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Colour Turn

I. Colour in Interdisciplinary Context

The Function of Colour: An Introduction to Colour Theory and a Definition of Terms

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Abstract

As a phenomenon, colour shapes how people experience the environment visually, while as a medium, it conveys meaning, emotional moods and functional information. As luminous colour it appears atmospheric and diffuse to the viewer, while as non-luminous colour, shape and form materialise from it. The antithesis of coloured light is darkness, which shows its influence on the aesthetics and function of the phenomenal world in the spatial play of shadows. The complex sensations of colour result from the interaction of light with the entire organism. Colour and light form two sides of the same phenomenon, since colour illuminates and light colours.

Colours shape the appearance of the natural environment, which varies in terms of climate and topography. They make it possible for diverse forms of life to orient themselves and to communicate in ways specific to their species. Colour creates identity. These biological functions do not only shape the natural environment – they also determine the aesthetics of the cultural space, which illustrates the forms of visual communication between people. Colour's potential for expression and communication evolves with the cultural development of individuals and societies. It finds expression in all manifestations of life, in words, pictures, objects, spaces and performances. Colour is the most important design tool for configuring the environment aesthetically, as the abstract lineal structures of the planning phase take on a physical form in the atmospheric and material manifestations of built space.

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Colour as a medium of visual perception

As soon as people open their eyes, information enters approximately 120 to 130 million photoreceptor cells in a permanent exchange of information with the environment. Not even 5 percent of these cells are able to transform the spectrum of light into colour signals, and yet they determine the form of visual perception. The fact that people still see a coloured, sharply contoured environment throughout the entire field of view is a result of processing methods in the brain, whose comprehension is essential for explaining visual perception and communication.

During the perception process, viewers ask questions about the colour appearance of the environment through their eye movements and, at the same time, look for answers. Through eye gestures, a viewer asks what something is, where it is, where it comes from, where it is going, what it has done, what it is doing and what it will do. This question and answer process determines the formation of the object in the process of visual perception. What is not questioned, whether through words, looks or artistic representations, remains in the background of perception and is not seen. These circumstances apply to the visual arts, which have long played a role in communication, as well as to the perception of architectural space. The meaning and significance of spaces, images and text are objectively present via the existence of a culturally determined domain of language. However, they still need to be subjectively understood. The extent, content quality and evaluation of the responses are determined by the viewer's attention, behaviour and previous experiences. Seeing involves the cognitive processing of visual and spatial data that exist objectively only as colour stimuli on the retina. Subjects must develop meanings and contexts autonomously via their previous experiences in the context of the use situation. Colour is therefore a medium of visual perception. For this reason, people are usually less interested in the colour itself than in the interpretations of the content that it facilitates. This difference becomes clear in the juxtaposition of abstract and concrete painting, where colour is applied as a pure form or as a conveyor of content and meaning (Figure 1 and 2). In architecture and design, colour is used in a similar way, as it can be effective as a pure form or as a conveyor of content.

Figure 1. Painting by Jonas Rebbelmund

Figure 2. Painting by Linda Prüfer

A holistic view of environmental perception explains the complexity of visual communication between experts and lay people, designers and users, locals and foreigners, and between people of different ages and with different social and educational backgrounds. The perception and effect of colours can thus only be planned in relation to the socio-cultural and developmental background of the target group, which can be included in the design process as individuals, groups, communities or societies.

From a physiological point of view, the question and answer process of visual communication can be read through the information flows in the perceptual system. This is because more motor data travel from the brain to the muscles of the eye than vice versa. Only those who actively observe and investigate the environment with an attentive gaze are able to construct complex content-related information from the distribution of coloured pixels within the field of view. At the same time, this process becomes faster with constant practice, since the brain automatically develops methods for asking the important questions by directing attention to significant points in the field of view. In the same way that people use the tip of their index finger to touch something, they constantly move their eyes across the temporally and spatially-structured network of colour-coded areas and discern letters, shapes and spaces. The content-related information and the function of built space is therefore not interpreted from what the designer draws, but rather from what viewers construct during the perception process. It is not the pen, but rather the direction of a person's gaze along the coloured areas in the field of view that determines the aesthetics of the phenomenon. In turn, this is influenced by the perception of the emotional content and function of all its parts in relation to one another and to the whole (Figure 3).

