Diplomarbeit

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Every Shade Is A Light. Artists´ Lightness Perception And Luminance Compression Strategies in Representational Art.

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„Die kleine Palette voll reiner, unvermischter Farben von hellster Leuchtkraft, sie war sein Trost, sein Turm, sein Arsenal, sein Gebetbuch, seine Kanone, aus der er nach dem bösen Tode schoß.“

(Hermann Hesse, Klingsors letzter Sommer)

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Abstract

Artists face two major problems when they render luminances from a natural scene onto a painting. First, they have to overcome lightness constancy, i.e. the fact that we don´t perceive luminances objectively but rather “interpret” them, and second, they must compress the high dynamic range luminances so that they fit on the restricted range the canvas presents. When artists render a natural scene, they must create an image, which is close to the retinal image of the scene in order to appear correct to us. In terms of luminances, they must therefore undo lightness constancy, either by accessing early visual processing stages, or by correcting their own perceptual errors in a second step. Indeed we find evidence for better perceptual abilities in artists, like better performance on a shape constancy task (Cohen & Jones, 2008). If artists were able to overcome lightness constancy perceptually, they should also be better at judging luminances objectively. To test this assumption, subjects were involved in a luminance judgment test. They had to choose whether real contrast stimuli or illusory contrast stimuli at varying contrast levels showed greater luminance difference. Non-artists (n=11) and artists (n=11) showed no difference in their luminance judgmental abilities; furthermore, artistic expertise was not correlated to luminance judgmental abilities, suggesting that artists when painting, cannot undo lightness constancy through more accurate perceptual processes.

In a second study I present a group of painter´s (n=10) luminance compression strategies, all originating in the same natural scene, which was painted under the same lighting conditions. I show a model that visualizes a given artist´s global luminance compression strategy — the “artist’s look-up table” – which seems to reflect fundamental stylistic components (Graham, 2009). The different “Artist’s look-up tables” appear to vary systematically across different techniques (such as aquarelle or ink painting). To the degree that certain luminance compression strategies are also a fundamental property of a given painter or grouping of paintings, the “Artist’s look-up table” can be a helpful tool in authorship debates and in stylometry.

1. Introduction

Any painter who wants to depict a natural scene or object in a representational manner[1] is exposed to a number of perceptual and visual-motoric problems. The focus of the present work is light and dark from a psychophysical and ergological perspective: how do artists perceive luminances, and how do they represent them when they paint? It is a complex issue: artists[2] must overcome certain visual corrections like the lightness constancy effect when they want to determine the accurate luminance to apply in the painting. But it gets even trickier: even if they are able to access the accurate luminance value on their retina, they might decide not to paint it, because the medium itself – the canvas and the colors they use - limits the range of applicable values, so that artists must find a compromise and compress the range of values so that it fits on the paper. In spite of these complex perceptual and technical challenges, there is no doubt that many artists in the past and in the present have been able to create naturalistic paintings with a life-like and even photorealistic claim. So we may assume that painters are successfully dealing with the perception and representation of luminances, which makes them and their creations an interesting field to investigate for perceptual Psychologists.

In the first section of the thesis we will deal with lightness perception and the question, whether artists are a group of people that have better perceptual abilities in the field of lightness computation. In the second part of the thesis we will proceed to the topic of luminance compression as an integral component of

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[1] We use the term naturalistic painting and representational painting synonymously. We refer to Naturalism as a tenor in Art, which aims to a highest possible life-like depiction of reality without stylization, abstraction etc. and that can be found like that in all epochs (Hirschmann et al, 1982).

[2] Whenever I speak of „artists“ in this context I usually refer to painters. More precisely, to painters whose aim it is to do representational Art, i.e. to create a naturalistic image of the world. I am fully aware that many people expressing their ideas in the Visual Arts are not interested in matching their painting to the outer world („Some artists seem to do nothing but make and make, never bothering to match. In fact, they are comparing what they make to a conception of reality they find somewhere inside themselves.“ Wood, 2009). Still, for the purpose of analyzing perceptual processes in the human brain it is useful to have a look at artists who are able to draw well in an „accurate“ sense, because their accurate drawing is not only impressive from a manual point of view, but also raises questions from a neurobiological and perceptual focus. See also footnote 5 for a critique of the „accuracy“-term.

painting and describe a model that visualizes an individual artist´s use of luminance compression.

2.1 Lightness Constancy in Artist´s Perception

Visual Constancies in Everyday – Perception

If we saw the world as it is represented on the retina, „objects would change size as they moved toward or away from us, change color as they moved into different lights, be cut into pieces as they moved behind other objects and jump to and fro every time we moved our eyes“ (Perdreau & Cavanagh, 2011; p.1). But this is not the case; moreover we experience a relative coherent visual surrounding. This is owed to perceptual processes that enable us to experience such a coherent, invariant visual representations of objects. Visual constancies are an essential achievement of visual perception. Through them, an organism knows about meaningful world-properties, such as size, shape, color or lightness. Since all of these constancies are not properties that lie explicitly in the retinal image, they must be computed by the visual system (Adelson, 2000). Lightness constancy is one of these perceptual achievements that help us decipher the surrounding world. It´s a fundamental aspect of every-day perception that we hardly ever consciously think about; yet, artists when painting cannot avoid putting their focus on lightness and luminances.

Lightness constancy

First, it makes sense to clarify some terminology. I follow Adelson`s (2000) suggestions (p. 341 f):

> *Luminance* is the amount of visible light that comes to the eye from a surface.
>
> *Illuminance* (or *Illumination)* is the amount of light incident on a surface.
>
> *Reflectance* is the proportion of incident light that is reflected from a surface.[3]

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[3] Reflectance varies from 0 to 1, or equivalently from 0% to 100% of the incoming light. 0% is ideal black; 100% is ideal white. In practice, typical black paint is about 5% and typical white paint about 85% (Adelson, 2000, p. 341).

Luminance, illuminance and reflectance are physical characteristics that can be measured by physical devices. But there are also subjective variables that are used in the academic discourse, most importantly for our purposes: lightness.

> *Lightness* is the perceived reflectance of a surface. It represents the visual system´s attempt to extract reflectance based on the luminances in the scene.

We perceive the lightness of objects via the light they reflect back to the retina. How much light that is, depends on two factors: the surface reflectance of an object and the illumination that falls on it (Gilchrist & Radonjić, 2010; Perderau & Cavanagh, 2011). If a visual system only made a single measurement of luminance, like a photometer for example, it would be impossible to distinguish a white surface in dim light from a black surface in bright light, when they have the same luminance values. Yet, human beings are able to judge lightness pretty well, i.e. to make this distinction between "black in bright illumination" and "white in dim illumination". This ability is owed to lightness constancy (Adelson, 2000). It is a perceptual achievement and does not lie in the property of the retinal image itself. The retinal image has access only to the luminance value.

From a physical point of view a certain luminance value is obtained by multiplying illuminance and reflectance. That means for our visual system when perceiving a certain luminance value, there are infinite possible combinations between reflectance and illumination values. Under these conditions, it may seem an unresolvable issue to extract the lightness of a given surface for our visual system. Fortunately, illuminance and reflectance are not a merely arbitrary function but are constrained by statistical properties of the world. It seems that guided by these statistical properties, humans are able to discount the illumination that falls on the object in order to estimate the surface reflectance of an object.[4] As a result, lightness can be estimated. Lightness computation works well in most natural situations, so well, that we hardly ever notice it happens. Lightness illusions, though, are a class of stimuli where the inner workings and the imperfection of human lightness computation are revealed (Adelson, 2000).

Some classic empirical examples, demonstrating the effect of lightness constancy were done by McCann (e.g. Land & McCann, 1971; McCann, 1999; 2005; 2008).

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[4] Gilchrist & Radonjić, (2010) suggest a model how lightness in complex scenes can be inferred by the visual system.

He conducted a number of experiments relevant to spatial interactions and lightness constancy, two of which (Land & McCann, 1971; McCann, 1999) will be described in this place. They illustrate how identical luminance values generate identical quant catches in the retinal receptors but do not generate identical lightness impressions.

The Black and White Mondrian (Land & McCann, 1971) used a single complex arrangement of black, grey and white papers. A single lamp lightened the display with much more light falling on the bottom than the top. The lamp´s position was fitted so that the same luminance values came to the eye from a white paper on the bottom, as a black paper on the top. Anyhow, viewers reported that the black paper appeared black and the white paper appeared white, regardless of the fact that they had equivalent luminance and therefore identical quanta catches.

In another series of experiments real life scenes were used (McCann, 1999), e.g. a scene with blue sky and dark shadows under a tree. It was measured by a spot photometer that the light from a white paper in the shade was identical to a black paper in sunlight. Observers stated that the black square looked black and the white square looked white, no matter that their luminance was the same. It turns out that humans, using spatial comparison mechanisms have no problem seeing in sun and shade at the same time (McCann, 1999).

Gilchrists anchoring theory

We have argued that, constrained by certain statistical properties of the natural world, humans are able to discount the illumination that falls on the object and infer its lightness. But how does this process unravel?

The anchoring theory by Gilchrist (2006) proposes a process where the visual system doesn´t require the absolute illumination values but rather takes account of relative intensity ratios within and between visual frameworks. He argues that the visual system “does not need to know how much illumination a surface is getting - it only needs to know which surfaces are getting the same amount of illumination” (Gilchrist & Radonjić, 2010p. 1). The visual system groups together surfaces that get the same illumination and infers their lightness values by comparing the luminances of those surfaces. In a further step, Gilchrist & Radonjić (2010) developed the framework theory: When a group of surfaces receives a common illumination, it can be called a “frame of reference”. Groups of surfaces are created through the gestalt grouping principles: similarity, proximity and good continuation, applied along the context of common illumination. Framework boundaries are created along fuzzy boundaries (penumbrae) and depth boundaries (corners and occlusion boundaries). Within the framework, the highest luminance is interpreted as white. Lightness values in the darker regions are estimated by the visual system relative to the highest luminance present, following a fixed ratio. In complex images, each patch belongs to two frameworks simultaneously: a global framework incorporating the whole visual field and one or more local frameworks. Weighting and averaging the different values from both the local frameworks and the global framework eventually allows obtaining a lightness value for the patch (Gilchrist & Radonjić, 2010). The existence of a framework effect was empirically shown in a series of studies (Gilchrist & Radonjić, 2010).

Painting and visual perception

Lightness constancy is one of the perceptual challenges for artists when they paint a scene and want to depict it in a naturalistic way. They must find a way to overcome visual constancies like shape, size or lightness constancy that their brains create. In order to paint a realistic image, they must undo these constancies and fall back to an impression that may be closer to their retinal image.

Different perceptual theories have dealt with the relationship between the retinal image and the final percept over the past century. At this point I will outline Rock´s theory of Constructive Perception who has introduced some useful terminology and concepts for the context of perceptual processing and drawing accuracy and who has been cited in the presented research.

Rock’s theory of Constructive Perception

Rock (1983) assumes that perception is governed by logical operations: “Perception seems to be shot through with intelligence” (p.2) with the goal of interpreting the sensory input in relation to an outer object or event. Rock (1983) distinguishes between the *distal stimulus* (i.e., the object in the world) and the *proximal stimulus* (i.e., the pattern of stimulation on our sense organ, in visual perception: the retina). Rock (1983) assumes that the initial perception of a stimulus is ephemeral and corresponds roughly to the proximal stimulus. After this initial perception an unconscious inference stage follows whereby the visual system recognizes the three-dimensional structure of the object. Assuming three-dimensionality leads to a final percept, which corresponds more closely to the distal stimulus than the proximal pattern. It is essential to Rock's theory of constructive perception that both the initial percept and the final percept can potentially be accessed. The proximal stimulus, however, is less important for our ability to identify the shapes and positions of objects in space, and thus is less relevant to survival. Therefore, perception is dominated by the final percept.

If Rock's theory of constructive perception is true, in order to accurately draw a stimulus, artists have to render the initial percept (i.e., the proximal stimulus). If the painting is close to the proximal stimulus, it will appear realistic: Because the observer's perceptual system will apply the same perceptual transformation on the drawn image as it before applied to the proximal stimulus and so the final percept will appear accurate.

Perceptual distortion and drawing errors

Perdereau and Canvanagh (2011) argue that according to Rock´s theory of constructive perception, drawing errors root in the attempt to reproduce the final percept, based in three-dimensionality, rather than in the initial percept.

Empirical evidence for the assumption that the cause of drawing errors lies in perceptual distortion has been reported by Cohen & Benett (1997), who showed in a series of experiments that the main source of artist´s drawing errors lies in the misperception of the object. Cohen and Benett (1997) argue that the misperception of the object is rooted in two different causes: illusions and delusions and that not both of these causes must lead to drawing errors. Illusions are defined as misperceptions that cannot be corrected through an act of will, whereas delusions are defined as false beliefs that are held in spite of invalidating evidence, like painting the river water blue when its true color is actually brownish green. Cohen and Bennett (1997) believe that such knowledge about the properties of the object interfere with perception and contribute to the misperception of the to-be-drawn object. Cohen and Benett (1997) suggest that illusions cannot be perceptually overcome, whereas delusions can be overcome by an act of will. Even though illusions cannot be perceptually overcome, they may not lead to drawing errors, because rendering such an illusion should theoretically create the same illusory effect – a thought that we will reencounter later in Gombrichs assumption of the drawing process (see Chapter: Making comes before Matching).

One restriction for Cohen and Benett´s (2005) study is that they were able to bring about only indirect evidence for the misperception of the object as a major cause of drawing errors, through a process of elimination. They ruled out various explanations for drawing errors, like the inability to make good representational decisions, deficient motor skills, and the misperception of artist's own drawing, however, they did not offer direct evidence to show a link between perceptual distortion and drawing errors.

Mitchell, Ropar, Ackroyd, & Rajendran (2005) fill this gap, using the Shepherd Illusion to show that the misperception of the object leads to drawing errors and that a differentiation between its causes (illusions versus delusions, or in the authors´ own terminology: low level perceptual processes versus perspective cues) can be made. The basic figure of the Shepherd Illusion is a pair of parallelograms; one is vertically, the other one horizontally orientated, whereas the second figure shows the same shapes but with features added to make them look like tables. Both pairs of shapes have exactly the same size but the horizontally orientated one appears to be wider and shorter. Mitchell and colleagues (2005) suspected that participants, having to adjust sizes of one part of the stimulus pair to the other, would err in the table version of the Shepherd Illusion to a much higher degree, due to the perspective cues present in the stimuli. These perspective cues in the table version of the illusion add to the effect of the simple parallelogram illusion a delusional effect: Participants´ stored information about tables and three-dimensionality distorts perception through framing the stimulus in a different perceptual setting. This is what they found: Participants had perceptual distortion of the parallelogram and the table stimuli when configured as the Shepard illusion, but copied parallelograms with added table legs less accurately than parallelograms. So the effect of the illusion plus perspective cues was stronger than the mere illusion effect. Mitchell et al. (2005) believe that the perspective cues present in the table pair of the Shepard Illusion give rise to perceptual processes associated with shape constancy. Shape constancy, again, has previously been reported to lead to errors in drawing (Thouless, 1931, cited according to Mitchell et al., 2005).

We may well interpret drawing errors in the Shepherd Illusion as an attachment to the final percept as proposed by Rock (1983) that has even been more strongly induced by the perspective cues in the table version. If we assume that we find a varying ability in artists´ to drawing accuracy, it seems plausible that skilled artists are able to somehow overcome the influence of the final percept.
What remains unclear is how artists achieve overcoming perceptual distortions: Do they have superior visual cognition or does their ability lie in the knowledge of the causes of visual illusions? Do years of training allow them to get access to earlier visual processing stages? Do certain people have an innate ability to overcome visual constancies? Or do artists just use tricks that help them not to be overly influenced by visual constancies?

