The Dessau colour observations – seasonal variations in outdoor colour assignment

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In the Dessau colour observation series, the colours that appear in the changing seasons were described on site at the Georgium Park in Dessau-Roßlau (Germany), according to sensory colour impressions without the use of measuring instruments. The descriptions follow the terminology of the NCS Colour System®©. The colour of the previously described objects and perceived colour areas was visually compared with the colour samples of the NCS Colour System®© and noted. Use of a modified colour atlas allowed direct comparison of the colour patterns with the colours of the Georgium Park. It was found that the winter colours cause perceptual shifts towards green and blue-green, while the colours in summer shift in perception towards blue and violet. In the transitional seasons (spring and autumn) the colours shift mostly in the direction of blue. The directions of the displacements are never really parallel to each other, but they shift out of centres scattering at different angles. These shifting centres lie mostly in regions of higher chromaticness, radially outward from the stock of currently existing compared colours. Different colour terms go through changes of hue assignment during the year, and these can be derived from the Dessau observations.

Received 30 March 2017; revised 27 August 2017; accepted 2 September 2017

Published online: 29 September 2017

Introduction

A colourful environment surrounds us every day. In addition to changing light and weather conditions – notably in the moderate climatic zones – it is also subject to major seasonal changes. This will have deterred many people interested in recording environmental colours from making an accurate investigation. The Dessau observations can help to answer these complex questions. The very laws of outdoor colour perception are expressed in the results of the observations, and the colour installations indicate how such findings could be applied to exterior design.

The author had been observing the changing colour in natural environments for several years, comparing the colours of nature with colour samples of the NCS Colour System (Figure 1). Basic statements on the inherent colours of a natural landscape were thus possible [1-2].

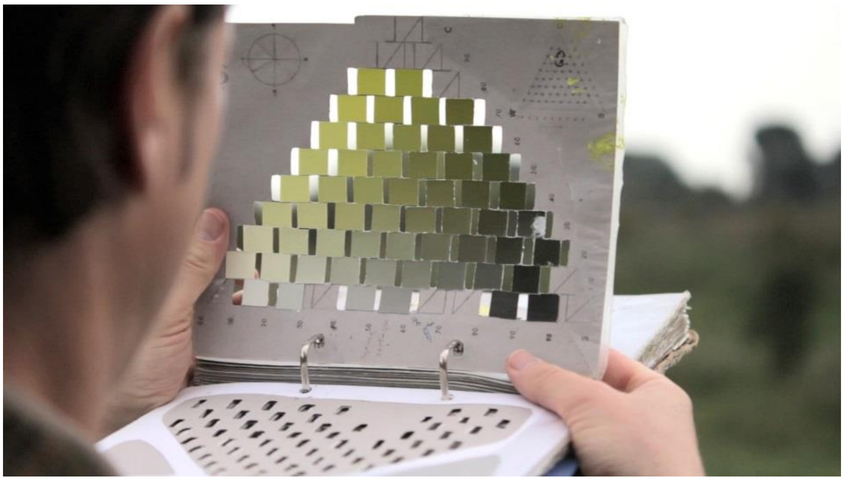

Figure 1: Direct visual comparison of environmental colour, using a modified NCS colour atlas.

It became evident that the natural colours of vegetation and soil could predominantly be found in and around the yellow hues – similar results were found by Fridell Anter [3] – and that a pendulum movement around the yellow region of colour space takes place during the course of the year (Figure 2). Also it seemed that the subjective colour sensations were always differentiated to a certain extent from the direct comparisons with the colour samples.

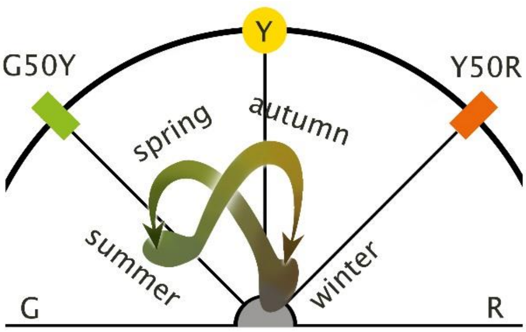

Figure 2: Schematic seasonal colour movement of a soft wood forest [1].

The high yellow component of natural colours is not felt subjectively. The differences between sensation and comparison characteristic for each season need to be understood better. Two colour researchers studied this question prior to this investigation. For her PhD thesis, Fridell Anter asked test subjects to assess the coloured architectural elements according to their colour perception in different seasons [4]. The result was that the colours of the architectural elements regularly appeared brighter, more intense, and mostly less yellowish than their inherent colour [3-4], but she did not find typical deviations in colour sensations according to different seasons.

The vision psychologist Michael A. Webster, however, confirmed the author's assumption in his investigations of the perception of the colours of a highland meadow on a calibrated video monitor [5]. In a further study he included the changing colours of the year [6] and discovered that the perception was influenced not only by the colours of the light, but also considerably by the changes in ambient colour [7].

The Dessau observations consisted of a year-long investigation which captured the subjectively perceived shifts in the colour perceptions and correlated them with the colours determined on site by comparison with colour samples. The colour values determined at the site are called here the “colour stock”, in contrast to the subjectively perceived colour sensations. The location of the investigation was a park in the Central European moderate climate zone, in which with deciduous forest showed an even clearer seasonal variation than the Indian field investigated by Webster, which was influenced by dry and rainy periods. The colourfulness of surfaces in this park location was judged in relation to human perception for the full annual cycle.

The Dessau observations and colour installations therefore establish a relationship between the colourfulness of outer nature and the colour perceptions of the inner nature of the human being, in a balanced equilibrium. Future colour design in architecture, horticulture and landscaping could be based on the findings presented here.

The NCS system

The matching of the natural colours was carried out using colour samples from the NCS Colour System. A modified NCS atlas was employed, which allowed direct visual comparison of the natural colours with the colour sample array by means of slots in the paper (see Figure 1). In addition, a grey card was used instead of white paper as the background for the attached colour samples.

In the NCS colour circle (Figure 3 left), the hue describes the similarity of a colour with one or two of the elementary colours of yellow, red, blue and green. For example, the orange hue Y50R is centred between the yellow (Y) and red (R) elementary colours, and the yellowish green hue G50Y is centred between the green (G) and yellow (Y) elementary colours. All of the colours for a given hue can be represented on a colour triangle (Figure 3 right), with vertices at the achromatic elementary colours of black (S) and white (W) and full colour (C). The blackness is defined as the degree of similarity to black (S). The chromaticness is defined as the degree of similarity to the full colour (C). For example, the colour marked here in the NCS colour triangle has a very low blackness of 10 and a high chromaticness of 80. The marked hue is therefore a brilliant yellow, slightly reddish.

