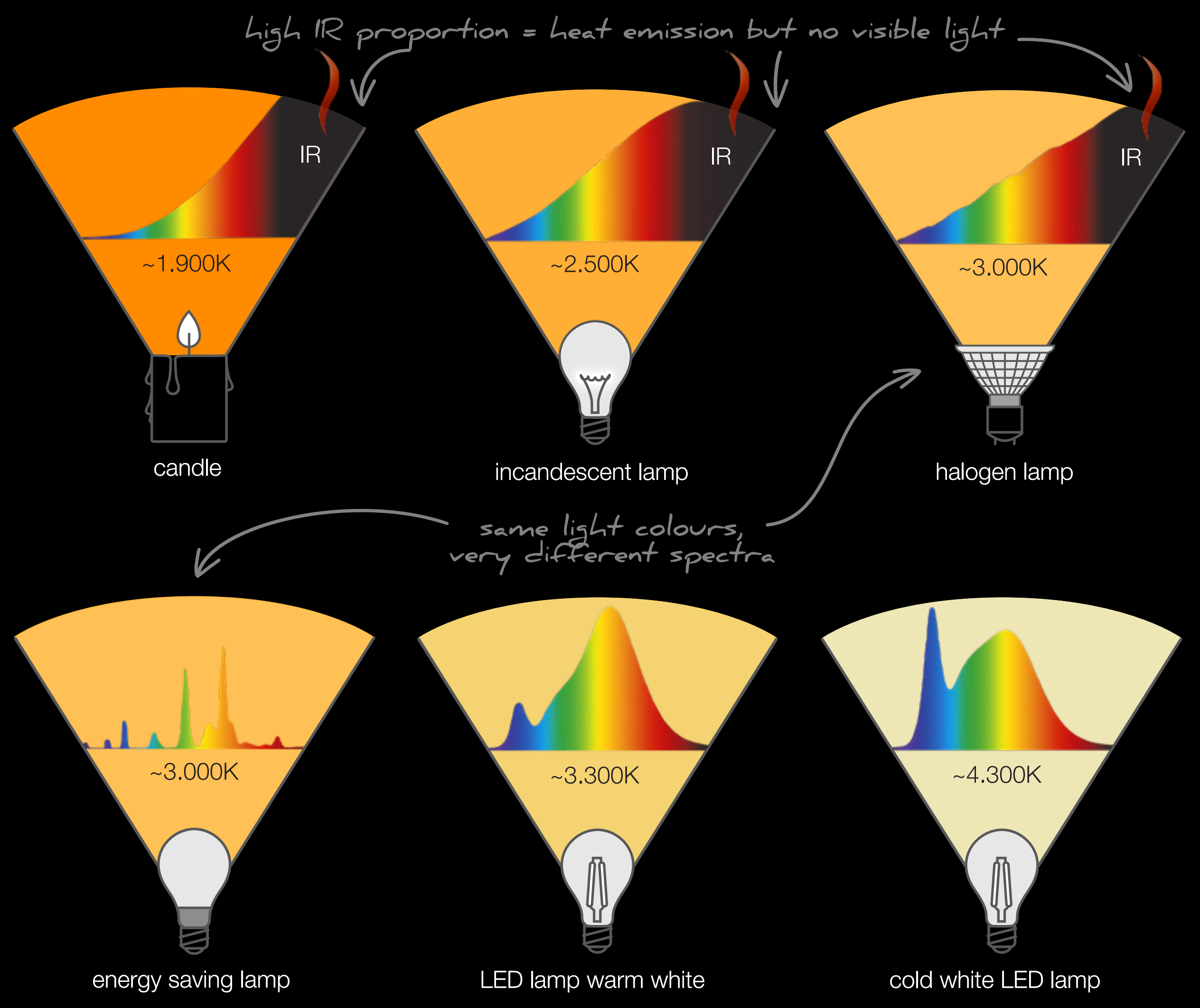


Fig. 5: light spectra of different light sources

2. The object

Lightness.

If light hits an object such as a rug, three basic scenarios are conceivable:

1. Complete reflection: The light is completely reflected, the textile appears bright (e.g. white) and remains cool.
2. Partial reflection: Part of the light is reflected, part is absorbed and converted into heat. The textile appears less bright (e.g. grey) and heats up a little.
3. Complete absorption: All the light is absorbed and converted into heat energy. This is why the textile appears very dark (e.g. black) and heats up considerably.

The amount of light reflected determines the brightness, the amount of light absorbed determines the heat.

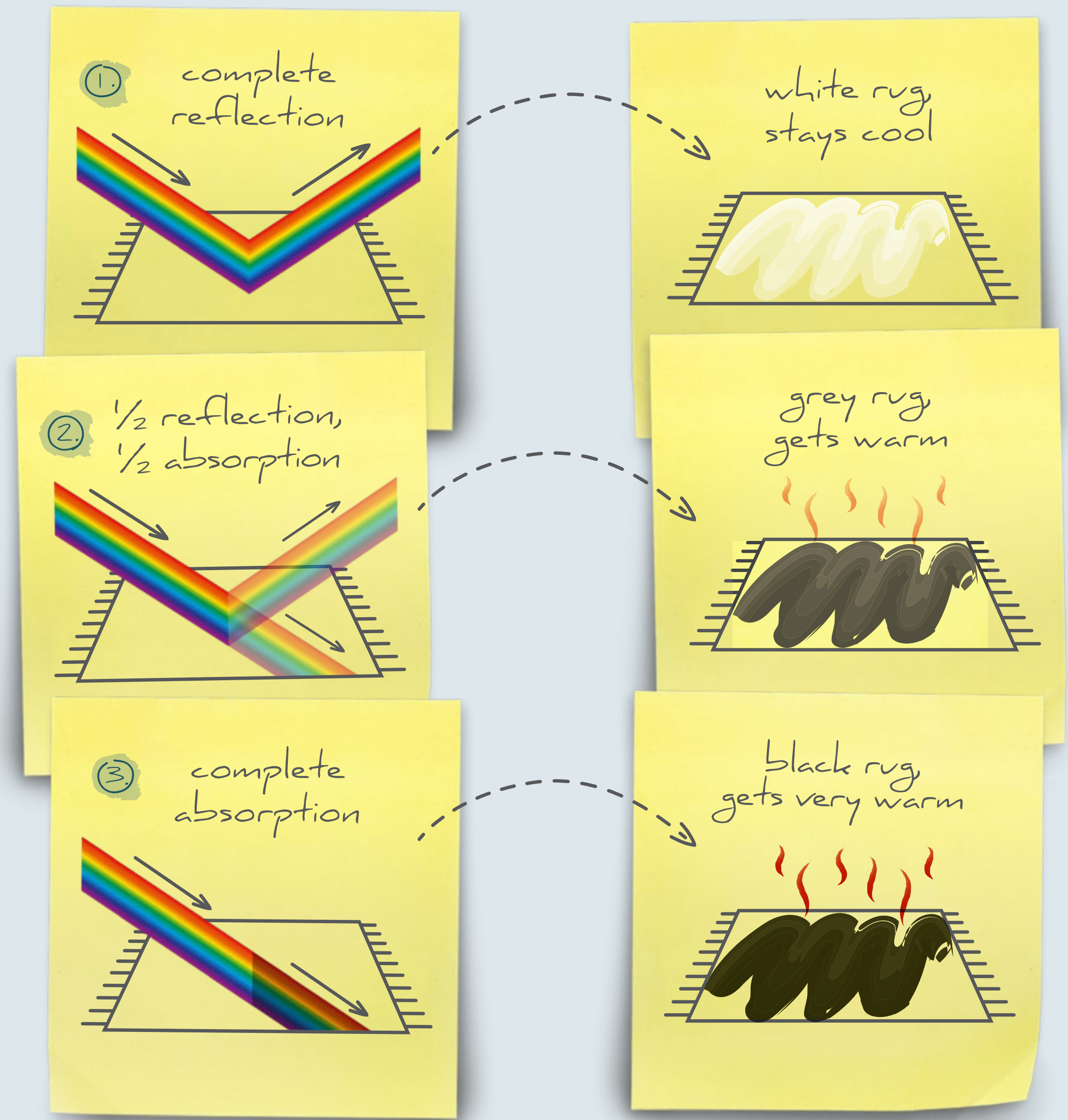


Fig. 6: the object - brightness

Colour. All spectral colours are contained in 'white' light. The decisive factor for the colour impression is which wavelengths of the overall spectrum are reflected. Here are three simple examples:

1. The 'red' wavelengths are reflected, all others are absorbed. The rug appears red to us.
2. The 'green' wavelengths are reflected, all others are absorbed. The rug appears green to us.
3. The 'blue' wavelengths are reflected, all others are absorbed. The rug appears blue to us.

A red carpet therefore appears 'red' because our eyes and brain interpret the reflected wavelengths as a red colour. This colour impression varies depending on external circumstances and the observer.

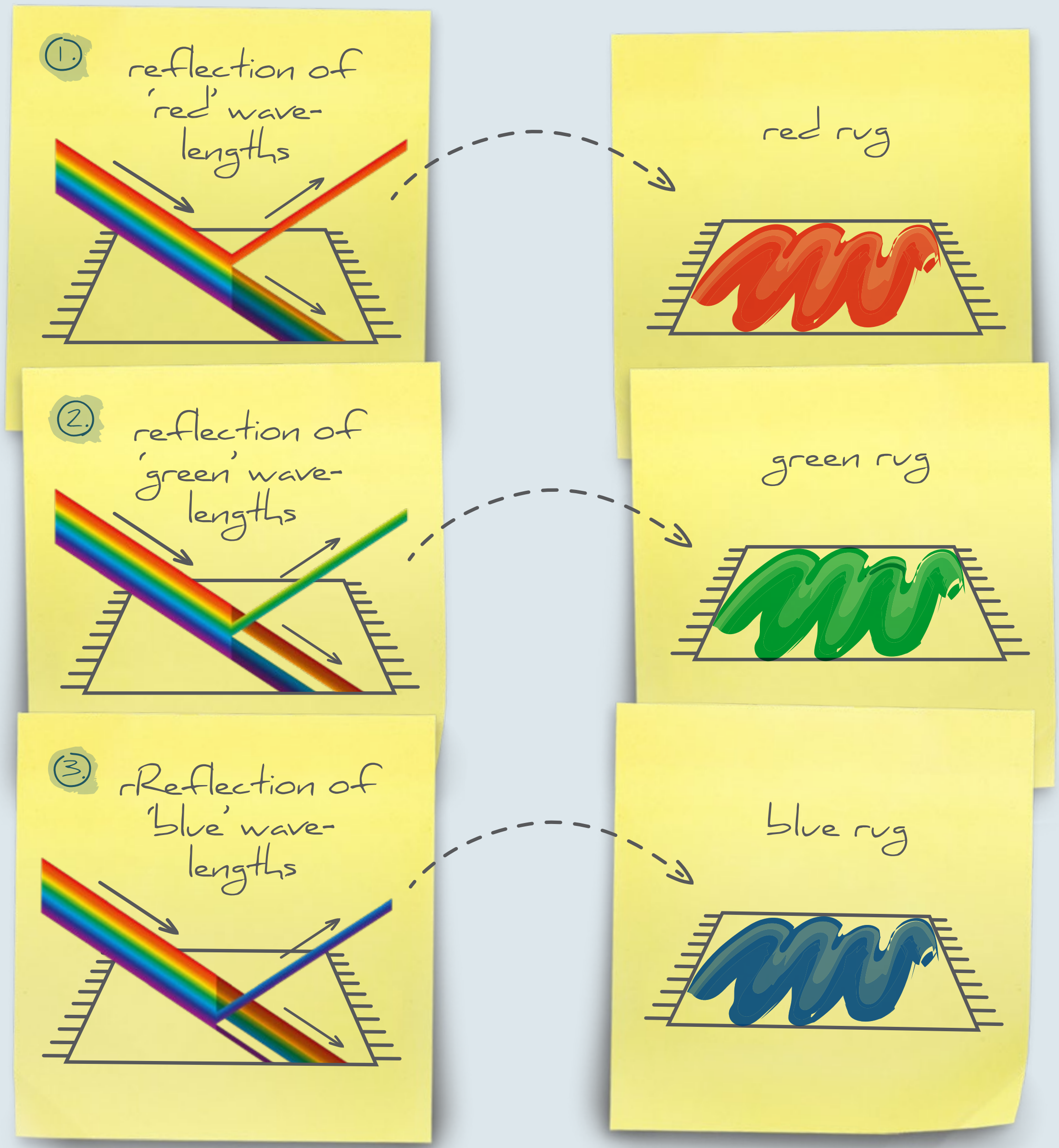


Fig. 7: the object - colourfulness

3. The eye and...

Light rays pass through the cornea and pupil into the eye and finally onto the retina. The light-sensitive rods and cones are located in the retina.

The rods are responsible for distinguishing between light and dark, are more sensitive to light than the cones but are colour-blind. They are responsible for seeing in poor light conditions. We have ~120 million per eye. **The cones** are responsible for colour and sharp vision and are only active when there is sufficient light. We only have ~6 million per eye, which can be divided into 3 types: **S**, **M** and **L** cones. They are named after the wavelength ranges that they perceive best (**s**hort, **m**edium, **l**ong wavelengths). Although the cone types are also known as **blue**, **green** and **red receptors**, their highest sensitivities are actually in the blue-violet, emerald green and yellow-green range. Nevertheless, the L cones enable red vision. The proportions of cone types vary from person to person; they are around 9-12% S cones, 55% M cones and 33% L cones. There are hardly any S cones in the area of sharpest vision and most S cones at the edge of the image. But one cone alone does not recognise a colour. The information from several different cones is always combined into **'receptive fields'** and evaluated in the nerve fibre layer of the retina.