Artists have better perceptual abilities

There has been a lot of evidence for a correlation between drawing accuracy[5] and performance on perceptual tasks (Cohen & Benett, 1997; Kozbelt, 2001; Cohen, 2005; Mitchell et al., 2005; Kozbelt & Seeleey, 2007; Cohen & Jones, 2008; Matthews& Adams, 2008; Graham & Meng, 2011b), leading to assume that artists do have a superior visual cognition.

One study that explicitly deals with the effect of visual constancies was conducted by Cohen and Jones (2008). They explored the relationship between shape constancy and drawing accuracy. Shape constancy was defined as "the phenomenon that obliquely presented shapes are perceived as less skewed than

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[5] As Cohen & Bennett (1997) point out, the term "drawing accuracy" suggests that an objective description of accuracy can be made, which is tricky, because it defrauds that a concept of "accuracy" is always culturally and historically determined. As a working definition I keep with Cohen and Bennett (1997, p. 609) who defined a

> "visually accurate representation as one that can be recognized as a particular object at a particular time and in a particular space, rendered with little addition of visual detail that cannot be seen in the object represented or with little deletion of visual detail. According to this definition, a photograph is an excellent example of a visually accurate, two-dimensional representation because it adds and deletes very few visual details."

I realize that even following this suggestion a decision about "accuracy" will always be a subjective one, but it will suffice for the purpose of distinguishing a rather photorealistic approach from other approaches in Art.

the shape projected on one´s retina” (Cohen & Jones, 2008, p.8). They were able to show that participant´s performance on a shape constancy task was a robust predictor of their drawing accuracy, which gives further evidence for the supposition that people who draw well, may be able to access early stages of perceptual representations. Cohen and Jones (2008) argue in this manner when they claim that their shape constancy task measures people´s ability to access the initial retinal image and thus predicts drawing accuracy.

In a small study that used the same methodology as our own empirical research (see chapter 2.3 Method), Graham and Meng (2011b) found professional artists to have superior luminance judgment in a two-alternative choice (2AFC) - task comparing a lightness illusion with real luminance differences. Additionally, they found that expertise, as measured by the hours-per-week-spent-painting, was significantly correlated to their ability to judge luminances. Graham and Meng (2011b) suggest that with training, artists achieve better luminance judgment.

It might or might not be true that artists can access the proximal stimulus. We do find that artists have better perceptual abilities in the reported studies (Cohen & Benett, 1997; Kozbelt, 2001; Cohen, 2005; Mitchell et al., 2005; Kozbelt & Seeleey, 2007; Cohen & Jones, 2008; Matthews& Adams, 2008; Graham & Meng, 2011b). But how are they cognitively different from other people?

Artists as Experts in Visual Cognition

Kozbelt (2001) tries to raise an answer to the question of what the nature of artists´ perceptual difference is. He compared the performance of artists and non-artists in a number of perceptual and drawing tasks. The perceptual tasks dealt with identifying blurred and incomplete pictures, finding hidden shapes in a more complex pattern and a mental rotation task. Artists outperformed non-artists in all of these tasks. Kozbelt (2001) performed a regression analysis showing that there were common visual processes in the perceptual and the drawing tasks. If a participant was good at drawing, this person also tended to do well on the perception tasks. He also found that artists’ perceptual advantage not sufficient on its own to explain their success at drawing; other processes, such as motor skill or perceptual-motor integration, also contribute to their drawing advantage.

Kozbelt (2001) concludes that artists are cognitively different to other people: they are „experts in visual cognition“. He argues that artists, when drawing, have to engage in intensive visual analysis and comparison, so that in their painting culminates their artist´s plan, what is seen in the visual world, and what has been drawn. Kozbelt (2001) promotes his concept of the artist´s plan to be comparable to Gombrich’s (2002) notion of *schemata*: a sort of explicit, declarative knowledge of the structure of common object types and means of depicting this information in a given medium. It is what an artist attends to over other visual qualities, e.g. an object´s three- dimensionality (Kozbelt, 2001). He claims that as artists gain experience in this interaction, they acquire declarative knowledge of the visual world and procedural knowledge of how to analyze and display it. According to Kozbelt (2001) it is the artist´s merged knowledge, which makes artists cognitively different: it makes them experts in visual cognition.

Gaze Frequency and Drawing Accuracy

Kozbelt (2001) makes a point about artist´s specialized procedural knowledge of depicting objects of the world. Together with other, declarative forms of knowledge, procedural knowledge creates artist´s expertise. Cohen (2005) may have found one contribution for this specialized procedural knowledge, asking the question: Which mechanisms allow artists to achieve superior visual cognition by overcoming the dominance of the final percept? Cohen (2005) found that skilled artists use higher gaze frequency between the to-be-drawn object and their painting compared to unskilled artists. Apparently, high gaze frequency reinforces the influence of the first perceptual percept and diminishes the influence of the final percept. Cohen (2005) believes that high gaze frequencies may facilitate drawing accuracy by allowing the artist to hold less information in working memory, reducing memory distortion, and facilitating the reduction of context effects through inattentional blindness (this means artists might want to make themselves “blind” to context effects by not devoting them any attentional resources). One part of the special artistic procedural knowledge may consist in this „technique“ of using higher gaze frequency.

Making Comes Before Matching

Going back to the question, how do artists overcome their distorted perception so that they can draw accurately, we find an alternative explanation that does not require direct accessing of the proximal stimulus. One explanation that famous Art historian Gombrich (2002) articulates, goes a different way. In his “Art and Illusion”, Gombrich makes a powerful claim against Ruskin (1857/1971, cited after Kozbelt& Seeley, 2007) who had proposed painters could achieve an “innocent eye”. According to Gombrich, this is not true: Artists might use special techniques to depict the proximal stimulus but their training could not lead them to get an innocent eye, i.e. a complete elimination of perceptual bias. Gombrich claims that the innocent eye is a myth. Perception is a learned practice, which involves an active construction of the world (Wood, 2009). Artists who seek realism must engage in a hypothesis-testing process in which discrepancies between achieved depiction and their perception of the world are unraveled. They test sets of strokes against their perceptual experience and evaluate how successful they are. In Gombrich’s formulation, “making comes before matching”: Artists might be exposed to the same visual constancies as non-specialists but in the progress of the drawing make corrections in the context of the drawing itself. Since the same visual constancies influence their perception in the real scene as well as in the painting, they only have to compare sizes, color, and lightness depicted and in the scene.

Empirical evidence that is better framed within Gombrichs approach comes from Perderau and Canvanagh (2011). They conducted a number of experiments related to size constancy, lightness constancy and amodal completion in a group of artists and non-artists. They found no evidence for special perceptual expertise in artists. Subjects had to adjust either the size or the brightness of a target, matching it to a standard. The standard was presented in a context that either induced visual constancy or not. In another task subjects had to find a L-shape in a camouflaged condition or a non-camouflaged condition, and the speed with which artists and non-artists accessed these visual representations was measured. In all three tasks artists were as affected by context as non-artists. Additionally they took significantly more time to take their decisions, which implies that they were trying to give their best but would still not achieve better perceptual performance.

Summary

Artists must be able to undo the visual corrections underlying their everyday perception in their paintings, e.g. make the distant object the correct size even though it is experienced as not very small. In the case of lightness constancy, a painter depicting a certain object must choose a pigment that corresponds to the luminance coming from the real object. When choosing the right pigment that "matches" the luminance from the object, the artist must ignore the perceived reflectance of the object and try to get access to its "real" luminance (Perdreau & Cavanagh, 2011). Artists, whose drawing accuracy is high, must be able to overcome lightness constancy.

What remains unclear, though, is how artists achieve that. Is it true that the years of experience changed the artist´s visual processing and their ability to access early levels of representation? Can they actually get access to the proximal pattern of light and dark on their retina? Or does their painting rather follow an iterative logic of making and matching, i.e. first producing and later correcting their own perceptual mistakes in the painting?

If it is true that training allows artists access to earlier stages of visual perception, they should be better than non-artists at a perceptual task involving an illusion that exploits lightness constancy.

Why is it interesting to find out about artist´s potential perceptual advantages? On one hand it is interesting for the whole field of Art Production itself. But on the other hand it is also interesting for Neuroscientists and Psychologists, because, in a more general term, we can learn about visual perception and whether there exists perceptual plasticity in the brain regarding visual constancies such as lightness constancy.

2.2 Goals and Research Question

Goals

In this study we are dealing with the visual perception of artists, more specifically with their ability to judge luminances. We want to find out if artists possess enhanced perceptual abilities in the field of luminance judging, which we theorize as an essential ability in the process of naturalistic painting. Can artists ignore the perceived reflectance and „see“ the actual luminance better than non-artists?

Hypotheses

Those who are able to accurately depict an object should be less susceptible to perceptual illusions (Cohen, 2005). We hypothesize that experienced artists develop superior ability to perceive natural luminances as a result of training and are therefore less susceptible to illusions that exploit lightness constancy.

2.3 Method

Participants

29 subjects participated in the test.

Artists: 14 artists participated in the test, including professionals and amateurs. 12 of them were approached in a local public artistic academy[6] in an advanced oil-painting class. The two professional artists were approached individually. One worked as a teacher for portraiture and nude painting in the same public artistic academy, the other one works as a graphic designer and painter for portraits-on-demand. Mean age of the artists was 47,5 years (Median = 46). Mean hours/ week spent painting was 17,4 (Median = 13). Mean years spent painting were 18 years (Median = 17,5).

Non-artists: 15 non-artists participated in the test; all of them were college students (seven of them from the general psychology participant pool and eight of them from other courses that were recruited through individual approaching). None of the non-artists had any formal training in the visual arts. Mean age of non-artists was 27,5 years (Median = 25,5).

All participants were given 15 Euros for taking part in the test. The seven psychology-pool students additionally received course credit for participating. All participants had normal or corrected-to-normal vision.

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[6] Künstlerische Volkshochschule, www.kvhs.at

7 participant´s data had to be excluded from analysis due to implausible results or instructional difficulties that were revealed after the testing (through comments made by the participants) so that in the end our sample consisted of 11 artists and 11 non-artists.

Materials

We used a two-alternative forced choice task that compared a lightness illusion, the Craik - O´ Brien - Cornsweet Illusion, with real luminance differences[7]. Graham & Meng (2011b) previously used this test with artists and non-artists to find out about their luminance judgmental abilities. This test provides an indirect way of assessing people´s ability to judge luminances (as opposed to matching procedures, like the one used in Perdereau and Cavanagh, 2011).

There were two stimuli that were displayed shortly after each other, first stimulus 1 appeared for 1500ms, then there was a black mask for 500ms, and then the second stimulus appeared for 1500ms. Both stimuli consisted of a pair of gray rectangles. One stimulus contained a real contrast in luminance between the two gray rectangles; the other stimulus was the Craik - O´ Brien - Cornsweet Illusion that contains no real luminance difference within the rectangles; the only luminance variation lies in the narrow edge and the ramp in the middle of the illusion producing a lightness illusion. In the middle of both rectangles in each stimulus there was a box that indicated the area for the participants to focus their gazes on (see figure 1).

The real contrast stimulus varied along the salience of luminance differences between the two flanks. There was a pool of real contrast stimulus sets with a difference in luminance, ranging from 0 to 0.4 with 0.005 steps.

For the illusory contrast stimulus, there were three different illusory contrasts levels used in the test (illusory contrast = 0.2; 0.5; 0.8)[8].

A questionnaire was filled out by each participant, containing questions about age, profession, diopters, and former experiences in the field of Visual Arts (see full questionnaire in the attachment section). Also, each subject reported the number of hours per week/ years spent painting or drawing.

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[7] Contact Daniel Graham via artstats@gmail.com for accessing the test used.

[8] Boyaci, Fang, Murray and Kersten (2007) report that the effect of the illusion gets stronger with increasing contrast.

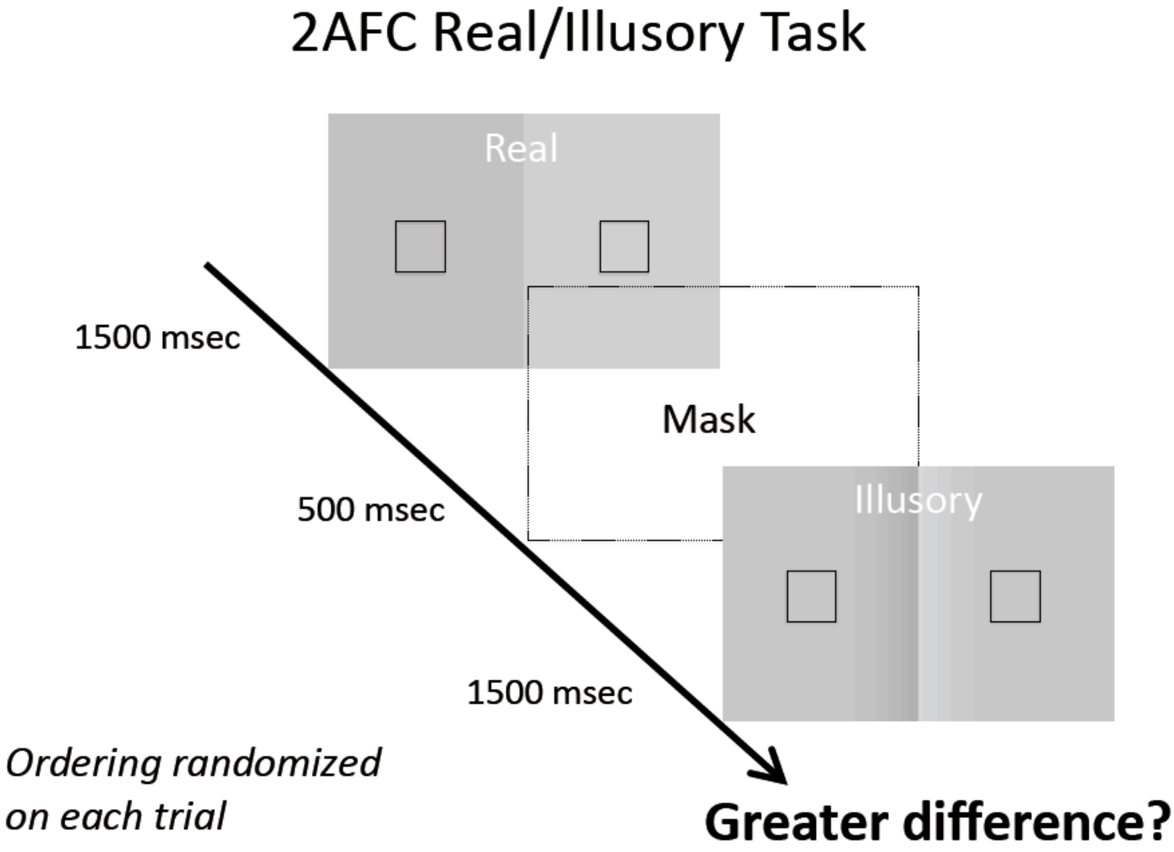

Figure 1: Formalized procedure of the 2 AFC Real / Illusory Contrast taks used. Subjects saw the real contrast for 1500 ms, then a black mask for 500 ms, then they saw the illusory contrast for 1500ms. The ordering of the stimuli was randomized in each trial. Subjects had to decide in which of the two stimuli luminance difference (between the boxes) was greater.

