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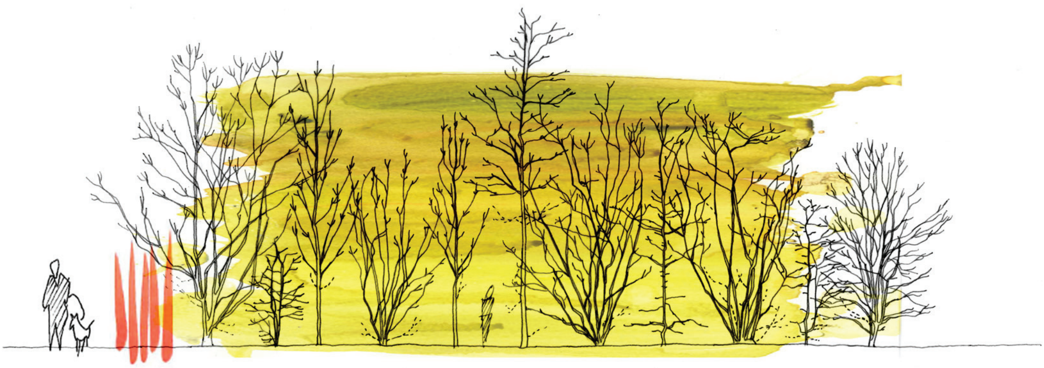
Green Is Not Just Green

Human colour perception in urban green contexts

Petra Thorpert



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Human colour perception in urban green contexts

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Green Is Not Just Green. Human colour perception in urban green contexts

Abstract

The thesis is intended to be part of a larger process and field, by helping to increase understanding of how changed colour characteristics in urban green spaces can influence human experiences. More specifically, the thesis explores whether human colour perception is influenced by factors such as viewing distance, seasons, species mixture, or colourful artefacts incorporated in urban green spaces.

In situ studies were performed in southern Sweden, using public parks and well-defined forest stands as experimental areas. Three empirical studies were conducted in the form of quasi-experiments and combined studies involving colour perception and environmental assessment methods. The main findings are structured around Johannes Itten's colour contrast concepts from the 1960s (Itten, 2002), Berlyne's arousal model (1971) and the concept of hedonic values. The main results are discussed in terms of the effect of viewing distances on colour perception and the effect of colour contrast on visitor experience. In addition, the findings are related to methodological considerations and constraints, with a discussion of a quantitative approach concerning determination of colours and the use of expert respondents.

In today's urban green spaces, bright and intense colourful artefacts are increasingly playing a role as visual contributors. According to the results, the coloured additions in green-dominated areas seem to affect human colour perception when viewed from both a short distance (3 metres) and a longer distance (15 metres) in a public park. These findings might also apply to colourful plantations in park environments like perennial- and annual borders. The results also indicate that human experiences relate to perceived colour characteristics, which in turn relate to surrounding environmental colours and viewing distance. The findings emphasise that awareness of colour aspects, such as perceived colour contrasts and the effect of viewing distance on perceived colours and related human experiences, should be addressed in the planning and design of urban environment processes. The knowledge from this thesis could support landscape and garden designers in their work to develop outdoor environments that are attractive for humans.

Keywords: colour contrast, characteristics of colour, viewing distance, season, RHS colour chart, Johannes Itten, Berlyne's arousal model

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Preface

In my professional career, I have had the opportunity to work with a variety of projects relating to my artistic background and training in landscape design. These include art exhibitions with my own paintings on display, as well as landscape projects for municipalities, tenant-owner associations and private property owners. These have provided me with many relevant and inspiring experiences and challenges that have benefitted my research.

During the past 11 years, my professional life has shifted from consulting assignments in garden and landscape design to teaching assignments, mostly at the Department of Landscape Architecture, Planning and Management at the Swedish University of Agricultural Sciences, Alnarp. Working in an educational situation, as well as being involved in artistic and landscape design creation, has generated personal and professional reflections and discussions about colour and human experiences. This has led to thoughts on how humans perceive and experience objects such as paintings and various outdoor environments from a colour perspective.

This thesis has enabled me to examine in greater depth the relationship between perceived colours in urban green spaces and human experiences. My background in art and landscape studies has been both an inspiration and an important platform for the planning and analyses of each paper included in this thesis and in my teaching. Two of the studies (Papers I and II) involved the participation of students. This has enriched me as a teacher and, according to the students, broadened their knowledge acquisition and awareness about colour influences and related experiences in outdoor environments. The work also increased my curiosity about the subject itself, but also for the interplay between teaching and research (Figure 1).

During the years working with this thesis, I have observed increasing interest in the influence of perceived colours in urban green spaces. My hope is that this interest will continue and, if possible, increase and lead to further exploration and knowledge development about outdoor colour influence on human perception and related experiences in urban green spaces.