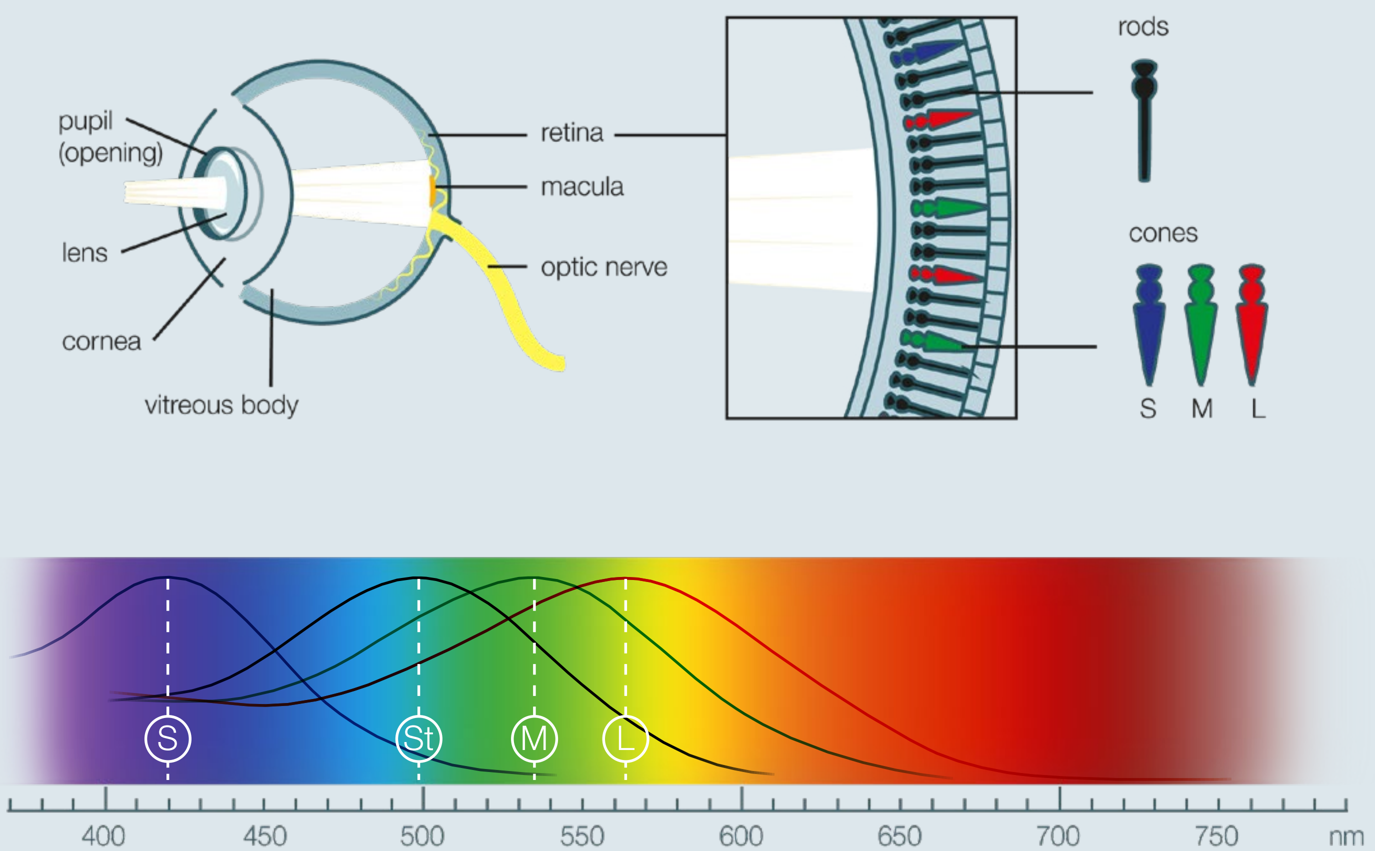
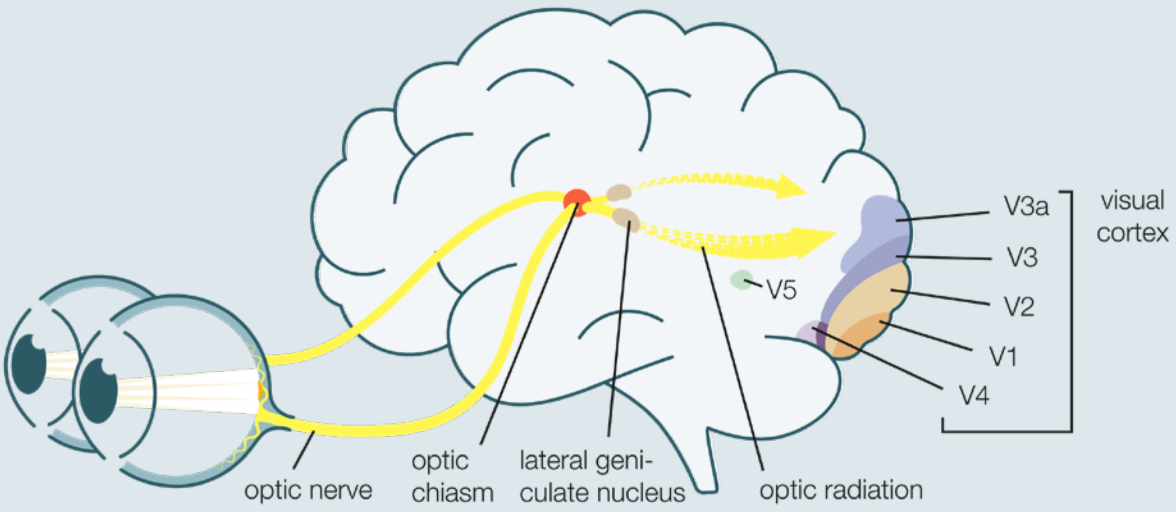


Fig. 8: the eye

4. ...the brain

Via the optic nerve, optic nerve junction and lateral popliteal tubercle, the information - ultimately in the form of visual radiation - reaches the **visual cortex**, the area of the brain responsible for visual perception. Visual impressions are evaluated in the main areas V1, V2, V3, V3a, V4 and V5 of the visual cortex, especially colour impressions in **V2** and **V4**.

The processing power of our eyes and brain until the impression of colour is finally created is nothing short of a masterpiece. Colour vision can be trained and thus the ability to distinguish colours can be improved. However, deterioration is also possible. An eye injury, ageing processes and illnesses can impair our vision. If, for example, an accident or stroke causes damage to one of the brain regions involved, this can also lead to limitations in (colour) vision. However, even the healthy eye and brain create an individual colour world for each person that deviates more or less from the average. Only when the ability to perceive and distinguish between colours is limited is it referred to as **'colour vision deficiency'** or **'colour blindness'**, depending on the type and severity.



primary vis. cortex	V1	input area for visual radiation, 1st rough projection of the overall image, pre-processing for V2
secondary vis. cortex	V2	recognition of complex shapes, contours, form, depth, **colours**
	V3	analysing the orientation and angular position of geometric shapes
	V3a	movement and direction analysis and planning
tertiary vis. cortex	V4	shape, size, object and face recognition based on **colour differentiation**
	V5	motion analysis, direction detection of moving objects

Fig. 9: the brain

What is your view of things?

Colour vision deficiency

Around 92% of all men and 99% of all women are ‘trichromats’ with three healthy cone types (S, M, L) and are considered to have normal colour vision. The most common causes of colour vision defects are:

1. three cone types are present but one perceives a deviating wavelength range (‘anomalous trichromats’). **Result: colour vision deficiency**
2. only two cone types are present or functional (‘dichromats’). **Result: colour vision deficiency**
3. only one type of cone is present or functional (‘monochromats’). **Result: colour blindness**
4. all cone types fail or are completely absent (‘achromats’). **Result: colour blindness**
5. age-related lens discolouration or clouding (‘cataracts’) as well as brain injuries caused by accidents or strokes lead to impairments. **Result: colour vision impairment/colour blindness**

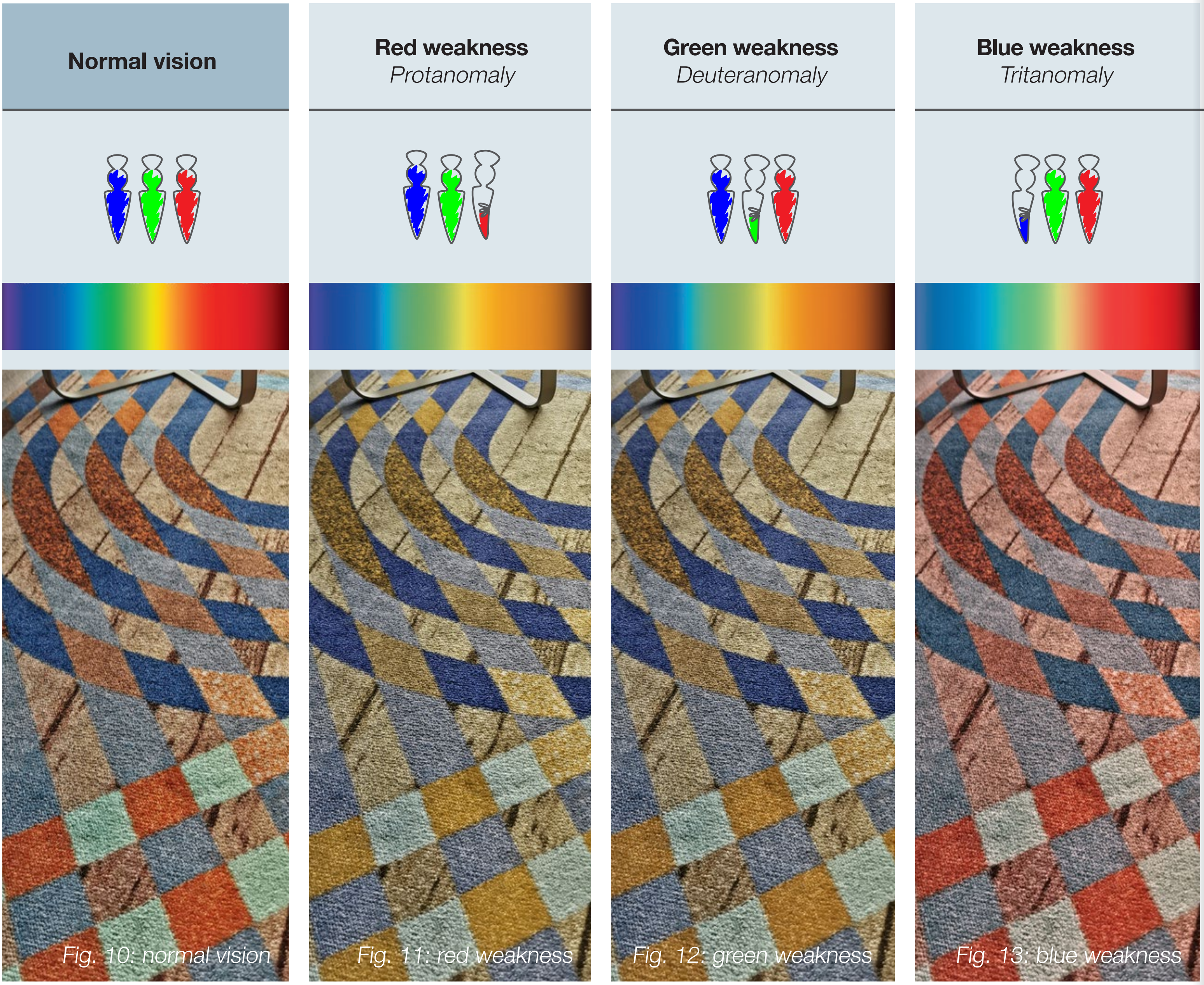


Fig. 10: normal vision
Fig. 11: red weakness
Fig. 12: green weakness
Fig. 13: blue weakness

Red-green weaknesses are the most common, and include **red weakness** and **blindness** (protanomaly and anopia) and **green weakness** and **blindness** (deuteranomaly and anopia).
The extent to which the visual impression deviates from the average varies from person to person. Nevertheless, the deviating colour spectrum and the resulting perception of the environment can be simulated for the individual colour vision defects. See below for examples.

> Would you like to check your design for accessibility? Photoshop has a simulation of prot- and deuteranopia integrated: View > Proof Setup > Color Blindness
> This free tool can be used to simulate other colour vision defects (see below):
https://barrierefreies.design/barrierefreiheit-interaktiv-testen/farbenfehlsichtigkeit-simulieren

Red blindness
Protanopia

Fig. 14: red blindness

Green blindness
Deuteranopia

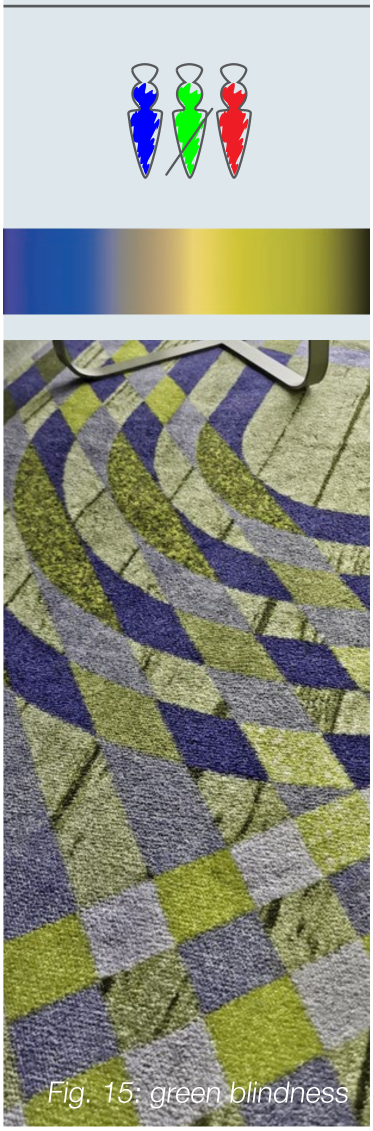


Fig. 15: green blindness

Blue blindness
Tritanopia

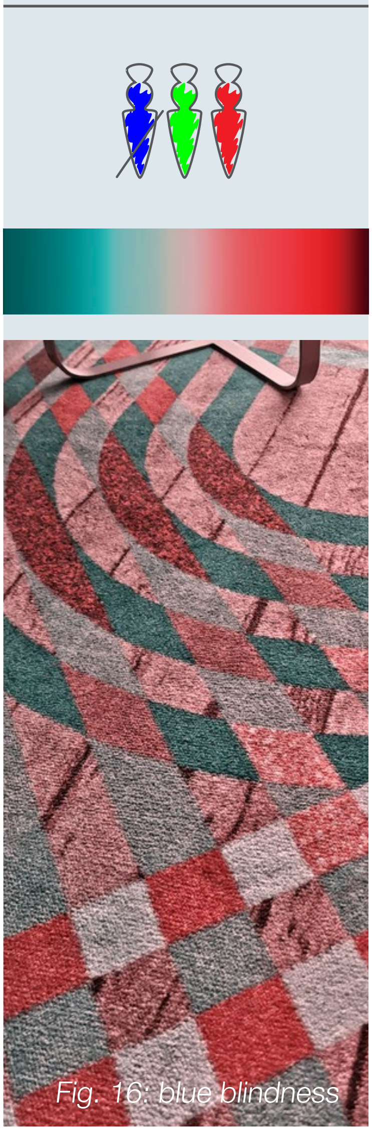
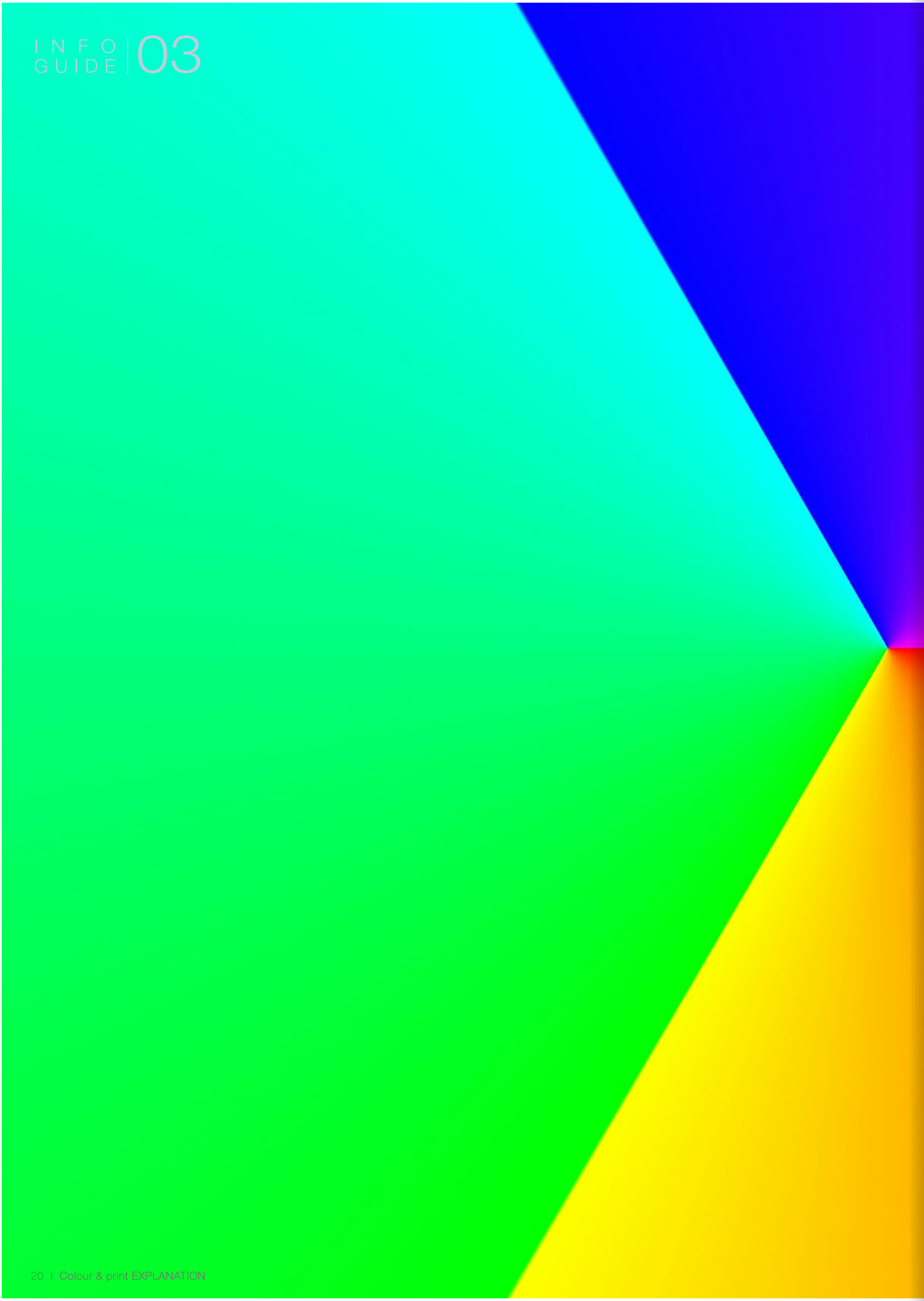


Fig. 16: blue blindness

Colour blindness
Achroma(top)sia

Fig. 17: colour blindness



COLOUR SYSTEMS

Light colours - additive mixing

Additive colour mixing begins in a dark room. The more lights are switched on, the brighter it gets, **the light adds up** and the light colours - if different - mix to form a new colour. A light colour tone is the result of a certain 'recipe' of wavelengths, which becomes visible unadulterated when the light falls on a white background. In practice, this means that a white carpet, for example, is 'coloured' by a mixture of light falling on it.