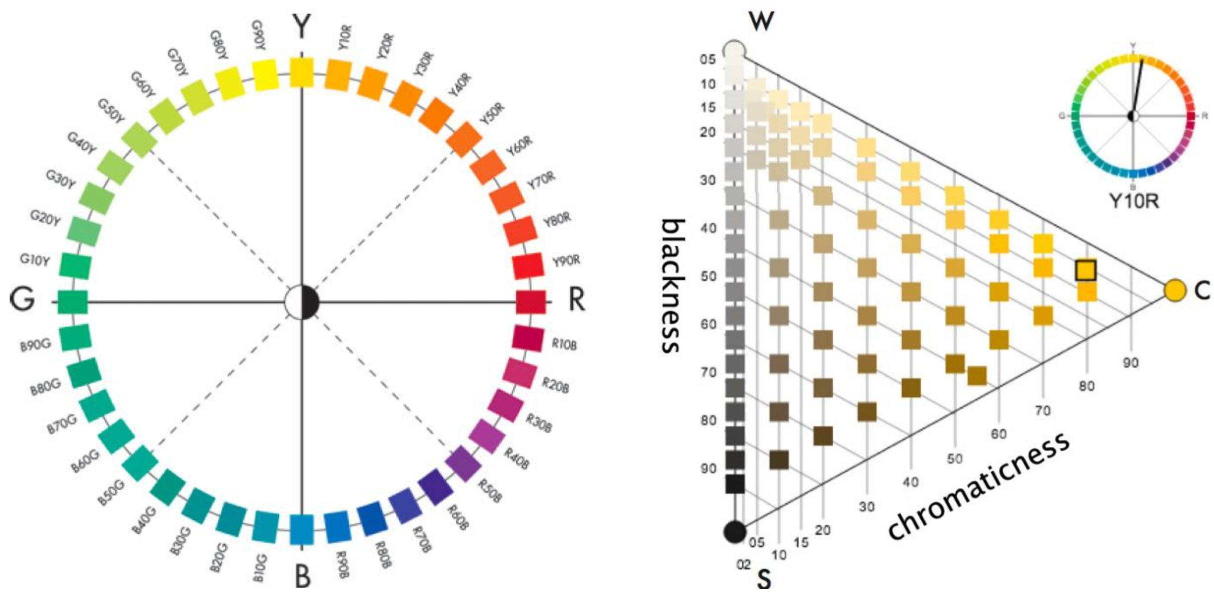

Figure 3: The NCS hue circle (left) and the NCS colour triangle (right).

The double cone of the NCS colour solid is the convex hull of the 40 NCS colour triangles arranged in the NCS colour circle (Figure 4). An NCS colour notation is derived from three visual properties that describe colour: blackness, chromaticness and hue. The NCS colour notation 1080-Y10R, for example, describes a colour that lies between yellow (Y) and red (R) and has the following characteristics: 10% perceived red (the remaining 90% tends towards yellow), 10% blackness and 80% chromaticness. The whiteness – in this case also 10% – is not mentioned in the NCS colour notation, because the values of blackness, chromaticness and whiteness always sum to 100%. The NCS Colour System was developed under neutral NCS laboratory conditions, with a reference illuminant of D65, i.e. simulated daylight with a correlated colour temperature of 6500K. This system is more suitable than other colour systems to capture the colours of a vegetal nature because it offers many finely differentiated yellow-green tones – especially in the hue range G50Y to G70Y.

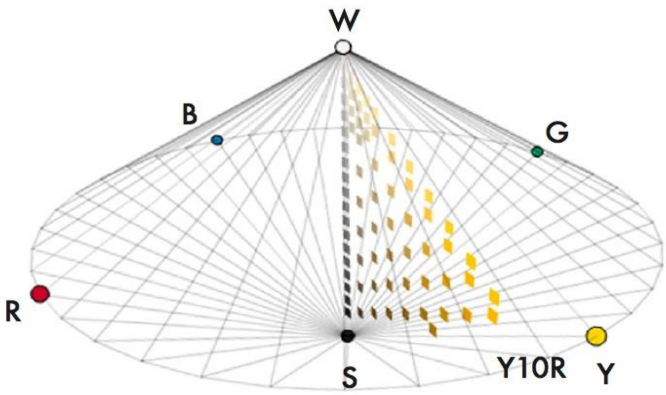

Figure 4: The NCS colour solid.

Method of the Dessau colour observations

The colours occurring during the changing seasons were described on site without the aid of any tools or measuring instruments, and the description was recorded on video to avoid the perceptual distortion that could be caused by looking at a white paper. The descriptions of the sensations followed the NCS notation (Figure 4). The observations were made by only one subject, the author himself, who is skilled in using the NCS colour atlas and experienced in colour observation outdoor for ten years (Figure 5). In further studies, the results could be examined by a larger number of subjects.

Figure 5: The author standing in front of the Fremdenhaus [8].

When the description of the colour sensations was comprehensively carried out and recorded on video, which took 45-60 minutes for about 55 colour values, the colour of the previously described objects and perceived colour areas was directly matched visually with the colour samples of the modified NCS colour atlas and recorded. The modification of the colour atlas allowed a direct visual comparison of the colour patterns with the colours to be determined – without white paper or other distortions (see Figure 1).

The compared colour values were handwritten in NCS colour notations along with a reference to the relevant object or colour area. The observations, including the comparisons, took about two hours each. They were conducted seven times during the year, in the morning between 9 am and 12 am. The results of this study are presented in images which show a plan view of the colour space. Here we distinguish the shifts of colour perception according to hue and chromaticness. The third colour dimension of blackness, which is brought about by the systematics of NCS, is not represented in the graphics in its depth dimension.

The research design of the Dessau colour observations provides a real and comfortable outdoor viewing situation. It allows a slow and conscious adaptation to each colour to be described, and includes in a holistic way the ability of a human to describe his own sensations.

Colour investigations that compare colours in an adapted part of the field of view with colours in a non-adapted part of the field of view, such as the study by Webster [5], get very close to the true sensation before any language assignment is articulated. But they require an unnatural fixation of the view, and are very uncomfortable for the subject, and they use an artificial representation of the colours with an RGB-monitor. A combination of the current study's method with measured spectral light distributions and measured object reflectances of the stimuli would deliver a more reliable basis for further studies.