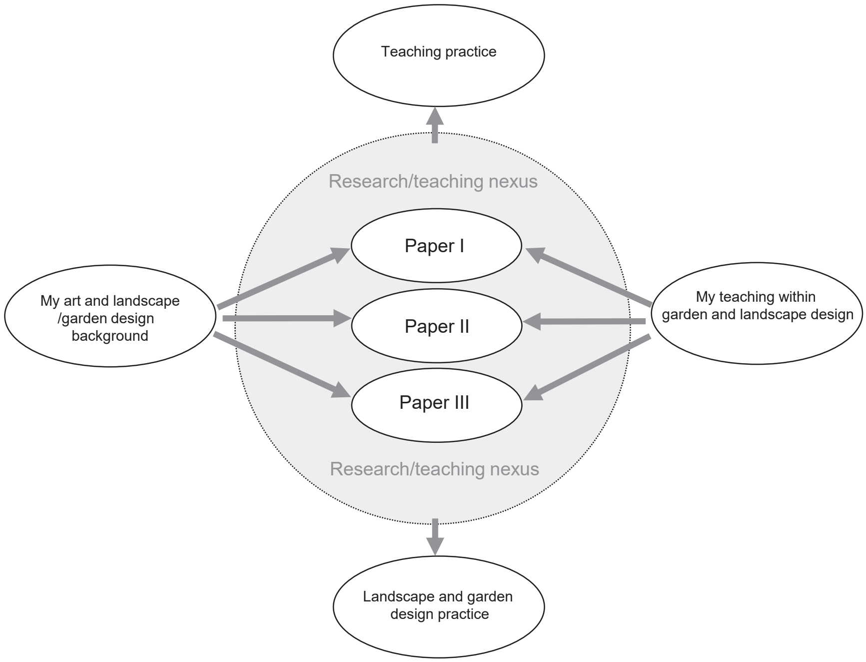

Figure 1. The influence of my professional background in art, landscape/garden design and teaching on the planning and implementation of the studies, and how the studies leading to the three articles evolved from and were embedded in the interplay between research and teaching. The diagram also illustrates a possible transfer of knowledge and know-how from the methodology and findings in my studies to teaching and landscape/garden design practice.

Alnarp, 5 May 2019

To my daughter, Thilda

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Thorpert, P., Nielsen, A.B. (2014). Experience of vegetation-borne colours. *Journal of Landscape Architecture* (JoLA), 1-2014: 60-69.

II Thorpert, P., Englund, J-E., Nielsen, A.B. (2018). The impact of the primary colours yellow, red and blue on the perception of greenery. *Landscape Research* 44 (1), 88-98.

III Thorpert, P., Englund, J-E. Perceived colours and visitor experiences of urban parks as influenced by colourful artefacts: An in-situ quasi-experiment. Under review at *URBAN DESIGN International*

Papers I-II are reproduced with the permission of the publishers.

The contribution of Petra Thorpert to the papers included in this thesis was as follows:

I Planned the study together with the co-author. Collected and analysed the data. Wrote the paper, with feedback and co-writing from the co-author.

II Planned the study and collected the data. Analysed the data and parts of the statistical analysis. Wrote the paper, with feedback and co-writing from the co-authors.

III Planned the study and collected the data. Analysed the data and parts of the statistical analysis. Wrote the paper, with feedback and co-writing from the co-author.

Definitions of terms and concepts

Urban green space: all private and public urban land covered by vegetation, including water bodies ("blue spaces") (WHO, 2017).
Environment: physical and symbolic conditions that directly surround human beings (Steg el al., 2013).

Colour: the perceptual experience of colour can be described in terms of three independent perceptual attributes (main characteristics of colours), i.e. *hue, saturation* (purity or Munsell chroma), and *brightness* (lightness or Munsell value) (Mather, 2016).
Hue: one of the main properties of colour, corresponding to the colour itself, e.g. red, blue, yellow (Mather, 2016).
Saturation: the purity of the hue (Mather, 2016).
Brightness: the perceived intensity of the light (Mather, 2016).
Munsell chroma: the purity of the hue in the Munsell colour system (Voss, 1992).
Munsell value: the perceived intensity of the light in the Munsell colour system (Voss, 1992).

Perceived colour: a conceptual definition regarding the colours of an object observed in any particular light and viewing situation (Fridell Anter, 2000).
Primary colours: red, yellow and blue hues, according to colour theorist Johannes Itten (2002).
Characteristics of colour effects: main characteristics of colours (hue, saturation, brightness) described through different kinds of colour contrasts (Itten, 2002).
Colour contrast: clear differences that can be perceived between two compared effects (Itten, 2002).

Complementary contrast: creating the strongest contrast between two or more colours placed next to each other, the colours mutually intensify their brightness to a maximum degree of vividness when adjacent. Red-green, orange-blue and yellow-violet colours attain their maximum degree of complementary contrast; this refers to diametrical complementary pairs. (Itten, 2002).
Light-dark contrast: corresponds to different brightness of the colours, where white and black are the most powerful expression of light and dark (Itten, 2002).
Cold-warm contrast: subjective feeling of colour temperature depending on contrast with surrounding colours, where the colours red-orange and blue-green achieve the greatest effect (Itten, 2002).
Colour constancy: the effect whereby the perceived colour remains stable despite changes in the intensity of the illumination (Foster & Amano, 2019).

1 Introduction

The visual aspects of a landscape are key qualities for human perception and related judgements of affordances and aesthetic liking. If we are to perceive and understand our surroundings, aspects of light, form and colour are essential, and when we perceive a landscape, we arrange the visual components into patterns (Dee, 2012; Bell, 2004). The most original and basic visual reaction is the pure perception of light, followed by colour vision (e.g. Mather, 2016; Yantis & Abrams, 2016), and from that perspective perceived colours occupy a central role in the visual landscape experience (Küller et al., 2009).

Previous research has shown the benefits provided by structural elements in urban green spaces (e.g. van den Bosch & Ode Sang, 2017; Wang et al., 2016; Nordh & Østby, 2013). Several studies show a positive experience effect of individual visual factors, such as level of vegetation (Peschardt et al., 2014; Arriaza et al., 2004), water structures (Nordh & Østby, 2013; Arriaza et al., 2004), perceived species richness (Wang et al., 2016, Arriaza et al., 2004), and well-maintained areas (Wang et al., 2016). Although the various visual qualities in the outdoor environment are well researched and explored, the perceived colours in urban green spaces have been less investigated, despite them comprising a fundamental aspect of human visual perception (e.g. Mather, 2016).