The basic colours (also: primary colours) of additive light mixing are red, green and blue. Each is only a subset of 'white' light. Cyan (blue + green), magenta (red + blue) and yellow (green + red), the secondary colours, can be mixed from these primary colours. A variety of hues are created by changing the proportions and intensities of these three primary colours. Of course, this **RGB** colour mixing is not used on carpets, but in **LED-based lamps, monitors, displays** and all systems that emit coloured light.

Fig. 18: light colours - additive mixing

Body colours - subtractive mixing

The white carpet initially reflects the entire visible spectrum as white light. If a yellow brushstroke is now applied to the carpet, only the yellow wavelength range is reflected at this point (or a 'wavelength recipe' that produces yellow). All other light components are absorbed. With each application of additional dyes, the **amount of light decreases**, i.e. it is **subtracted**. The principle applies to all physical bodies - hence the term '**body colours**'.

The basic colours here are **c**yan, **m**agenta and **y**ellow. For pastel colours, only the pigment proportion needs to be reduced (e.g. by thinning). If the sheet is not white, additional white pigments are required. Dark shades are created by mixing all three colours. When printing, a black ink is added. The colour system used here is named after the three basic colours and the **black** reference printing plate (**k**ey plate): **CMYK**. It applies to **all work with physical colours**.

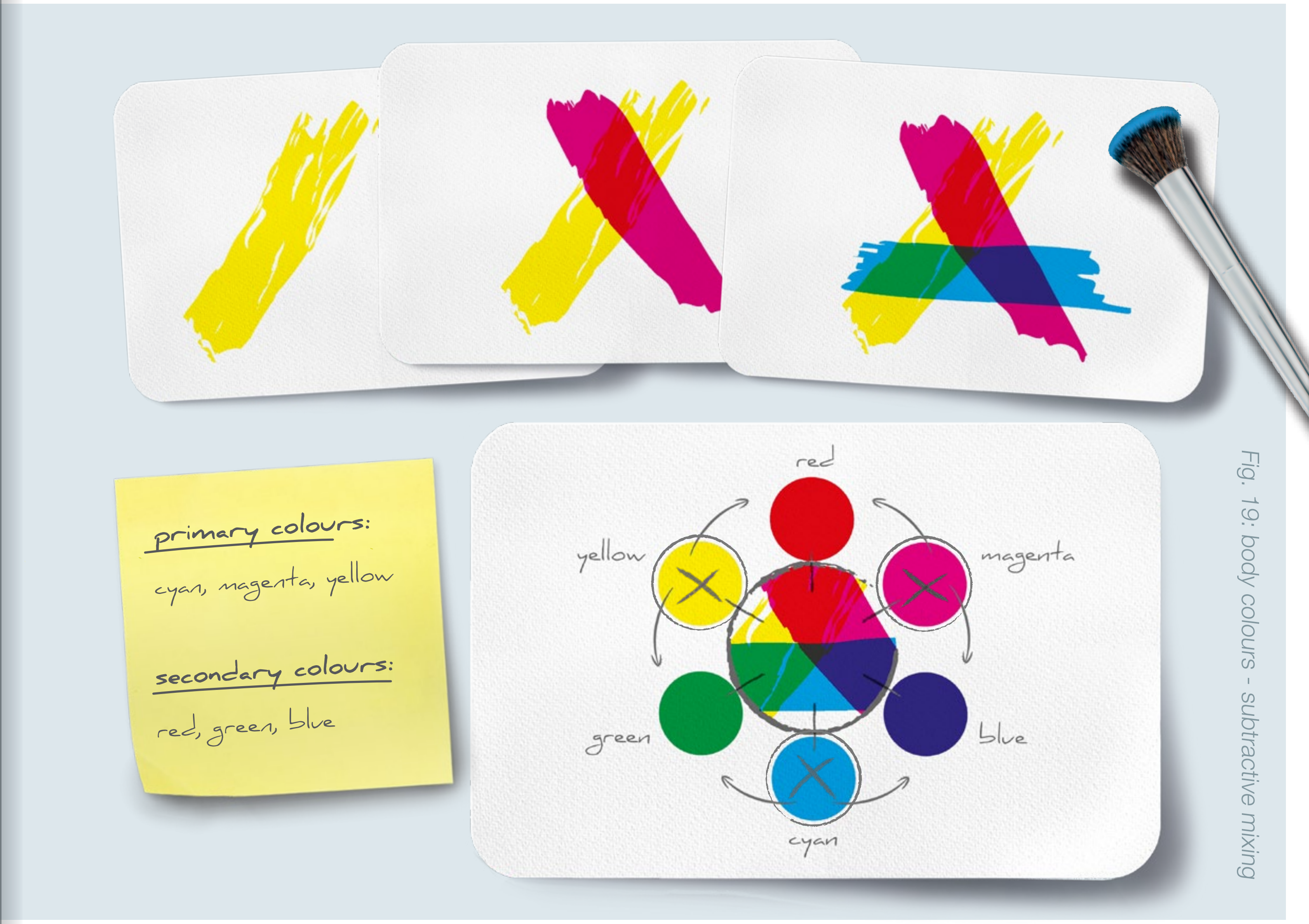


Fig. 19: body colours - subtractive mixing

Colour theories - past...

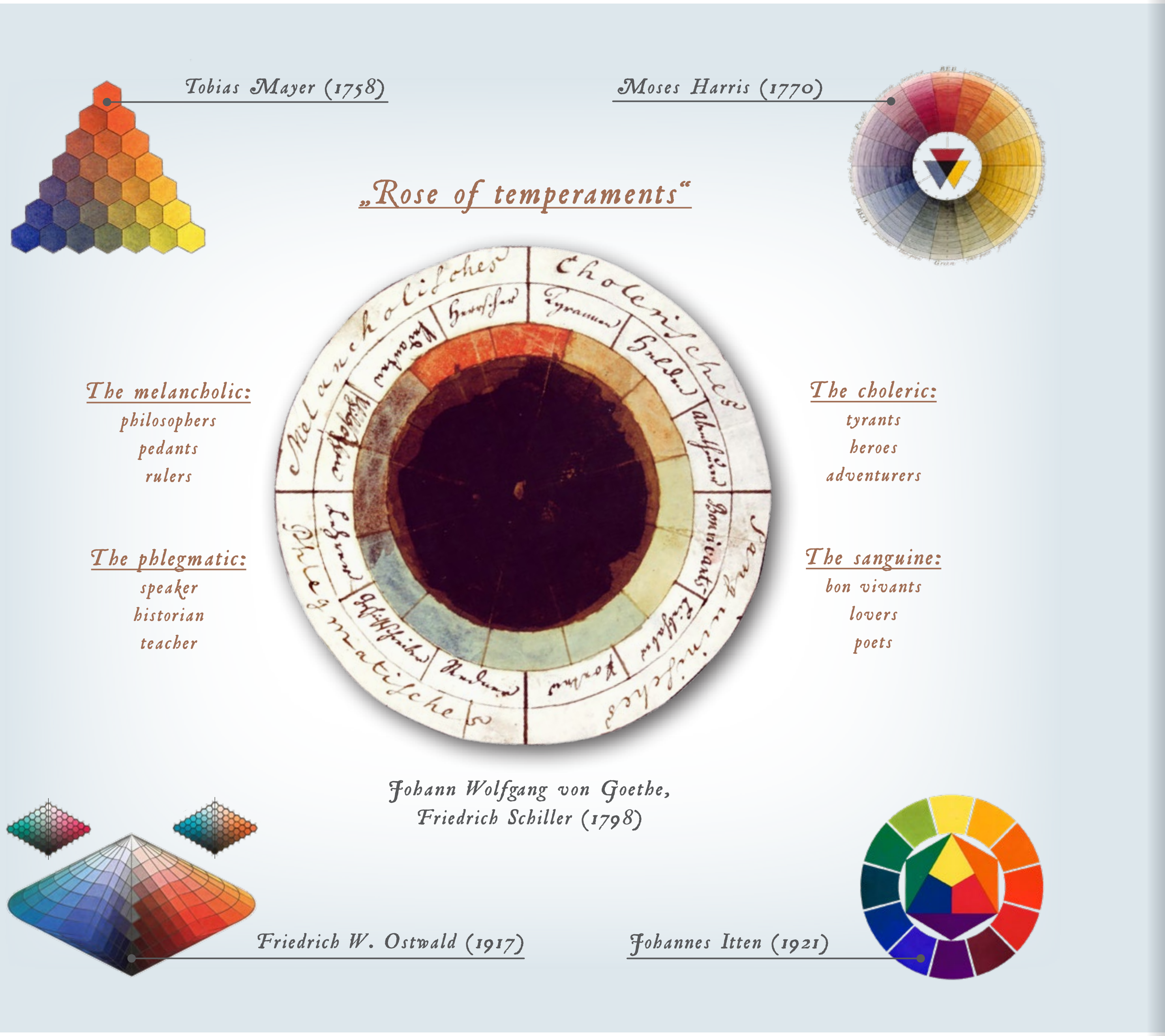


Fig. 20: colour theories - past

The history of colour theories dates back to antiquity. Renowned philosophers, scientists and painters have tried to explain the phenomenon of colour. While subtractive colour mixing was more intuitive (every painter worked with it), the phenomenon of light colour mixing could only be explained thanks to Newton‘s optical physics. The realisation that ‘white’ light could be broken down into spectral colours like those of a rainbow using a prism supplemented the understanding of colour and the subsequent theories - but not immediately. Goethe‘s colour theory was even broader: for example, the ‘temperament rose’ assigns human traits to groups of colours on the colour wheel, thus adding a psychological component.

...and present

Colour type hexagon

Harald Liebedank Küppers (1972)

Tip: For practical work with opaque colour pastes, Küppers recommends using all six primary colours as well as white and black for maximum luminosity, instead of creating mixtures of cyan, magenta and yellow.

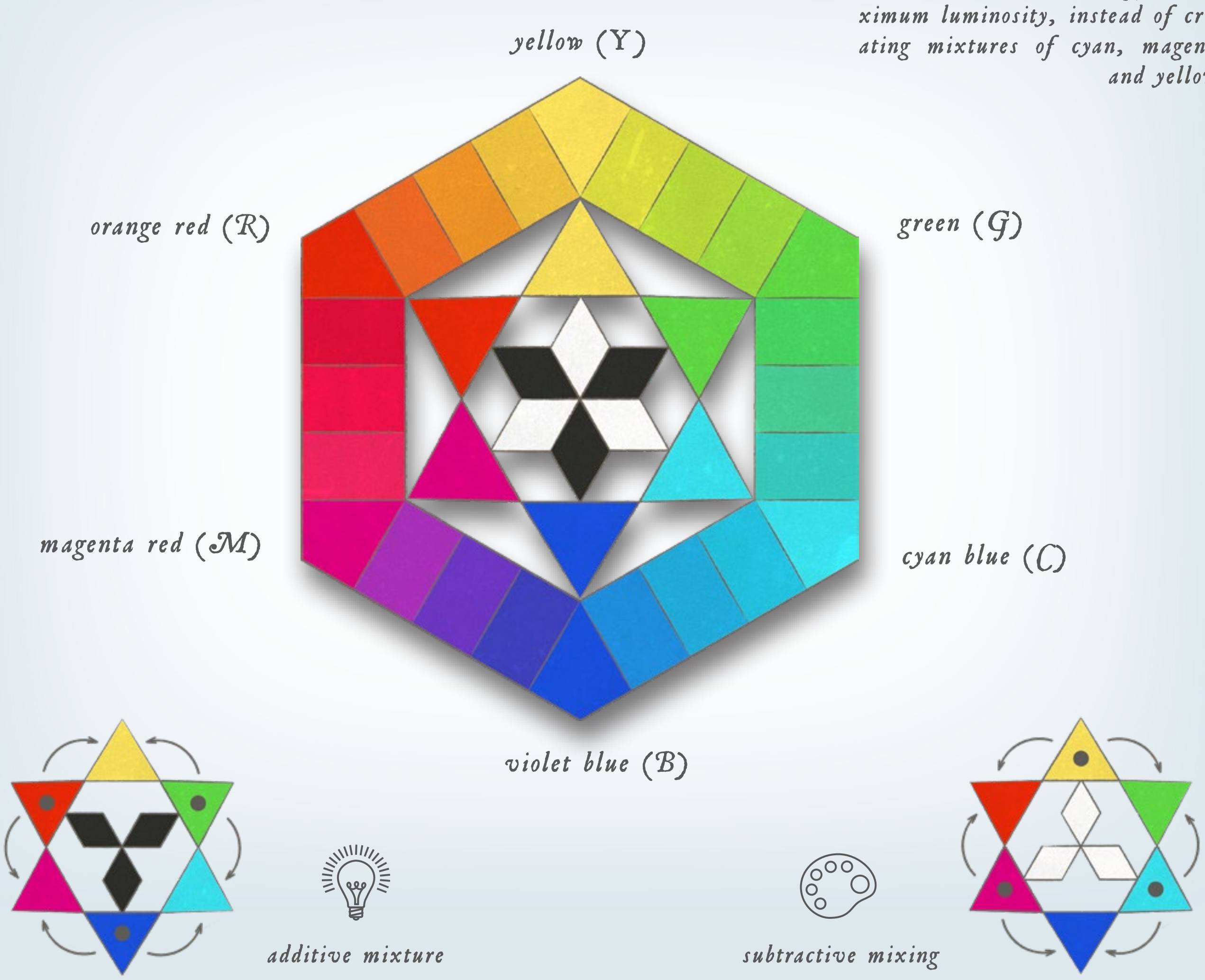


Fig. 21: Colour theories - present

Today, the colour theory of printing technician and colour researcher Harald Liebedank Küppers is taught in German schools. His illustrative models, such as the chromatic hexagon, depict both subtractive and additive colour mixing, depending on how they are read:

◆ Starting from black, the **light colours** or 'Urfarben' orange-red, green and violet-blue are mixed **additively** so that yellow, cyan-blue and magenta-red are created from two of these colours (see also page 22).

◇ Starting from white, the **body colours** or 'Grundfarben' yellow, cyan blue and magenta red are mixed **subtractively** to create orange red, green and violet blue (see also p. 23).

Colour terms

Colour system/scheme

A colour system is an approach or method for organising colours. Known colour systems are **colour circles**, **colour catalogues**, **colour fans** or **colour models**. Colour models are special colour systems that are often mathematically defined by a coordinate system and are based on the mixture of a few defined basic colours.