Location of the Dessau colour observations

The location of the colour observations was the Georgium Park in Dessau-Roßlau (Germany), a part of the "Dessau-Wörlitz Gartenreich", the first English landscape garden in continental Europe, which sought an ideal balance between landscape and architecture, and has been declared a UNESCO World Heritage site [9]. The observation position was ten steps to the south of the southern entrance to the "Fremdenhaus" (guest house) near the Georgium palace.

The field of view was about 100° horizontal and extended from a group of linden trees in the background on the left side to the plane tree near the right side of the house. The part of the Georgium park under observation is, according to the overall situation, to be considered a location that would naturally be covered by a hardwood forest. See Figures 6 and 7.

The present state is a park in the style of an English landscape garden, which also has exotic and evergreen trees. Oaks, Norway maples and linden trees dominate the wood, but there are also yew trees, a Japanese larch and a plane tree in the field of view. A fruit orchard with plum and apple trees can be seen in the distance through a row of trees. The meadows are mown twice a year. The relative constancy of the green throughout the seasons caused by evergreen yews and mown meadows distinguishes the place from a near-natural environment that is characterised by exclusively summer-green shrubs. It is a man-made park that keeps sight-lines open and offers green elements throughout the year. The place is not suitable for the presentation of colour dynamics that are truly close to nature, since the winter would be less green in a situation close to nature, but it is typical for a free space situation created by man according to an ideal landscape.

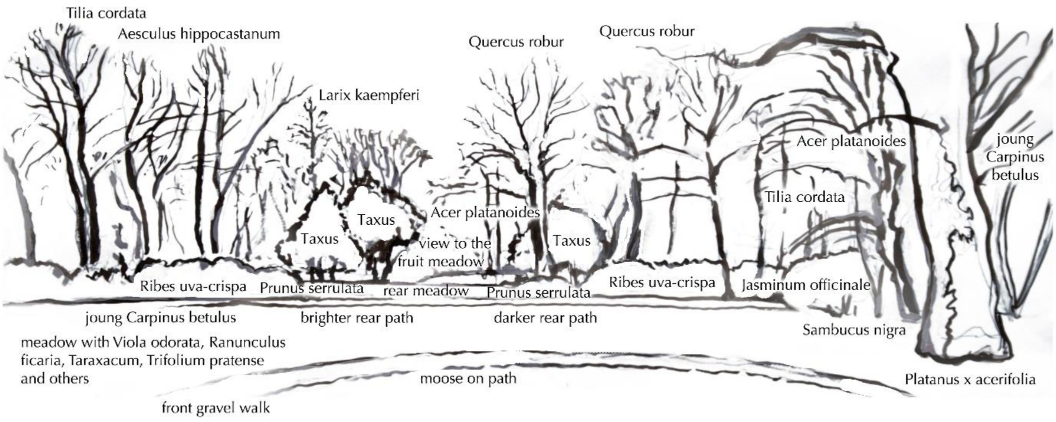

Figure 6: Sketch of the field of view with the entry of plant species.

Figure 7: Photographic presentation of the field of view (June 2012).

Observations in single presentations

The observations took place between 6 May 2012 and 24 April 2013, on seven days throughout the year. They are presented here in an order from winter towards fall. In the following diagrams you will find a top view of the NCS colour space, from which the colours determined in the visual comparison can be recognised (coloured dots). They represent the colour stock of the location at that time of year and thus to a certain extent the objective side, the individual colour of the place, which can be determined through direct comparison with colour samples.

The arrows on these dots indicate where the perceived colour shifts to (arrowheads) in the colour perception at this time and place. The location to which the arrows point is the virtual location in the colour space of the described sensory colour impressions.

If, for example, the arrows point exactly to the green axis leading to the left, this means that the corresponding hue, wherever it can be found as a coloured dot within the colour space, is perceived as green. Since the following diagrams are top views on the NCS colour space, in which statements are possible about the hue and chromaticness but not blackness, coordinate positions in these views are described with abbreviated NCS colour notations such as 40-G50Y (chromaticness 40, hue green 50% tending towards yellow) omitting the first pair of digits, which represent the blackness.

The graphics presented here do not reproduce the described NCS colour values reliably. Particularly when viewed in artificial light conditions, serious deviations are to be expected. For a reliable colour guide, the purchase of original NCS colour samples [10] or of Bertolt Hering's "Kleiner Naturfarben-Kanon" (Little Nature's Colour Canon) [11] is recommended. There the colour references are designed to be stable and reliable against the changes of colour in different illumination.

Winter – 30 December 2012

Colour stock

The compared colours cover a relatively small area at the end of the year. It forms the shape of a lying 8, its narrow point in the range of 15-G80Y, while at its outer points are significant clusters of colour values: in the green region at 25-G35Y and 40-G50Y and in the brown region at 30-Y25R and 05-Y30R. It is typical for vegetation colours that they appear almost exclusively on the yellow side of the colour circle. However, between 20-G60Y and 20-Y10R or 10-G75Y and 10-Y, row structures can be seen which seem to mark possible transitions between the green and brown regions as usual in autumn colouration. The brown tones predominate only slightly (see Figure 8).

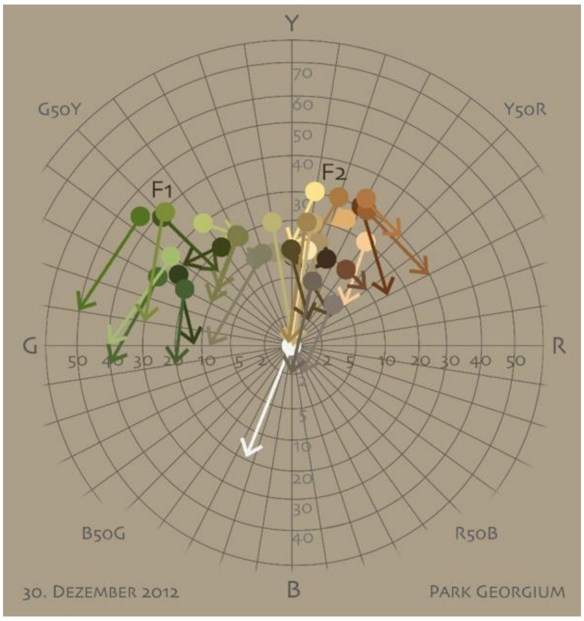

Figure 8: Colour stock and perceptual shifts on 30 December 2012 in Georgium Park.