The current trend to incorporate colourful artefacts in urban green spaces turns the spotlight onto how we perceive and experience these new outdoor conditions. Traditionally, artefacts such as playground equipment or mail boxes have been the most colourful objects in urban green spaces, but bright colours are now a common feature, such as red-, yellow and orange street furniture (Figure 2, right; Figure 9, left; Figure 11, right), blue and yellow playground equipment (Figure 11, left; Figure 12, right), yellow fitness equipment (Figure 13, right) and coloured paved ground surfaces (Figure 10, left; Figure 13, left). Flowering vegetation also comprises intense colours, especially summer flowers and, to some extent, perennials densely planted in borders (Oudolf & Kingsbury, 2013), and the growing use of meadows dominated by colourful exotic species and cultivars (Hitchmough, 2016) is a common feature in urban contexts. This invites exploration of the current addition of bright and intense colours and their impact on human perception and related experiences.

Since the 15th century, visual effects of different colour combinations have been discussed and visually expressed in paintings by artists such as Jan van Eyke (c. 1390-1441), Piero della Francesca (1410-1492), Leonardo da Vinci (1452-1519). The tradition of studies in colour theory and colour design principles, such as the work of Johann Wolfgang von Goethe (1749-1832) and Johannes Itten (1888-1967), opened the way for development of artistic tradition in the 19th and 20th centuries. The coloured paintings of Wassily Kandinsky (1866-1944) and Piet Mondrian (1872-1944) are striking and good examples of a conscious balance of colour. Traditionally, colour composition is an important part of a painter's profession, as well as a natural part of landscape design compositions. Colour compositions can be created in urban green spaces in various ways, such as by arranging colours in a way that creates the effects of colour contrast (Figure 2, left).

Studies have reported that perceived colour effects, such as colour contrast in the outdoor environment, are an important parameter in the assessment of visual beauty and experiences of harmony (Huang & Lin, 2019; Oleksiichenko et al., 2018; Eroğlu et al., 2012; Arriaza et al., 2004). In contrast, the lack of such a contrasting effect can result in less-appreciated environments (Polat & Akay 2015; Arriaza et al., 2004). Another aspect is how scale and distance influence human perception. A recent study by Wang et al. (2016) showed no correlation between different views and colour contrast effect, but other studies have shown a correlation between perceived colour contrast and viewed scale (Arriaza et al., 2004). Colour contrast and viewed distances seem to affect human colour perception and related experiences, which invites further exploration of colour contrast and distance effects in various urban green contexts.

Both harmony and pleasurable experiences are important factors in our understanding of the outdoor environment, where experienced pleasantness brought about by aesthetic values can be linked to levels of arousal (Berlyne, 1971). This can be seen as an essential aspect, since aesthetic conditions are important contributors to perceived quality in our daily life (Berleant, 1970). According to Berlyne (1971), visible changes in light and hues affect the arousal level, and intense colours such as red are associated with high arousal, more so than cool colours (blue, green) (Wilms & Oberfeld, 2018; Hanada, 2018). Fluctuations in arousal level might be connected with visual properties, such as colours in the outdoor environment (Motoyama & Hanyu, 2014), where plant colour composition positively affects the visual quality (Polat & Akay, 2015). Consequently, it seems that the expected perceived colour contrast and related levels of arousal should play an important role when placing coloured artefacts in the outdoor environment, especially as human experiences in relation to intense colours vary according to the context, as well as the interactions between colours (Wilms & Oberfeld, 2018; Palmer, et al., 2013).

A significant body of research suggests that humans prefer both low and high radiant hues (e.g. Crozier, 1999; Berlyne, 1971), where Asian cultures show a strong liking for colours with symbolic associations. In China, red hues are symbols of good luck (Hurlberg & Ling, 2007) and white colours in Japan are associated with purity (Palmer at al. 2013). As reported in Palmer et al. 2013, liking for colours has the potential to vary, which automatically also influences the level of arousal as a function of cultural background, where the levels of arousal increase as a consequence of perceived colour (Wilms & Oberfeld, 2018; Hanada, 2018). This indicates that the placing of colourful artefacts in urban green spaces should be carefully considered.

As colourful artefacts and accentuated meadows and perennial borders are a common phenomenon in urban green spaces, researchers have called for more in-depth examination of the subject (Southon et al., 2018; Polat & Akay 2015). This thesis could be considered a step in that direction.

Figure 2. Left: example of a meadow border designed with focus on complementary and cold-warm contrasts. Right: example of contemporary landscape architecture/red street furniture in central Lund, Sweden.

2 Aim of the thesis

The intention behind the work described in this thesis has been to draw attention to colour aspects in urban greenery, with special focus on the use of colourful artefacts in urban green space and the way they influence the colour experience of the environment as a whole. The thesis is intended to be part of a larger process and field, by making a contribution towards a growing understanding of how changed colour characteristics in urban green spaces can influence human visual experiences. The fundamental aim of the thesis is to investigate the importance of colour in the outdoor environment, but not including the influence of surface characteristics or the correlation between natural illumination and perceived colour.