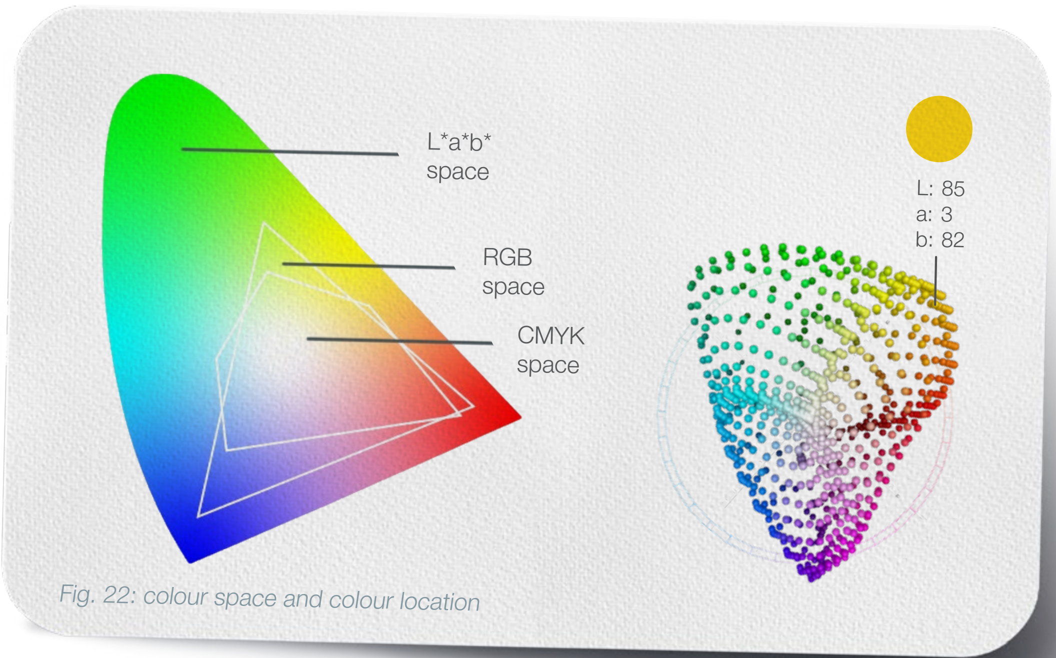


Fig. 22: colour space and colour location

Colour space

A colour model includes three-dimensional colour spaces (e.g. AdobeRGB as a colour space of the RGB model). Within a colour space, each colour - e.g. that of a given measurement object - has an exact colour location, which is usually defined by three coordinates.
The **L*a*b* space** corresponds to the area perceptible to the human eye and is therefore the largest. The **RGB space (e.g. monitor)**, like the **CMYK space (e.g. printer)**, is only a subset of the L*a*b* space. Both (RGB & CMYK) have large overlapping areas but also areas in which they do not overlap. If the latter is the case, the colour cannot be displayed in the other colour space - **a common cause of discrepancies between colours on the monitor and colours on the carpet!**

There are colours in the Lab colour space that cannot be represented by either RGB or CMYK colour values. This practically means that such Lab values cannot be achieved by mixing the four basic print colours. However, the more basic colours are used for the mixture, the more colours of the Lab colour space become printable (relevant for so-called ‘custom colours’).

Gamut

Gamut refers to the total range of colours that a device (e.g. a TV set or printer) can display or reproduce, i.e. the device-specific colour gamut at a specific point in time. The limitation here is directly related to the technology used. For example, a certain monitor can reproduce a different colour gamut than a mobile phone (although both work according to the RGB principle with light colour mixing) and a different one with an inkjet printer (CMYK principle). The gamut - in contrast to the colour space - is variable, as ageing, wear and tear or technical damage to a device affect the result just as much as the use of new inks, for example.

Colour profile

The gamuts of two devices are always different, sometimes also their colour spaces. Colour profiles (also called ICC profiles: International Color Consortium) are used to ensure the 'jump' from a monitor (RGB) to a printer (CMYK) without significant colour shifts. They are a kind of translation or conversion tool between two devices that is intended to maximise the approximation of the visual print result to its digital original. Colour profiles even take into account the medium to be printed on, i.e. the type of paper or - in the case of carpet printing - the type of pile.

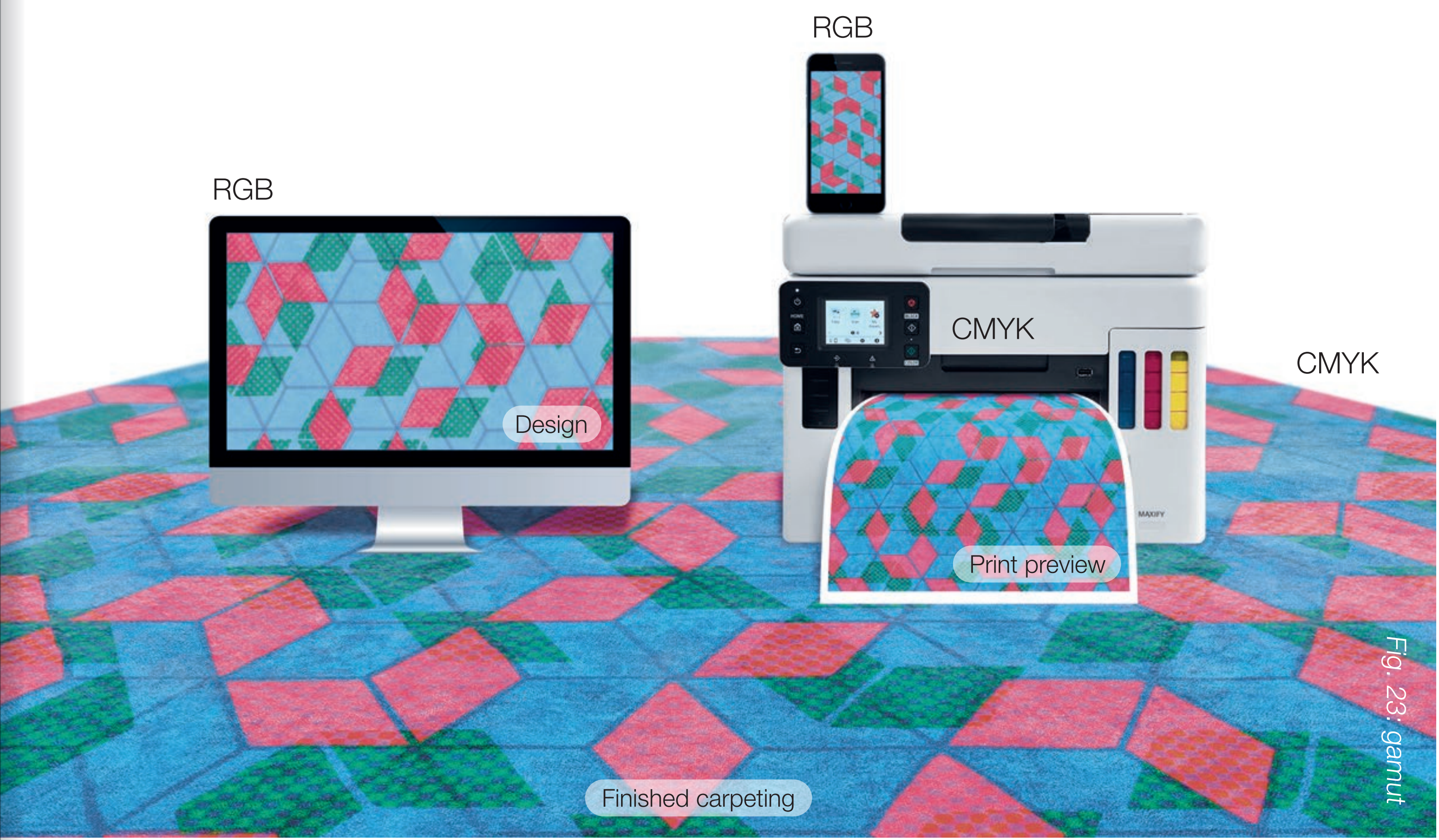
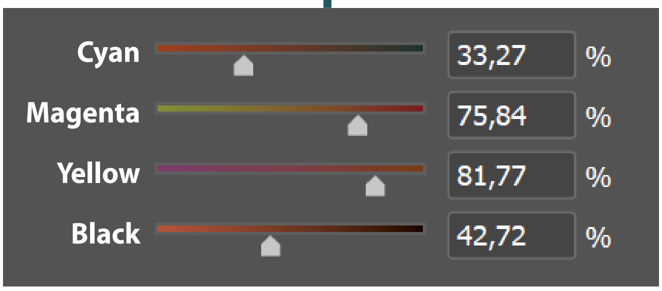


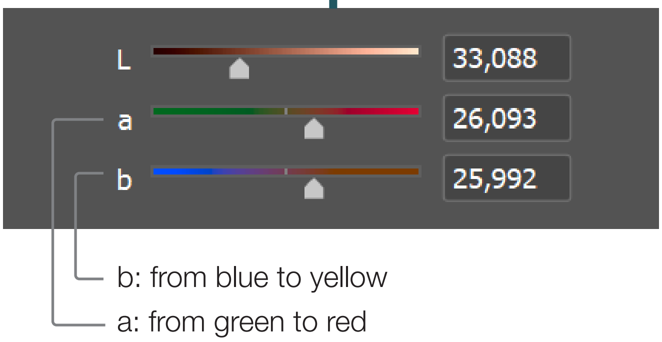
Fig. 23: gamut

Colour models, spaces &

Colour spaces are important in the day-to-day work of print shops. The user interfaces listed below, so-called ‘colour pickers’, for colour models are mainly encountered when working in graphics programs. The selected colour space not only determines the subsequent print result, but also determines the file format in which a design can be saved (e.g. as PNG for transparency -> only in RGB mode).

> Are you working in Photoshop and would like to know which colour space/mode is set for your file or change it? Both are possible under ‘Image > Mode > ...’.





	CMYK	L*a*b*
USAGE AREA	for all **colour printing processes** on physical substrates (e.g. photo and textile printing)	when **converting** between different devices (e.g. from digital camera to printer as part of print preparation)
BASED ON	subtractive colour mixing	visually perceptible colours
DATA	Cyan: 0 - 100% Magenta: 0 - 100% Yellow: 0 - 100% Black: 0 - 100%	L (Luminance/brightness): 0 - 100 a (colour component): -128 - 127 b (colour component): -128 - 127
FILE FORMAT	JPG, TIF, PSD, PDF, EPS, ...	JPG, TIF, PSD, PDF, EPS, ...
COLOUR PROFILES	Coated FOGRA39 (ISO 12647-2:2004), ISO Coated v2 ...	*> as device-independent reference colour space in the background*

pickers

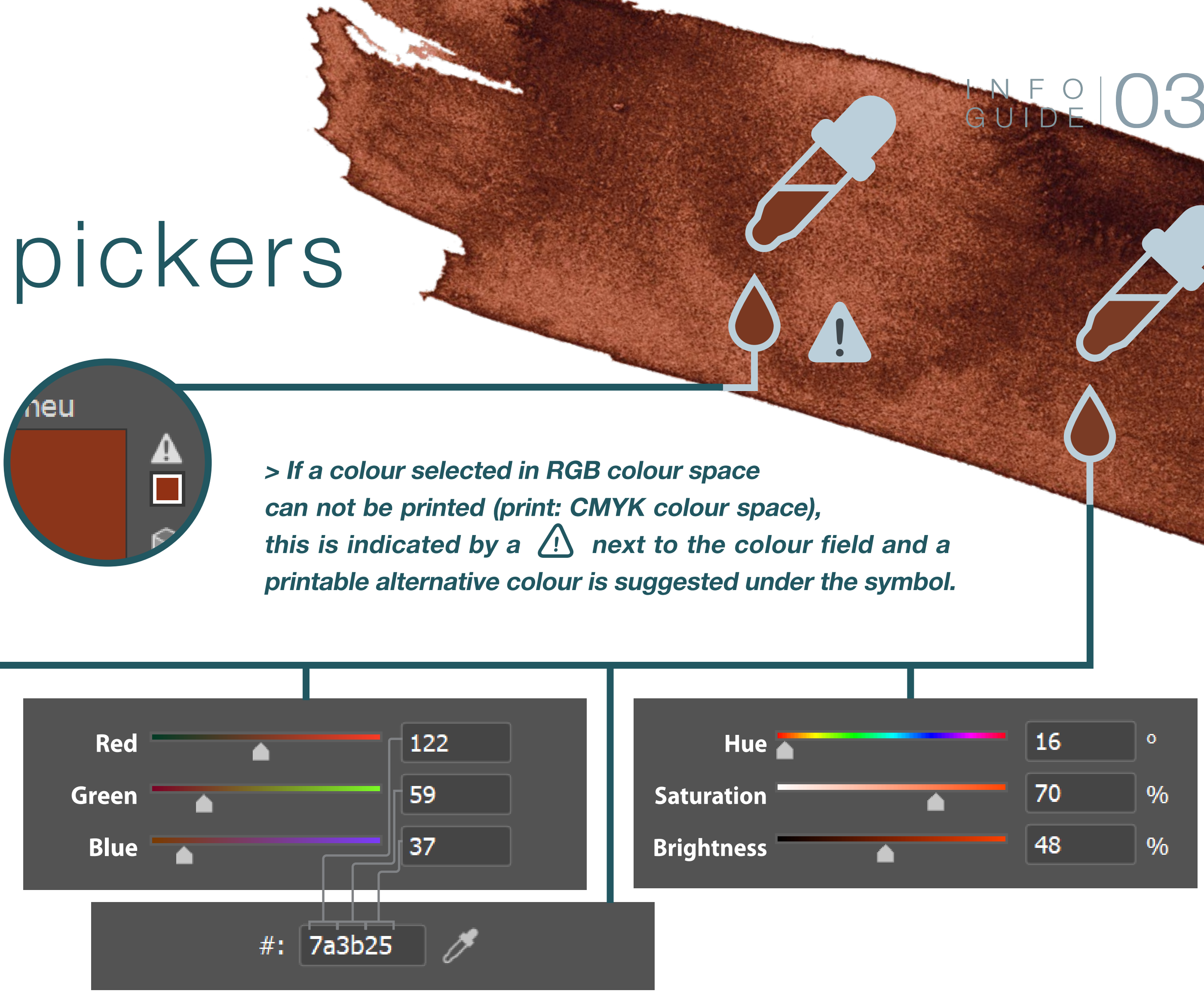
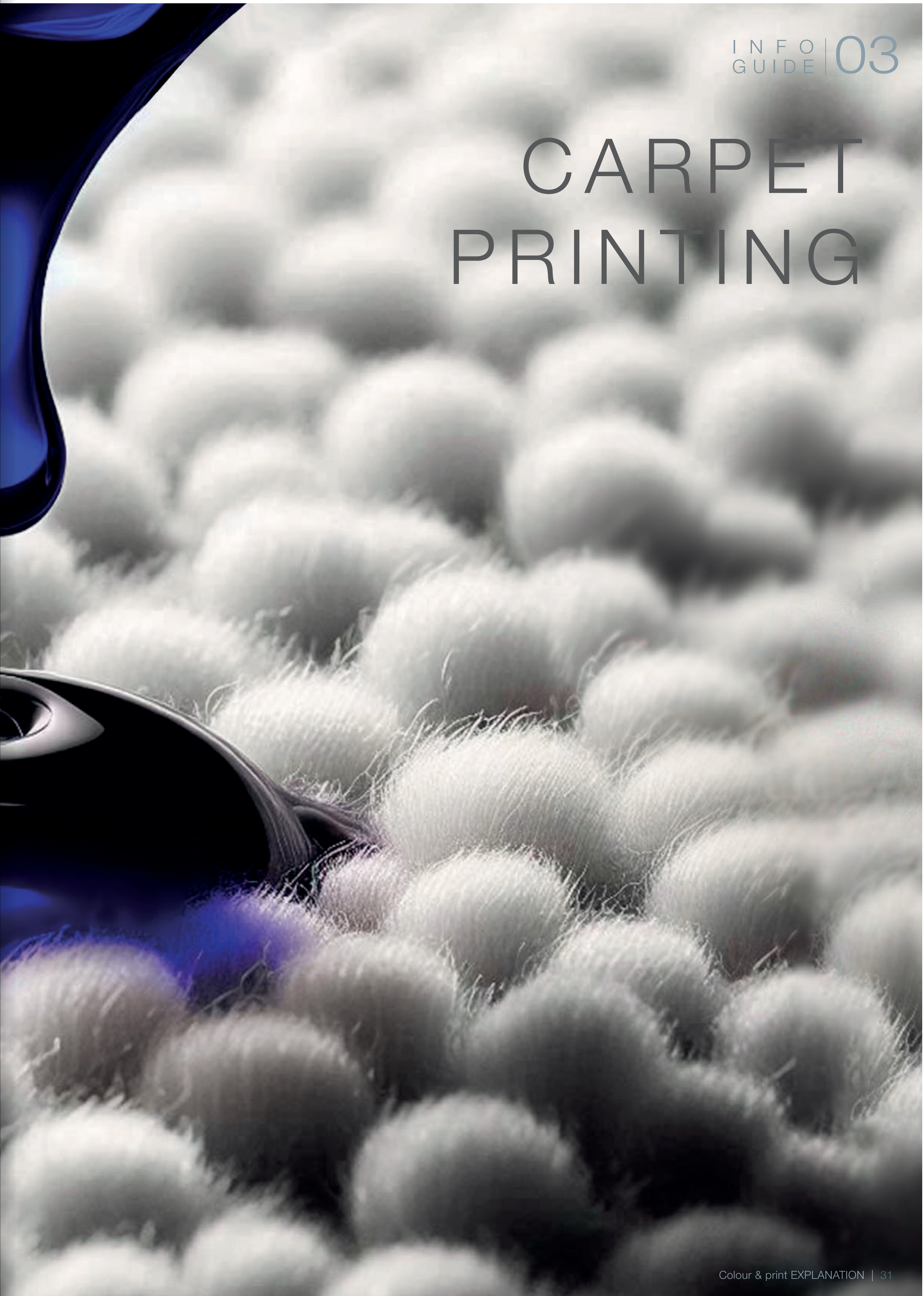