Sensory colour impression

On site, the colour of the park is still very diverse, as in late autumn. In contrast to the stock of compared colours (coloured dots), in the perception (arrowheads) a larger colour space is created. There are strong shifts to the green and red axis, while overall the perception shifts to the bluish side. The tones perceived as grey have a particularly surprising chromaticness in direct comparison (e.g. 4020-Y10R and 3020-Y10R). The only really neutral grey tone of the colour stock (00-N), which is presented in a metal building fence, is perceived as blue-green (20-B25G). According to the division of the colour stock into green and brown sides, the directions of the perceptual shifts are also different. For the green group, a correctly defined shifting centre ("Fluchtzentrum") is to be found at 40-G50Y (F1). From here, the yellowish-green tones are perceived to be greener than they were in comparison with the NCS patterns. The shifts of the more yellowish, weaker colours seem to be influenced by the brown area (F2). The separation boundary between the two groups is between 30-G60Y (green group) and 20-G60Y (olive value of the brown ochre group). The brown and ochre tones appear to move away from the range between 10-G95Y, 45-Y15R to 30-Y35R (F2). The movement also takes place predominantly in the green-bluish direction, but on the reddish margin of the colour stock there are clear reinforcements of the red perception reaching outwards. The perception of the colour stock predominantly moves the perceived colours in the direction of blue-green; only on the right-hand edges of the shift zones F1 and F2 does the perception tend towards blue-violet.

Late winter / pre-spring – 9 March 2013

Colour stock

There had been a long snowy winter before the observation day, which itself saw light snowy drizzle. In the park there were no indications of spring to be seen, but nearby the hazelnut blossom was in bloom. The expansion of the compared colour stock in the NCS colour space was much more restricted and less colourful compared to the previous observation date. The field of the colour stock, which in December was much closer to the green and brown edges, was now more evenly distributed and closer to grey-brown, while at 10-Y20R and also at 30-Y40R – at the reddish margin of the brown – there was an increase, as if the tones were compressed here at a maximum of materially possible redness (see Figure 9).

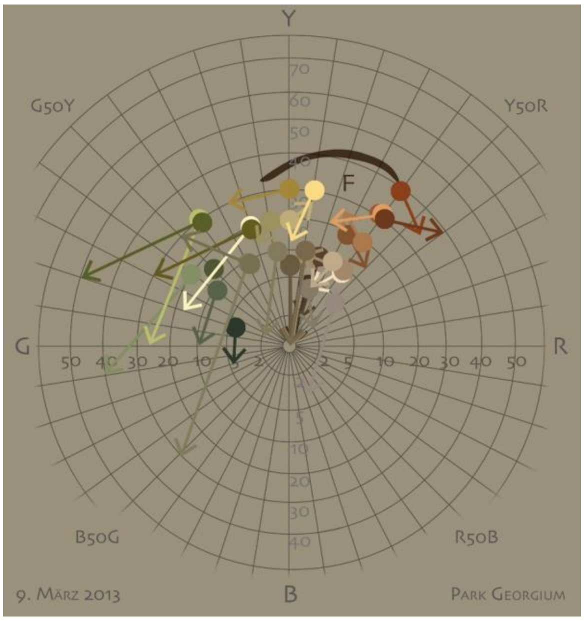

Figure 9: Colour stock and perceptual shifts on 9 March 2013 in Georgium Park.

Sensory colour impression

In the perception, the weakening of the green tones of the meadow, which had been bleached and yellowed under cover of the snow, was not noticeable. Strong values of perceived chromaticness (50%) were recorded. A very yellowish green (30-G60Y) was perceived as a medium green in an environment dominated by the brown wood. The yellow portion of an inherent colour, which was perceived as a medium green, was the highest for the whole year (G60Y). The sensory impression also showed a high uniformity in its perceptual shifts. One single shifting centre (F) could now be described as 35-Y20R, the parallelism of numerous shifts to an elongated centre between 30-Y and 45-Y35R, from which almost all displacements have resulted. A zone of a certain indifference of the displacements lies at 20-Y40R, as contradictory assignments took place in this region. The medium colour shift in perception took place in a blue-green direction on this date, clearly caused by the predominant brown, but the displacements move outwards radially from the centre. It is reasonable to suppose that the shift centre of the colour perception is to be found in the proximity of the statistical mean colour tone (here a brown of Y20R hue). The shift centre, however, has a higher chromaticness outside of the field of the colour stock, possibly because the colour adaptation shifts the sensation of the entire stock so far that the centre point of the colour space is achieved within the stock, which is perceived as grey. The group of the tones described as yellow was somewhat greenish in a direct comparison with the March observation date.

Early spring – 24 April 2013

Colour stock

What is noticeable in the colour stock on 24 April is the high chromaticness of individual tones. Compared to 9 March, the field of the colour stock has expanded almost explosively. This was influenced by the blossom colours such as those of the lesser celandine (*Ranunculus ficaria*, 80-Y) and the hairy violet (*Viola hirta*, 40-R40B), and also the fact that this was the only day in the series of observations on which a visually direct comparison of the sky colour was possible (30-R80B). The fresh greens of the oaks (*Quercus robur*, 50-G80Y) and the Norway maple (Acer platanoides, 50-G60Y) are more present. The greens of the grass in the meadow correspond to the photosynthetically active maximum, as is often the case with other soil-covering plants and seedlings. The freshly emerging plant immediately shows a maximum green (hue-plane G40Y), while in the wood young leaves first appear yellow-green. However, the brown woody colours still occupy the largest share, as the foliage is only just beginning to unfold (see Figure 10).

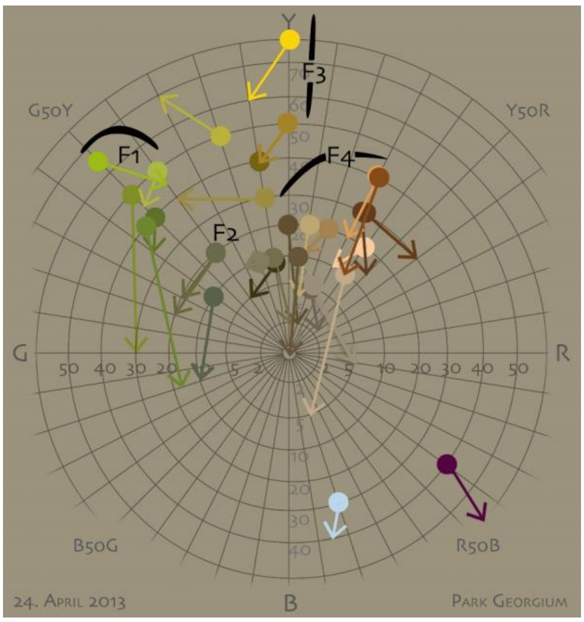

Figure 10: Colour stock and perceptual shifts on 24 April 2013 in Georgium Park.