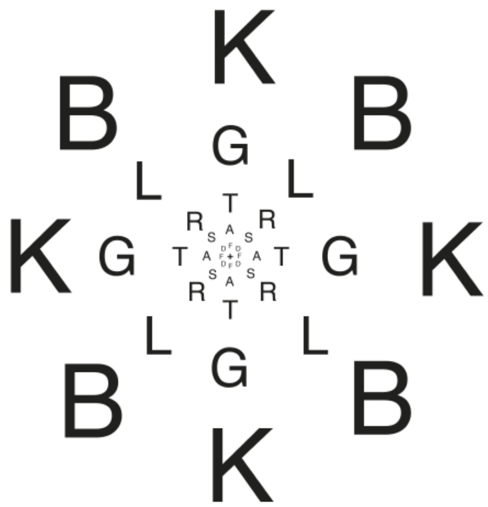

Figure 3. Visual Cells Density of Retina

Form follows colour

While eye movements are guided by the lines in a drawing, they follow colour in built space. The eyes' orientation movements in the field of view can be recorded via mobile and stationary eye-tracking methods that allow the neurosciences and the communication sciences to engage in the systematic study of visual perception and communication. Extensive psychological studies on user behaviour, as well as effective, practical applications have evolved in the field of marketing and advertising in recent years. In architecture, art and design, the use of eye-tracking measurements has only just started, with mobile eye-tracking systems also playing a role. Such measurements can demonstrate how a specific observer sees images, objects and spaces, as it is possible to record the temporal sequence of fixations or pauses by the eyes, during which information can be perceived. The longer the eyes remain fixed on any particular element, the more intense is the interaction with the form and content of the colour composition. Plans, drawings, prints, paintings, photographs, films, sculptures, performances, and architecture are perceived in different ways. The legibility of the content and function varies with the form of representation, thus forcing the designer to select the technology and to restrict the media employed. Any change to the colour coding or contrast can influence the eye movements and thus the interpretation process. The decision on where and which surface colours are to be used in the design should therefore rely less on subjective opinions than on proven knowledge of the viewing conduct of the users or target group. Orientation in space is not random, but rather the result of messages designed in a way that can be understood. The observer's eye movements focus involuntarily on the most meaningful spatial data, through which orientation is created and maintained in the environment.

At this point, the formal effects of colour should be addressed, since they derive from the physiology of the perceptual system and can be explained using examples. Visual perception always starts with the creation of orientation in space. This involves determining the location of the elements of relevance to the content in relation to the light source, the topographic reference level and the observer. Orientation is therefore created by the brain only in so far as contents can be interpreted and located in a familiar spatial reference system.

This makes clear why and when people experience problems with spatial orientation. Major infrastructure such as railway stations and airports may confuse inexperienced users just as sprawling or monotonously designed suburbs or foreign cultural spaces can. The spatial reference system in an observer's memory consists not only of striking colour features, but also, to a far greater extent, of shape and motion coding. This is also perceived via colour codes, especially when touch is not possible[1]. The larger the spatial scale and the less

[1] For further information, see the comparison of the spatial perception abilities of blind and sighted people in Axel Buether, *Die Bildung der räumlich-visuellen Kompetenz: Neurobiologische Grundlagen für die methodische Förderung der*

the other senses are able to assist in orientation, the more important colour becomes.

The grammar of seeing

Eye-tracking demonstrates the need for the composition of all important elements in the field of vision into a clearly perceptible and comprehensible sensory whole. Since only two degrees in the field of view can be focused on and consciously seen, the entire remainder forms the background to the perceptual situation at that moment. This background is not only important for atmosphere, but it also directs the eye to the next important goal in view. The eyes frequently do not focus on the elements, a process requiring about one second, but only look at them in a sweeping glance. As a result, many elements are not consciously perceived, although they are evaluated by the implicit memory. Optical illusions and effects provide extensive illustrative material on how the visual perceptual system works. This process can be observed particularly clearly in perimeter areas[2] (Figure 4). Peripheral perception is sufficient in order to identify important interior and exterior reference elements such as the sky, topography and forests or buildings, walls, ceilings, floors, doors, and corridors. Individual shapes merge to form larger contexts if there is insufficient colour differentiation, as the peripheral regions of the retina can hardly recognise any details. For this reason, people can find their way around natural and urban spaces without having to recognise or remember many elements. Colour can move things into the foreground of perception or leave them in the background. It thus has a crucial influence on the culture of memory and visual education, on all visually coded information that people retain in their memories of images, objects, and spaces. On the basis of colour differentiation, the brain provides orientation in just a few seconds. However, the conscious perception of all substantive and functional components in a space calls for closer observation and considerably longer viewing

anschaulichen Wahrnehmung, Vorstellung und Darstellung im Gestaltungs- und Kommunikationsprozess (Halle: Burg Giebichenstein Kunsthochschule, 2010), 183–230.

[2] On the topic of visual illusions, see Jürg Nänni, *Visuelle Wahrnehmung* (Sulgen and Zurich: Niggli, 2008).

time than that involved in the purely orientation process. Vision and memory follow the visualisation or explication of implicit information in the peripheral part of the field of view. A person usually only invests the time needed to do this if they are interested in interpreting the visual information or feel an emotional connection[3]. Colour creates awareness and interest in the perception situation, an effect that can be heightened to fascination. If one allows oneself to be inspired by the colours of the natural or cultural realm and to pause before them in amazement, one will perceive the associated locations, content and events more intensely and coherently, as well as in greater detail, and remember them for longer.

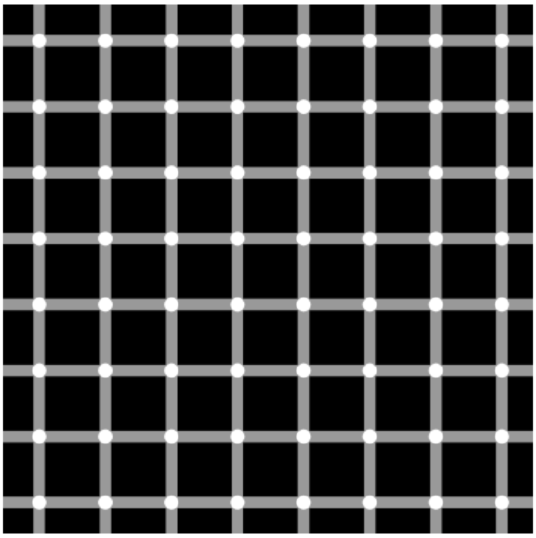

Figure 4. Scintillating grid illusion, discovered by E. Lingelbach

Environmental perception versus plans

For planners and users, however, misinterpretations of colour perception can cause great difficulties, since these can only be detected in the transition between drawing and implementation. While colour materials are transformed in painting or three-dimensional representations using varying techniques until the desired relationships between the shapes are achieved, the operating principle of visual perception is reversed in the process of line or plan drawing. The restriction of the representation to light and shade or

[3] Gerhard Roth, *Aus Sicht des Gehirns*, (Frankfurt/Main: Suhrkamp, 2003), 87; Gerhard Roth, *Fühlen, Denken, Handeln: Wie das Gehirn unser Verhalten steuert*, (Frankfurt/Main: Suhrkamp, 2003), 94.

the palpable contrast boundaries between objects and spaces means that the relationships between the shapes emerge more strongly and become more important. This abstraction process characterises all methods of creative design that serve to direct the attention in media-specific ways.