Fig. 24: colour pickers

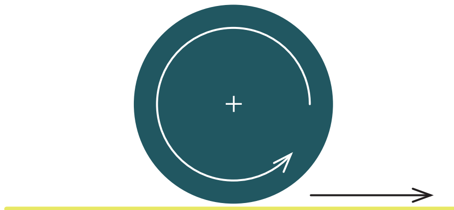
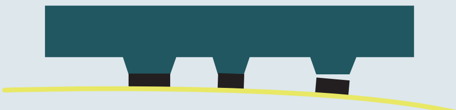
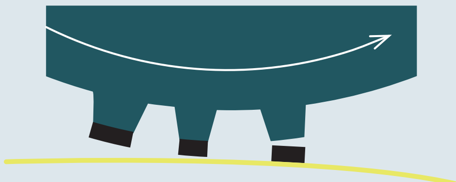
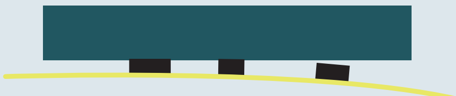
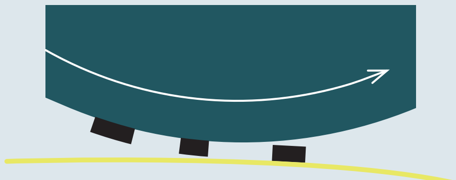
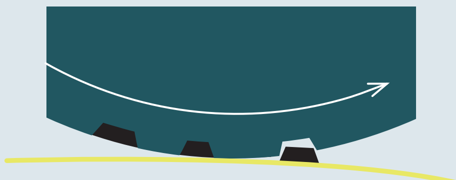
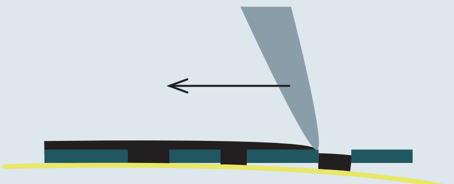
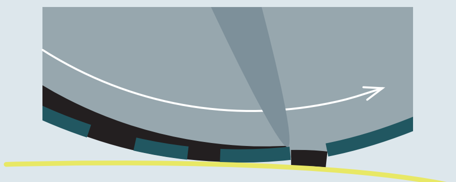
RGB	HEX	HSB = HSV
for image material **on all mobile devices** (e.g. photos on digital cameras and mobile phones, images and logos on websites)	in the context of **web design** as a short, practical way of displaying an RGB value (can also be integrated into html codes!)	in design work for the **intuitive choice** of colours, as it is based on human colour assessment (hue, saturation, brightness)
additive colour mixing	RGB model -> short form	RGB model -> intuitive interface
Red: 0 - 255 Green: 0 - 255 Blue: 0 - 255	# RRGGBB -> two-digit letter and number code for each colour component	Hue: 0 - 360° Saturation: 0 - 100% Brightness: 0 - 100%
< < < JPG, TIF, PSD, PDF, EPS, GIF, BMP, PNG, WEBP, ... > > >		
sRGB IEC61966-2.1, Adobe RGB (1998), ProPhoto RGB, ...		

Tab. 1: colour spaces

CARPET PRINTING



Printing processes
in general

PRINTING WITH MOULD *With these methods, a separate* ***printing form*** *must be produced* ***for each motif****.*	Surface to surface 	Cylinder to surface or cylinder 
Letterpress printing The print motif stands out and absorbs the colour like a stamp.	e.g. platen printing (letterpress), **woodblock printing on textiles** 	e.g. rotary letterpress printing 
Flat printing The ink adheres to the (almost) flat printing surface and is printed from it.	e.g. lithography (stone printing) 	
Gravure printing The print motif is incised, the grooves fill with colour and release it during printing.	e.g. etching, copperplate engraving 	e.g. rotary intaglio printing 
Screen printing The print motif consists of open (screen) holes, the rest is impermeable. The colour is pressed through the holes using a squeegee.	e.g. **flat stencil/ screen printing** 	e.g. rotary stencil printing, rotary screen printing 

Tab. 2: printing methods

HALBMOND today: Immediate design change, very small quantities possible!

INDIRECT/ TRANSFER PRINTING

With indirect printing methods, the print motif can be created both ***with and without a printing form****. It is transferred to the medium to be printed through a carrier.*

Offset/pad printing

Here, the print motif created using flat or gravure printing, for example, is picked up by a rubber cylinder or pad (stamp) and rolled onto the object to be printed.

Dye sublimation printing

Firstly, transfer foil is printed with special ink and then placed on the object (usually a textile). Heat and pressure cause the ink to become gaseous and penetrate the fibres.

Digital transfer printing

As with dye-sublimation printing, a transfer film is printed digitally. However, different printers and inks can be used here. Heat and pressure fix the print motif.

Plot printing

A transfer foil carries the actual print material (e.g. flock foil). The motif is cut out of the film composite using a cutting plotter. All remaining pieces must be removed. The flock side is placed on the medium to be printed and fixed by pressure and heat. Each colour is applied individually.

PRINTING WITHOUT MOULD

No printing form *is required, but each motif is temporarily generated technically.*

Inkjet printing

A print head deposits individual drops of colour without contact using fine nozzles. Each colour is applied separately. The methods of droplet generation can be very different. One area of application is **spray printing on carpet**. Here, a CAD system controls when the nozzles open or close, which results in the colour being dispensed. **Piezo technology** is also used in carpet printing. Using electrical currents - again controlled by a computer - piezo crystals are deformed in such a way that they press ink out of the nozzle.

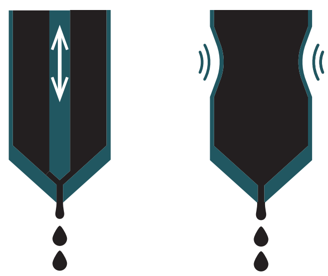


Fig. 25: printing nozzles

Carpet printing at Halbmond...

1968 - SPRAY PRINTING WITH MECHANICAL JACQUARD CONTROL

The printing width of this first spray printing machine was just 1.20 metres and it printed on a white surface produced using Malimo technology. This system was limited by the inflexible control of the nozzles using punched cards. For this very reason, there was no real industrial breakthrough for this technology, which had been developed to series maturity at Halbmond. The patent was sold to a textile company in the USA in 1971 and is still used in carpet production today.

1974 - LARGE STENCIL ROTARY PRINTING

In 1974, the world‘s most modern large stencil rotary machine by Mitter went into operation. Each design colour required its own roller group with stencil belt, the repeat length was limited and custom-made products were uneconomical. Flat stencil printing was used to print both web goods and overlay carpets - a total of in total several million square metres of Malimo goods (similar to tufting quality) per year. Ultimately, this printing technique was only really efficient with large quantities per colour and design.

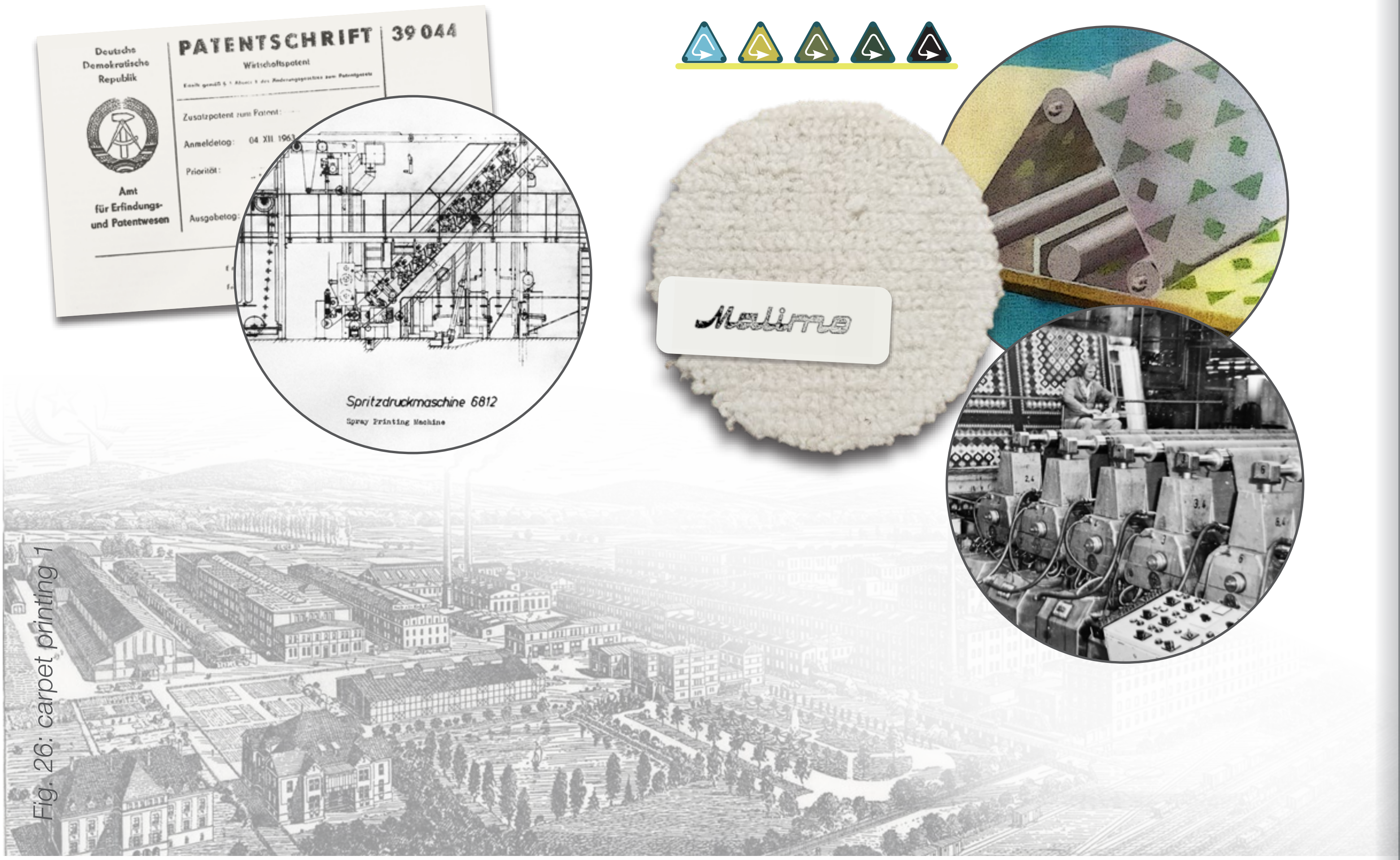


Fig. 26: carpet printing 1

today

...for over 55 years

SINCE 1994 - DIGITAL SPRAY PRINTING

1994 - 1. Chromojet
With the loss of volume markets, particularly in the former Soviet Union, the move towards smaller, more customised designs and colours began. In 1994, the Mitter large stencil rotary printing system was replaced by the first chromojet injection moulding system. The rest of the production line (especially dampers and dryers) initially remained unchanged. A transition to the shapeless spray printing process with a width of 4m required the digitalisation of design creation and printing machine control, which had progressed accordingly in the meantime.

1999 - 2. Chromojet
As part of further technical development, the first Chromojet injection moulding machine was replaced by a second one, whose improved resolution enabled a finer print image at a higher speed.

2008 - 3. Chromojet
The replacement of the second Chromojet spray printing system with a third represented another significant technical advance: the number of colour systems doubled to 24 with a total of 12288 nozzles. This made even more colourful designs possible and increased the variability of the machine. The printing carriage now weighed over 6 tonns. At the same time, the infrastructure along the entire printing process was modernised and expanded.

2012 - Chromojet for mats
With the purchase of a 2 metre wide chromojet system, mats could now be produced and sold under the brand name 'Jobet'.

2019 - Colaris inkjet printing line
With this innovative spray printing technology, the limitation to a fixed number of colours was lifted and an almost unlimited variety of colours became possible. At the same time, the resolution increased to 400 dpi, which even allows the realisation of photorealistic images.

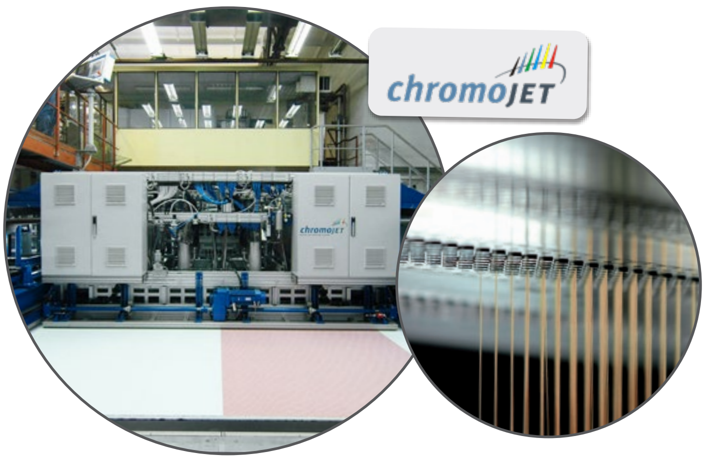


Fig. 27: carpet printing 2

Chromojet

Halbmond works with **two printing techniques**, which do not differ in the preparation and post-processing of the goods:

1. Feeding the selected quality:

The desired quality is brought to the printing line and presented for printing.

2. Steaming:

The raw material is steamed immediately before the final carpet printing.