Sensory colour impression

The unfolding colourfulness felt cheerful on this mild sunny day. The fresh green of the trees appeared as a field of bright green dots in the predominantly dark woods. The green group (around 30-G45Y) is indicated by a direct shift to the green axis. The green is no longer felt more strongly than the direct comparison in the NCS system, as was very clearly the case at the beginning of March, when it was equal in chromaticness or perhaps even weaker. This is due to a larger presence of green tones and the corresponding adjustment in the perception. The direction of deviation is somewhat inconsistent, sometimes more bluish-greenish, sometimes more in a purely green direction. The group of tones perceived as greyish (around 12-Y) drifts slightly to the green side and is now approximately positioned on the yellow axis of the NCS system.

A single shifting centre of the perception is not to be ascertained on this day. Instead, different starting points of the displacements seem to appear in the different colour groups. In addition, on this day, there are more shifts that go against the general tendency (65-G50Y). Lighter green-tinted tones begin their shift with about 55-G55Y (F1), and dark, green-tinted notes with about 20-G60Y (F2). The slightly greenish-yellow tones (80-Y and 50-Y) seem to be displaced from a parallel line (F3). The reddish-brown tones and a violet-blue tone have their shifting centre at about 35-Y30R (F4). The displacements of the tones on the blue side of the NCS colour circle continue to shift on their described courses: sky blue and flower violet follow the shifting centre F4.

Full spring – 6 May 2012

Colour stock

The foliage is now largely complete. Values of around 50 represent over half of the greenish colour stock. The tones of vegetative green are displayed in a loosely occupied area, which shows clusters of 50-G50Y. The stock colours on the green side of the colour circle have a noticeably high chromaticness (see Figure 11).

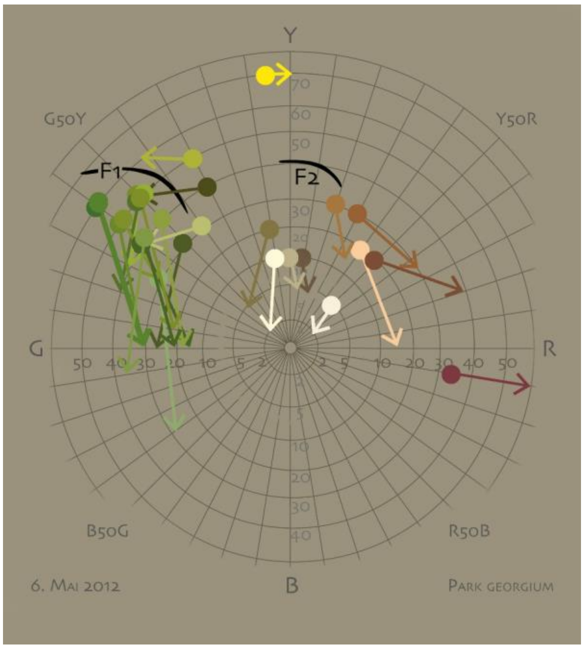

Figure 11: Colour stock and perceptual shifts on 6 May 2012 in Georgium Park.

We can find a compression at the margin, which represents the normal vegetative green maximum of 60-G40Y to 40-G40Y. It is on the border of what is physiologically possible, congruent with the colour of fully developed chlorophyll. A Japanese larch provides an exception with 20-G30Y, which differs in bluish colour and tends towards green. The colour stock shows three clearly distinguishable groups and two individual flowering tones further out. In the brown group, on the reddish side of the colour circle, there is a slightly stronger extension leading to the Y50R cluster, while the red maximum of the vegetation was still at Y40R at the end of April. Similar to the end of April, however, there are also single cases caused by blossom colouring: dandelion at 70-G95Y in the highly saturated yellow area; and, in the reddish direction far from the field, red clover with 35-R10B.

Sensory colour impressions

The colour groups in the stock can be assigned to colour groups in the perception: green and yellow-green, grey and red-brown. Two individual blossom tones lie outside the field of data. The perceived shifts to the green describe a direct path to the green axis and lead to it with a slight deviation to blue (right of the diagram). This means an unusual weakening of the perceived chromaticness in comparison to the chromaticness of the colour stock. In the perception, an elongated shifting centre approximately parallel to the green axis between 65-G45Y and 30-G70Y (F1) can be assumed. On the other hand, yellow-green tones are perceived with a higher chromaticness. The hue difference clearly led to the perception of greater chromaticness in the statistically rare hue. However, a maximum chromaticness of 60 is reached in two entries for the green, with NCS hue level of G40Y, and for the yellow-green level of G70Y we find only one entry with a maximum chromaticness of 50. All other shifts can be derived at this date at the beginning of May from a common yellow shifting centre (F2) at 50-Y. The predominant direction of deviation at the beginning of May is towards the red-green axis to a more bluish and reddish perception. In the yellowish-green and red-tinted notes, the deviation goes further outwards in a yellow-green and reddish direction. The displacements in the reddish direction (from F1) are particularly strong on this date.

End of early summer – 24 June 2012

Colour stock

The colour inventory shows a clear division between a yellowish and a brownish field. The weight is on the green side of the colour circle. The tones on this side form a fairly compact field extending approximately between 50-G50Y and 20-G35Y. Between the hue levels 60Y and Y lies a great caesura, filled only by a blossom tone (Linden tree blossom 40-G80Y). The brownish group shows a line of accumulated values from 30-Y20R to 05-Y15R. What is noticeable is the strong restriction of the stock in the reddish direction. There is only a single tone in the sampling of the stock, which reaches hue level Y30R. The redness of separated discoloured leaves reaches an atypically high colouring (plane leaf of a broken branch 45-Y20R).