In order to achieve this aim, the focus has been on human colour perception and linked experiences in relation to woody vegetation systems and groundcover perennials, as well as the interaction between colourful artefacts and surrounding green environments. More specifically, the objective of the thesis was to explore how human colour perception is influenced by factors such as viewing distances, seasons, species mixture or colourful artefacts incorporated in urban green spaces. An additional objective was to link perceived colours to human experiences, using Berlyne's (1971) arousal model and the concept hedonic values as a frame.

The thesis is structured around three co-authored papers (Papers I-III). The interrelationship between the individual papers and how their focus balances between perceived colours and hedonic values is shown in Figure 3. All papers address the general aims of the thesis, but each has a special focus. Paper I examined perceived characteristics of colour effects in relation to distance, seasonal change, complexity of vegetation systems and human experiences. Paper II examined how artefacts with primary colours (yellow, red, and blue) with various shapes, sizes and positions placed in a green colour palette of ground-covering vegetation, influence human colour perception. Paper III examined the relationship between human experiences and perceived colours of an orange artefact placed in a public park.

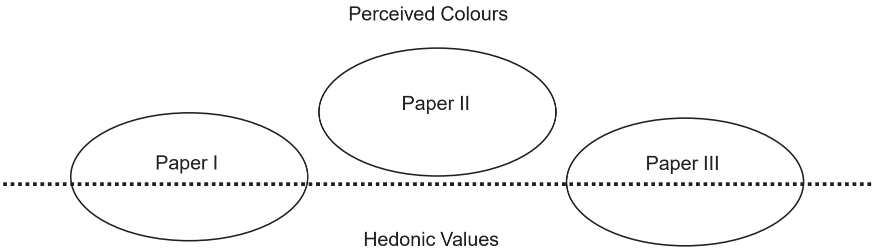

Figure 3. The interrelationship between the individual papers and how their focus balances between perceived colours and hedonic values.

3 Theoretical framework

The thesis has its starting point and focus in the field of landscape architecture, but the theoretical base and methods mainly stem from other research areas. In landscape architecture research, a multidisciplinary approach is a fruitful way to develop new knowledge (van den Brink, 2017), as well as for producing knowledge in general. This enables different disciplines to borrow and combine theories and methods with no substantial adjustment in the course of interaction between fields of research (Mobjörk, 2010; Huutoniemi et al., 2010). To reach the aim, the works included in this thesis have therefore borrowed and combined theories, concepts and methods from different disciplines like environmental psychology and colour theory. From that perspective a multidisciplinary approach has been used. The following sections present the theoretical frame within which the PhD research has been conducted.

3.1 The human visual system and colour perception

Human vision is considered to be the most important sense, accounting for no less than 80 percent of a human's information intake (Haupt & Huber, 2008), where pure perception of light has been shown to be the most basic reaction, followed by colour vision (e.g. Mather, 2016). We perceive form and colours of objects by their capacity to reflect wavelengths of light, where the aim of the perception is to understand and find a relationship to our environment (Gibson, 1966). There is a widespread assumption that internal representation of colour is necessary (universal) for humans to distinguish a particular colour (Robertson et al. 2000) and that biological evolution gives humans (and many animals) an innate ability to define colours and the ability to react to universal features, and relate these experiences to a particular colour (e.g. clear sky and clean water relates to blue, and rotting food relates to dark yellow) (Palmer at al. 2013). Colour vision also depends on individual perceptual differences (Kuehni, 2003). Personal attitudes and cultural background, biases, or variations in value systems (Patton, 2002) all contribute to how we perceive surrounding colours. Perception of colour is also influenced by age and changes in the eyes that start to take place after the age of approximately 45 (Nguyen-Tri et al., 2003; Werner et al., 1990).

3.1.1 Light and colour perception

The eyes and the retina represent the first stage of the human visual system (HVS), where high-level perception occurs through our vision centre and the visual cortex (Nadenau et al., 2000). Wavelengths of light have the capacity to stimulate receptors in the eye (Mather, 2016) and through the mechanism for adaption of the iris, which controls the retinal illumination, the retina and the HSV are able to handle a widespread range of light intensities (Shapley & Enroth-Cugell, 1984), which influences the perception of colours (Webster, 1996).

Object colours are perceived through their capacity to reflect the different wavelengths of light (electromagnetic radiation) (Bruno & Svoronos, 2006), and each hue can be precisely defined by its wave length (red 740-625nm; orange 625-590nm; yellow 590-565nm; green 565-500nm; cyan 500-485nm; blue 485-450nm; violet; 450-380nm) (Bruno & Svoronos, 2006). The perceived colour depends on the relationship between, e.g., the nature of the radiation, distance from the object, surface reflections of the object, and its surrounding context (Klarén, 2017), where the perceived colours might be affected by reflections from nearby coloured surfaces (Billger 1999). The perceptual experience of colour can be described in terms of three independent perceptual attributes: hue, saturation (purity or Munsell chroma), brightness (lightness or Munsell value) (Mather, 2016).

Perceived characteristics of colour effects

In the 1960s, Johannes Itten framed a systematic overview and practical exploration of a far-reaching theory of colour as well as a colour contrast interpretation model (Bláha & Štěrba 2014; Itten, 2002). Since then, Johannes Itten's concepts have been used in various studies, linking plant composition to colour schematic diagrams in educational situations (Nilsson, 2013) and relating Itten's colour theory to educational practice (Raleigh, 1968). In a study by Agahchen & Branzan Albu (2014), Itten's colour concepts were used as a tool analysing aesthetics of colour with focus on colour modulation and by Bláha &

Štěrba (2014) using the colour contrast principles when analysing cartographic works of landscapes. From the perspective that Johannes Ittens's colour concept has been used as an interpretation step in works related to plant design and landscape structures, as well as to perceived colours qualities, the use of Itten's colour contrast concepts appears to be suitable and reliable in the context of this thesis.