There are two machine types to choose from for the printing process itself:

3. a) Printing with the Chromojet:

With the third chromojet generation at Halbmond, the use of up to 24 colour pastes has become possible. To do this, the individual colour powders must first be weighed and mixed before they are dissolved in hot water, boiled and added to the already prepared thickener mass. After thorough mixing, the colour pastes are ready. Now the colour tanks can be connected to the Chromojet. The carriage now moves over the pole, its spray nozzles opening up to 400 times per second according to the design to be printed, thus applying the colour paste in measured droplets. After each row (print head back and forth once), the product moves a tiny bit further until all rows have been printed.

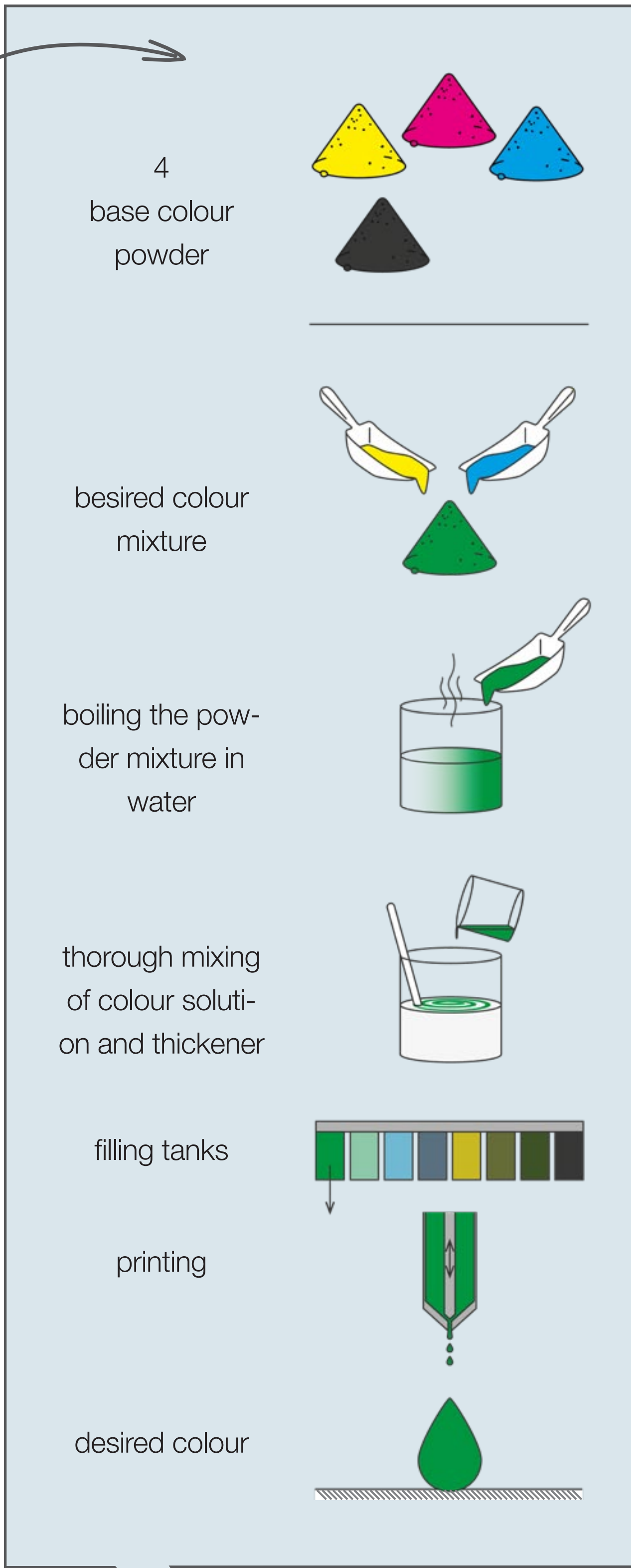
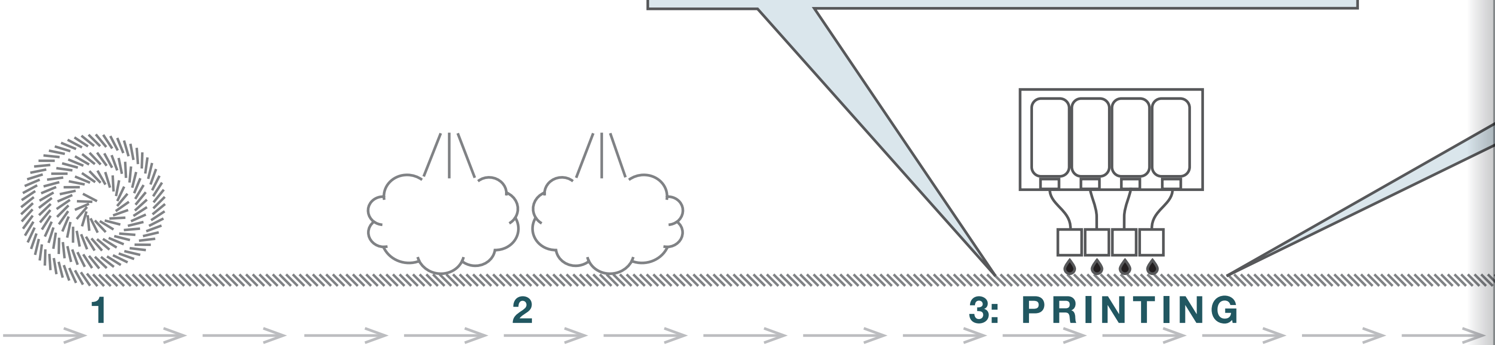


Fig. 29: Chromojet



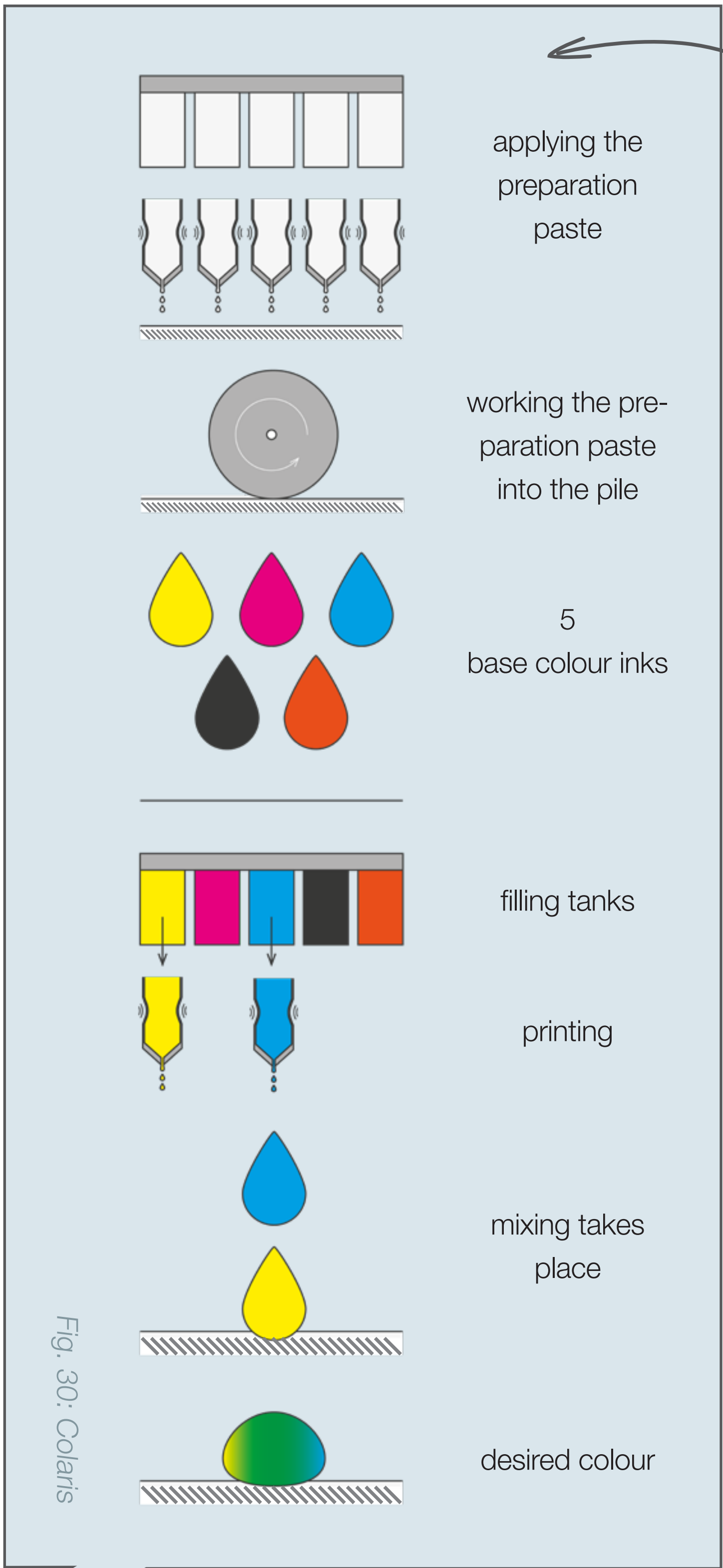


Fig. 30: Colaris

Colaris

3. b) Printing with the Colaris:

Colaris eliminates the need to mix colour pastes beforehand. This is because colour inks are used here, which - based on the principle of the domestic inkjet printer - only mix to the final colour shade on the fabric. This enables an almost unlimited variety of colours. As the inks are more fluid than pastes, a further work step is necessary here: the application of the preparation paste that is matched to the respective ceiling. Once this has been incorporated, the actual printing process can begin. Colaris works with a moving print head and piezo technology, in which the ink droplets are formed by the expansion and reformation of piezo crystals (similar to cyclical muscle contractions). Complex computer calculations are required to generate the optimum droplet size and quantity for the respective product and the selected design.

4. Steaming:

The carpet is steamed again to fix the colour.

5. Washing:

The wash cycle removes excess colour and preparation paste.

6. Drying:

Finally, the wet fabric is dried. This completes the printing process.

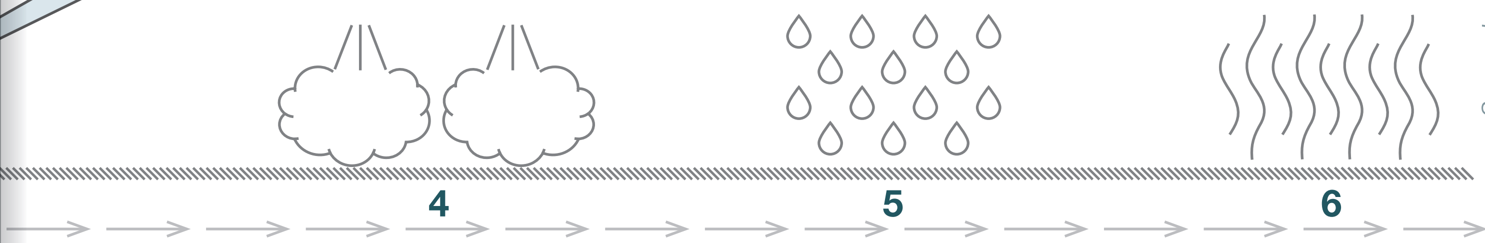


Fig. 28: printing line

Machine comparison

TECHNOLOGY	Chromojet	Colaris
printing technique	digital spray printing	digital spray printing
print head and print nozzles	12.288 print nozzles	Fujifilm Dimatix StarFire^{TM}, piezo nozzles
variants at Halbmond with print width	2 m width 4 m width	2 m width
resolution	25 dpi	400 dpi
COLOURS		
dyes	pastes	inks
colour units	2 m width: 32 4 m width: 24	6
colour mixing	in advance, 1 paste per design colour	during printing
design colours max.	2 m width: usually 32 fixed (colour bank) 4 m width: 24 freely selectable	virtually unlimited (in gamut)
Halbmond standard colours see following pages!	2 m width: 32 fixed (colour bank) 4 m width: *'Colour Box 500'* with colour samples, colour fan deck *'Colour Set 500'*, colour poster *'500 Chromojet Colours'*	carpets: carpet *'500 Colaris Colours'*, colour overview *'500 Colaris Colours'* mats: colour overview *'100 Standard Colours'*
special colours	colours can be selected according to sample or colour chart; dyes are chosen accordingly	desired colours according to sample, colour template or 'true colour' are possible, must be within the gamut or will be shifted into it (colour deviation)
FASTNESS PROPERTIES		
	carpets: priority on light fastness and rubbing fastness mats: priority on wash fastness	carpets: priority on light fastness and rubbing fastness mats: priority on wash fastness
CHECK LIST		
print design	• design with defined colour areas • standard and special colours	• design with defined colour areas • standard and special colours • photorealistic design in almost unlimited colours
details	• line thickness min. 1-2 mm	• line thickness < 1-2 mm possible
gradients	• subtle stepped colour gradients made up of visible dots or lines	• continuous colour gradients