Procedure

The 2 AFC task was presented on a Samsung SyncMaster SA 300B, 24-inch, that was luminance calibrated. Luminance calibration of the monitor had the goal for a specific unit change of pixel values to relate linearly to a unit change of luminance values. The procedure for monitor calibration was as following: Out of 9 spots on the monitor that were uniformly distributed across the monitor surface, luminance measurements were taken with a photometer. 6 different pixel values were displayed one after each other on the monitor (0, 50, 100, 150, 200, 255). Measurements of these displayed pixel values were taken at the 9 different spots and compared with the pixel value. A nonlinear relationship between the pixel values and the actual displayed luminance values resulted. Luminance calibration of the monitor consisted in correction for this relationship so that a linear function resulted.

Screen resolution was 1920 x 1080 pixels. Subjects used a chin rest that was placed 71 centimeters before the monitor. Gaze focus was held constant by the chin rest at a distance of 10,5 cm from the upper edge of the monitor. The laboratory room was darkened with the exception of a small LED light source, approximately 3 meters behind the participant, illuminating the back wall dimly in a distance of 13 centimeters.

Subjects were instructed verbally about the procedure of the test with the following words: “You will now see two different stimuli that arise for a short time, one after the other. Please compare the luminances between the left and the right rectangle of each stimulus by looking at the marked boxes. Make this comparison for the first stimulus as well as for the second one. Then, try making a decision whether in the first stimulus or in the second stimulus the luminance difference between the boxes was greater. If you believe the luminance difference was greater in the first one, press the left arrow key, if you believe it was in the second one, press the right arrow key”. Participants were allowed to do a few test items and ask if they had any questions. After that, the test began.

In the beginning of the test there was a written instruction: *“Unterscheiden Sie ob beim ersten oder beim zweiten Bild der Helligkeitsunterschied zwischen den Kästchen größer ist. Drücken Sie die Leertaste zum Beginnen”.*
After both stimuli had arisen, there came a white text on a black surface, telling the subjects to make their decision*: “Unterschied beim ersten Bild größer – LINKE Pfeiltaste drücken; Unterschied beim zweiten Bild größer – RECHTE Pfeiltaste drücken”.* Subjects had to press the left arrow for indicating a higher luminance contrast in the first stimulus and the right arrow for designating it to the second stimulus. Once the subject had made a decision and pressed an arrow key, the next stimulus was displayed.

The ordering of the real contrast stimulus and the illusory contrast stimulus was randomized within each trial.

The real contrast stimulus was varied using a PEST Staircase Adaptive procedure (Findlay, 1978; Taylor & Creelman, 1967; Taylor, Forbes, & Creelman, 1983). The idea of such a procedure is that some portion of the response history determines the stimulus placement for each trial. The real contrast moved up and down the stimulus range in step sizes of 0,005 within a 0-0,4 range. In order to determine the optimum stimulus placement on each trial, maximum likelihood procedures fit a series of parametric models of the psychometric function to the data collected on all previous trials (Meese, 1995).

There were three different illusory contrasts levels used in the test (illusory contrast = 0.2; 0.5; 0.8). Each illusory contrast condition comprised 50 trials. The ordering of each illusory contrast condition was randomized on each subject, so that it was random whether a subject would start with illusory contrast 0.2, 0.5 or 0.8, and after the 50 trials of that condition, it was again random which of the remaining two illusory contrast conditions came next.

A psychometric function fit and the subject´s Point of Subjective Equality (PSE) were calculated at the end of each subject´s responses. The PSE indicated the point for each participant, where the decision for stimulus 1 (real contrast) and stimulus 2 (illusory contrast) is equally likely: it marks at what ratio of the real contrast it gets too hard for a participant to see the luminance differences in the boxes and therefore make a proper decision between the two stimulus conditions. It is a measurement for luminance judgment between 0 and 1, where 0 indicates the (improbable) case of perfect luminance judgment, and 1 indicates total chance level between the two different stimuli (see figure 2 for a visualization of one subject´s response pattern, which serves to obtain the PSE).

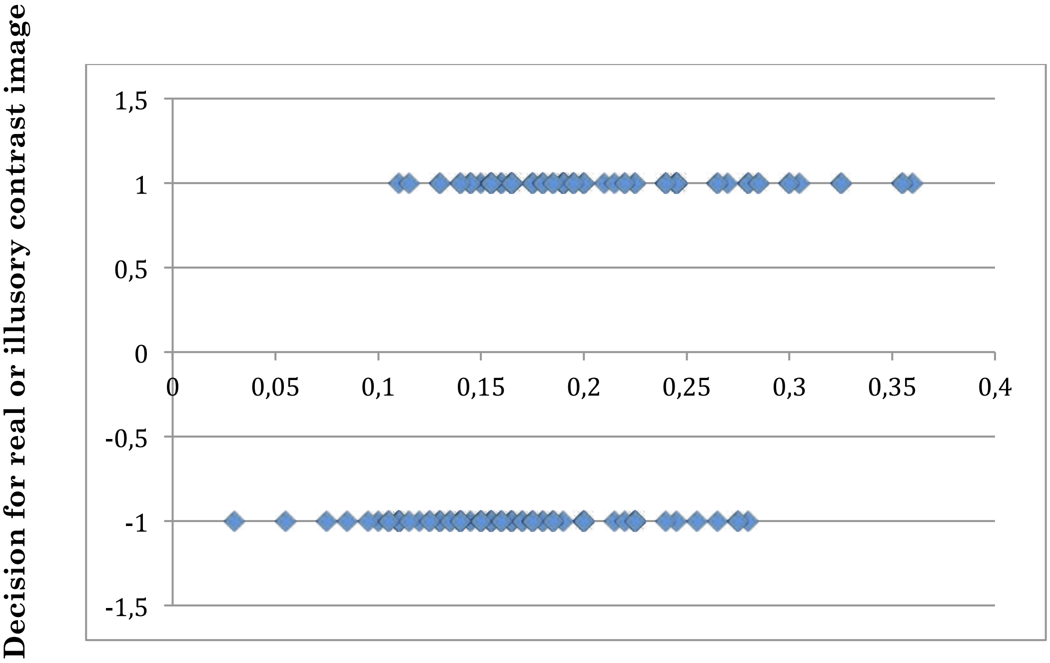

Figure 2: Graphic of one participant´s response pattern which serves as a base to calculate the psychometric function fit. The pool of real contrast images ranged from 0 to 0.4 with 0.005 steps. Participants could always decide whether the real contrast image had higher contrast (which was always the right answer, but was distorted by the illusionary contrast images) or the illusionary contrast image. -1 means a decision for the illusory contrast level, 1 means a decision for the real contrast level. A sigmiodal function can be calculated of these data, indicating the point of subjective equality for a participant.

There was no time limit, experiment duration very much depended on the participant´s speed at making the decision when pressing the arrow keys; for the whole test it was not less than 15 minutes.

2.4 Results

Luminance judgment in artists and non-artists

Performance in luminance judgment for the two groups was assessed comparing subject´s PSEs, obtained as described above, for the three different illusory contrast levels. There were no significant differences in performance between artists and non-artists in any of the illusory contrast conditions: „0.2“ (t-test, P....), „0.5“ (t-test, P....),. or „0.8“ (t-test, P....), or when PSEs were averaged across the illusory contrast conditions (see figure 3).

Illusory Contrast Level	Group	PSE Mean	t-test	SD
0.2	artists	M= 0,1781	-1,271	0,1101187
	control	M= 0,1325	-1,271	0,0449558
0.5	artists	M= 0,2230	0,788	0,1381479
	control	M= 0,3024	0,788	0,3037613
0.8	artists	M= 0,1749	- 0,185	0,0891989
	control	M= 0,1749	- 0,185	0,1364419

Averaged across the three illusory contrast levels	artists	M= 0,1950	0,195	0,0680502
	control	M= 0,2033	0,195	0,1229828

Figure 3: Summary of performance in luminance judgments (as indicated by the PSE) for artists (N=11) and control-group (N=11).

Painting Expertise and Luminance Judgment

We analyzed the correlation between expertise (as measured via „hours per week painting“ and „years spent painting“) and luminance judgmental abilities (as measured via subject´s PSEs for the different illusory contrast levels, obtained as described above) calculating Pearson´s r. There was no significant correlation between luminance judgment and expertise in painting; more specifically, none of subject´s PSE of any of the three illusory contrast levels was correlated with the amount of years spent painting. None of the subject´s PSEs at any of the three illusory contrast levels was significantly correlated to the hours per week painting. Neither was there any significant correlation when the PSEs of the illusory contrast level were averaged. See figure 4 for details. Figure 5 shows the correlation between participant´s averaged PSEs across the three different illusory contrast levels and the hours/ week spent painting. Figure 6 shows the correlation between participant´s averaged PSEs across the three different illusory contrast levels and the years spent painting.

Illusory Contrast Level	**PSE and Hours per week painting**	**PSE and Years spent painting**
0.2	r = - 0,005 p = 0,492	r = 0,081 p = 0,360
0.5	r = -0,088 p = 0,348	r = -0,128 p = 0,285
0.8	r = 0,094	r = 0,008

	p = 0,339	p = 0,486
Averaged across contrast levels	r = -0,036 p = 0,437	r = -0,076 p = 0,368

Figure 4: Pearson correlations between subject´s (N=22) painting expertise (hours per weeks painting; years spent painting) and their luminance judgmental abilities, as measured with the PSE (among different illusory contrast levels). Significance level was set at $p < 0.05$.

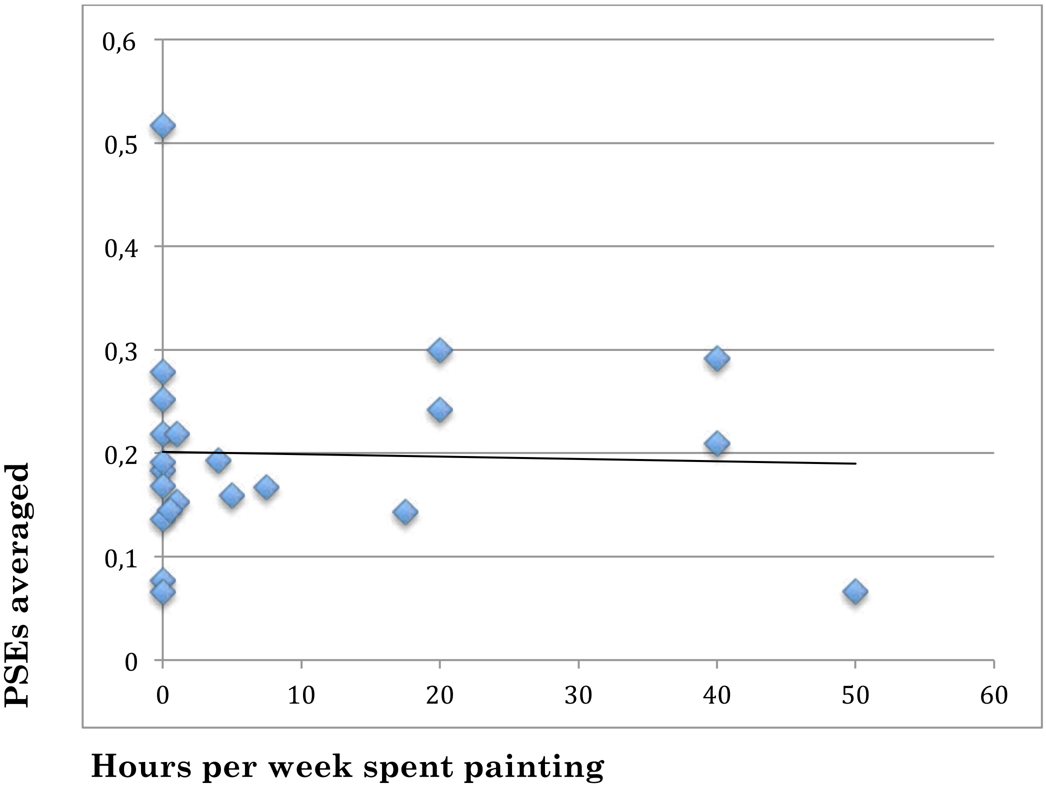

Figure 5: correlation between participant´s averaged PSEs across the three different illusory contrast levels and the hours/ week spent painting (N= 22).

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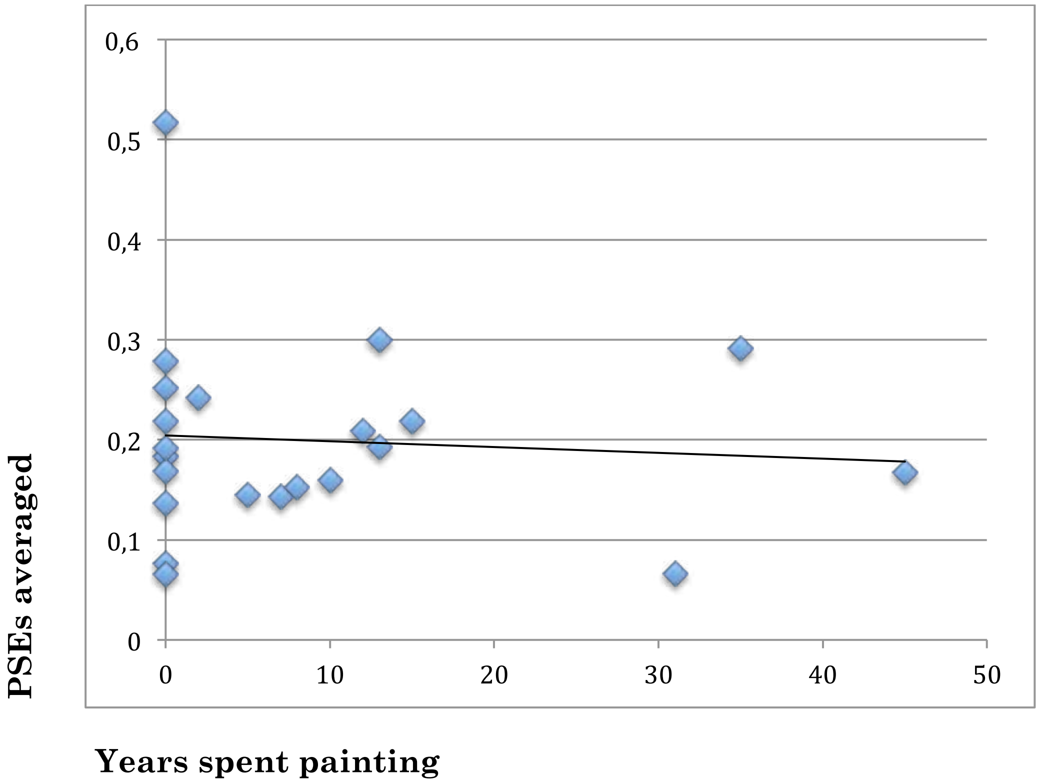

Figure 6: correlation between participant´s averaged PSEs across the three different illusory contrast levels and the years spent painting.

2.5 Discussion

When we perceive the world, visual constancies like shape, size and lightness constancy help us recognizing an object for what it is. Particular details on our retina are not so important for object recognition in our every day perception, but their interpretation by the visual system is; anyhow, they should be important for visual artists dealing with naturalistic painting. Our question was if Artists have a superior ability to perceive natural luminances. Indeed we find evidence for better perceptual abilities in artists (Cohen & Benett, 1997; Kozbelt, 2001; Cohen, 2005; Mitchell et al., 2005; Kozbelt & Seeley, 2007; Cohen & Jones, 2008; Matthews& Adams, 2008; Graham & Meng, 2011b). We expected if artists are truly better at perceiving objects more accurately, they should be less susceptible to an illusion that exploits lightness constancy (in our case the Craik-O´ Brien-Cornsweet Illusion). If they had better luminance judgment, their PSE (in any of the illusory contrast conditions of the test used) should be lower than the PSE of non-artists. In our sample, we did not found any difference between artists and non-artists in their luminance judgment as obtained by a 2AFC task taking advantage of lightness illusions.