Once spaces are implemented in reality in accordance with design drawings, perception shifts from the line to the surface. Geometric and free line illustrations are based on the extensive abstraction abilities of the brain, as designers take geometry and the perspective of the boundary lines as a starting point in such drawings. The contrasting effects of luminous and non-luminous colours are deliberately neglected, so that the constructive relationships of the image space come to light more clearly. Architectural drawing requires an intensive learning process in the brain, in which the motor power of the hand movement increases simultaneously with the cognitive performance of visual perception. Contrast borders are not automatically lines, but are made visible, conceivable and representable through the abstraction of colour information in the process of environmental perception. Only a fraction of the borders of contrasting areas of colour is displayed in a line drawing. Specific knowledge and skills in representing the processes of abstraction between colour and shape determine the formation of drawing skills. Non-experts find the clarity of thought and design required by drawings or line sketches to be as difficult as reading plans.

However, the acquisition of drawing skills does not mean that the implementation of the design in the reality of a built space can be equally taken into account and is mentally present in every line of the design process (Figure 5). The differentiated planning of atmospheres and material colours determines the perception of light and shadow, depth and surface, proximity and distance, and objects and space. The spatial perception of the environment is influenced by so many factors that it can only be simulated to a very limited extent by rendering programmes. Any change of scale, lighting or surrounding colours alters the effects of luminous and non-luminous colours. In turn, this has major implications for the perception of shape and space. The abstract structure of the line drawing becomes discernible according to the rules of colour perception.

Figure 5. Rietfeld Schröder house, Utrecht, image by Axel Buether

The spatiality of retinal projection

The first physical contact between the environment's irradiation and the body occurs in the cornea of the eye. This is where the light is broken before being directed onto the retina by the circular pupillary opening in the iris and by the lens. The iris allows the pupillary opening to adapt to the energy conditions in the environment, as it functions as an intelligent, muscularly controlled 'aperture' and regulates 'exposure' to the retina. It limits the expansion and the solid angle of the incoming irradiation, thus regulating the brightness, depth of field and vignetting (the shading at the edge of the image) of the retinal projection. The terms can be understood by means of comparison with the optical system of a camera, as all parameters can be controlled by changing the aperture and focal length. The light sensitivity of the sensory elements is continuously adjusted, thus transmitting the necessary information on the colour temperature of the light source for the brain to produce a white balance. As a result of this sensory information, the brain can control all of the contrast ratios of the retinal projection and create a uniform impression of perception that is known as colour constancy. When two identical hues are suddenly perceived as different due to a change in the light source, this gives rise to the effect of metamerism. The opening width of the iris (aperture), the direction of both eyes in relation to each other (vergence) and to the focal point, and the curvature of the lens (depth) are controlled by the brain via the complex coordination of the eye muscles (Figure 6). Through these sensory-motor signals, the brain receives sufficient information on depth for the spatial interpretation of the colour signals from the retinal projection[4]. Because of this muscularly generated spatialisation of colour information, observers can usually distinguish very clearly between the reality of a built space and their own image. Through the intersection of the incoming rays in front of the retina's projection area, an upside-down projection of the field of view is formed, as the optic system of the eye functions like a *camera obscura*[5]. Those who conclude that a 'perceptual image' arises at this point are at the same level of knowledge as René Descartes, who introduced the notion of a mechanically functioning organism to the world of science 400 years ago[6]. The optical process forms an integral part of the organic and communicative processes, whose importance for visual perception is elaborated in the following sections.

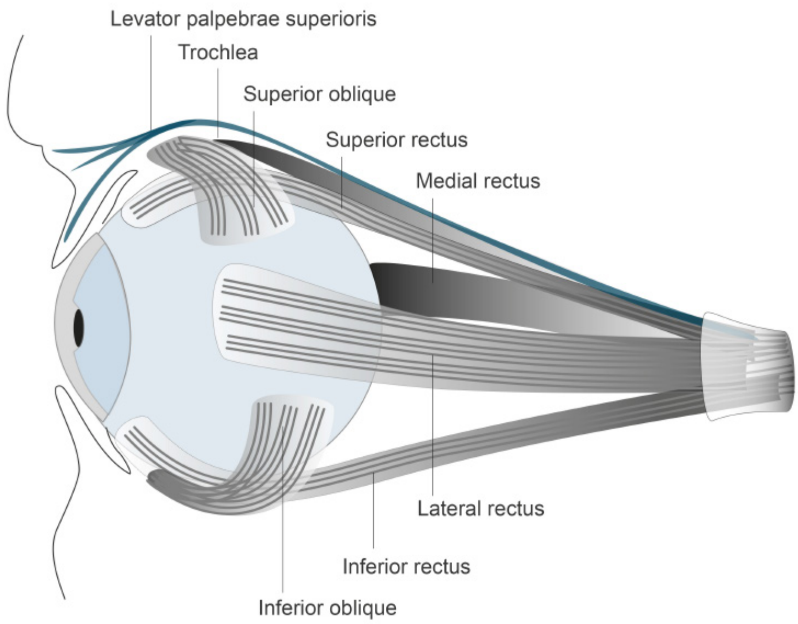

Figure 6. Human eye muscles

[4] Hermann Mühlendyck and Walter Rüssmann, eds., *Augenbewegung und visuelle Wahrnehmung*: Physiologische, psychologische und klinische Aspekte (Stuttgart: Enke, 1990).