Tab. 3: machine comparison

Fig. 31: Chromojet print

Fig. 32: Colaris print

Fig. 33: 500 colours Chromojet

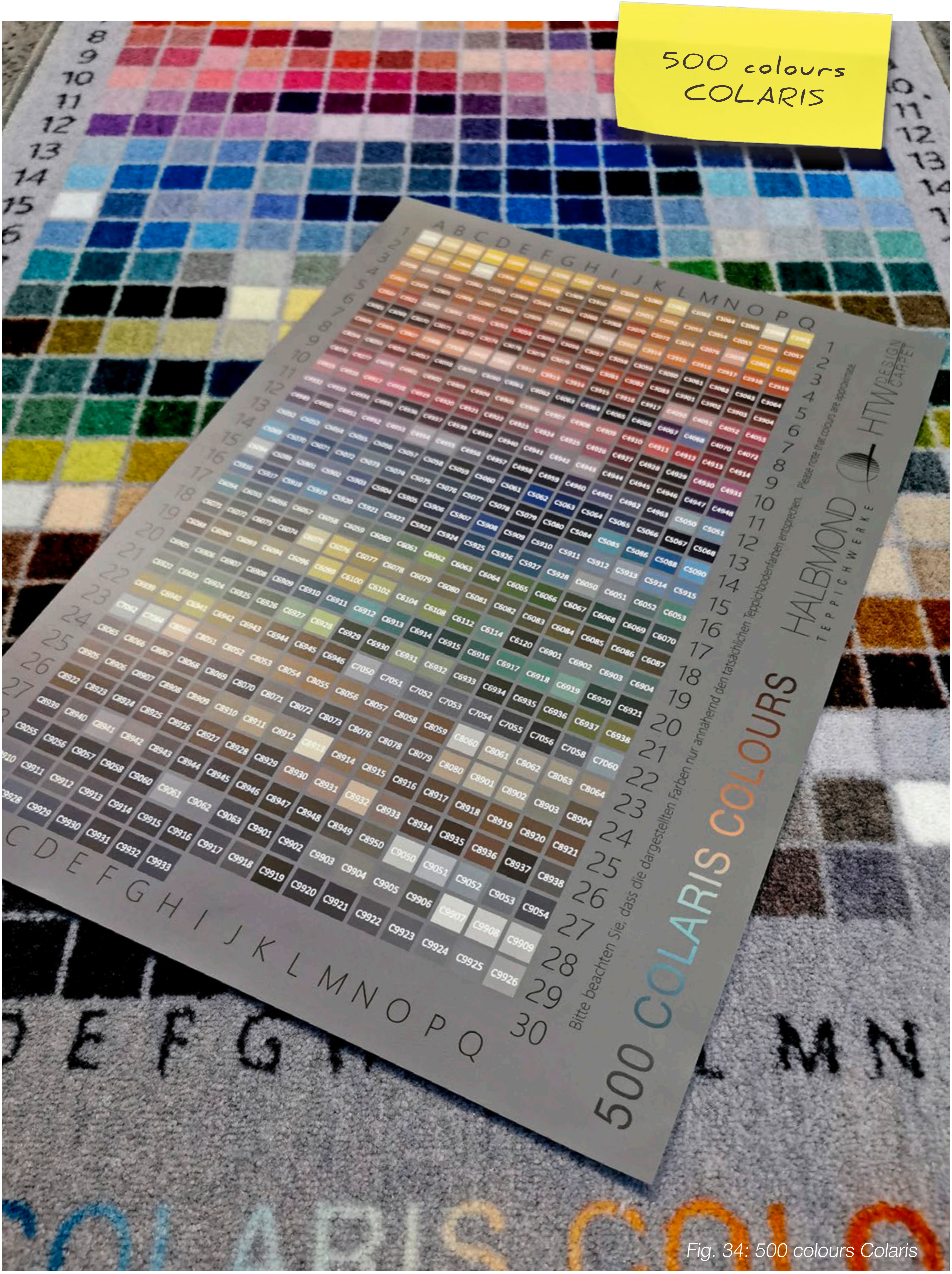


Fig. 34: 500 colours Colaris

What affects the print

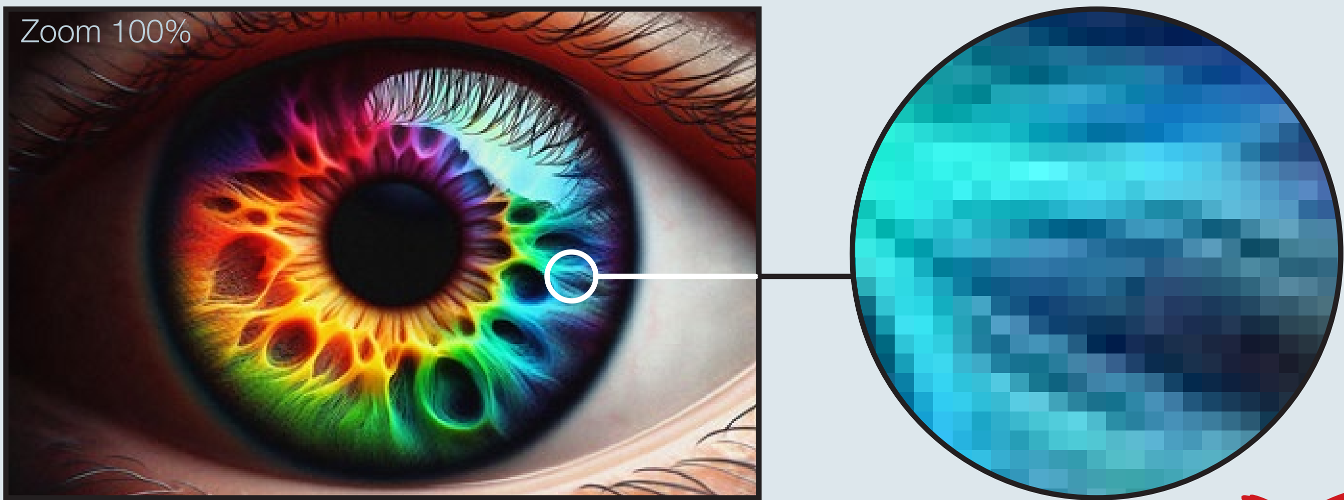
Customer file, colour choice, gamut mapping

Customer file. Your print design should meet the following conditions:
-> file dimensions corresponding to carpet dimensions (1:1)
-> resolution at least 100 dpi
-> for lettering and simple patterns: vector file preferred
-> if applicable, information on colour preferences (e.g. special colours), max. 24 colours for Chromojet

Colour choice. First, the customer decides whether their design should use **fixed colours** or whether **a harmonious overall impression with smooth transitions** is more important, even if this requires slight colour shifts. If the former is the case, the image must be reduced to a manageable number of colours (**„color reduction“**). A maximum of 24 colours may be used for Chromojet printing. Significantly more colours may be used on Colaris (although the processing effort increases with each colour). These individual colours can now be replaced by custom colours or the 500 standard colours. If, on the other hand, the complete colour range of the original image is to be retained (**„true color“**), single colours cannot be selected. But photos and colour gradients retain their smooth gradients (nur auf der Colaris).

Gamut mapping. In order to print your design on a specific Halbmond carpet quality, colour profiles are required to serve as a conversion basis from the colour space of the file (e.g. RGB or CMYK) to the individual gamut of our printing machine (see page 27). The conversion process using a colour profile is called **‘gamut**

CUSTOMER FILE - TOO SMALL | **PRINT SIZE 1:1**



carpet dimensions: 60 x 100 cm
file dimensions: 6 x 10 cm -> too small for carpet size
resolution: 100 dpi

print result: no details visible

Fig. 35: file too small

result?

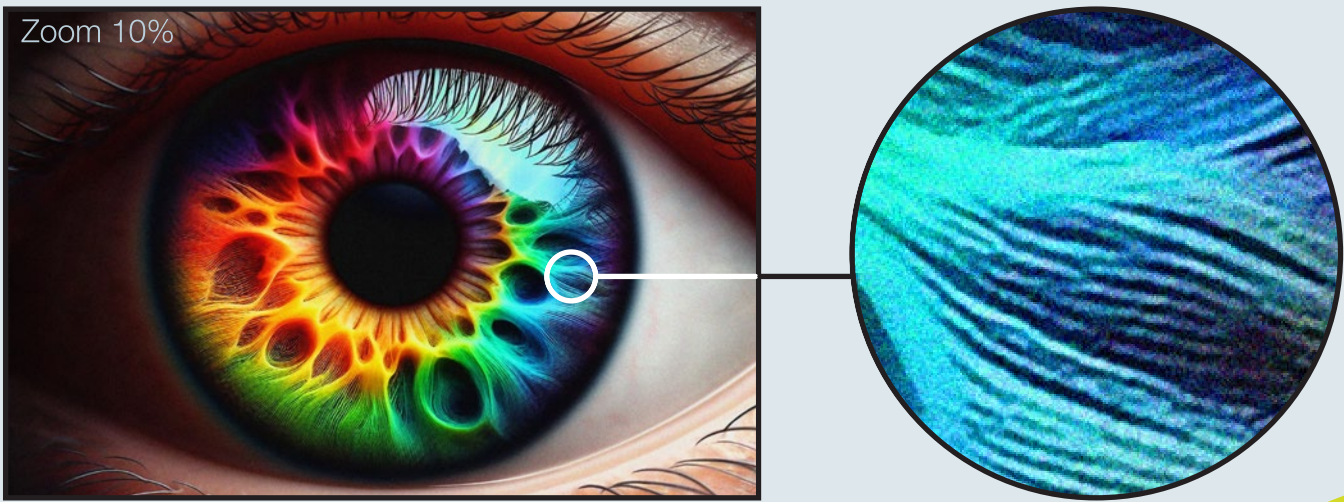
mapping' (colour space transformation). In carpet printing, a separate colour profile is created for each pile quality, in which the output quantity of the individual colour inks is specified depending on the pile material, pile weight and other factors. These colour profiles have been created in complex calibration series. Nevertheless, a more or less significant colour deviation is unavoidable with every design, as the light colour mixture on the monitor always differs from the body colour mixture in the print (see p. 22), even if all the original colours are also within the colour space of the carpet printing machine. The colour deviation becomes greater if not all the colour values in your file are within the target colour space.

Perceptual or absolute colorimetric? Then there are various methods available for shifting them into the target colour space. **Perceptual conversion** ensures harmonious distances between the new individual colours, but changes them slightly in the process. **Absolute colorimetric conversion** takes all colour values that are also in the target colour space and shifts all others to its edge. However, the colours that are retained and those that are shifted are not matched to each other, which can result in stepped gradients, for example.

Would you like to decide for yourself what the colour result should be? Halbmond's **500 Standard Colors** (also known as **'chain colors'**) were developed to enable the color output of a design to be assessed before printing begins. Each color was printed on the respective printing machine and is therefore not only proven to be within its gamut, but also shows a particularly low deviation from the digital template. We have other standard colors for mats – please feel free to ask us.

CUSTOMER FILE - FITTING

PRINT SIZE 1:1



carpet dimensions: 60 x 100 cm
file dimensions: 60 x 100 cm -> fitting for carpet size
resolution: 100 dpi

print result: details visible

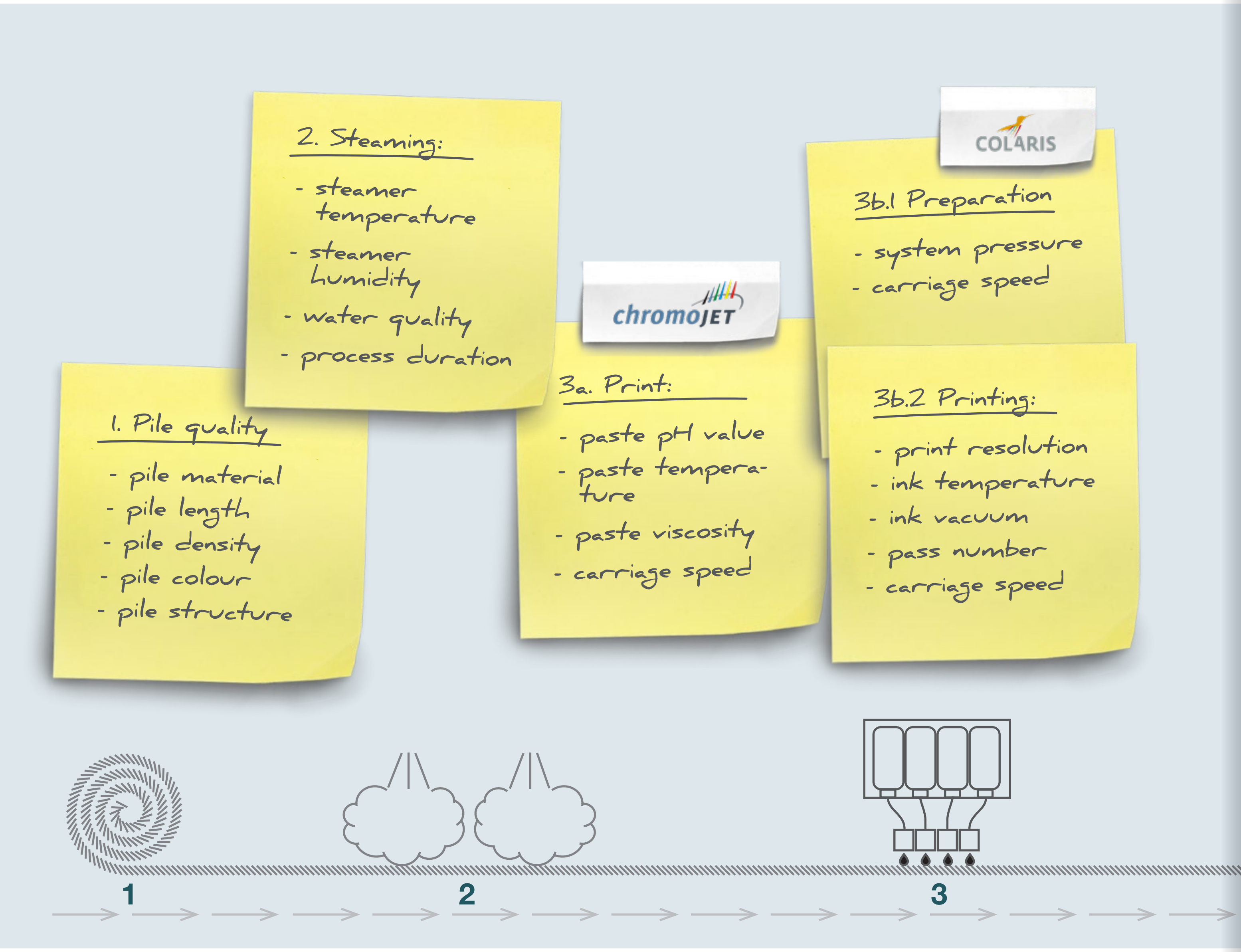
Fig. 36: file fitting

What affects the print

Production factors

There are far more factors involved in carpet printing than, for example, printing on paper. Each individual factor can affect the colour result and must therefore be taken into account as a possible variable but also as a source of faults.

What are the differences compared to printing on paper, and what factors influence the print result? When printing on paper, the ink is simply absorbed by the paper and does not form a strong bond with the paper fibres (meaning that the print is neither washable nor permanently lightfast). In contrast, when printing on carpet, the printing ink chemically bonds with the pile fibres, forming a strong bond. However, this requires the ideal starting conditions to be created.



result?

Is a print result exactly reproducible? All processes are standardised and constantly monitored, as evidenced by our certifications. Nevertheless, conditions that depend on so many factors can never be recreated exactly the same way twice. This means that when reordering the same product, there are sometimes variations in colour, which are acceptable to a certain extent (namely when the measured values are within the specified tolerance range). In order to always remain within this range, the process conditions are adjusted until the result passes our quality control. The customer has the final say: based on the hand proof (small advance print), they give their 'OK' for production.

You can find out how this works in detail on the following pages...

Fig. 37: production factors

Print preparation

1. Defining the colours

1a — or — 1b

Chromojet:
If your design contains more than 24 colors, a "color reduction" will be carried out first (see p. 42). You can now use your **desired colors** or a selection of the **500 Chromojet colors**. The advantage of Halbmond Standard colors is that you can see in advance how each color will look after printing by looking at the samples.

Colaris:
Normally, we print in 'true colour' (see p. 42). This preserves the full colour range, but it may be necessary to replace non-printable colours. This guarantees smooth transitions! If you would like to choose your **desired colours** or select from the **500 Colaris colours**, colour reduction will also be carried out first.

Fig. 38: 500 colours Halbmond

Desired colour according to sample:

Only when colours need to match a sample exactly does this need to be measured colorimetrically. To do this, carpet, wallpaper, fabric or another template is placed in the camera system and the areas to be measured are defined. A spectral curve and the exact colour coordinates (L*a*b* values) are output for each colour.

Fig. 39: scanning the pattern

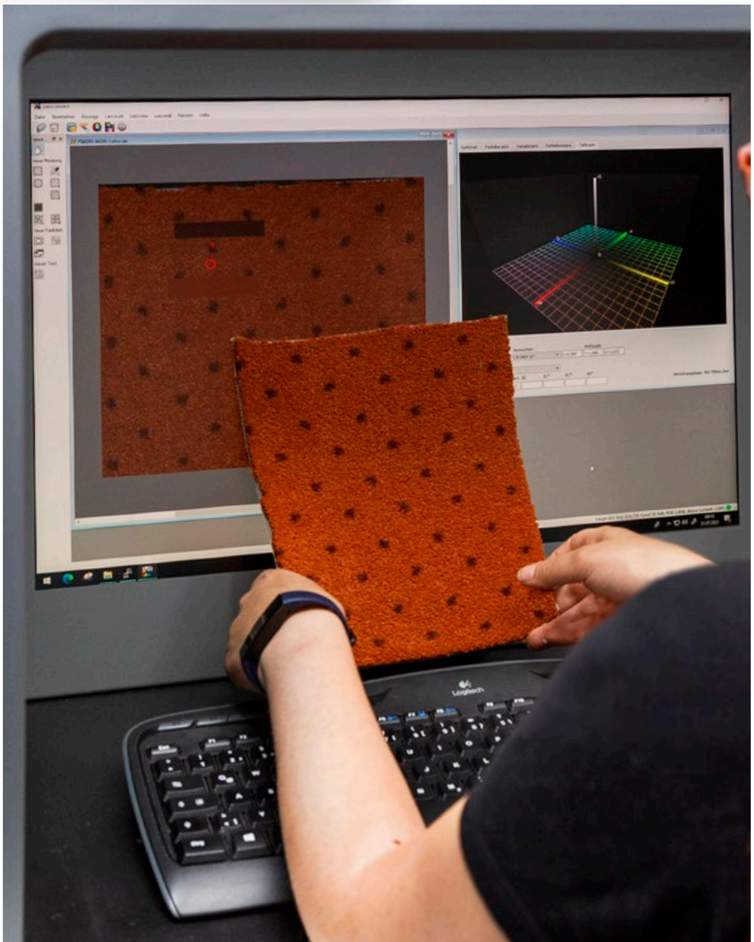


Abb. 40: comparing the pattern and screen

Print preparation

2.-5. Lab-scale printing

2

Mixing the color pastes (Chromojet only):

First, a recipe sheet is created, which specifies the printing sequence, individual dyes, the initial recipe, the amount of paste per color and other things. When mixing the color pastes, it is important to pay attention to the specified pH value and viscosity, as these have a decisive influence on the print result.