We also suspected that artist´s luminance judgmental abilities would get better the more expertise they achieved. It is plausible to think that extensive training of artists changes the functional structure of the visual system so that artists get better access to early visual processing. In our study, training was operationalized by the hours somebody spends painting per week and, as a second variable, the years involved in painting. Indeed Graham and Meng (2011b) found evidence for a relationship between expertise and artists´ ability to estimate luminances, using the same test we did in this study. Anyhow the sample they used was quite small (artists = 5, non-artists = 9). If abilities in luminance judgment rest to a certain degree upon training, there should be a negative correlation between a person´s artistic expertise and their PSE obtained by the test we used.
In our sample, we found no significant evidence that a gain in time spent with painting would relate to better luminance judgment.

Baddeley, Attewell and Patel (2010) challenge the notion that Human beings have good lightness constancy at all. In an abstract of their study they argue that lightness constancy, when measured in a real world situation is rather bad. Good Human lightness constancy performance might be an artifact of typical experimental conditions. Even if Humans are not actually good at natural lightness judgments, we may still believe that artists could be at least a little better than visually untrained people. In fact we did not find this in our data.

Artists were not better at judging luminances in the test, nor did their luminance judgment as measured by the test depend on their expertise. Taken together, these results do not support the notion that naturalistic painters have enhanced luminance judgmental abilities. These results argue against a notion that artistic accuracy is related to perceptual accuracy.
It is possible that we found some significant differences between artists and non-artists if we had more than the 11 artists and 11 non-artists that participated in our test.

Other confounders would have to be excluded in a follow-up study. For example, we asked participants if they could think of anything that might have trained their visual perception (when people asked for examples, we told them “a certain kind of artistic training; high interest in visual Art; a particular kind of sport that involves high visual precision”). Anyhow, we did not explicitly check for previous knowledge concerning optical illusions. People familiar with such illusions may have an advantage in the task we used. Both artists as, particularly, psychology students may have a specialized knowledge about optical illusions. Participants made no comments that alluded to a recognition of the optical illusions we used in the experiment, but it cannot be ruled out as a further influencing factor.

Another confounder may be difference in computer literacy between the artist´s sample and the student´s control sample. Artists were on average much older than the control group. Whereas for my generation it is obvious to deal with computers, for people around 60-70 (some of the artists´ age) it might be a challenge to be in a situation where they have to deal with a computer, using a keyboard. Due to comments made during the testing (for example, one person did not know where the space key was), we have reason to believe that for at least a few of the artists, computer literacy cannot be taken for granted. Their subjective lower capacity to handle computers may have influenced their attentional resources during the test and influenced the results. Also the educational level and subject´s familiarity dealing with complex instructions may have had an influence on the results. On average, the artist´s sample´s educational level was lower than the student´s educational level. Two artist´s data had to be excluded because they made comments after the test that revealed that they had not gotten the instruction right. There might be some “hidden” cases within the data-pool where the same problem occurred. It might be a good idea to hold educational level constant between samples to avoid that a complex instruction, like ours, creates potential result bias. For future research, parallelization of the samples in terms of age and educational level may contribute to less confounded data. It might be worth recruiting an artist´s sample at a Fine Arts University, where a younger and highly educated sample can be recruited.

On the other hand, it remains unclear how reliable the 2AFC test we used is determining luminance judgment. Looking at the individual functions of subject´s PSEs, we found rather expanse patterns of decision for either the illusory contrast or the real contrast stimuli. It is hard to extract a reliable psychometric function fit when data are noisy.

An alternative could be using a simpler test, like the one Perdereau and Cavanagh (2011) used in their lightness constancy experiment, where participants actively adjust luminances of a test ellipse to the actual luminance of a standard ellipse. It might produce more reliable data than inferring somebody´s luminance judgment indirectly from a comparison task as we used it.

Following Gombrich´s (2002) model of schemata, artists begin with a rough matching to the scene they are painting, and afterwards continue comparing and correcting their depiction to what they see. In this view it is dispensable for them to have access to the retinal image. They may be as affected as other people by lightness constancy, just like our results suggest, but the are able to compare the context of their image and the context of what they see and thereby correct their mistakes. As long as there is no direct evidence for artists to have better absolute luminance judgment, we are inclined to believe that Gombrich is right, when he assumes a copyist approach in painting.

3.1 Paintings and Luminance Compression

Introduction: Art as a field to learn about visual processing

Graham & Meng (2011a) argue that artists have the ability to create representations of the real world that are highly efficient for transmitting perceptual information to the human brain. They looked at artists´ representations of objects and found that they are efficient at transmitting diagnostic information about the object depicted, in their study´s case, faces. They manipulated Art images in various ways, altering intensity distributions and spatial contrast in artworks, displaying faces. In spite of these modifications, informative features of faces could still be recognized. Graham and Meng (2011a) conclude that artist´s representational strategies when they paint are efficient at capturing such salient features. Graham and Meng (2011a) attribute this efficiency partly to artist´s freedom at local contrast scaling. Local contrast scaling is one of the advantages of painting because it allows locally increasing and decreasing contrast and therefore helps to emphasize certain features so that they might be more efficient for human visual processing. If it is true that Art is efficient at transmitting visual information, then artwork is an interesting field to learn about visual processing. We will learn about the interconnections of Art and natural scenes and visual processing in the next chapter (Art is made for the Human Eye). This will give us the soil for introducing a model that demonstrates how artists operate with a particular kind of visual information: patterns of dark and light, or, dynamic range of intensity.

The focus of the present work is such: we will stick with the topic of luminance treatment in painted Art. In Nature, there are high dynamic range intensities that cannot be directly transferred to the canvas. One of the (perceptual) difficulties in the transfer is lightness constancy, which has been discussed in the previous section. Another difficulty consists in technical restrictions and limitations that lie in the material, which forces artists to restrict themselves in their rendering of luminances; they have to apply compressing. We base our survey on the assumption that in spite of technical and perceptual challenges, artists are efficient at compressing luminances.

We propose a model that seeks to be capable of visually displaying an individual artist´s use of luminance compression. But let us first go deeper into the field of artworks and in what way they are efficient at transmitting visual information.

Art is made for the Human Eye

Classical visual stimuli like depth illusions, sine-wave gratings are artificial in the sense that they are created for their perceptual effect but often lack the properties of the natural environment, e.g. like nonlinear structure (Field 1987; 1994).

Recent research has demonstrated that the structure of natural scenes affects visual coding strategies in vertebrates and invertebrates (Redies & Graham, 2010). Through evolution the visual system adapted to its natural surroundings so that efficient processing could be ensured. Gibson (1966) makes a similar point when he says that one cannot look at visual perception without looking at the function of the perceptual apparatus. One must understand what we need to perceive in our natural surroundings in order to be able to act, before one can understand the underlying perceptional processes. Thus, one must understand the nature of the environment before one can understand visual processing (Gibson, 1966). It seems crucial to see the visual system from a perspective that emphasizes its evolutionary development within natural surrounding. This is where Art comes into play.

Art is a product of mankind and is particularly made for the Human Visual System - with all of its efficient coding strategies that have evolved from adapting to Nature. So Art should exhibit some of the regularities also natural scenes possesses because it is produced for the Human eye and the Human Visual system that works efficiently when facing certain statistical regularities (Graham & Field, 2007). This has also been shown (Graham & Field, 2007). It seems that when Humans produce Art they do not extend their Art production to all possible visual manifestations, even when doing abstract Art, but prefer to stay within a statistical range that their visual system is adapted to (Graham & Field, 2007). This is a point, which is interesting on its own, but in this context it suffices to argue here that Art can be useful when hoping to get insights into the structure of the visual system.

Art can be a bridge in visual perception research as it closes a gap: it is created for the Human eye and is a more realistic set of stimuli: Unlike classical artificial stimuli it shares some characteristics with natural scenes (Graham & Meng, 2011).

Natural scenes and Art: regularities and differences

So what is the nature of the shared characteristics in Art and natural scenes?
On one hand, it is undoubted that Art and Natural scenes are often perceived as esthetically pleasing (Redies, 2007 for a review). Then again, it has been shown that both types of visual stimuli share a number of statistical features (see Graham & Redies, 2010 for a review). This can be explained by the fact that the visual system, which has evolved along a natural scenes environment, takes advantage of existing redundant statistical properties (Field, 1987). We have already said that visual artwork is a medium that is specifically made for the human eye and thereby will embody some sort of visual information that the early visual processing strategies in the human brain are adapted to (Graham & Field, 2007). It has been shown that some of the natural scene´s typical statistical properties are also present in artwork. Surprisingly this is the case not only for representational, but also for abstract Art (Graham & Field, 2007), which stresses the fact that humans replicate the statistical properties that their visual system is adapted to when producing visual Art. Redies, Hasenstein and Denzler (2007) speculate that both “graphic Art and natural scenes share statistical properties because visual Art is adapted to the structure of the visual system, which, in turn, is adapted to process optimally the image statistics of natural scenes”. Image statistics that are shared by natural scenes and Art comprise spatial structures such as the amplitude spectra and the fractal dimension, whereas we can find some differences in the sparseness and luminance distribution.

Spatial Structure

The Fourier spatial frequency power (or amplitude) spectra, when applied to visual Art or other images, indicate the relative contribution of certain spatial frequencies to the image as a whole. Graham and Field (2007, 2008a) compared a number of randomly selected artworks from a major university museum with natural scenes from van Hateren´s Database. They found that the amplitude spectra of painted Art are similar to those of natural scenes: Art has a 1/f shaped amplitude spectrum just like natural scenes - but the mean fall-off of the amplitude spectrum for the artworks was significantly less than that of the natural scenes (measured as slope of the spectrum plotted on log-log axes; for natural scenes, the slope was -1.4, for Art it was -1.2; see Graham 2009, p.2). It remains unclear why the fall-off was different, but might be due to sampeling bias (Eastern Hemisphere works were overrepresented in the sample). Redies et al. (2007) did not find any significant difference between the mean amplitude spectrum slopes for Western Graphic Art (drawing, engraving) and natural scenes.

The 1/f shaped function of Art and natural scenes implies another common regularity, which can be described as the fractal dimension (Graham&Field, 2007; Redies et al., 2007). Visual Art and natural scenes share fractal-like, scale-invariant statistical properties. That means that when one zooms in and out of the images within a range of scales, there is little change in the statistical properties of the Fourier spectral components (Graham&Redies,2010). Fractal images have been shown to be preferred by humans, no matter if natural, man-made or computer-generated (Hagerhall, Purcell & Taylor, 2004; Spehar, Clifford, Newell & Taylor,2003). Different styles of visual Art and artworks throughout different cultures revealed the universal property of this kind of scale-invariance (Redies et al. 2007).

Luminance statistics

Whereas spatial structure is similar for Art and natural images, paintings cannot reproduce the dynamic range of intensities in natural scenes. Luminance statistics in Art distinguish in essential ways from those of natural scenes due to the optical properties and illumination of paintings. The possible range for luminances in artworks is much smaller than in the natural world (Graham & Field, 2007, 2008a). As a consequence, artworks show a much smaller dynamic range of luminances than natural scenes. This is because in natural scenes, luminances depend on luminous sources like the sun, sky and reflectances from other surfaces in the environment (Dror, Willsky & Adelson, 2004). Scenes with specular reflections, containing reflected images of the sun have the greatest ranges (McCann, 2012). There is usually no glossiness or 3-D-structure in a painting and typically paintings are shown inside a museum with one diffuse light source illuminating that picture: that is why in images that hold this assumption it is valid to believe that the luminances are a function of their reflectances only (Graham & Field, 2007). Jones and Condit (1949) suggest an average intensity range for natural scenes of about 760:1, a number that has been cited often in the literature (Graham&Field,2007). For images there is rarely an intensity ratio greater than 30:1, because reflectances in an image are hardly ever less than 3% or larger than 90% (Gilchrist, 1979).

Additionally, natural scenes on average have high skew, whereas Art images usually have no skewness, i.e. they have an almost Gaussian luminance distribution. This affects the intensity distribution´s kurtosis, a measure of sparseness, which is higher for natural scenes than for Art images (Graham & Field, 2007). In spite of these obvious differences, when the luminance range of natural scenes has been compressed to match that of Art, then Art again shows sparse structure, which approximates that of Art (Graham & Field, 2007).

Many of the deviations in the luminance distribution in Art are a direct outcome of artist´s efficient, non-linear luminance compression strategies when they model a real-world scene on a medium that is restricted in its intensity representation (Graham & Field, 2008b; Graham, Friedenberg & Rockmore, 2009). Following Graham and Meng (2011a), I assume that these transforms that artists create when they represent the real world, are highly efficient for transmitting perceptual information to the human brain.

Taken together, Art and Natural scenes have a lot in common, due to the fact that the visual system developed in order to efficiently decode its natural surrounding, and Art is made for this very visual system. Due to physical limitations of their tools (paper and colors), though, artists have to compress luminances when they transfer the impression of a natural scene to the paper. It is assumed that this transfer is highly efficient for transmitting perceptual information to the brain. Let us now have a closer look to the "luminance problem".

The Luminance Problem

Whenever I speak of the "luminance problem" I talk about a process where transmitting high dynamic range intensities to a smaller dynamic range is necessary. Neural coding of intensities faces such a problem and artists when they paint, face a similar problem.

Luminance compression in the human brain

The ability of human beings to perceive details of objects and scenes is determined to a large degree by its capacity to differentiate contrasts, i.e. luminance differences between neighboring spatial areas (Campbell & Maffei, 1986). In natural surroundings contrasts between neighboring areas –and more generally, the dynamic range of luminances- can be quite high. What are the strategies of the visual system to deal with the range of naturally occurring contrasts?

McCann (2005) argues that the visual system can process a span a 10^{10}:1 of luminance range. The dynamic range of rod and cone sensors is over 10 billion: 1. This corresponds to „the range of radiances from snow on a mountaintop to the half-dozen photons needed for a dark-adopted observer to say he saw the light“ (McCann, 2005, p.20). It is interesting that the dynamic range of rod and cone sensors is 10^8 times greater than the dynamic range of the ganglion cells, which fire only at rate of about 100:1. So already on the retinal level some sort of luminance compression is taking place.

In most visual systems cone photoreceptors in vertebrates show roughly log-like transforms, which indicates that transmitting high dynamic range intensities to a smaller dynamic range is typically is solved through nonlinear compression on a neural level (Graham & Field, 2008b).

What processes are involved in nonlinear luminance compression on the retinal level?

Tollhurst (1989) suggests that response averaging, either in time or across neurons, may enhance the efficiency of the cortical code.

It might as well be that different groups of cells react to different ranges of contrasts, as Albrecht and Hamilton (1982) propose when they show that cortical cells differ in the positioning of their dynamic range.

Another process that has been proposed for overcoming a limited dynamic range is the case of contrast gain control (Ohzawa et al, 1985) or contrast normalization (Bonds, 1989, 1991).

That means that the visual system operates with a gain control mechanism in the cortical coding of contrast. The response of each cell is normalized by the integrated activity of neighboring cells.