[5] Olaf Breidbach, Kerrin Klinger, and Matthias Müller, *Camera Obscura: Die Dunkelkammer in ihrer historischen Entwicklung* (Franz Steiner Verlag, 2013).

[6] Antonio R. Damasio, *Descartes' Irrtum: Fühlen, Denken und das menschliche Gehirn* (Munich: Deutscher Taschenbuchverlag dtv, 1997).

Photoreceptor cells and the contrast principle

The retina acts as an energy sensor and transducer, through which the incident electromagnetic radiation is changed via a photochemical process to nerve arousal patterns. The output of a single photon is sufficient to activate one of the 60 to 125 million brightness-sensitive rods in the retina; the 3.2 to 6.5 million coloursensitive cones require 200 times as much energy. The difference in the number of photoreceptor cells is the cause of individual variations in the spatial resolution of the perceptual space[7]. Due to the high response threshold of the colour-sensitive cones, people only perceive their environment in full colour and spatial resolution if there is sufficient daylight or artificial light. For the same reason, the red-orange and finally the violet-blue areas of the spectrum regularly disappear at dusk and dawn. That the world appears an intense red-orange just before sunset and sunrise is due to the shorter distance that light must travel through the atmosphere when seen horizontally. Through its scattering and absorption of parts of the light spectrum, the atmosphere's particle structure also makes the sky appear cyan or whitish-grey in colour and shows the further consolidation of the shining white and grey shadowed cloud formations.

The perception of colour stems from the nervous system's connection of three different types of cones that respond to the short-wave, medium and long-wave parts of the spectrum[8]. The principle of lateral inhibition, which inhibits the surroundings of a source of stimulation in favour of the signal in the centre, enhances colour contrast and thus the perception of form. The orange-red, green-yellow and violet-blue colour signals are not seen directly, since they are previously evaluated by the downstream retinal ganglion cells, converted and sent to the brain.

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[7] Journals frequently give different figures for the number of photoreceptor cells in the human retina. These differences stem from increasingly accurate measuring methods. The information on this topic used here is based on the publication: http://www.retinascience.de/krank_kell/anatomie_physiologie.html, (accessed 18 July 2013) supervised by Prof. Ulrich Keller, Centre for Rare Retinal Diseases at Siegburg Eye Centre.

[8] Also referred to in a simpler form as RGB mode, that is, additive colour mixing on a monitor.

Visual pathways and the basic colour principle

The three visual pathways between the eye and the brain are referred to as the red-green channel, the blue-yellow channel and the bright-dark channel. This is because all brightness and colour signals are pre-structured in accordance with the principle of maximum contrast formation. These complementary contrasts therefore simultaneously determine the basic colour signals (black, white, red, green, blue, and yellow). All other hues are derived from various mixtures of these basic colours. The composition of basic and mixed colours in the visible spectrum thus results from the specificity of receptor types and processing mechanisms. Complementary coloured after-images are generated because the photochemical activity of the receptors continues for some time, depending on the intensity of the light stimulus. The brightness of a colour indicates the intensity of the sensation of light registered by the rods and cones alike. This can be perceived separately from the colourfulness of the spectrum and the saturation of a hue. The light-sensitive rods only react to light in the mid-green wavelength range, which people only perceive as brightness in the absence of a nerve connection. Colourfulness is only perceptible through the comparison of different signals. The strongest form of brightness is associated with the experience of glaring, blinding white light, while the intermediate stages of twilight are perceived as a darkening or opacity until darkness falls. The maximum spatial resolution of the colours of the field of view results from the distribution of the perception areas of all types of receptor, while the quality of the resolution is determined by the overlapping of all frequency ranges. The stimulation range of all cones is superimposed in the middle wavelength range of the spectrum (Figure 7). The biological function of colour is also evident here, as the visual perceptual system was developed in an environment characterised by vegetation in which a high degree of spatial resolution in the green spectrum was necessary for survival. In contrast, the red area aids the perception of significant individual events such as human emotions, the degree of ripeness of fruit and the freshness of meat. The composition of the spectrum and the differentiability of individual hues are therefore not random but instead demonstrate the principles of evolution.