Different piles require different color recipes, which must be created individually. It is therefore not possible to simply print the selected design on a second or third pile quality using the same color paste. The same design, the same colors, but a different pile means a **completely new work process from steps 1 to 5**.

Fig. 41: pipetting system

Fig. 42: mixing colour pastes (Chromojet only)

3

Lab-scale printing:

The finished color pastes are used to fill the tanks of the laboratory Chromojet printing system. Colaris, on the other hand, always works with its standard inks. The selected pole quality is pre-steamed, pre-laid, and printed with the desired design. A **“hand sample”** has been created, but it still needs to be post-treated.

Fig. 43: laboratory printing

After approval of the hand sample by the customer, production can begin!

4

5

After-treatment:

As in later production, the hand sample is steamed, washed, dried, and then sheared again. Only after these after-treatment steps have been completed and the material has been conditioned do the colors reach their final state and can be visually evaluated.

Check and approval:

The hand sample must now be evaluated in terms of the specified colors and general design appearance under **standardized daylight D65** (6500 K). In the event of deviations, a new print is made until the laboratory colorist finally gives approval and the hand sample is sent to the customer.

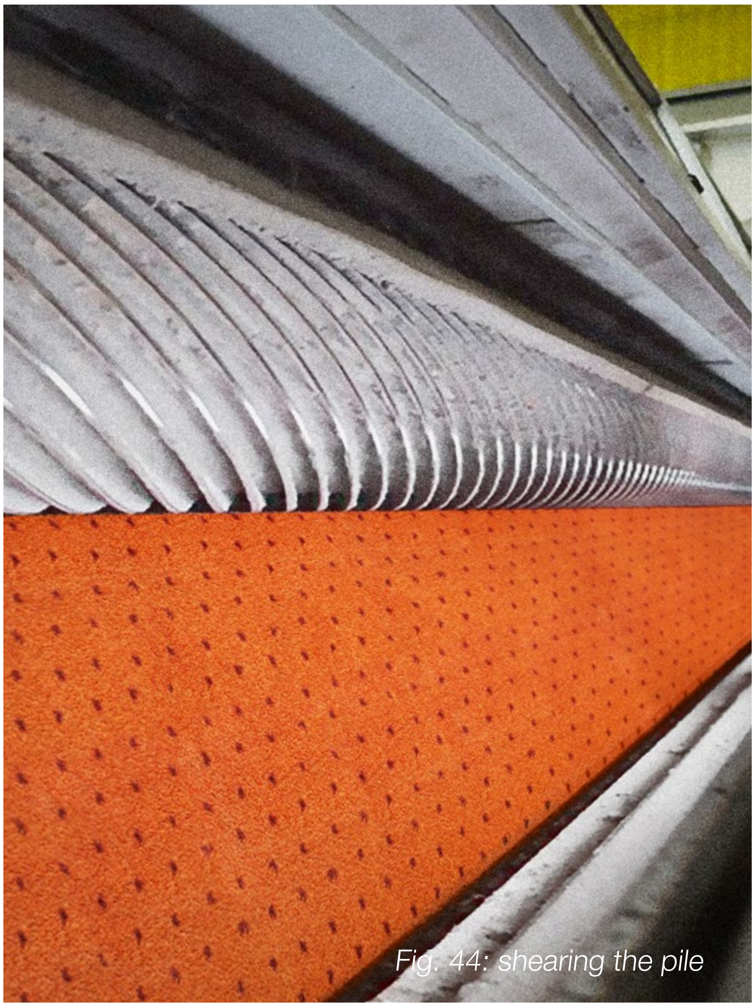


Fig. 44: shearing the pile

Fig. 45: lighting situations

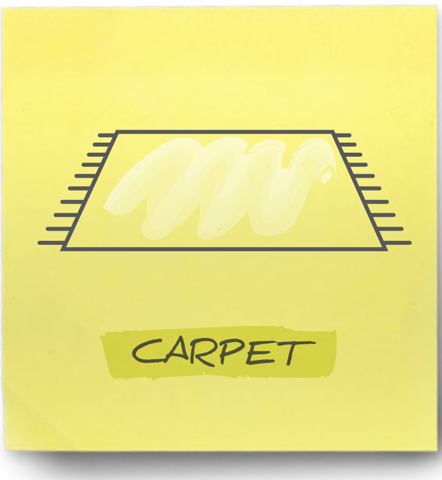
Fig. 46: final inspection

Assess hand sample

WHAT CONDITIONS ARE RECOMMENDED?

We assess under **standardised daylight D65**. Shop light or UV light can also be used if desired.

A hand sample should be assessed under a light source similar to the light used for sampling. Other lighting conditions (e.g. evening light) and mixed lighting situations (e.g. daylight and artificial light) are misleading and should therefore be avoided. (see p. 13)



The carpet quality on which is printed also determines the colour effect. For example, a shiny yarn reflects its surroundings much more strongly, which visually blends in with the colour of the design.

Different carpet qualities look different despite having the same print. This should be taken into account when ordering or reordering.

The direction of the pile also influences the colour effect. If pieces of carpet are to be compared, they must be laid in the same direction and viewed from above, looking into the pile..

A hand pattern is more than the sum of printed colour dots. Only in combination with a design does a coherent whole emerge for the viewer. The overall impression is therefore decisive.

Before a sample is dispatched, it is approved by a small group of designers at our premises. This means that individual visual preferences or habits can be balanced out among each other.

Fig. 47: differences of carpet qualities

Recognising print quality

WHICH CHARACTERISTICS ARE ASSESSED?

Penetration

Penetration indicates how far the printing paste penetrates into the pile. If penetration is insufficient, the "feet" of the pile yarn are white; if penetration is ideal, the pile is dyed through to about 90%, i.e., just before the tufting base.

If the cut edges are not visible and the carpet to be tested cannot be creased, it is also possible to spread the pile apart with the hands in order to obtain a pile lane that can be used to assess the penetration.

Contour sharpness

Although contour sharpness is already a challenge with certain adjacent colour areas (e.g. blue next to yellow without mixing green by overlapping), delicate lines on twisted yarns are the supreme discipline. This requires knowledge of the flow behavior of the printing pastes (e.g., tendency to "run"). The design must also be adapted to the rheology of these pastes in order to obtain cleanly defined, continuous lines in the desired width.

To assess contour sharpness, areas with lettering, hatching and fine contours as well as the transition areas of surfaces are examined closely: Are the individual colours clearly delineated, is no line 'swallowed up' and is none disproportionately wide or narrow?

Colour clearness

Colours should appear clear and unclouded. In particular, colour tones that appear 'frosty' or 'milky' must be avoided during production. This is where the interplay of colour paste, printing parameters, post-treatment and shearing is required.

The carpet can be assessed using the following characteristics: Are the lightest tones suitably bright and luminous or do they appear cloudy? Are the black/darkest areas sufficiently dark or too pale? Do the colours in between have harmonious spacing and are they as saturated as desired? Is the overall impression harmonious?

Fig. 48: bad penetration

Fig. 49: good penetration

Fig. 50: bad contour sharpness

Fig. 51: good contour sharpness

Fig. 52: bad colour clearness

Fig. 53: good colour clearness

SUMMARY

COLOUR VISION

Humans can distinguish between ~2.3 million shades of colour. Linguistic colour designations are therefore far from sufficient and are also used differently from culture to culture. Colours are usually adjusted/judged on the basis of the following criteria: Hue, saturation, brightness.
The ability to distinguish between colours decreases with age. Colour vision deficiencies can also be the cause of impaired colour differentiation. Colour vision tests make it possible to assess this ability.

THE PROCESS. The colour impression depends on: light, object, eye and brain.
Light. The light source emits a certain mix of wavelengths, which results in a corresponding light colour. Conversely, the wavelength composition cannot be deduced from the light colour. In midday light, all visible wavelengths and spectral colours are mixed to form an almost 'white' light colour (daylight standard = 6500 Kelvin). Caution: The same artificial light colour can conceal a wide variety of wavelength profiles, depending on the design!
Object. The wavelength profile of the light influences the colour impression of the object. The object surface always reflects a subset of the available wavelengths. This residual light mixture is the object's own 'spectral fingerprint'. The absorbed part of the light is converted into heat.
Eye. The residual light mixture stimulates the cones and rods in the retina of the eye. The cones are responsible for colour vision, there are: S cones ('blue receptors'), M cones ('green receptors'), L cones ('red receptors'). The rods are responsible for light and dark vision and are particularly active in poor light conditions. In complex processes, the perceived colour stimulus is translated into a colour code.
Brain. The colour code is transmitted via the optic nerve to the visual cortex of the brain. Here it is read out and the sensory impression 'COLOUR' is created. It only applies to the conditions of the particular moment and varies from viewer to viewer.

COLOUR SYSTEMS

Light colours. There are so-called 'light colours', which are based on the principle of additive colour mixing (RGB). The primary colours are red, green and blue. The RGB principle applies to monitors, displays and LED lamps.
Body colours. There are so-called 'body colours', which are based on the principle of subtractive colour mixing (CMY). The primary colours are cyan, magenta and yellow. Black is added for printing (CMYK). The CMYK principle applies to all physical bodies, in painting and in printing processes.
Colour systems. To sort colours, man has invented colour systems. These include colour catalogues, colour fans and colour models.
Colour models and spaces. Colour models are usually based on a few base colours, have a mathematical basis and are often geometric in shape. A colour model is used to represent associated, three-dimensional colour spaces and gives each colour an exact colour location with associated coordinates. The RGB model includes, for example, the AdobeRGB colour space as well as the sRGB colour space. Mapped in the same colour model, the differences between the two colour spaces become clear. Another is the CMYK model with the associated colour spaces that it can depict. RGB and CMYK colour spaces have large overlapping areas. Where they do not overlap, a colour cannot be displayed in the other colour space - the printed image (CMYK) of this colour is clearly different to the monitor view (RGB). The L*a*b* colour space is the largest, it includes

all humanly perceptible colours and therefore also the RGB and CMYK colour space. It therefore serves as a reference colour space for conversion processes (e.g. print preparation).

Gamut. Gamut is the colour range that can be displayed or printed by a particular device. It changes and is never identical to that of another device.

Colour profile. A colour profile, 'ICC' for short, is a translator between different devices and their colour spaces - e.g. from monitor (sRGB) to printer (CMYK). The colour profile is intended to ensure that colours are as similar as possible. It often even takes into account the material to be printed.

CARPET PRINTING

Carpet printing processes. Halbmond only uses informal printing processes. This means that very small quantities can be produced cost-effectively and design changes can be realised immediately.

Both processes used at Halbmond are inkjet printing, whereby the technologies for droplet formation vary. Carpet spray printing with the Chromojet printing machine is the older of the two processes, but has been continuously developed further, while Colaris technology is the newer. Halbmond can produce on three printing lines: Carpeting up to 4 metres wide (Chromojet), fitted mats (Chromojet), carpeting up to 2 metres wide (Colaris).

Chromojet and Colaris. The main differences between Chromojet and Colaris technology lie in the resolution, color gamut, dyes used, and minimum order quantity. Chromojet printing pastes must be mixed in advance in the final colors, and their number per design is limited. Colaris inks correspond to permanent base colors, from which the desired color tone is mixed when printing on the product. This makes the number of Colaris colors virtually unlimited (within the machine's color space). Colaris also allows for very small quantities, while Chromojet offers slightly better color fastness. A variety of factors influence the color result. Repeat orders of the same design may therefore differ slightly in color from initial orders.

Print preparation. The printing machine and colors are selected depending on the design and order quantity. The Chromojet can print with a maximum of 24 colors, and fine details and color gradients are only possible to a limited extent. All colors can be specified individually and corrected during printing. With its virtually unlimited color gamut and high resolution, the Colaris offers the possibility of photo-realistic and highly detailed printing. However, the colors cannot be selected and corrected individually. The Colaris can also be used to produce color-reduced designs with significantly more than 24 selectable colors. A hand sample is now produced on a laboratory scale and sent to the customer.

Hand sample and print quality. The proof should be evaluated by the customer as follows:
- lying on the floor under a deliberately chosen light source, under no circumstances under mixed light
- when comparing with an existing carpet: poles brushed in the same direction, looking into the pile (-> Note: different pile qualities printed with the same design show different color results)
- according to penetration, i.e., the depth of penetration of the color into the pile (90% is ideal)
- according to contour sharpness, i.e., clean demarcation of the color areas without bleeding or overlapping
- according to the desired line thickness and visibility of all details
- according to radiance and color temperature (not "frosty"), corresponding brightness/darkness of the individual colors
- according to the harmonious interplay of all colors, overall impression of the design

English	French	German
additive mixing	mélange additif	additive Farbmischung
body colours	couleurs de corps	Körperfarben
brightness, lightness	luminosité	Helligkeit
chromaticity	chromaticité	Farbigkeit
colour blindness	achromatopsie	Farbenblindheit
colour clearness	clarté de couleur	Farbklarheit
colour location	emplacement de couleur	Farbort
colour model	modèle de couleurs	Farbmodell
colour picker	sélecteur de couleur	Farbwähler
colour profile	profil de couleurs	Farbprofil
colour space	espace de couleurs	Farbraum
colour system/scheme	système de couleurs	Farbsystem
colour tone, hue	nuance/valeur de couleur, teinte	Farbton
colour vision deficiency	dyschromatopsie, daltonisme	Farbenfehlsichtigkeit, Farbsehschwäche
cone	cône	Zapfen (Auge)
contour sharpness	netteté des contours	Konturschärfe
cornea	cornée	Hornhaut (Auge)
digital transfer printing	impression transfert numérique	Digitaltransferdruck
dye sublimation printing	impression par sublimation thermique	Thermosublimations-druck
flat printing	impression à plat	Flachdruck
gamut	gamut	Gamut
gravure printing	héliogravure	Tiefdruck (Verfahren)
hand sample	échantillon	Handabschlag
hue, colour tone	nuance/valeur de couleur, teinte	Farbton
inkjet printing	impression jet d'encre	Inkjetdruck
intensity, saturation	saturation, intensité, brillance, pureté	Sättigung
large stencil rotary printing	impression rotative de grands stencils	Großschablonen-Rotationsdruck
lateral geniculate nucleus	corps géniculé latéral	seitlicher Kniehöcker
lens	cristallin	Linse (Auge)
letterpress printing	impression en relief	Hochdruck (Verfahren)
light colours	couleurs de lumière	Lichtfarben
lightness, brightness	luminosité	Helligkeit

English	French	German
macula	macula	Makula
offset printing	impression offset	Offsetdruck
optic chiasm	chiasme optique	Sehnervenkreuzung
optic nerve	nerf optique	Sehnerv
optic radiation	radiation optique	Sehstrahlung
pad printing	tampographie	Tampondruck
penetration	pénétration	Penetration
plot printing	impression de traçage	Plottdruck
primary colours	couleurs primaires	Primärfarben
pupil	pupille	Pupille
red-green weakness	daltonisme/faiblesse rouge-verte	Rot-Grün-Schwäche
retina	rétine	Netzhaut/Retina
rod	bâtonnet	Stäbchen (Auge)
saturation, intensity	saturation, intensité, brillance, pureté	Sättigung
screen printing	sérigraphie	Siebdruck
secondary colours	couleurs secondaires	Sekundärfarben
spray printing	impression par pulvérisation	Spritzdruck
subtractive mixing	mélange soustractif	subtraktive Farbmischung
visual cortex	cortex visuel	visueller Cortex
vitreous body	corps vitré	Glaskörper (Auge)

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CARPET INFO GUIDE

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