There is evidence that simple cells have a contrast below or above they do not respond and they use response compression and saturation at high contrasts (Albrecht & Hamilton, 1982). Additionally the excitatory response of a simple cell to its aligned stimulus may be contained or inhibited by the presence of a second stimulus, which helps to normalize a cell´s response within a given neighborhood regarding the stimulus contrast (Bonds, 1991).

Recently, cortical cell responses are modeled by an initial linear stage and a following normalization stage. In the initial stage the response of a cortical simple cell depends on a linear sum of local image intensity, whereas in the normalization stage the cell´s response is divided by the averaged activity of a number of neighboring cells (Carandini and Heeger, 1991). Brady and Field (2000) compared the distribution of response activity using oriented, frequency-tuned filters when analyzing natural scenes. They looked at the distribution of response activity before and after implementing contrast normalization. They were able to show that contrast normalization reduces the variability in the modeled neural response to local image contrast. They suggest that the information-carrying capacity of neural coding is raised by contrast normalization. It has been shown that the contrast normalization model of vertebrate cone receptors is efficient also because it turns intensity differences into ratios (Field, 1994).

Luminance compression in paintings

Not only our visual system, also artists face a luminance problem. According to Jones and Condit (1949) an average intensity range for natural scenes is about 760:1, whereas paintings cannot display a higher range than 30:1, mostly less (Graham & Field, 2007).

If we look at Art History, we see that chiaroscuro first introduced high-dynamic-range-scenes in low-dynamic-range media (McCann, 2008). Chiaroscuro was an answer to the representational problem that limitations of paint and canvas make it impossible to truthfully depict the world in an image. Any representational painter has to find his or her own solution for the luminance problem when painting a scene.

How is it that paintings can still transmit visual information about a scene efficiently, despite the restrictions present? One advantage of painting is definitely the fact that contrast in local regions can be modified easily – more easily even than in analogue or digital photography, where burning and dodging tools can be applied, but are difficult to operate on objects with fractal edges. Fractal edges are very common features in natural images (Redies, Hasenstein & Denzler, 2007; Graham & Meng, 2011a). Modification of contours can be applied selectively across the image and on any relevant object contour. Graham and Meng (2011a) point out that „paintings can perhaps be seen as a natural scene that has in a sense been „optimized“ for the *human* visual system but which yet retains statistical regularities to which *mammalian* visual coding is efficiently adapted“. Of course this is an insufficient generalization, but shared strategies in many different paintings to deal the luminance problem deserve our attention.

According to Graham (2009) „the chief technology that permits imaging is compression” - i.e. the mapping of the intensities of the natural world to the limited sensitivity range available in photographic film or sensors. Obviously this is also true for mapping intensities of the natural world to the limited displayable intensity range on canvas.

Any artist, who wants to paint in a realistic way, might pose him- or herself the question: What is the most perceptually lifelike transformation of luminances under the assumption that the luminance range must be significantly reduced? It might seem obvious to transform linearly. However, if an image has a high positive skew (like natural scenes often have, due to a zone of very high luminances, like the sky), a simple linear compression winds up in a very dark image with few bright regions, which is not an appealing image (Graham& Field, 2007, see Fig. 7).

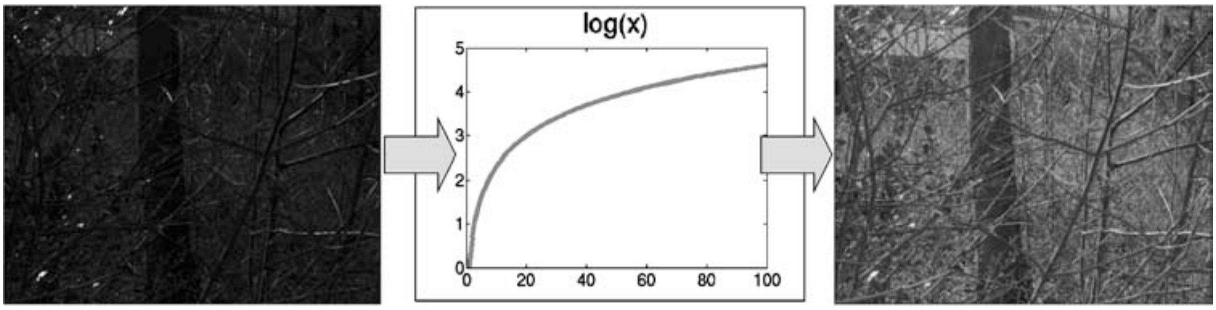

Figure 7: A natural scene from van Hateren’s collection (image no. 619, van Hateren and van der Schaaf, 1998) displayed with linear scaling in luminance (left) and after application of a log(x) luminance nonlinearity. Note that the latter image appears less dominated by very dark and very bright regions.

Considering the non-Gaussian-shape of an average natural scene intensity distribution and the almost Gaussian shape of intensity distribution present in Art – any effective transform must be a kind of compressive non-linear scaling (Graham & Field, 2007), which is the same solution that neural coding takes to compress luminances (Graham & Field, 2008b).

So any artist dealing with the depiction of a natural scene must perform some sort of luminance compression. Non-linear scaling follows to be a useful way for approximating the way in which artists solve the luminance problem under the premise to create an efficient (and, esthetic) representation.

The Artist-lookup-table as a map for luminance compression in paintings

As natural scenes tend to have highly skewed, high - dynamic range scene luminances, whereas Paintings have more Gaussian-distributed, low dynamic range luminances, artists must compress intensities they perceive when they paint a natural scene. As we argue above, this compression process or transform requires non-linear scaling in order to produce an aesthetically appealing image. If both, the natural scene from which a painting originates and the painting (more specifically, their luminance distributions) is available, the nonlinear function underlying this process can be calculated. This function, converting the scene luminance histogram into the painting luminance histogram, can be seen as a look-up table and is called the “artist´s look-up table” or ALUT for paintings (Graham, 2009). It is obtained by the technique of histogram matching and models the effect of luminance compression in a raw estimation, but will never be a full model of the drawing process (see limitations at the bottom).

Practically, to calculate an ALUT one needs to map luminances from the scene that inspires the painting onto the intensity distribution of the resulting painting (see Graham & Field, 2008b for details of the mathematical process underlying the histogram matching procedure).

Since it requires a suitable scene to map the original tableau it is more difficult to calculate the ALUT for older works in Art History. It worked out for one painting of Van Gogh from his Arles period (1888-1889), though. Graham, Friedenberg and Rockmore (2009) were able to find a representative scene for one of Van Gogh´s works (“Harvest Landscape”, 1888) and calculate the ALUT for this painting. In another study (Graham & Field, 2008b) the ALUT was calculated for a painting of a contemporary artist (Neil Berger), where it was possible to find the original scene.

Limitations of the ALUT

Graham and Field (2008b) point out the inherent limitations of the histogram matching-method, which is the technical base of the Artist´s look-up-table. Histogram matching is necessarily imperfect (Gonzalez, Woods & Eddins, 2004) because it does not allow choosing a fraction of pixels at a given intensity to transform while leaving the rest at that intensity unchanged. But this is exactly what artists might be doing a lot. They can freely choose a part of the scene where they locally change the contrast. Other parts of the scene that have the same intensity as the fraction they chose, they might decide to depict in another luminance value. It is an artist´s particular freedom to choose certain elements in the scene that she or he wants to emphasize by locally changing contrast, since it might not be the goal of every representational artists to create a mainly photorealistic reproduction of the scene.

The ALUT does not allow reconstructing these fine artistic decisions. It neglects local contrast adjustments and is therefore only a global approximation to an artist´s treatment of luminances.

Also there remain technical limitations with respect to very high dynamic range scenes, like landscapes, containing large amounts of sky (Graham & Field, 2008b). So calculating an artist´s look-up table is presently most profitable for scenes with dynamic ranges that are significantly smaller than that for typical landscapes (but which are still much larger than the range available in paint).

3.2 Goals and Research Questions

Art is a category of stimuli that is designed for the human eye, which makes it a good field to learn about visual processing. It is believed that our visual system developed along natural regularities and we find that those regularities are reproduced in Art to a certain degree. There seems to be some efficiency transmitting visual information in Art, that´s why it is worthy looking at paintings in order to investigate about an individual artist´s way of solving the luminance problem. We have heard that all representational artists face a luminance problem, i.e. they have to compress luminances from the natural scene range to a much smaller range available on the paint medium. We hypothesize that if artworks are efficient with respect to early visual system processing, artists will often employ highly efficient tone mapping strategies. The artist´s look-up table (ALUT) can be used to describe how artists compress the high-dynamic range of luminance present in natural scenes into the far smaller range available on paper. We will be looking at different tone mapping strategies as an approach to how artists solve the luminance problem. Our questions are:

How do different artists transform natural luminances from the same natural scene into a recognizable picture, regarding the limitations inflicted by the materials they use?
How can different artistic approaches to solve the luminance problem be visualized?
Are there any observable similarities in the artist´s look-up table when comparing different techniques?

3.3 Method

Participants

10 artists participated in the experiment. 8 of them were artists from the public artistic academy[9] and were recruited from an advanced oil-painting class. One of the participants worked as a teacher for portraiture and nude painting in the same public artistic academy. Another artist was personally known to the author. Mean age of artists was 48,1 years (Median = 46 years). Only subjects with at least one year of extensive training in naturalistic painting were recruited. The mean of years spent painting was 15,8 years (median = 11,5). The mean of hours-per-week spent painting was 16,2 (median = 16,25). All subjects received 100 EUR for participating in the experiment.

Materials

A luminance-calibrated camera (EOS 5d Mark II) was used to take pictures of the selected natural scene during the drawing process. The same camera was used to create reproductions of the paintings the10 artists produced. The EOS 5d Mark II camera is described as following: It was equipped with a Canon EF 50 mm, f / 1.4 /

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[9] Künstlerische Volkshochschule, www.kvhs.at

USM lens. The 5d Mark II´s sensor provides a raw resolution of 5.616 x 3.744 pixels. The camera documentation indicates that the 5d Mark II has native 14-bit-per-pixel intensity resolution and that the RAW compressed image format supports this resolution.

Camera calibration

For performing the histogram matching procedure, which is the technical base for the artist´s look-up table, the distribution of intensities for the scene and the paintings are needed. Photographing both, the natural scene and the painting provides their intensity distribution histograms. It is crucial for the further calculation of the ALUT, though, that we can base our calculation on the assumption that the histogram establishes a linear function between the pixel values from the camera and the actual luminance values in the scene. It must be assured that a change in 1 pixel value corresponds to a change of 1 candela/m^2. The relationship between the RAW pixel values, as recorded by the camera sensor, and the scene luminance values, as measured by a photometer, need to be calibrated for this purpose. For camera calibration procedure we followed Tkačik et al.´s (2011) suggestions and modified them slightly.

Intensity-Response Function

First we checked if the Canon 5d Mark II´ s sensor response is related to a range of luminances in a linear way. To measure the 5d Mark II's intensity-response function, a Gretag McBeth Color Checker´s chart was placed 179 cm in front of the camera in a uniformly luminated room (only indirect light on a cloudy day came through one pair of windows that was exactly opposite the wall where the Color Checker was placed). Only the six different gray scale patches of the chart with their standardized reflectances (ranging from black to white) were photographed, since for calculating the ALUT we are not interested in color but in luminances. We measured the sensor´s response to the luminances of the six gray scales patches. We did this in order to check if the sensor´s response was linearly related to six different luminances. If this was the case we should see a linear function between the patch luminances and the pixel values recorded for the different patches. Camera settings were as following: shutter speed was 1/60 s, ISO was set on 100 and aperture was 2.

Response values from the sensor for each of the 6 gray scale patches were obtained by extracting and averaging RGB values from a 64 x 64 pixel region in the corresponding image section. We found that the relationship between the actual luminances of the six gray scale patches and the pixel values of the corresponding patches was nonlinear – a fact that further on has to be corrected for. Figure 10 shows the distribution of Luminance and Camera Response for f = 2, ISO = 100, shutter speed = 1/60 s.

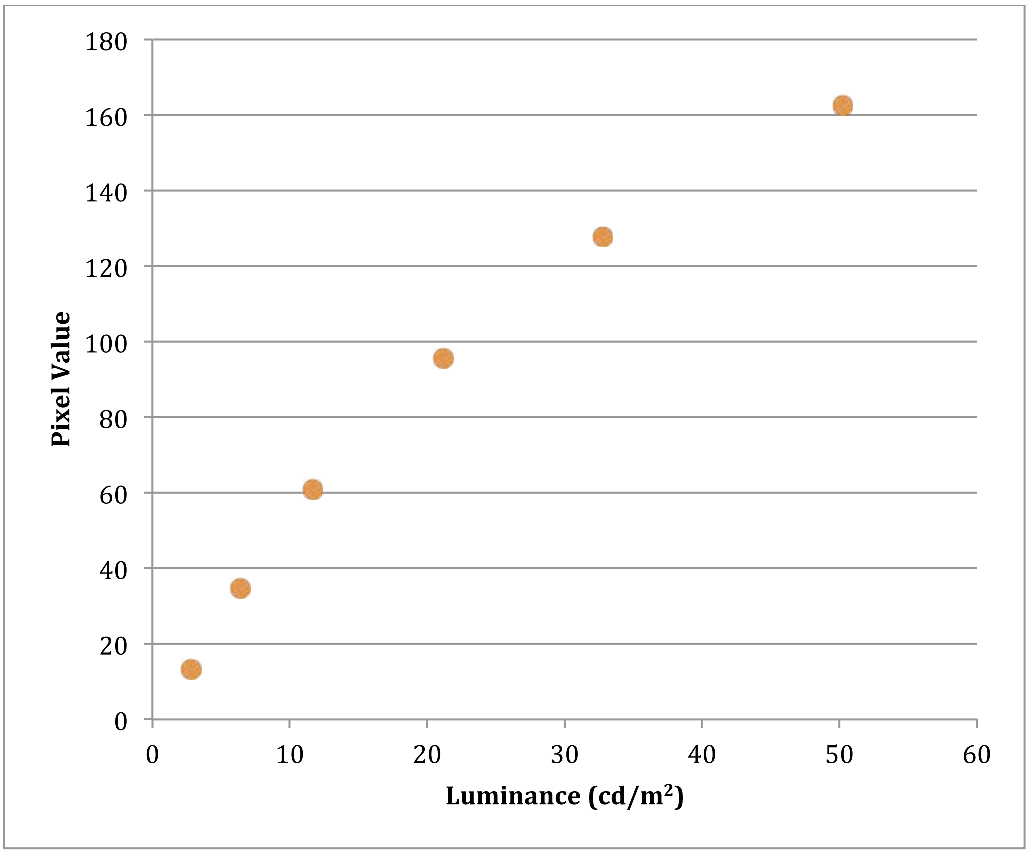


Figure 8: Sensor response (pixel values) are plotted against the actual luminances (cd/ m²) for 6 gray scale patches of the Gretag McBeth Color checker. Settings were f= 2, shutter speed =1/60s, ISO = 100. One can see that there is a non-linear relationship between the pixel values the camera records and the actual luminances; a fact that has to be corrected for.

To get a linear relationship between pixel values of the sensor and luminance values of the scene we had to correct with **f (x) = a*x^b** with the following coefficients (95% confidence bounds in parenthesis):

a = 10.29 (5.531, 15.05)
b = 0.7121 (0.5819, 0.8422)

Response linearity

Next we checked if the Canon 5d Mark II´ s sensor response is linear across a range of incident light intensities, as regulated by different aperture sizes. The aperture size (f-number) of a lens influences the amount of light, which reaches the camera’s sensor. We measured the sensor responses to the white test patch at three different aperture sizes to confirm that the sensor´s response was linearly related to the amount of light falling on the sensor.