Sensory colour impressions

Interestingly, the clear polarisation of the colour stock is not really noticed in the perception on site. Both the green group and the brown ochre group are closing the gap in the perception. The caesura between the hue planes 60Y and Y is bridged by opponent shifts in perception from both sides. For example, a tone patterned as 30-Y is classified in the perceptual description at 28-G50Y, whereas, conversely, a tone determined as 30-G50Y in the sampling is classified as 20-G70Y. This indicates that the perception in this case may differ in conceptual object level, for example wood and leaves, to handle the colour adjustments differently in the two regions. This must be carried out at a high cognitive processing level since shape phenomena are also involved.

The green and yellowish-green group, which forms a fairly consistent field, is distinctly split in perception into green and yellow-green. The green tones seem to flee from a shifting centre at 60-G60Y and the yellow-green from a centre at 50-G40Y. On the reddish side of the colour circle brown-grey tones at 05-Y15R shift slightly towards violet, while the brown, ochre and orange tones could be described – a little simplified – to shift from a centre at 20-Y20R (F3). At Y05R runs a sharp boundary: the tones at the hue plane Y are perceived as yellow-green, 20-Y shifts to 25-G50Y, while 20-Y10R is perceived as 10-Y40R (see Figure 12).

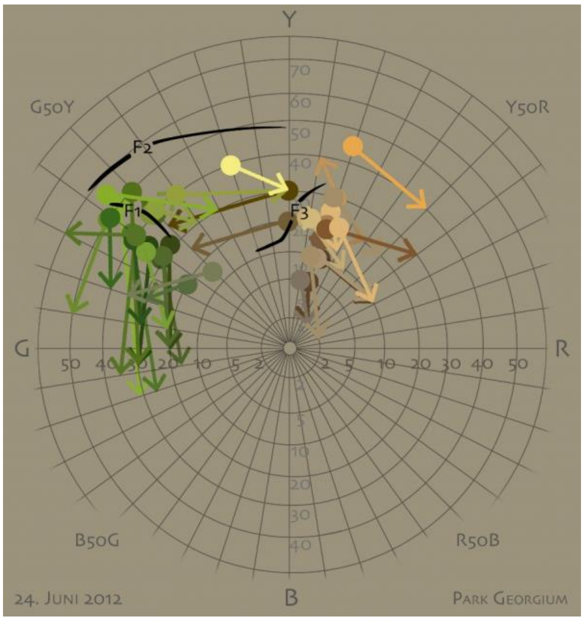

Figure 12: Colour stock and perceptual shifts on 24 June 2012 in Georgium Park.

High summer – 12 August 2012

Colour stock

The polarisation of the colours in two groups is somewhat bridged now by yellowish-green tones, but between G60Y and G70Y there is a clear caesura. Isolated tones appear in the chromaticness range of Y20R and Y30R. We can find one red-violet blossom colour. The green tones form a field that extends between 50-G50Y and 25-G30Y. Compared to the stock at the end of June, it is stretched now in a yellowish-green direction to 60-G60Y. In the colour stock the lighter green tones are more yellowish and have a higher chromaticness than the dark tones, which are predominantly bluish and show a lower chromaticness. The achievement of the hue level G30Y, not only by exceptions (three of 36 entries), is characteristic of high summer. It represents the green maximum in the annual pendulum movement (see Figure 13).

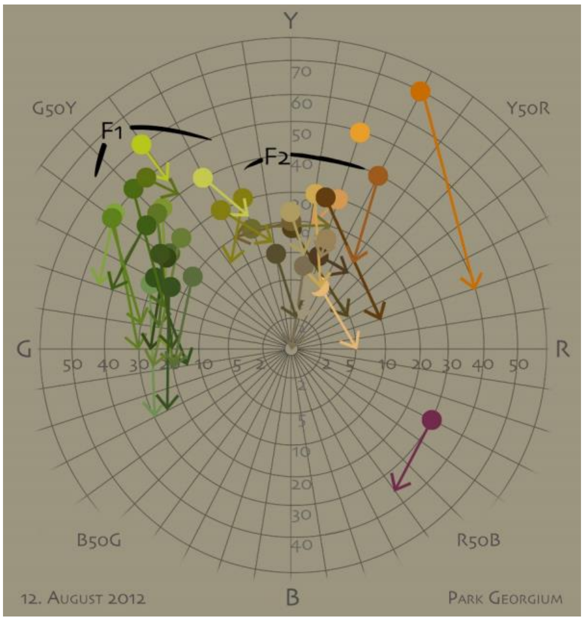

Figure 13: Colour stock and perceptual shifts on 12 August 2012 in Georgium Park.

Sensory colour impressions

In the compared colour stock, intermittent tones occurred between the polarised fields, but perceptual shifts that would bridge this distance are now less present than at the end of June. The deviation of the sensations of the inherent green colours of the colour stock is approximately perpendicular to the green-red axis. A strong concentration of green perceptions around 25-G is noticeable. Instead of speaking of a shifting zone, from which the differentiation takes place in all areas, one is inclined here to adopt a kind of suction field, which summarises various tones to the range around 25-G. The oblique position of the green field in the colour space is thereby retained.

Between 20-G50Y and 70-G55Y there is a separation limit of the assignments to yellow and green. At the top of this line there is a vanishing point (F1) of yellowish green tones, 50-G60Y. The displacement direction starting from F1 predominantly continues into the brown region. It is striking that there is no shifting centre in the field of brown tones. From a line from 70-Y30R to 30-Y, one could imagine shifts in the brown-ochre-orange range (F2). The shift in perception proceeds in a bluish and slightly violet direction.

Full autumn – 6 November 2012

Colour stock

The stock now shows a higher chromaticness of 40 and 50 and has moved significantly towards yellow, resulting from the degradation of chlorophyll in the leaves. The yellow carotenoids previously 'masked' or hidden by the green chlorophyll, now become visible. Row structures correspond to temporal sequences: 30-G60Y to 30-Y30R and 20-G70Y to 20-Y. The number of tones on the greenish and reddish sides of the colour circle is roughly balanced when the limit at the hue Y is assumed. The field is quite compact overall, due to the advancement of green tones to yellowish values, and to the series mentioned above in the centre of the stock field. The midpoint of the stock field, at G70Y and G80Y is still recognisable. Due to the overcast weather, the differences arising from directly illuminated and shaded objects are missing, meaning that the colour splendour of the autumn here appears only in its inherent colouration. The compounds show as 40-G50Y, 10-Y20R and 20-Y30R – apart from the series mentioned above. The yellow area (visible carotenoids) is much more occupied than before. The compression of darker tones at 10-Y20R is noticeable. The discolouration has slightly exceeded the zenith in the direction of a warmer yellow (Y10R), indicating the approaching end of autumn (see Figure 14).