Colour contrast refers to clear differences that can be perceived between two compared effects, like light-dark contrast. According to Itten (2002), complementary contrast is the strongest and the colours white and black the most powerful expression of light and dark. Cold-warm contrast depends on which colours are used and the difference between them. A complementary contrast used in its proper proportions has its own peculiarities and each colour may retain its intensity. In this thesis the focus has been on the diametrical complementary pair red-green, as well as the complementary pairs orange-green, which are also the extremes of cold-warm contrast (Itten, 2002).

In order to obtain a comprehensive understanding of the perceived characteristics of colour effects in each investigated area, Johannes Itten's descriptions about complementary contrast, light-dark contrast and cold-warm contrast are used as an interpretation step. The current trend to incorporate intense red, orange and yellow artefacts in urban green spaces could potentially increase the perceived complementary contrast as well as the cold-warm contrast in urban green spaces. From this perspective, Itten's complementary and cold-warm contrast approach was used as an interpretation step. In landscape architecture, it is common to use the variation in brightness in order to achieve contrast and variation in plantations (Bell, 2004; Robinson, 2004). In accordance with this, Itten's concept of light-dark contrast was used as an analysis tool.

3.1.2 Colour perception in a landscape context

The colour perception in an outdoor context is influenced by the spectral composition of natural illumination, which means the observed property and effect of light in the outdoor environment (Foster & Amano, 2019). A clear sky and visible sun causes direct illumination with spectral reflections, while local shadows or indirect illumination caused by extent of cloudiness produce changes in the light distribution and colour temperature (Matusiak, 2017; Foster, 2011; Arend, 2001). The daylight intensity also depends on variables like mist or air pollution, influence and characteristic of the regional and local climate, and geographical orientation (Matusiak, 2017); for example, Nordic landscapes share a subdued light that is considered to infuse the landscape with mystery

(Plummer, 2012). Changes in daylight intensity, from the reddish direct sunlight to indirect natural illumination of bluish light from the north (Foster, 2011), also change the perceived landscape colours. The surrounding vegetation and changes in observation angle and viewing distance also have a profound impact on the perceived colours in outdoor environments (Foster, 2011; Fridell Anter, 2000).

In an outdoor situation, the illumination shows greater variation than in a laboratory situation, with foliage and flowers having multiple absorbance peaks because of the mixtures of pigments, such as chlorophyll and carotenoids, as well as inconstant and changeable natural illumination (Foster & Amano, 2019). This makes it problematic to define colour constancy in outdoor environments (Foster & Amano, 2019; Arend, 2001), where variation of daylight intensity and complex natural structures are part of the colour experience. Colour constancy as a concept is not addressed in this thesis.

3.2 Models of landscape experiences

In an attempt to measure landscape quality, Daniel and Vining (1983) developed a framework for use when classifying and explaining reactions to landscapes. The model is divided into five approaches: the psychophysical, the psychological, the phenomenological, the ecological aesthetic, and the expert/formal aesthetic.

According to Lothian (1999), the psychophysical, psychological and phenomenological model relates to the subjectivist/psychological paradigm, while the ecological aesthetic and expert/formal aesthetic model relates to the objectivist/physical paradigm. The physical paradigm sees the landscape quality as an intrinsic attribute related to the physical landscape. In contrast, the psychological paradigm views the landscape quality as a human construction, based on, for example, associations, imagination and memories, where the landscape quality or beauty is an attribute in the eye of the beholder (Lothian, 1999).

The expert/formal aesthetic and psychological approach forms a framework for the perspectives and methods in this thesis. Figure 4 shows the relationship between the theoretical framework and the Papers (I-III) that make up this thesis.

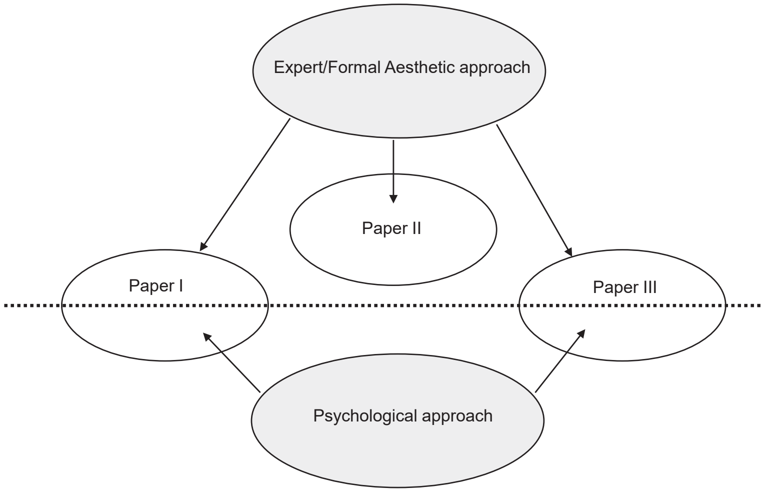

Figure 4. Relationship between the expert/formal aesthetic and psychological approach in the thesis. Papers I-III have an expert/formal aesthetic approach that, in Papers I and III, was complemented with a psychological approach

3.2.1 Expert and formal aesthetic approach

The expert/formal aesthetic approach has its origin in design theory, and aims to imply a relationship between landscape quality, formal properties (e.g. colour, form, size) and interrelationships within the physical attributes (e.g. scale, contrast, shape, diversity) (Bell, 2012, 2004; Dee, 2001; Daniel and Vining, 1983). Empirical studies in landscape assessments of visual quality focusing solely on the formal aesthetic model show low reliability (Daniel, 2001), but can still contribute with valuable information about the characteristic qualities of physical attributes in the landscape. In the expert/formal aesthetic approach, the principal observer of landscape beauty is a skilled respondent with expert knowledge (Uzzell, 1991). The skills are developed through training in, for example, art and design, and the respondents' expertise is seen as a base for aesthetic evaluation (Zube at al., 1982).