Shutter speed was held constant at 1/60 s, ISO was set on 100 and three different f-stops were used to take pictures of the with test patch (f = 2, f= 2.8, f= 3.5) to provide different light intensities on the sensor. Response values from the sensor for the white test patch were obtained by extracting and averaging RGB values from a 64 x 64 pixel region in the corresponding image section. This was done for each image with its different aperture settings.

Note that the actual luminance for the white test patch always remained the same across the three photographs taken. Only the amount of light incident on the sensor changes, because the aperture size changes (whereas everything else stays constant). Due to the optical properties of a camera lens, the amount of light transmitted from an object in the lens's field of view to the sensor decreases with the square of the f-number. We took the square of the f-number as a measure of the proportion of light falling on the sensor. For the camera´s sensor response we inferred a fictitious luminance value for the white test patch on each of the three photographs taken. Each of the photographs differed only by aperture size, and therefore the amount of light falling on the sensor. We based the fictitious luminance of the white patch on the pixel value for the white patch of each image, and corrected for non-linearity of the intensity-response function described in the section above. For example, in one image the obtained pixel value was 107,2178. We corrected for gamma with above described coefficients: $(107.2178/10.29)^{(1/0.712)} = 26.88$. The fictitious luminance for the white patch in the image with its particular aperture settings was therefore 26.88.

In order to confirm that the sensor´s response was linearly related to the amount of light falling on the sensor, we plotted our “fictitious luminance” value for each of the three photographs of the white test patch (as a measure of the sensor´s response) against 1/f-stop^2 (as a measure of the proportion of light falling on the sensor).

The camera´s sensor response was linear over the three different aperture settings (see Figure 8 for the inferred luminance values for the white patch across the three different aperture settings). We may assume that the Canon 5d Mark II´ s sensor response is linear across a range of incident light intensities.

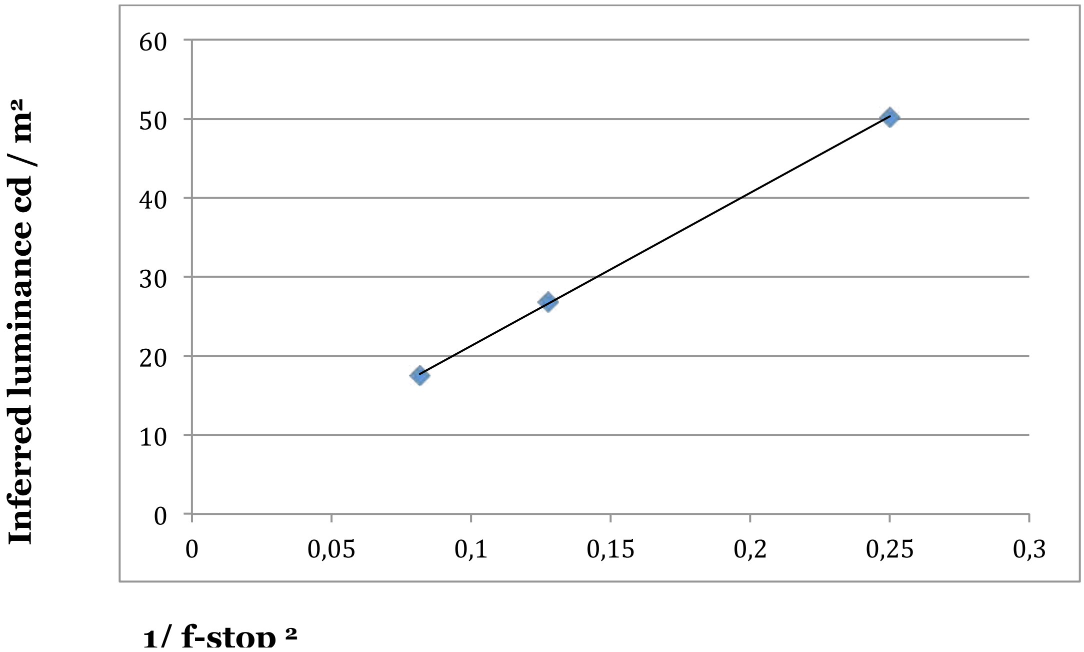


Figure 9: Inferred luminances of the white patch under different aperture settings (as a measure for sensor response) are plotted against the square of the f-stop, which illustrates the proportion of light falling on the sensor. ISO was held constant at 100, shutter speed at 1/60s. One can see that for three different apertures to the square (f= 2, f= 2.8, f = 3.5) and therefore three different light intensities on the sensor, the sensor responds linearly.

ISO linearity.

To examine the effect of the ISO setting on the raw camera response, we acquired two more images of the Color Checker´s gray scale chart. One was set with ISO=800, exposure was set at f = 5.6, shutter speed was 1/30 s. For the second image, ISO was changed to 100, aperture size was 2, shutter speed was 1/60 s.

Response values from the sensor for each of the 6 gray scale patches were obtained by extracting and averaging RGB values from a 64 x 64 pixel region in the corresponding image section.

We plotted actual luminances of the six gray scale patches against pixel values of the images for the corresponding gray scale patches. Functions of the two different ISO settings were not perfectly linear, but tended towards linearity, which allows us for our purposes to assume ISO linearity. See Fig. 9 for details.

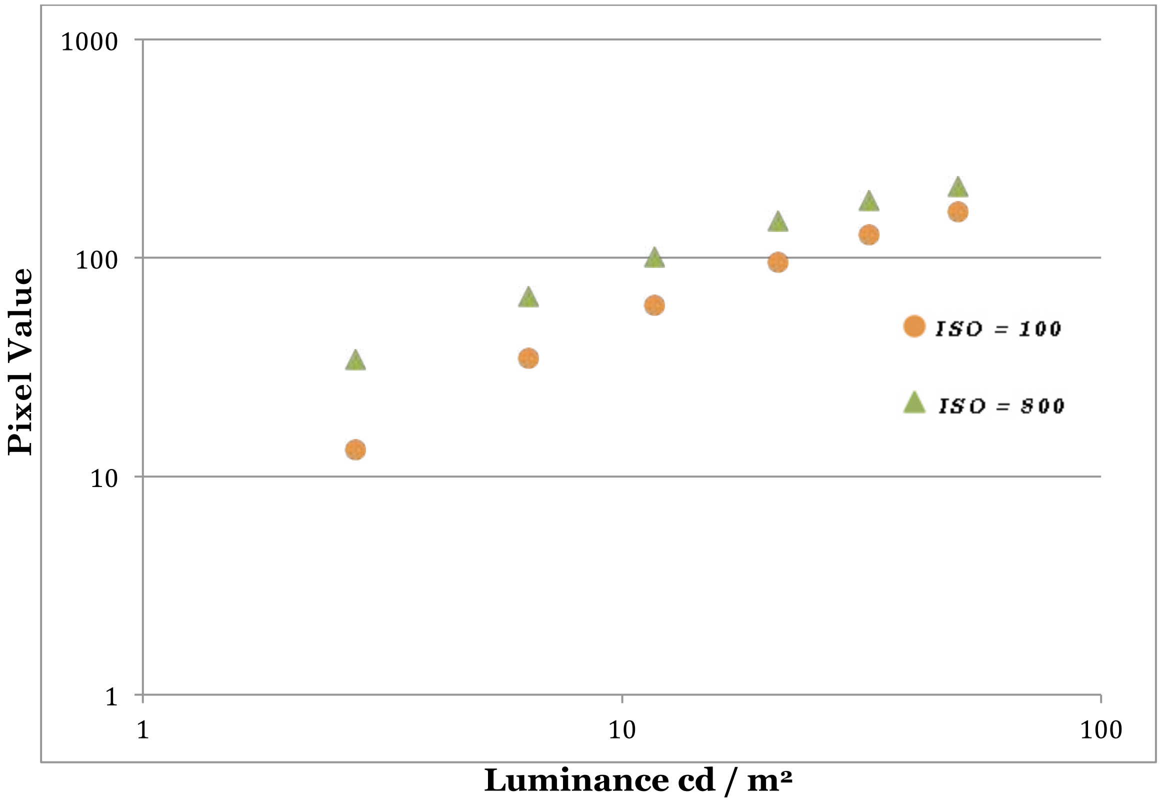


Figure 10: ISO linearity. Sensor response (pixel values) and luminance (cd/ m2) across 6 gray scale patches of the Gretag McBeth Color checker. One can see that for different ISO settings response linearity can be assumed approximately.

So, first we found a model to make sure that nonlinearity between actual luminances and camera´s sensor response is corrected. Then we showed that the camera sensor responds in a linear way to different proportions of light, as regulated by subsequent aperture sizes. Third, we showed that the camera sensor works close to linear for different ISO settings.

Procedure

The procedure of the second study shows an example for a rather unconventional and innovative approach in empirical Psychological Research in the field of Arts and luminances. At cost of some empirical control we are able to gain very life-like and creative insights in artists solutions to the luminance problem.

Painting Experiment

On April 21st, 2012, a sample of 10 artists came together to paint the same natural scene on a rather sunny day between 11am and 3pm. The scene was located in a major Viennese park (Stadtpark). All artists used A3 sized paper. Four artists used aquarelle or a combination of aquarelle and other techniques (ink; pencil; color pencil; pastel chalk). Four of them used ink to make their painting. One artist used watercolor; one artist used color pencil.

We used a luminance - calibrated camera (EOS 5d Mark II) with a 50mm lens to document the scene. It was put on a tripod and photographs were taken every half hour. Afterwards, we selected one representational photograph of the scene (see figure 11). Settings for this photograph were: f = 18, shutter speed = 125, ISO=200. We chose the photograph because there were no clouds present in the sky in order to prevent a too high dynamic range for the camera sensor. We took care that histogram intensity distribution variability during the three hours time span of the experiment was not too important so that it was legitimate to choose one of the photographs as a reference image.

Figure 11: The scene, which was painted by a cohort of artists in a Public Viennese Park (Stadtpark) on april 21st. Picture taken at 12:58 (noon). Settings for the image were as following: f = 18, shutter speed = 125, ISO=200.

Artists decided themselves when the painting was done. Interestingly, all of them came to an end after 3 – 4 hours painting. After the painting experiment was finished, the paintings were collected and photographed with the same camera in the studio.

Reproduction of the paintings

The paintings were put up in a studio wall at a height of approximately 150 cm. Two flashes (Bowens, GM500 digital) with a maximum stored energy of 500 ws were placed 2m away from the wall, left and right to the painting, so that the painting was in the middle between the two flashes and a uniform lighting could be established. The height of the lamps was 170 cm from the floor. Both flashes were equipped with a softbox, whose cross-section-dimension was 98cm, in front of the lamp. The lamps were adjusted to a power-value of f = 6 each. The photo was taken with the same Canon EOS 5d Mark II camera described above. Aperture was 8, shutter speed 1/ 125. The photograph was taken in RAW format.

Calculation of the ALUTs

Photographs were cropped using Adobe Lightroom 4, with the purpose of avoiding large areas of paper white without image content (see Figure 12; minimized reproductions of all paintings in their original and cropped proportions can be found in the attachment section). TIFF images (8 bit) were extracted and imported into Matlab (Version 7.1) where they were converted into gray scale. Histogram matching with the calibrated images was performed (see Gonzalez, Woods & Eddins, 2004) and ALUTs were created for each painting using Matlab. ALUT transforms were applied onto the grayscale images of the scene to get an “artified scene” with the intensity parameters of the painting (reproductions of the “artified scenes” can be found in the attachment section along the paintings).

Figure 12: Painting before (left) and after cropping (right). The goal of cropping was to avoid large areas of paper white that would not contain any information about an artist´s luminance compression – strategy (from a

technical, not an aesthetic or composition point of view). Further analyses were performed on the cropped version of the paintings.

3.4 Results

I illustrate in one example how the ALUT transform can be interpreted. One Aquarell painting, the Stadtpark scene the painting originated from, their corresponding histograms and their ALUT will be shown (see Figure 13a and 13b). Note that the Stadtpark scene has a skewed, high dynamic range luminance distribution (dynamic range of 100:1), whereas the painting has a more Gaussian, low dynamic range distribution (dynamic range of 10:1). In the ALUT we can see where the artist compresses values from the scene to display them in a smaller range, and where he expands values from the scene (see Figure 13b).

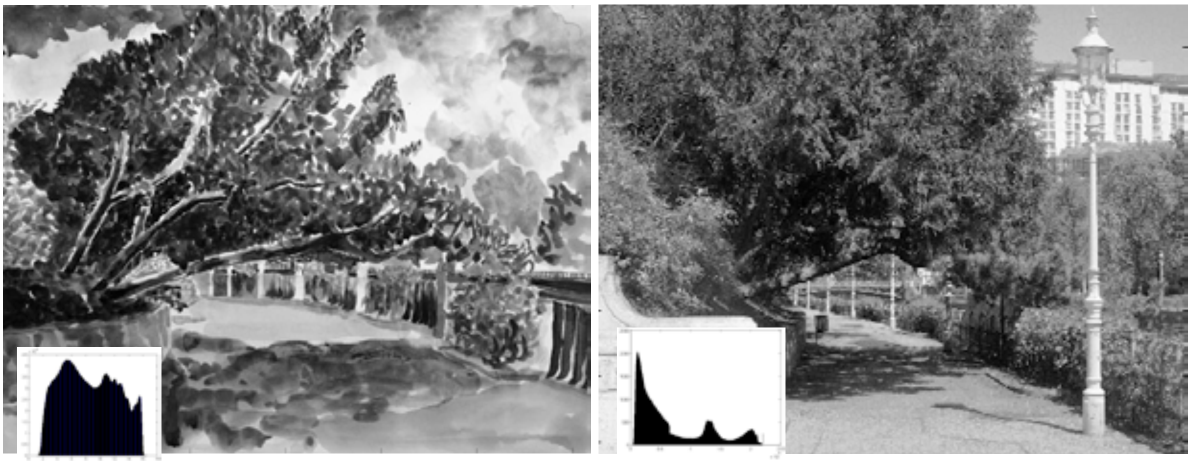


Figure 13a: Gray scale image of an artist´s painting (9080.tif) and the corresponding histogram (left), gray scale photograph of the natural scene and its corresponding histogram (right). Scene and painting were calibrated as described in the text. Note that the scene has a skewed, high dynamic range luminance distribution (dynamic range of 100:1), whereas the painting has a more Gaussian, low dynamic range distribution (dynamic range of 10:1). Transformation between these images requires a compressive nonlinearity.