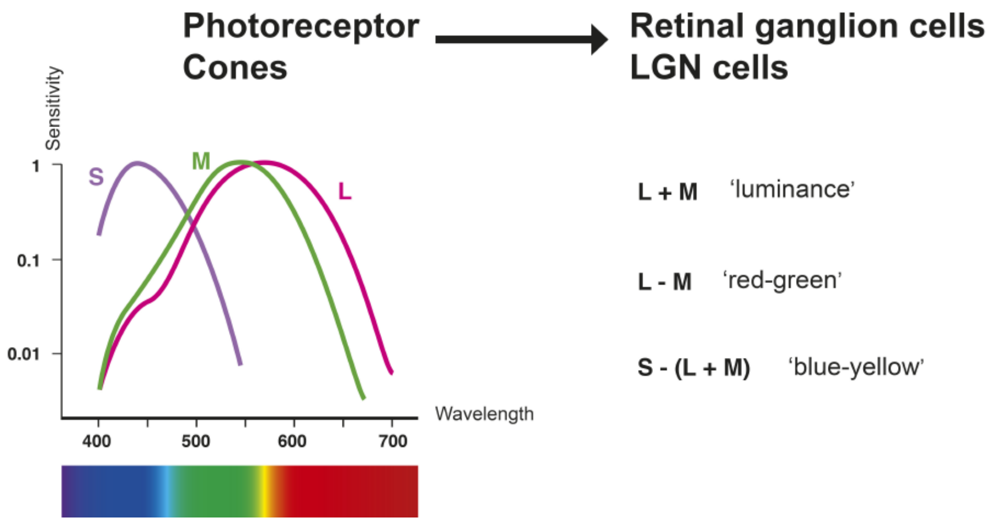

Figure 7. Cones and colour sensitivity

From the perception of colour to visual communication

Recent research in neuroscience shows that the processing of visual information accounts for about 60 percent of all activity in the cerebral cortex[9]. Colour is therefore decisive in the perception of built space. Its appearance provides people with more information than all the other sensory perceptions combined. This is not to dismiss the performance of the other senses. The physical encounter with the feel, smell and sound of architecture also contributes significantly to the overall experience of a space. However, sight is known as the guiding sense in humans for a reason, as the brain constructs a meta-representation of the environment from the arrangement and variation of colour-coded retinal signals. Colours refer to tactile, auditory, vestibular, gustatory and kinaesthetic experiences. This is the reason why people are more or less able to see how something feels, tastes, smells or sounds, how it moves or if something is in balance. The network of visual, tactile and kinaesthetic experiences functions in an amazingly sophisticated way. Therefore, after a period of multi-sensory experience, people can feel certain that the movement space will appear to recede as they step towards it, while the tactile space will exist whenever something is

[9] Karl R. Gegenfurtner, *Gehirn und Wahrnehmung. Eine Einführung*, 3rd edn. (Frankfurt/Main: Fischer Taschenbuch, 2005).

touched. Perceptual effects[10] or optical illusions refer to the threshold areas of visual perception, while the survival of the human species proves the success of this principle.

During the perception process, colour signals enter the three opposing colour channels from the eyes to the brain stem, where they are compared with data arriving simultaneously via the other senses before being emotionally pre-assessed. For this reason, people cannot perceive colour without emotion, regardless of whether it involves atmospheric phenomena or a concrete object[11]. A change of atmosphere or striking colour events prepare the viewer for the coming experience in a split second by altering vital bodily functions such as hormone production, blood sugar levels or breathing. A glimpse of blood-red instinctively draws the eye to the source of the colour and leads to an increase in bodily activity before the viewer is aware of what the colour entails. These involuntary emotionally controlled responses to colours can be traced back to an evolutionarily important fact. Bodily functions vital to survival are activated involuntarily in split seconds by colour stimuli. The process of visual comprehension takes place in periods of seconds to minutes. Advertising and marketing have long used these key stimuli professionally to manipulate the attention and mood of potential target groups. In architecture and design, key stimuli are used, for example, in colour guidance systems, where the aim is to warn people and deter them from inappropriate actions. Nobody runs without hesitation in the dark. Everyone's gaze focuses involuntarily on red.

Colour and memory

After the preliminary assessment, the signals in the visual cortex are processed and sent to memory via two main processing streams. The 'where and how stream', which flows to declarative memory, is used in the perception of movement, action, place and position, while the

[10] Nänni, *Visuelle Wahrnehmung*. In a field trial, subjects were asked to change the image of a banana on the screen to a neutral shade of grey. The majority of the results showed colour shifts that went well into the complementary blue range. In contrast, an image in grey tones appeared yellowish.

[11] Thorsten Hansen et al., 'Memory Modulates Color Appearance,' *Nature Neuroscience* 9, no. 11 (2006): 1367–1368.

‘what stream’ that flows to semantic memory evokes the perception of meaning[12]. This memory structure for knowledge acquired and stored via images is thus similar to the semantics and syntax of verbal language, which enables people to perceive and describe the world in an auditory form. While the verbal form of perception functions via sounds that a listener selects from the audible spectrum and links to form meaningful entities, visual perception is based on the same principle, using colour. The selection principle follows the importance attached by viewers to a perceived event in relation to the previous experiences stored in their memory. Visual perception is therefore subjective where it reflects individual experiences and objective where it records socially accepted knowledge and empirically verifiable observations. The combination of sounds in the form of words and sentences or of colours in the form of pixels and pictures, as well as hybrids of both communication media in the form of writing and images, are the result of cultural evolution.

The context of a perceptual situation determines the interpretation of the spatial data, which are almost always ambiguous. In verbal language, these distinctions arising from situations are referred to as denotations (literal meanings) and connotations (associative meanings). A colour code can therefore have many meanings and still be understood correctly. Blushing thus indicates a specific state of excitement that may signal emotions such as shame, anger, desire, combat readiness, interest or rejection. A colour code cannot be clearly determined without reference to the context of its use. The same applies to the perception of space – hence a building’s colours can appear harmonious in one context and totally out of place in others. The legibility of the function and the qualities of usage may change as a result of changes in colours in the built context.

Colour language: The function of colour in biology

The sensations of colour that people can feel and experience particularly intensely during dramatic atmospheric phenomena such as sunsets enrich existence but do not sustain it in terms of

[12] Buether, *Die Bildung*; Karl R. Gegenfurtner and Lindsay T. Sharpe, eds., *Color Vision: From Genes to Perception* (Cambridge: Cambridge University Press, 1999).

survival. The colours of nature form a universal code system, which is used by many living organisms to convey messages that serve to preserve their species. Since many messages are not addressed to humanity, the aesthetics of the environment are often perceived as a wasteful diversity, whose ornamental beauty triggers admiration and fascination. This point of view ignores the wide-ranging visual forms of communication that take place between members of a species or form the basis for symbiotic lifestyles.