In Papers I-III, all colour assessments were mainly carried out by expert respondents, using a method related to the formal aesthetic approach.

3.2.2 Psychological approach

Studies based on a combination of approaches from physical and psychological paradigms have proved valuable when interpreting visual quality in the environment. This means that assessment studies of, for example, formal properties and physical attributes in the landscape, in combination with methods from a psychological approach, can generate comprehensive knowledge about, for example, the relationship between various design elements in urban recreation areas (Polat & Akay 2015), visual characteristics of roads (Blumentrath & Tveit, 2014), outdoor environments at nursing homes (Bengtsson et al., 2015), and perceived flower colour diversity (Hoyle et al., 2018). In Papers I and III, a combination of expert/formal aesthetic approaches and psychological approaches are used

3.3 Arousal and aesthetic concerns

Arousal is an intensity degree activated in the human being (Küller, 1991; Berlyne, 1971). It could be described as a physiological and psychological state of wakefulness where stages of arousal or activation and sleep (resting or slow wave sleep, asleep and dreaming) are controlled by the reticular activating system (RAS) (Garcia-Rill, 2009). The level of arousal or activation will reach the lowest levels during sleeping hours, and will undergo fluctuations during periods of waking hours. Psychological arousal has been receiving attention from researchers since the beginning of the 20th century (Silva, 2005). In the 1960s and 1970s, Daniel Berlyne developed an arousal theory with special concepts of aesthetics and hedonic qualities (Silvia, 2005; Walker, 1980). Since then, Berlyne's model has been used as a lens in various landscape studies (e.g. Motoyama & Hanyu, 2014; Mok at al., 2006; Wohlwill, 1979), but was mostly used during the 1970s (Silva, 2005).

Levels of arousal are influenced by immediate response (phasic arousal) as well as of more long-lasting activation (tonic arousal) (Howells et al., 2010). The studies included in the thesis do not separate the responses into phasic or tonic arousal, but it is likely that the result associates more with the phasic arousal that is directly stimulus related, whereas tonic arousal refers to slow changes. The reticular system responds to both under- and over-stimulation, so activities of varying degrees respond to levels of attention. When the attention is directed towards a stimulus, an orientation reaction occurs. Attention and orientation form a unified process where reactions of attention/orientation will be followed by increased levels of arousal (Küller, 1991). Reactions of attention/orientation are directed towards our environments, and especially in response to new and unexpected stimuli. Human experiences of being alert or excited are a result of stress, fear or anger (Berlyne, 1971), and could be connected to unexpected and new stimuli in the environment. A change in the attention/orientation, and consequently in the arousal level, is often accompanied by an altered change in pleasantness (Berlyne, 1971; Levi, 1972).

Stimuli such as exposure to different hues with both low and high radiant activity can generate pleasantness and aesthetic experiences. According to Berlyne (1971), bright light and intense stimuli activate the arousal level, and intense and bright colours have been found to be more arousing than pale colours (Wilms & Oberfeld, 2018; Al-Ayash et al., 2016). For a detailed description of the different visible wavelengths of light, see section 3.1.1 Light and colour perception.

Links between psychological arousal and the active colours red, orange and yellow, as well as the passive colours blue and green, have been shown in a number of experiments, where the link between red and excitement/stimulation and blue and calmness/relaxation is the most explored (Elliot, 2018). The literature shows some indications that red is more arousing than orange and yellow (Clark & Costall, 2008). However, some studies have shown no clear relationship between perceived colours and levels of arousal (Elliot, 2018; Hanada, 2018), indicating that the overall experimental set-up, various colour properties as well as situational factors interact in predicting levels of arousal.

The concept of hedonic value (Berlyne, 1971) shows the connection between arousal (activation) and the biological responses, reward and aversion (Berlyne, 1971). Hedonic values (degree of positive, indifference and negative values related to experiences of any activity) are intimately associated with how arousing or unarousing a stimulus is. Berlyne's arousal model proposes that a reduction in high arousal and a modest increase in low arousal may be experienced as pleasant (area B in Figure 5) (Küller, 1991; Berlyne, 1971). According to Berlyne (1971), pleasure is a question of experienced degree of arousal, where arousal in turn is dependent on three psychobiological variables: collative, psychophysical and ecological variables (Palmer et al., 2013). The collative variables, e.g. novelty, complexity, expectations and conflict, involve comparison and response to similarity or differences, while psychophysical variables relate to sensory dimensions of the perceived object, e.g. colour, size and visual forms. Associations linked to environmental objects relate to ecological variables (Palmer et al., 2013; Berlyne, 1971). According to Berlyne's theory, the collative variables are the most important when connecting degrees of arousal to pleasantness (Palmer et al., 2013; Berlyne, 1971), where the hedonic concept in assessment studies is commonly referred to as aesthetic studies (Küller, 1991).

The collative variables – novelty and complexity

Formal properties and physical attributes such as colour and contrast seem to influence arousal and experiences of aesthetic satisfaction. Through Berlyne's (1971) collative variables, stimuli patterns can be discussed in relation to levels of arousal and aesthetic pleasure (hedonic values).