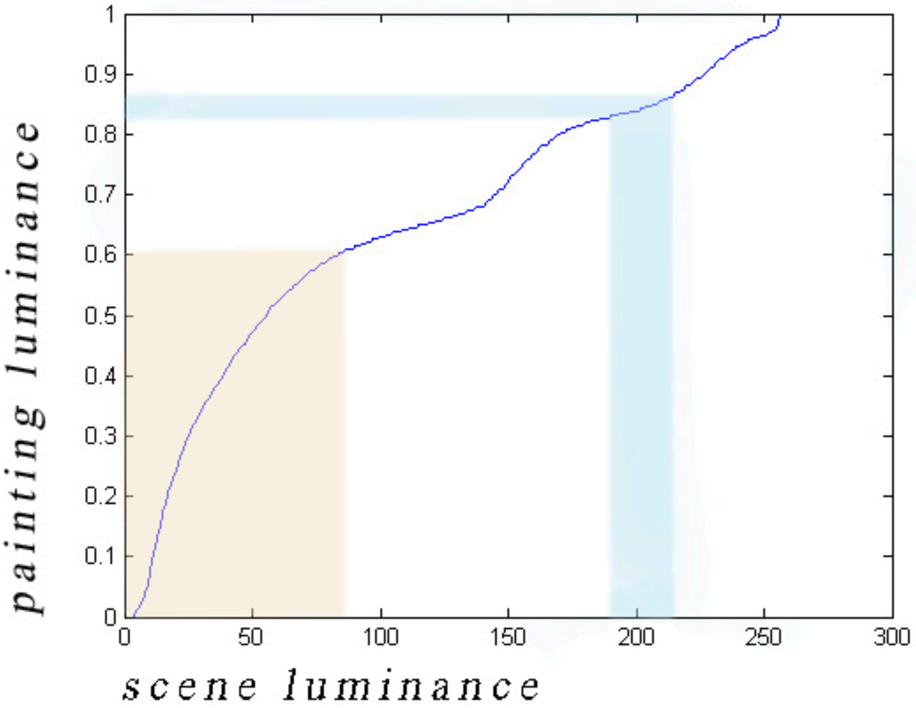


Figure 13b: Model of the Artist´s look-up table for painting 9080.tif. Artists have only a restricted range of values that they can display in the painting, so they must decide which luminances from the natural scene to compress, and which ones to expand. The ALUT shows us graphically how artists map scene luminances into painting luminances. Here, we see that in the orange section the artist decided to devote a larger section of his displayable range for an area of dark tones from the natural scene - he expanded these values. This means that the darkest values from the natural scenes are displayed in the painting with a range that is proportionally much larger, because it uses also some of the painting´s available mid-tones. In the blue area we can see the opposite: the artist devoted proportionally less values of his available range for a certain section in the natural scene´s mid-tones: he compresses. Note that the dynamic range for scene luminance is much higher than the dynamic range for painting luminances.

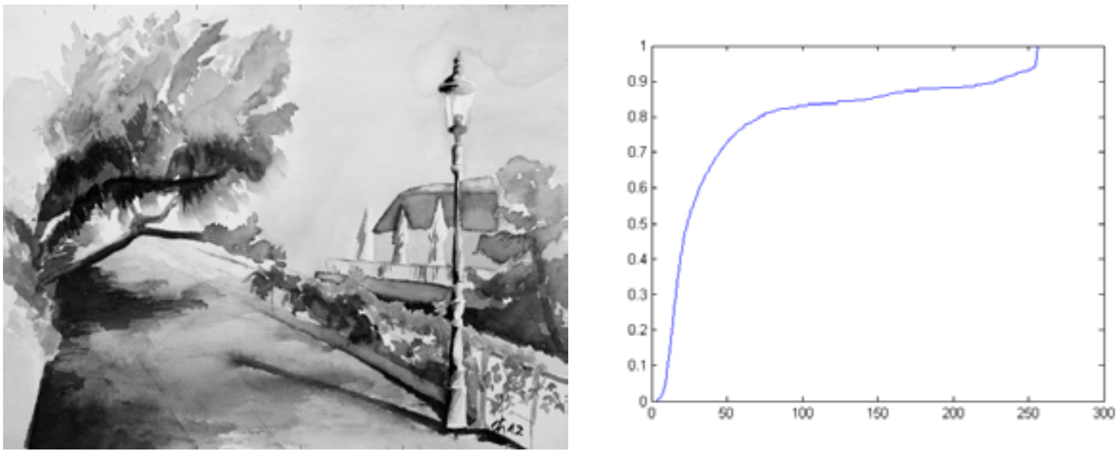
After receiving the ALUT transform, it is possible to apply the transform onto the gray scale photograph, which shows us how the “artified scene” would look like (see Figure 14). It is a photographic analogy to the painting, using the intensity range the artist used in the painting (see in the Attachment section for reproductions of all the paintings and their corresponding “artified scenes”). When one compares the “artified scene” with the painting, the ALUT´s strengths and weaknesses get obvious in a quite illustrative way: it appears to be a good model for the global intensity range used, but is not taking into account spatial structure and local contrast scaling, that´s why there is still quite a discrepancy between the painting and the “artified scene”.

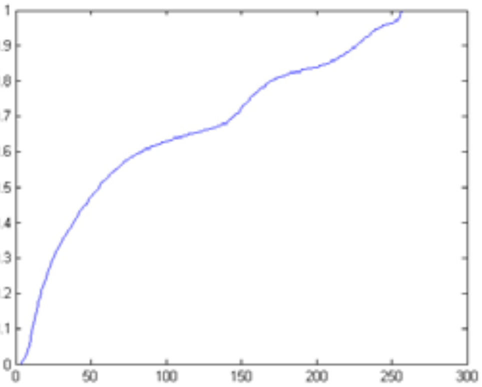
Figure 14: The painting (left) and the "artified scene" (right), after the ALUT transform has been applied. It gets obvious that the same intensity range is present in both images, though spatial structure and local contrast scaling, which lies within the artistic freedom, cannot be formalized by the ALUT.

In the following section, I will show the paintings and their corresponding ALUT - transform. I am grouping the paintings according to the different techniques used, so that similarities and differences within a category of painting technique become obvious.

Aquarelle / Watercolor

Figure 15 shows four different aquarelle paintings and one watercolor painting and their corresponding ALUT transforms originating from the Stadtpark scene. One can see by eye that the luminances used are quite different across the paintings, which is also reflected in their diverse ALUT transforms.

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100
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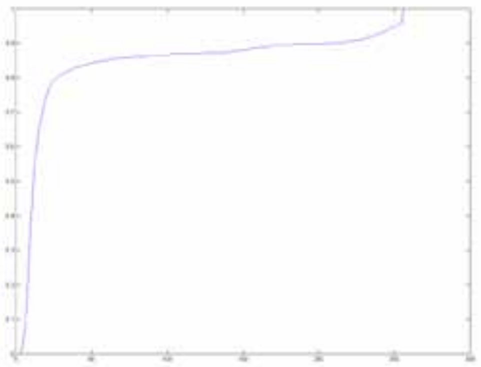

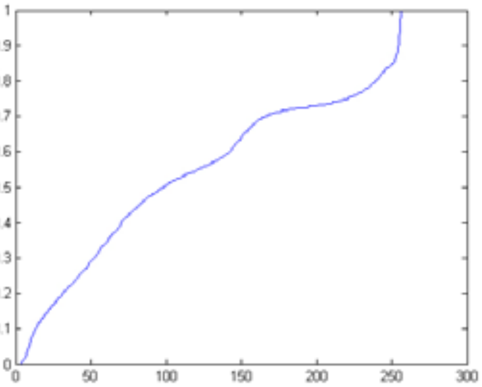
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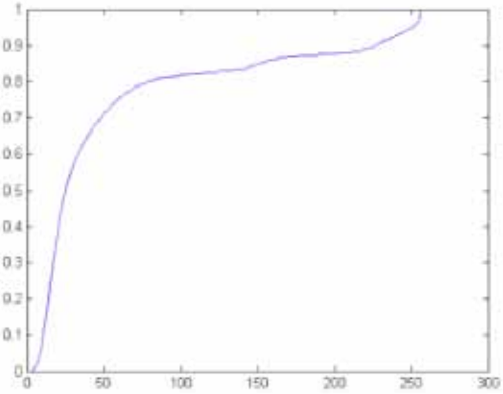
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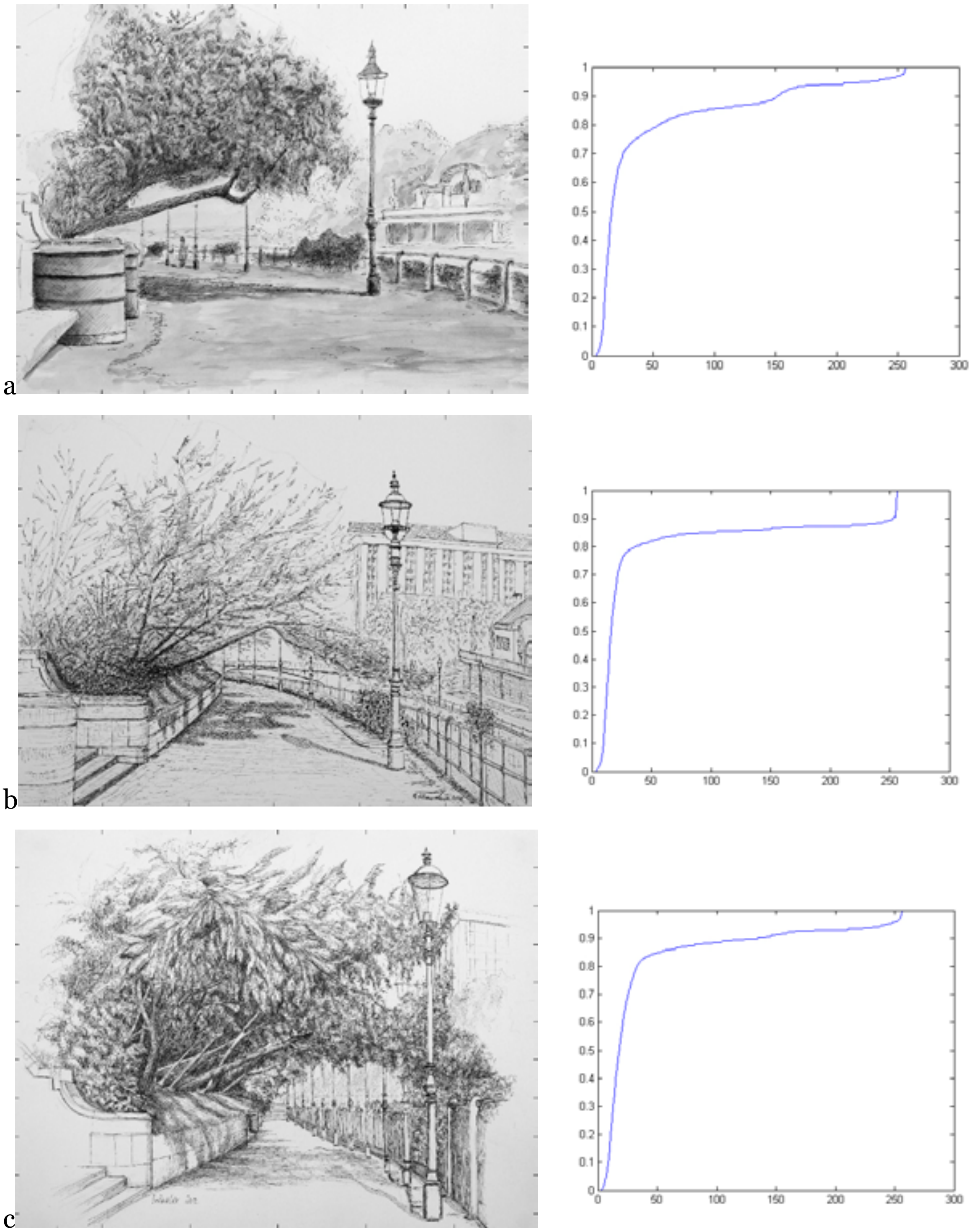
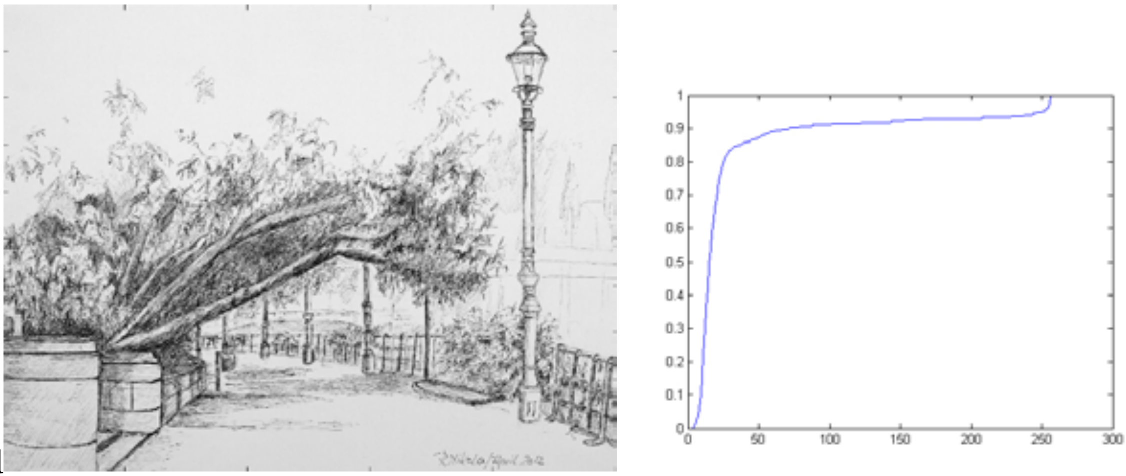
Figure 15: Aquarelle paintings that were made from the Stadtpark scene and their corresponding ALUT transform. Luminances used to depict the scene vary a lot across the different images, which is also reflected in the diversity of the ALUT transforms.

Ink

Figure 16 shows four different ink paintings that were made from the Stadtpark scene and their corresponding ALUT transform.





d

Figure 16: Ink paintings and their corresponding ALUT transform. Painting a shows a mixed technique (ink & aquarelle), which produces a slightly richer intensity range. This is reflected in the fact that the slope in the light parts of the painting scene range is less steep than in the other ALUT transforms (b, c, d). The artist is able to compresses less than the other artists using only ink. ALUT transforms of theis genre still tend to have a very similar shape, since very few values can be displayed in the paintings, they mostly concentrate around black and (paper-) white and a few light gray values. Looking at the ALUT transforms one can see that a lot of compression happens in all the range from the middle dark luminances up to very bright luminances of the scene.

Color pencil

Figure 17 reproduces one color pencil painting that was made from the Stadtpark scene and its corresponding ALUT transform.

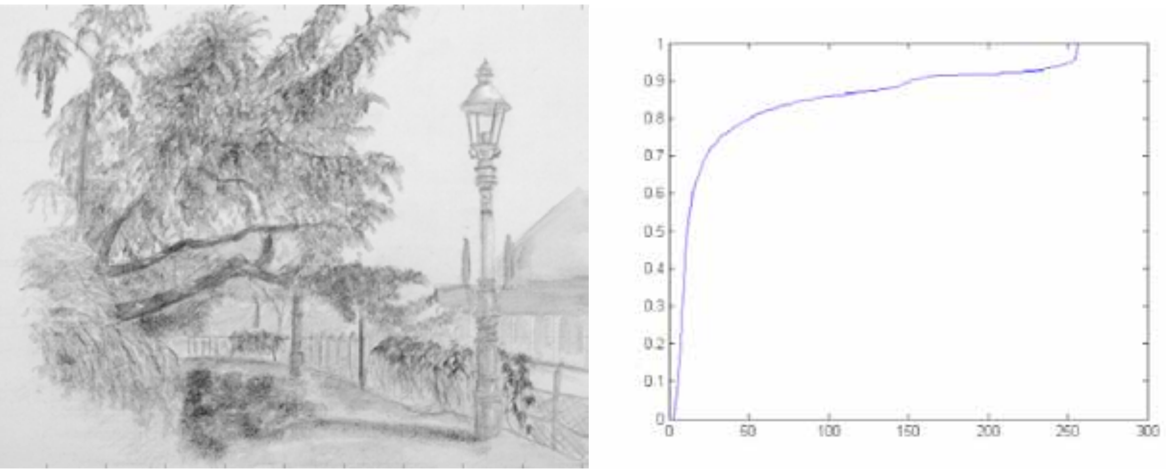


Figure 17: Color pencil painting and its corresponding ALUT transform.