Plants thus use the colours of their flowers and leaves to communicate directly with insects and animals that are attracted by the particular shades and combinations they display, in order to ensure pollination and the dissemination of their seeds. In addition to the use of colour to attract or deter – a frequently observed process in flora and fauna – nature also understands the principle of camouflage, that is, deception and illusion. The process by which chameleons can change their body colour to serve specific purposes is particularly striking (Figure 8 and 9). However, the greatest degree of change occurs not in matching the body colour to the background but rather in communication among a species. A chameleon is able to send complex messages to other chameleons by changing its body colour. The colour codes are used to convey intended actions such as combat readiness, submission and interest in mating. In addition, responses to received messages are sent, as can be observed when a chameleon changes its skin colour indicating whether a request to mate has been successful or not. The exchange of messages takes place over very short intervals so as not to attract the attention of enemies. Due to the brevity of these intervals, the messages are often not recognised by other species as such, which is why these communication skills were only recently discovered[13]. This example demonstrates the function of colour in biology. People use its communicative potential in all artistic, sculptural and spatial cultural techniques in order to design information. Architecture and design form part of visual communication, be it in the retrospective interpretation of cultural studies or the design of the present and future.

[13] Devi Stuart-Fox and Adnan Moussalli, 'Selection for Social Signalling Drives the Evolution of Chameleon Colour Change,' *PLOS Biology*, 2008, https://doi.org/10.1371/journal.pbio.0060025.

Figure 8. Chameleon, image by Nandhu Kumar, CCO Creative Commons

Figure 9. Chameleon, image by Marcel Langthim, CCO Creative Commons

Colour language as a conveyor of culture

The cultural evolution process of colour perception and colour language is reflected in the aesthetics[14] and function of media and technologies. Images, objects, built spaces and performances, as well as the technological developments of the information, learning, planning, navigation and communication systems of modern societies, illustrate the qualitative leap in performance in the processing of colour codes in the brain. The aesthetics of the socio-culturally designed environment does not serve to create an abstract idea of beauty but rather to communicate thoughts, feelings and action options. The colour mutations seen in nature reveal a creative principle, as living organisms of every kind use changed colour codes to tap into previously unknown communication partners, means of distribution and habitats.

An innovative colour design opens up new applications and promotes the development of aesthetics and visual perception. The variety of colours in a flowering meadow demonstrates both the rules and the variation possible within colour codes. Hence, not only the expedient, but also the experimental is aesthetic in visual culture, insofar as the unintelligible colour codes address the viewers and challenge them to develop mentally, emotionally or practically[15].

[14] *Aisthetikos* in Greek, meaning 'what can be perceived'. Only developed much later, after 1735, by Alexander G. Baumgarten as a parallel science to logic for the study or the laws of beauty. Originally published in 1750, Baumgarten's *Aesthetica* remained in print until 1958.

[15] Axel Buether, *Wege zur kreativen Gestaltung: Methoden und Übungen* (Leipzig:

The appearance of residential areas, buildings and infrastructure reflects the function of society in a clear way, thus making a significant contribution to the cultural evolution of the human species. In terms of visual perception, cultural space functions as a form of 'vivid memory storage'[16], whose formal structures and meaning content safeguard the transfer of knowledge between generations. The mediating function of verbal language forms the basis for the rules of social coexistence inferred from the use of buildings, streets and squares, whose functions can be read in a clear way. Illustrative learning forms the basis for the archaeological reconstruction of society: for understanding the present and for planning the future. Urban spaces are inexhaustible learning spaces. The cultivation of the language of colour through the colour codes used in clothing, products, interiors, buildings and cities creates identity and provides guidance in an increasingly complex world. The age, gender, cultural affiliation and socialisation of people, as well as the era, district formation and regional variations in appearance of places can be read through the conventional use of colour codes (Figure 10 and 11).

Figure 10. Traditional architecture, Verdone, image by Axel Beuther

Seemann Henschel, 2013); Bernd Weidenmann, *Handbuch Kreativität* (Weinheim and Basel: Beltz, 2010).

[16] Buether, *Die Bildung*.

Figure 11. Shanghai China Skyline, CCO Creative Commons

With the development of visual orientation skills people also acquire fundamental knowledge of the colour language specific to their cultural space. From that point on, they interpret and use the language in the same way as their 'mother tongue'. While those who live in cities recognise and use culturally specific urban colour codes that are self-evident to them, the diverse colour codes in rural regions seem like a foreign language to them. The first stay at the seaside, in the mountains or in the desert allows the urban resident a completely new perception of the phenomenon of colour, but offers little by way of orientation. For local residents, the colours and their changes signify meanings that indicate, among other things, underwater currents, impassable paths, edible fruit, sudden temperature changes and severe weather. The various colour codes of landscapes and residential areas condense to form site-specific atmospheres and generate an intuitive perceivable colour space that shapes the image of a colour home[17].

The most reduced form of this identification is reflected in the colour codes of national flags, clubs and folkloric elements in architecture, design and craftsmanship[18]. The most extensive form in terms of space is determined through atmospheres defined by geography and

[17] Christoph Johannes Häberle, 'Zur Entwicklung individueller und kollektiver Farbpräferenzen' (PhD diss., University of Wuppertal, 1999).