Novelty and complexity are part of Berlyne's collative variables. The link between degree of complexity and novelty, and the effects on aesthetic value (hedonic value) and levels of arousal interpreted with the Wundt curve and Berlyne´s model, are shown in Figure 5. The degree of novelty and complexity is related to whether a pattern or environment has been seen before or has not been seen at all. According to Berlyne (1971), it is likely that familiarisation in relation to a perceived stimulus, reduces perceived complexity and reduces complex patterns by grouping the elements to logical structures.

Berlyne (1971) also suggests that, if the levels of complexity or novelty increase, the primary reward system becomes increasingly active, generating positive experiences and pleasantness. In turn, if complexity or novelty continues to increase, an activity is created in the aversion system, generating an unpleasant experience. The argument is connected to an inverted-U function, with aesthetic pleasure as a consequence of increased activation in levels of arousal, and a reduction in pleasantness if the level of arousal increases too much.

All stimuli patterns and their properties that can increase arousal can be referred to as arousal potential (Berlyne, 1971). In Figure 5, region A represents stimuli with simple properties and attributes and a situation of familiarity. In region B, the stimuli generate moderate complexity and moderate novelty, where moderate complexity has shown the ability to generate aesthetic pleasure (Marin & Leder, 2013). In region C, the stimuli are characterised by maximum complexity and maximum novelty.

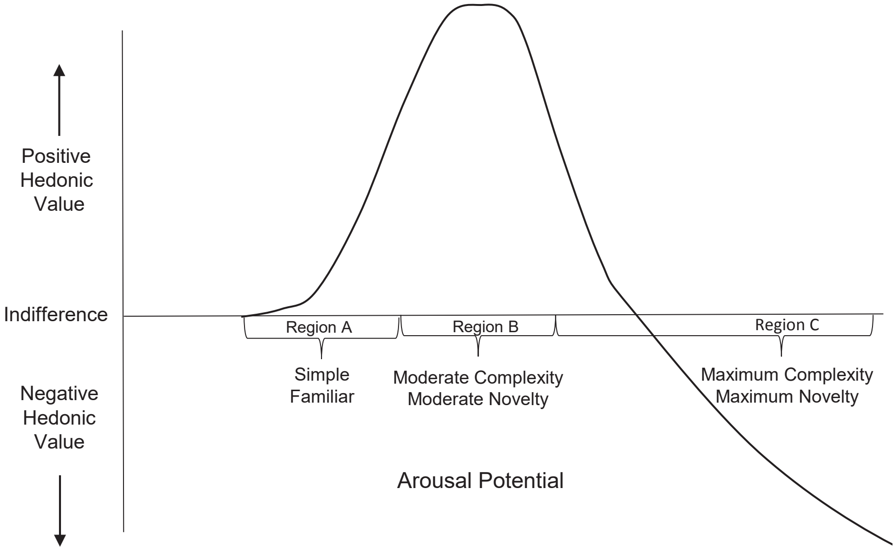

Figure 5. The relationship between arousal and reward/aversion. Berlyne´s model suggests that an increase of low arousal (Region B) or a decrease of high arousal (region C) produces moderate arousal (Region B) and will be experienced as pleasant. The figure also shows three areas (regions A-C) of novel and complex situations that have an effect on the hedonic value and levels of arousal. When a stimulus generates maximum complexity and maximum novelty, the arousal level is at the right end of region C, and can be expected to be referred to as unpleasant (negative hedonic value). After a while, a stimulus can represent less arousal potential and progressively move towards moderate complexity and moderate novelty (positive hedonic value), and gradually becomes indifferent (simple and familiar). The figure is developed after Berlyne (1971).

3.4 Summary of the theoretical framework applied in the thesis

From a theoretical point of view the studies are linked between the expert/formal and psychological approaches within the physical and psychological paradigms. The motivation behind such a methodology was to reach a broad understanding about human perceived colours and linked experiences relating to perceived characteristics of colour effects in urban green spaces.

All empirical studies (Paper I-III) conducted in this thesis use the formal aesthetic approach to obtain an understanding of the connection between colourful design solutions and experienced colours. To link perceived colours to human experiences, Papers I and III used a psychological approach and Berlyne's arousal theory as a framework.

The main findings from the empirical studies in this thesis are structured around Johannes Itten's colour contrast concepts from the 1960s (Itten, 2002) and Berlyne's arousal model (1971) and the concept of hedonic values. Johannes Itten's explanation of the concepts complementary contrast, light-dark contrast and cold-warm contrast are used as a frame and interpretation tool in relation to the main results. Since Berlyne (1971) connects and discusses colour in relation to arousal and aesthetic pleasure, and the aim of the thesis is to understand human colour perception and linked experiences, Berlyne's arousal model has served as a structural frame. The use of the arousal model is especially important in Papers I and III, where it acted as a frame and lens in the interpretation of the main results discussed in the thesis and in the discussion about practical implications.

4 Research design

The research was conducted in the form of quasi-experiments and combined studies of colour perception and environmental assessment methods. The studies (Papers I-III) were performed in situ, and were designed from a colour point of view in various urban green contexts.

In many urban green spaces, limited size and surrounding buildings imply that vegetation structures are mostly experienced from relatively short distances, where the distance between our perception and what we see adjust to each situation in a continuous alteration (Bell, 2004). According to Gehl (2006), even a slight change in viewing distance alters our sensory impression, with nuances clearly perceivable at distances of up to only 0.5 metres. Clarity of the visible situation is reduced as viewing distance increases from 0.5 to 7 metres, while at a distance of around 20 to 25 metres, perception is directed more towards atmospheres and movements. The studies here therefore involved different viewing distances, to reflect situations found in many urban green spaces.