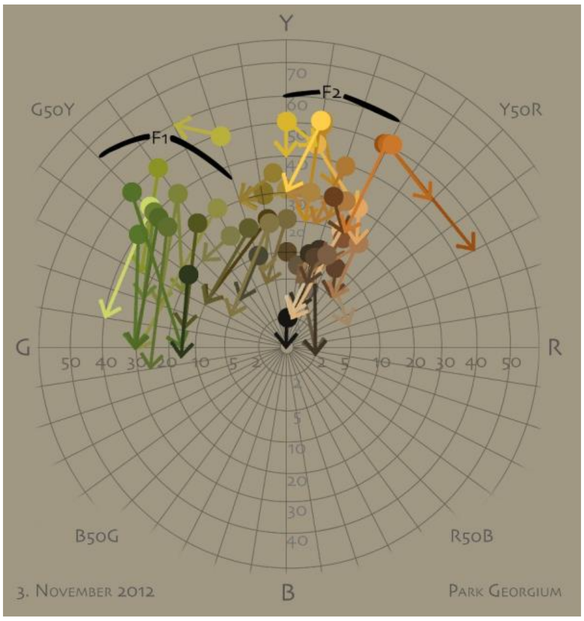

Figure 14: Colour stock and perceptual shifts on 3 November 2012 in Georgium Park.

Sensory colour impressions

An approximation of the shifts in perception that occur in winter is significant. The group of perceived green tones with its stock centre around 40-G50Y are no longer perceived as weaker than the compared versions in August. The sensations in the yellowish green colour stock are almost at right angles to the green axis. Now in the autumn, a more yellowish green is perceived as medium green (G50Y). The shifting centre of the green group (F1) extends between 55-G50Y and 35-G80Y, while tones of yellow green, yellow and brown ranging from 60-Y to 60-Y30R seem to spread further to the left in the direction of blue-green (F2). This difference of a drifting of the colour sensations according to the seasons to blue-green or violet is a summary result of the observations. In this autumn chart it is easy to see how from the perceived green colour, the sensations correspond to the transitional time shift perpendicular to the green-red axis, while the sensations in the yellow-brown range move “winter-like” toward blue-green. This is also apparent when looking again at the March chart, in which the shifting centre of a warm yellow tone also influences the green area, which then appears more colourful and cool blue-green

Discussion

From the course of the year at a glance, the following behaviour appears. The winter colour stock (centre of the entire field at 10-Y10R) causes perceptual shifts toward green and blue-green (left and bottom left of the Figure 15 left), while the colour stock in the summer (main emphasis on green of 30-G40Y) shifts toward blue and violet (bottom right of the Figure 15 right).

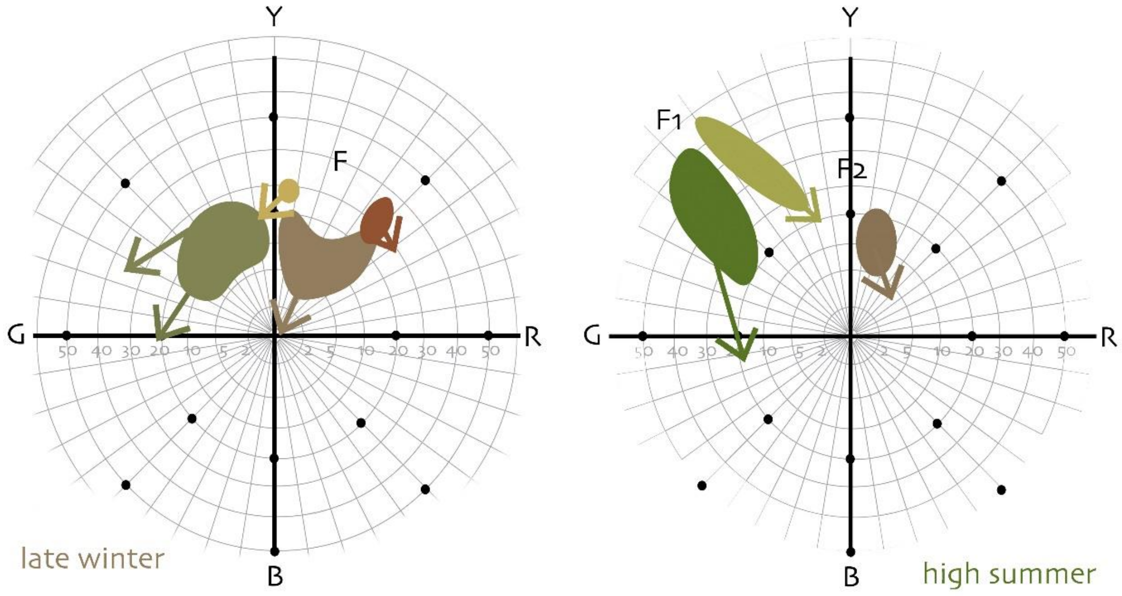

Figure 15: Schematic perceptual shifts in late winter and high summer in the NCS colour space.

In the transitional periods (spring and autumn), the displacements are generally towards blue. The directions of displacement are never really parallel to each other, shifts occur out of centres ("shifting centres"), and the displacement directions scatter in various angles from these centres. Usually these shifting centres of perception are in the higher saturated range radially outside the colours, as if they were caused by a predominant middle tone, and there are separation boundaries of the assignments between adjacent tones. For example, there is often a clear separation in perception between green and yellow-green. The present study describes these shifting colour zones for the first time. In further studies a quantification of each colour (estimated percentages of the field of view) should be added.

Juricevic and Webster [7] observed similar shifting directions of colour adaptation in a lush environment in India as were observed in this study in European summer. They found that the adaptation in an arid environment shifts to blue and violet, while in the present study a shift to a greenish blue was found in European winter. Other studies, summarised by Foster [12], have shown that colour constancy works in human vision most effectively under natural outdoor conditions, and that the influence of the illumination's spectral power distribution on human perception is regularly overestimated. However it would have delivered a more reliable basis for this study if the light and reflectance data had been measured additionally.

The logical continuation of this study would be to capture natural landscapes covering the various climatic zones of the earth, and of civilised urban environments on different continents. Moreover, an increase in the number of observers would further underline the significance of the study.