[18] Karl Schawelka, *Farbe: Warum wir sie sehen, wie wir sie sehen* (Weimar: Bauhaus-Universität Weimar 2007).

climate, the colours of flora and fauna, and a region's built, deformed and depicted natural materials[19]. The legibility and interpretation of content and function are complicated, distorted or prevented if the colour scheme focuses solely on formal effects. The natural colour of the raw materials, along with the colours of coatings and claddings, indicate the substance of the material, the manufacturing process and the intended use. The aesthetics of a colour scheme is therefore primarily used to designate the content and purpose of an object, as well as to create identity and representation. Nowhere are the effects of globalisation seen as clearly as in the colours of cultural spaces, where regional identity has given way to a unifying language of colour associated with social change. Colour and content form a unit; the transformation of the appearance of cultural spaces is not a new phenomenon. Even today, the extent of past empires can be detected in the uniformity of colour and shape language that was put in place and used to indicate the extent of the empire's sphere of influence. Pigments and building materials also indicate technological achievements, religious and secular systems of symbols, customs, traditions, and trade routes. The question of whether the loss of colour languages of entire regions is an inevitable price of social change, like the reduction of biodiversity, is beyond the scope of this text. When it is appropriate to preserve cultural heritage and maintain a region's appearance or where space can be opened up for new ideas is an issue that can only be resolved by means of social discourse. This needs to be conducted in a new way[20].

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[19] Schawelka, *Farbe.*

[20] Lino Sibillano and Stefanie Wettstein, 'Colour in the City: Colour in the Countryside: Consultation and Planning Instruments for Colour in Public Space,' in *Colour*: *Design Principles, Planning Strategies, Visual Communication,* ed. Axel Buether et al. (Munich: Institut für internationale Architektur-Dokumentation. DETAIL, 2014), 60–69; Thomas Danzl, 'Colour in 20th Century Architecture: Identification, Understanding, Preservation', in *Colour: Design Principles, Planning Strategies, Visual Communication*, ed. Axel Buether et al. (Munich: Institut für internationale Architektur-Dokumentation. DETAIL, 2014), 70–79; AnneMarie Neser, 'Colour in 1970s Architecture in Berlin and Zurich. On the History of Colour Culture for the Use of Colour Now and in the Future', in *Colour: Design Principles, Planning Strategies, Visual Communication*, ed. Axel Buether et al. (Munich: Institut für internationale Architektur-Dokumentation. DETAIL, 2014), 80–87.

Colour, music, aesthetics

From antiquity to the present, the similarities between music and aesthetics have stimulated a tremendously productive form of discourse, ranging from the classification system of harmony[21] to the multimedia experience of time-based media[22]. Tones, sounds, rhythms, overtones, beats, transparencies, dissonances and harmonies can be heard through the medium of sound and rendered visible through the medium of colour. The organising principles discussed here are explored in science, music and fine art.

In principle, any phenomenon can be investigated in terms of its formal qualities while the contextual relationships remain hidden, thus shifting the structural elements to the foreground of perception. In the process of visual perception, the formal linking of all elements to each other and to the whole takes place via the colour structures of light, material and atmosphere. The aesthetics of architecture is determined by the arrangement and construction of spaces and forms, the rhythm of the openings and the surface structures of the material. Visual perception of architecture is based on movement of people in spaces; less on ongoing touch than on the continuous changing of surface colours and atmospheres. When viewers can perceive something clearly, the object has an impact and becomes something that can be experienced and used. Everything else remains an ineffectual intention on the part of the author. Architecture becomes static via the building material, whose immobile and heavy weight can therefore be described and designed using a system of lines. Plans, drawings and photographs of buildings and objects represent momentary excerpts of continuous action, in which dynamically changing perspectives unfold for the viewer through changes in angle and atmosphere in time and space. The tension between order and momentum has led to architecture being perceived as 'frozen music' and described as such for more than 200 years[23].

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[21] Andreas Schwarz, *Die Lehren von der Farbenharmonie: Eine Enzyklopädie zur Geschichte und Theorie der Farbenharmonielehren* (Goettingen and Zurich: Muster-Schmidt, 1999).

[22] Time-based media include film, television, interaction design, 2D and 3D animation.

[23] First mentioned by Friedrich Schlegel in 1803, also explored by Friedrich Wilhelm

The biological cause of the productive interactions between music and aesthetics can be attributed to the way that the perceptual systems involved work. The ear's sensory cells are stimulated by the auditory perception of sound events and sense-specific vibration patterns whose shape properties are interpreted by the brain.
The same applies to the photoreceptor cells in the retina, which are stimulated in the process of visual perception to constantly produce new patterns of activity. Colour composition is generated by the dynamic between eye movements over time and the rhythm of colour structures. Even if the environmental situation remains unchanged over time, viewers select shades in the field of view and combine them into new entities through patterns of eye movement. Viewers can follow the designer's colour composition provided that they recognise it or are able to make their own interpretations of the formal structure. The aesthetic experience of the environment is determined by the searching movements of the body and the eyes in architectural space, of the paintbrush on a surface, of the chisel on stone and of the camera used to film or take a picture. Without the structuring of the colours in the field of view and without the creation of soft and hard transitions, rhythms and intonations, viewers would perceive a single uninterrupted and undifferentiated shade. As a result, there would be no place for the eye to rest and no stimulation for the body. The minimalist aesthetic of an unstructured colour used throughout a room can be likened to a continuous tone in music.