3.5 Discussion

We based our research on the assumption that the artist´s look-up table (ALUT) can be used to describe how artists compress the high-dynamic range of luminance present in natural scenes into the far smaller range available on paper. So far there has not been any study collecting the different solutions of many artists painting the same scene. Graham and Field (2008b) and Graham, Friedenberg and Rockmore (2009) have proposed the ALUT transform as a model for illustrating luminance treatment looking at the work of single artists. This work goes one step further and compares different artist´s ALUTs who all painted the same scene under the same lighting conditions.

One result of our empirical research was that no simple ALUT of our cohort of painters was exactly like another. We found different luminance compression strategies for every artist, even though all of them had to deal with the same luminance problem and with similar restrictions regarding the materials used. They all used non-linear scaling, though, which has shown to be an effective transform (Graham & Field, 2007) and that can also be observed in neural coding to compress luminances (Graham & Field, 2008b).

Despite the differences in the ALUT transforms, it became obvious that some genres inspired compression strategies that are more alike. Especially ALUTs for those paintings created with ink had rather similar shapes. Steepness of the ALUT slope was much higher in those paintings than in other genres. Very small areas of dark luminances from the natural scene were expanded onto a large range of the painting´s present luminance range, and all the rest of tone range from the scene was compressed to a very small range of bright intensities in the painting. This makes sense if one notes that a fine ink pen allows only you to make black marks in a higher or lower concentration on a white surface. Such a technique will have troubles displaying a very big range of tones. So a lot of luminance compression has to happen using this technique. In contrast to this, other techniques allow artists more freedom in expressing and translating a certain intensity range. For example, aquarelle or oil painting colors, which can be applied laminar with a pencil, enable representing a higher tone range because glossy whites and matte blacks can be produced.

We are describing two ways to visualize the artistic process in luminance treatment. One is the model of the ALUT itself, which shows the areas of expansion and compression within a painting regarding its original scene´s luminances. The other one is the more poetic approach of applying this ALUT transform onto the photograph of the natural scene – it visualizes the effect of the artist´s luminance range used in the painting, if applied to the scene. Of course both ways are but global approximations of the artist´s use of luminances. They do not intend to describe the artistic process per se. Local contrast scaling is not captured within the model, neither is color information or spatial structure. All of these components are important contributors to an artist´s style. Still, luminance compression is something all artists must do and for this aspect the ALUT can be a useful approximation and visualization and therefore a clue to capture an artist´s style at least in this aspect.

It might be interesting to see if paintings that perceptually appear similar, i.e. paintings that share stylistic characteristics, also reflect these similarities in their ALUT transforms – a notion that seems plausible.

We have heard that the artist´s look-up table is not a full model of the artistic process. Nor does it prove that the artist´s used the most efficient compression. We rather saw that there is a pool of equally compelling images all stemming from the same scene, showing quite different global luminance compression strategies but that there is a visible effect of medium.

One difficulty the process of obtaining the ALUT from a painting created under natural scene-conditions is the lack of control of conditions, as compared to a laboratory setting. Lighting conditions can change quickly when one is outside, depending on clouds but also on the simple position of the sun. We assume that artists when facing these problems make a sort of averaged version of lighting conditions in their image, whereas we just used a single photography as a reference image. It might be useful for future research working with this technique to find a way to merge photographs from different points in time to an image, which still possesses the qualities of displaying intensities in a valid histogram.

Future research might also be interested into finding a way to quantify similarities and differences between individual ALUT transforms. One idea is to look at the second derivative of the ALUT transform, in order to find the inflection points of the function; i.e. where the curve accelerates and decelerates and where luminance compression or expansion takes place in the transform.

Why is it useful to investigate in artist´s luminance compression strategies?

Establishing a way to visualize how different artists deal with luminance compression can be helpful in many ways. One question that can thereby be addressed is: What do shared strategies among artists tell us about early processing stages of the visual system? If many artists use similar representational strategies to deal with the "luminance problem" this leads to the assumption that they do so because these strategies are especially well adapted to mammalian early visual processing stages. To the extent that many artists use similar strategies, these transforms can provide information about perceptual representations of real-world scenes and objects. We can find out about possible neural encoding mechanisms of luminance ranges, and so shed a little more light on the still rather unknown structures of the visual lightness processing.

The ALUT might also be a useful tool for measuring the stylistic specifics of single artists – if an artist´s way to deal with luminances is relatively constant over a range of works this fact will be reflected in their “typical” ALUT – function. The ALUT might therefore be used as a stylometric tool in authorship – debates or in historical ordering of works of unknown provenance.

4. General Discussion: Lightness Perception in Artists and Luminance Compression in the Artistic Process

At the beginning of this work was the astonishment, as in all awareness conductive processes. It was the astonishment about mankind´s ability to make creations of its surrounding world that seem so realistic that they capture the essence of a scene. Out of this wondering, fed with some background knowledge we developed two basic questions: 1) how do artists perceive luminances? And 2) how do they represent them when they paint?

1) We wondered, more specifically, if artists show better abilities in luminance judgment, like Graham and Meng (2011b) insinuated in a small study, in accordance with a whole cluster of research that attributes better perceptual abilities to artists (Cohen & Benett, 1997; Kozbelt, 2001; Cohen, 2005; Mitchell et al., 2005; Kozbelt & Seeleey, 2007; Cohen & Jones, 2008; Matthews& Adams, 2008). Actually, we found our group of artists to show equally good or bad luminance judgment as a group of untrained non-artists, so basing on our own study, we have no reason to believe that artist´s lightness perception works differently to other people´s lightness perception. This was a rather unexpected result for us and may root partly in confounding variables that cannot be ruled out, like individual differences in computer literacy or come people´s holistic way of processing in the perceptual task; against the instruction some people may have used a holistic way of processing as a heuristic for decision making in the perceptual task (which leads to a higher optical illusional effect) rather than strictly comparing luminances in the two boxes. Future research should prevent for those possible confounders by matching samples in education and age, or by using a more intuitive lightness task.

2) It is evident from the technical restrictions and those of the material used by artists that they could never display a natural high dynamic range linearly onto the canvas. If they choose a scene that has high dynamic range, like it is common in natural scenes, part of their artistic creation process implies luminance compression. Each single artist has his or her way of compressing luminance ranges when painting, which may well constitute large part of his or her personal artistic style. Acknowledging this fact, we proposed a model that visualizes an individual artist´s intensity compression strategy, the artist´s look-up table (ALUT, for example, see

Graham& Field, 2008b). The ALUT requires the intensity distribution of the scene painted and the one of the painting itself to calculate a map, how the painting range relates to the natural scene range. It shows globally, in which way an artist compressed natural luminance range in order to take advantage of the available painting range. We could show in the study that some of the used techniques (like ink painting or aquarelle paintings) produced more similar ALUT transforms, which is an evidence for the assumption that style, which is closely related to a painters technique, reflects in the ALUT transform – an important perspective for using the ALUT transform in stylometry.

If it is true that artists posses no better absolute luminance judgment, as our perceptual study suggests, and luminance compression is such an integral part of their painting process, it might well be that what does make the skill of an artist, apart from obvious motoric skills, lies somewhere in the decision process which luminances to compress and which luminances to expand when painting. We have seen across all the artist´s ALUT transforms that they use non-linear scaling for their luminance treatment. It may be that it is essential to an artist´s ability to use his or her available tone range efficiently. This may be more important than having absolute luminance judgment, which would produce a linear relationship of values if it could technically be transferred to a painting. Yet, it is technically impossible to recreate a natural high dynamic range scene in a painting. Efficiency in compression might be crucial in the artistic process. In this case "efficiency" could mean representing an aesthetically appealing image that still remains a close relationship to a realistic depiction. It remains open for further research to use the technique of ALUT transformation to dig deeper into the question, how more "effective" luminance compressions in paintings look like in comparison to "less effective" ones, and what can be inferred about artist´s specific perceptual abilities in this context. What perceptual components in luminance compression can be described for a successful artist? Is accessing early stages of visual processing, such as obtaining the original retinal impressions, part of such a process or not?

Together, the culmination of knowledge about artists´ perceptual lightness abilities and their evident compression strategies as reflected by the ALUT may contribute to a better understanding of visual luminance processing per se. If it could be shown that lightness perception is plastic and that training may enable accessing early stages of visual representation, this is an important insight for neuroscience but also for ongoing artists and their teachers.

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6. Attachments

Experiment Questionnaire of the Psychophysical Experiment

Gender: M F

Age:

Highest Education Level:

Profession:

Do you use eyeglasses? Y N
Prescription if known:

Handedness: L R

Estimated Number of Hours Per Week Spent Painting or Drawing:

Estimated Number of Years Spent Painting or Drawing:

Do you have any experiences in the field of Visual Arts?

Can you think of anything that might have trained your Visual Perception?

Index of Figures

Reproductions of the paintings in color, their cropped versions in gray scale and their corresponding „artified scene“

Painting 9080 © Klaus Henkelmann, 2012. Original measures 30x40 cm

Painting 9081 © Camilla Joseffson, 2012. Original measures 30x40 cm

Painting 9082 © Franziska Schiller, 2012. Original measures 30x40 cm

Painting 9083 © Yukiko Sakabe, 2012. Original measures 30x40 cm

Painting 9084 © Christine Heugenhauser, 2012. Original measures 30x40 cm

Painting 9085 © Annemarie Innthaler, 2012. Original measures 30x40 cm

Painting 9086 © Tomas Kamolwan, 2012. Original measures 30x40 cm

Painting 9087 © Franz Klaudusz, 2012. Original measures 30x40 cm

Painting 9088 © Renate Nikola, 2012. Original measures 30x40 cm

Painting 9089 © Rudolf Friedl, 2012. Original measures 30x40 cm

Painting 9080

Painting 9081

Painting 9082

Painting 9083

Painting 9084

Painting 9085

Painting 9086

Painting 9087

Painting 9088

Painting 9089

Zusammenfassung auf Deutsch

Künstler_innen stehen zwei grundlegenden Problemen gegenüber, wenn sie die Tonwerte einer natürlichen Szene in ein Gemälde übersetzen wollen. Zuerst müssen sie mit dem Phänomen der Helligkeitskonstanz umgehen, also der Tatsache dass wir Tonwerte nicht objektiv wahrnehmen, sondern diese von unserem visuellen System interpretiert werden, und zweitens müssen sie die den hohen Tonwertumfang komprimieren, sodass dieser auf der Leinwand, dargestellt werden kann.

Wenn Künstler_innen eine natürliche Szene abbilden wollen, müssen sie ein Bild schaffen, das dem Bild der natürlichen Szene auf der Netzhaut nahe kommt, damit uns das Bild korrekt erscheint. In Bezug auf Helligkeiten müssen sie die Wirkung der Helligkeitskonstanz unterbinden, entweder, indem sie auf frühe Verarbeitungsstufen des Perzepts zugreifen können, oder indem sie ihre eigenen wahrnemungsgebundenen Fehler in einem zweiten Schritt zu korrigieren vermögen.

Tatsächlich ist bekannt, dass Künstler_innen bessere Wahrnehmungsfähigkeiten haben, z.B. schnitten sie besser bei einem Formkonstanz-Test ab (Cohen & Jones, 2008). Wenn Künstler_innen tatsächlich die Wirkung der Helligkeitskonstanz über Prozesse der Wahrnehmung abwenden können, so sollten sie besser darin sein, Helligkeiten objektiv zu beurteilen. Um diese Annahme zu testen, nahmen Testpersonen an einer Aufgabe teil, in welcher sie Helligkeiten beurteilen sollten. Sie mussten entscheiden, welcher von zwei Stimuli einen größeren Unterschied zeigte: einer, der einen tatsächlichem Kontrast beinhaltete oder einer, welcher lediglich die Illusion eines Kontrasts bot. Die Höhe der jeweiligen echten oder illusiorischen Kontraste variierte. Nicht-Künstler_innen (n=11) und Künstler_innen (n=11) zeigten keinen Unterschied in ihren Fähigkeiten der Beurteilung von Helligkeiten. Zusätzlich zeigte sich kein Zusammenhang zwischen der künstlerischen Erfahrung und der Fähigkeit zur Helligkeitenbewertung. Die Ergebnisse weisen nicht daraufhin, dass Künstler_innen die Helligkeitenkonstanz durch spezielle Wahrnehmungsprozesse überwinden können.

In einer zweiten Studie präsentiere ich die Strategien zur Helligkeitenkomprimierung einer Gruppe von Maler_innen (n=10). Alle diese Strategien fußen in der selben natürlichen Szene, welche unter den selben Lichtverhältnissen gemalt wurde.

Ich zeige ein Modell, welches die umfassenden Helligkeitskomprimierungs-Strategien eines Malers oder einer Malerin veranschaulicht – der “artist’s look-up table” (Graham, 2009). Dieser scheint grundlegende stilistische Komponenten

erfassen zu können. Unterscheidliche “artist’s look-up tables” scheinen sich systematisch über verschiedene Techniken hinweg zu unterscheiden (z.B. Aquarell oder Tusche). In dem Maße wie manche Maler_innen oder Gruppen von Gemälden durch eine gewisse Helligkeiten-Komprimierungs-Strategie beschreibbar sind, ist der “artist’s look-up table” ein nützliches Werkzeug in der Stilforschung oder auch in Autor_innenschaftsdebatten.

7. Curriculum Vitae

Maria Noisternig
Born on 02/ 01/1985 in Brixlegg, Austria
Nationality: Austrian

Education

2003	Austrian A-Levels (Matura) with excellence
2001 - 2002	exchange year in Barquisimeto, Venezuela, during high school (11th grade)
1995 - 2003	high school, Akademisches Gymnasium Innsbruck
1991 - 1995	primary school, Volksschule Matrei am Brenner

Academic Studies

2004 - 2012	studying at the University of Vienna, course: Psychology
2007	ERASMUS - exchange at Universidad de La Laguna, Spain (course: Psychology)
2003-10	studying at the University of Vienna, course: Social & Cultural Anthropology. Bachelor of Arts

Professional Education

2008 - 2010	College for Photography and Audiovisual Media, Die Graphische, Vienna

Work Experience (selection)

2011	image editor for an Austrian school book publishing house (*Verlag Jugend & Volk*)
2010 - today	working as a freelance photographer, marianoisternig.com
2010 - today	assisting Bettina Frenzel (Vienna), frenzel.at
2008 - 2009	employed at the Vienna Institute for International Dialogue and Coooperation (VIDC), *Kulturen in Bewegung*; Tour coordination of a three weeks tour in Austria and tour guidance for Venezuelan music band *LatinNeo*
2008	assisting Frank Rothe (Berlin), frankrothe.com and Katsey

	(Vienna), katsey.org
2008	six weeks` internship in the General Hospital of Vienna (AKH) at the University Hospital for Psychiatry, Department for Behavioural Therapy
2006 - 2007	personal assistance to an elder lady with Parkinsson syndrome
2006	working as tourguide and translator for Nicaraguan music band *Perrozompopo* for the Vienna Institute for International Dialogue and Coooperation (VIDC), *Kulturen in Bewegung* during the *onda latina* festival
2005	internship (60 hours) at the therapy institute *Keil*, Vienna, working with people with special needs

Languages

German	Muttersprache
English	very good
Spanish	muy bien
French	un peu

Vienna, September 2012