Prospects for application: the Dessau colour installations

The Dessau colour installations provide the basis for future colour design in architecture, horticulture and landscaping, which may balance the colourfulness of the outer nature and the colour perceptions of the inner nature into a harmonic equilibrium.

Starting from the observations, the author was able to realise several colour installations at the "Fremdenhaus" (Georgium palace guest house) from 2012 to 2016, which nowadays houses the graphic collection of the Anhaltische Gemäldegalerie Dessau, in which the office Otto Koch im K.I.E.Z. organised the art programme "Kunst der Gegenwart in Beziehung zum Georgium" (Recent art in relation to the Georgium).

The colour stock installation in the windows on the south side of the "Fremdenhaus"

The colour stock of four observation dates, corresponding to the four seasons, were added in the windows of the south façade. See Figures 16 to 18. They were arranged in spectral hue order from blue to green and red, according to their perception. The colour tones were applied as acrylic colours on primed paper. Four vertical panels fill each window pane. In the surrounding area, the colour installation, which at first seems colourful, fits to every season. Visitors can see that the colour of the installation does not go beyond the colour space of the surrounding park.

Figure 16: Draft of the window installation (2012).

Figure 17: The two right windows with yellowish and reddish colours from the Dessau observations.

Figure 18: The "Fremdenhaus" with the colour installation in the windows in the four seasonal states of the park: spring (top left), summer (top right), autumn (bottom right) and winter (bottom left).

The colours in the windows look like a reflection of the colours of the surrounding area in an abstracted order, while at the same time the darker colour areas reflect those of the present condition of the park. See Figure 19.

Figure 19: Mirrored nature, conserved colours of past seasons and sensational notes overlap.

Installation of the colour sensation octagons south of the "Fremdenhaus"

From the descriptions of the sensations of the Dessau observations one can make statements as to which tones were perceived as "green", "blue", "red" or "yellow" at each time of the year. A yearly movement of the conceptual shifts can be observed. See Figure 20.

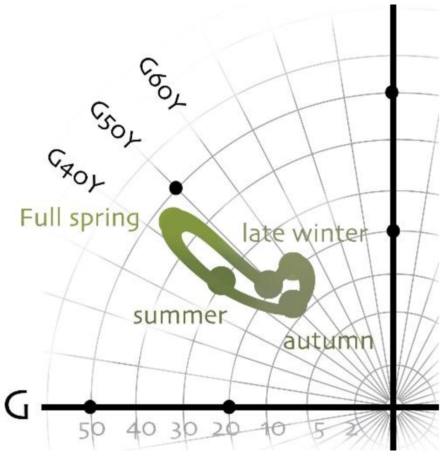

Figure 20: Scheme of the seasonal movement of compared colours perceived as medium green.

These results were developed and executed in the colour sensation octagons (Figure 21). The octagonal shape of the panels reflects the eight directions of the four primary hues and their intermediate hues. In the middle of each octagon, the tone is grey for each of the four seasons, with the handwritten reference to the season, and the corresponding colour sensations (Figure 22). They give the key to colour designs that relate to a natural, human perceived colour space.

Figure 21: Overall view of the exterior installations in the Georgium Park, August 2013.

Figure 22: The four plates of the colour sensation octagons: (left to right) winter, spring, summer, autumn. (Acrylics on wood, 2014, property of the art collection of Sachsen-Anhalt).

The tones perceived as grey in the arch window on the south side of the "Fremdenhaus"

Grey deserves a special role in the colour space, because it forms its centre. For completion of the colour installation, in June 2016 the central arch window above the door on the south entrance of the "Fremdenhaus" was filled with tones that were perceived as grey in different seasons on the site in the Dessau observations. The semi-circular field at the centre reproduces the sensation in early spring, from there the movement to the second field to the left, which represents full spring. On the far left is the grey sensation of the summer, autumn, and winter follows to the right. See Figure 23.

Figure 23: The installation of the perceived greys in the arch window.

The grey tones represent the heart of the colour space found and felt in the Georgium Park, which can be seen as a substitute for other park situations in temperate climates. They and the colour-sensation octagons give the key to a colour scheme that puts nature and human feeling into balance and does not try to rise above nature.

Acknowledgements

The author would like to thank the following for helpful advice: Prof. Dr. Otti Wilmans (Geobotanics), Ekko Bruns (Phenology of the German weather service), Prof. Dr. Hartmut Dierschke (Plant phenology), Karin Fridell Anter (Environmental colour), Michael A. Webster (Perception), Chloë Spreadborough (Translation), Johanna Bartl (Büro Otto Koch im K.I.E.Z. e.V.) and Anhaltische Gemäldegalerie Dessau.

References

1. Hering B (2004), *Colours of the Seasons – draft for a Colour Phenology of Central Europe*, Hamburg: Bertolt Hering Atelier.
2. Hering B (2007), Symphänologie der Farben – Der Farbwechsel von Pflanzengesellschaften und Landschaften, *Tuexenia*, **27**, Göttingen, 402-416.
3. Fridell Anter K (1996), *Nature's Colour Palette: Inherent Colours of Vegetation, Stones and Ground*, Stockholm: Scandinavian Colour Institute.
4. Fridell Anter K (2000), What colour is the red house? Perceived colour of painted façades, *PhD Thesis*, KTH Royal Institute of Technology, Trita-ARK-Akademisk avhandling, Stockholm (Sweden).
5. Mollon JD and Webster MA (1997), Adaptation and the color statistics of natural images, *Vision Research*, **37** (23), 3283-3298.
6. Webster MA, Mizokami Y and Webster SM (2007), Seasonal variations in the color statistics of natural images, *Network: Computation in Neural Systems*, **18** (3), 213-233.
7. Juricevic I and Webster MA (2009), Variations in normal colour vision. v. simulations of adaptation to natural colour environments, *Visual Neuroscience*, **26** (1), 133-145.
8. Hering B (2013), Farbempfindungsbeschreibungen, *Video Corpus of the Dessau Colour Observations*, Hamburg [see also http://www.bertolt-hering.de/ – last accessed 12 September 2017].
9. Dettmar E (no date), *Informationsblatt zum Fremdenhaus*, Anhaltische Gemäldegalerie, Dessau-Roßlau.
10. NCS Colour Atlas (2008), Production 2, Stockholm: Scandinavian Colour Institute.
11. Hering B (2013), *Kleiner Naturfarben-Kanon* (Limited Edition), Hamburg: Bertolt Hering Atelier.
12. Foster DH (2011), Color constancy, *Vision Research*, **51** (7), 674-700.