The micro- and macro-structure of colour

The aesthetics of the natural environment is determined at the macro-level of the field of view and at the micro-level of the surface structures by colour compositions and combinations that seem harmonious. The biological reason for this intuitive assessment stems from the evolutionary adaptation of the visual perceptual system to the appearance of the environment, whose micro- and macro-structures have both formal and content-related contexts. The micro-structure

Joseph Schelling, Arthur Schopenhauer and Johann Wolfgang von Goethe. Further reading see Pascha Khaled Saleh, '"Gefrorene Musik": Das Verhältnis von Architektur und Musik in der ästhetischen Theorie' (PhD diss., Technical University of Berlin, 2004).

of nature can be equated to the sound vibrations of a string and comprises a basic tone and multiple overtones, whose relationships are reflected in the macro-structure. Mineral pigments are composed of mixtures of complementary coloured crystals that are barely visible to the naked eye. Nevertheless, a unique depth of colour and brilliance can be perceived, as the countless crystals are penetrated by light, thus making the surface structure shine from within, following multiple reflections[24]. In addition to their particle composition, the colour surfaces of natural materials have characteristic surface structures, whose diverse nuances determine how they are perceived. This harmonious unity in diversity causes an inner connection between the whole and its details that continues up to the macro-level. Looking across a desert demonstrates the inner harmony[25] between the coloured detailed effects of the grains of sand, their wave structure and the whole landscape of wind-shaped dunes. The macro-structure of the colour is formed by the inherently harmonious arrangement of its components, creating an overall composition that can be understood in itself. Each shade produces proportional relationships to the same, similar or contrasting areas in the field of view, from which rhythmic structures, prominent figures or new formal entities are formed.

Internal consistency cannot be reduced to the formal aesthetic level of the appearance of a colour, but instead includes the content-related context. If the aesthetics of the appearance does not refer to the content, this will result in misperceptions that can animate the viewer towards creative achievements or senseless acts, depending on the context. The study of nature leads to the biological principles of colour perception, but this does not mean that these rules are equally applicable to the design of cultural space. It is therefore more important that planners deal during the design process with all levels of colour effects in terms of both the details and the overall impact, and that they develop a design position that produces aesthetic quality by means of variety and internal consistency. For discerning graphic designers, it is self-evident that their work does not end with image

[24] Stefan Muntwyler, *Farbpigmente, Farbstoffe, Farbgeschichten* (Elsau: Alata Verlag, 2011).

[25] Harmony: Congruence, melodiousness, acquiescence.

editing, but also includes the choice between thousands of types of paper[26] and a wide variety of printing techniques, as well as the finished printed product. By adjusting the micro-structure of the paper, the appearance of printed colours can be changed significantly and may affect the emphasis of the content. In product and spatial design in architecture, interior design and design, the search for innovative materials and manufacturing techniques is becoming increasingly important[27]. Each particle is equally an effective static material and an aesthetically effective colour pigment. Once a particle of the micro-structure is visible on the surface, it becomes an 'ambassador of light', and provides the viewer with information that modifies the content-related and emotional effects of the macro-structure.

Colour as a design tool

Parallel to the development of Modernism, the professional design field divided into a planning/conceptual part and a manual/implementation part. For many reasons, this separation was problematic. As a result, only a few architects and designers can now base their design work on their own technical experience, which is essential for the visual design of material culture. However, colour only becomes a modern design tool if designers have extensive theoretical knowledge that they can apply in the context of their own practical experience. While it was possible to base Bauhaus training in the field of colour[28] on practical skills and theoretical knowledge, the Ulm School of Design shifted the focus of design training to scientific, technological and methodological strategies[29]. The newly created specialisation in visual design included film, photography, graphic

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[26] The Paperwood 2014 Trade Fair in Frankfurt/Main had 2,967 exhibitors and provided a lot of new information on this topic.

[27] Andreas Kalweit, 'Materiality and Technology', in *Colour: Design Principles, Planning Strategies, Visual Communication*, ed. Axel Buether et al. (Munich: Institut für internationale Architektur-Dokumentation. DETAIL, 2014), 20–31.

[28] Hajo Düchting, *Farbe am Bauhaus: Synthese und Synasthesie* (Berlin: Gebr. Mann, 1996).

[29] Hartmut Seeling, 'Geschichte der Hochschule für Gestaltung Ulm 1953–1968: Ein Beitrag zur Entwicklung ihres Programmes und der Arbeiten im Bereich der visuellen Kommunikation' (PhD diss., University of Cologne, 1985).

design and typography and was subsequently extended in the degree in visual communication to include product design, architecture, urban planning and art. As a medium of visual design, colour, as well as shape and writing, formed an integral part of visual communication. This semiotics-based field of knowledge has so far only become established in the visual design of image media, benefiting numerous practical applications. Professional image producers in the fields of graphics, illustration, printing, internet and film are familiar with the formal and content-related effects of colours. They are able to use these effects on the basis of practical and application knowledge in a targeted and efficient way to convey messages. Degrees in subjects such as communication design and information design still offer untapped opportunities for a holistic exploration of visual design and communication in images, sculpture, performance and space[30].

In architecture and urban design, technical training became an academic subject, and as a result, the curriculum is based on engineering subjects. Consequently, the communicative aspects of built space recede into the background. This is the reason why colour cannot be used strategically as a design tool for the visual communication of content and functional meanings. Colour's complex communicative effects must be taken into account in the same way as the technological effects throughout the design, planning and implementation process. To this end, colour must first and foremost undergo a holistic perception of its function as an element that shapes lines, areas, objects and spaces; as a communication medium that triggers emotions; as an orientation system that forms identity; as a visual and tangible surface quality; and as an atmospheric light quality. An exploration of colour from a communication studies, cultural-historical, natural scientific, technological, aesthetic and practical point of view should therefore be undertaken in all educational institutions involved with the trades, technology, design, art and architecture. No one can avoid interacting with colour, as Paul Watzlawick's axiom can also be applied to the medium of visual design and communication: one cannot not design in colour[31].

[30] Buether, *Die Bildung*.

[31] Based on Paul Watzlawick et al.'s axiom 'One cannot not communicate,' 1969, 53.

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