In Paper I, three young woodland systems (monoculture, two-species mixture and species-rich mixture), were analysed from three viewing distances (inside the stand, from 7 metres and from 20 metres) on four season-related occasions (winter, spring, summer and autumn). The methods in Paper I enabled an understanding of how experienced colour contrast is related to long (20 metres) and short distances (inside the stand), species mixtures and recurrent colour schemes in a full-scale experimental setting in southern Sweden.

To further investigate the colour phenomena in relation to perceived characteristics of colour effects and various viewing distances, the study in Paper II focused on a short viewing perspective (3 meters). The study examined colour theory and considered the consequences of using yellow, red and blue artefacts in plantations dominated by green hues. Artefacts with the primary colours (yellow, red and blue) were placed as a screen behind the vegetation and on the foliage (patches) of 'dark', 'average' and 'light' green ground cover plants. The study was theory driven, with the aim to determine whether primary colours have an impact on the perceived colours of green vegetation. The outcome from Paper II served as inspiration for the methodological design in Paper III. Paper III explored how coloured artefacts (orange hue) influence the perceived colour situation and related experiences in a public park. The viewing distances in Paper III were on average 15 metres (Figure 6).

The environment used for the study in Paper II was characterised by low structural complexity, while the environments in Papers I and III were characterised by slightly higher and clearly higher structural complexity. The following sections present the main methodological set-up for this thesis, with a research design mainly focusing on colour perception and related characteristics of colour effects and environmental assessment methods.

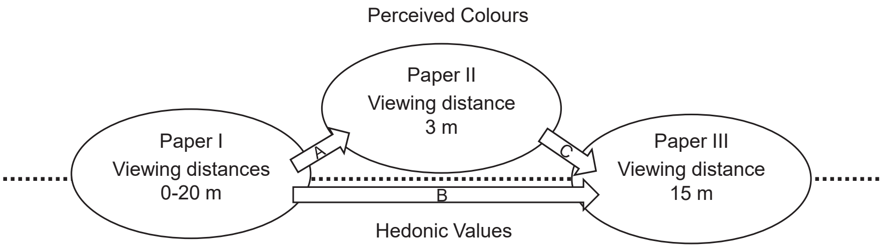

Figure 6. The process in the figure shows how knowledge generated from the initial studies in Paper I guided the study design in Paper II (arrow A). The results from both Paper I and Paper II guided the study design in Paper III (arrow B-C).

4.1 A quasi-experimental approach

In order to meet the objectives and increase understanding of human perceived colours in urban green spaces, the studies applied quasi-experiment strategies with two or more treatment levels or changed conditions as a research method. The quasi-experiment method is a valuable strategy for maintaining an experimental approach in research studies outside the laboratory, and is one of the most common experimental strategies used in landscape architecture (Swaffield & Deming, 2012; Robson, 2011; Deming & Swaffield, 2011). Using such an approach is also suitable when the research subjects are human beings (Deming & Swaffield, 2011). In a quasi-experiment approach, conditions in the landscape setting that can influence the variation can be selected for observation, by matching similar characteristics but with changed treatments or by observing alterations in time (Butsic et al., 2017; DiNardo, 2008).

A combination of different data sources ensures a broad perspective and understanding in the studies that make up the thesis. A triangulation approach to research studies increases the validity of findings and helps consider complex situations and phenomena, such as studies performed in real world settings (Denzin, 2009; Bryman, 2006). A triangulation approach was therefore used to reach a comprehensive understanding of the situations studied.

In the three papers, the landscape variation is used as a frame, either by modifications of, e.g. viewing distances or changes in visual composition, or by alternating between grey and green environments. Different treatments and conditions characterised all three studies. In Paper I, a repeated measure design was used, with a focus on time (seasons), distance and vegetation structures. A more experimental character was apparent in Papers II and III, where coloured artefacts were placed and tested in various environments. Paper II focused on colour aspects in relation to ground cover vegetation and Paper III on effects of artefacts in various landscape environments. In Paper III, a balanced factorial design was used, with a representative selection of respondents, while in Paper II the respondents were block in a complete block design.

Triangulation

Papers I-III are based on three separate empirical studies. I used a strategy of multiple triangulation, linking theories, data and observer strategies, to attain the aims and answer the research questions. In Papers I and III, concepts from a psychological approach were used together with a formal aesthetic approach. In Paper II, an expert/formal aesthetic approach explored colour design qualities.

All studies involved an observer triangulation, using multiple or single observers (Denzin, 2009). The multiple observer triangulation increases the reliability in the observations and reducing possible bias (Denzin, 2009). In Papers I and III, a data triangulation approach was used, and the method of data collection comprised measurement of colours, human aesthetic evaluation (written reflections on colour), written colour notations and free reproduction of the colour experience (Paper I). In Paper III, observations, questionnaires and colour measurement form the study design, and in Paper II, colour measurement was the main evaluation tool.

4.2 Selection of method for determining outdoor colours

Colours can be evaluated and recorded in several ways. In laboratory conditions, the studies are controlled, and the setting makes it possible to carefully choose and isolate the colour stimulus. In contrast, colour perception in outdoor conditions is influenced by weather and light conditions at the time of the observation (Oleksiichenko et al., 2018; Arend 2001). A convenient method in outdoor settings is to use either a portable colour-measuring instrument (colorimetric method) that measures, for example, chromaticity coordinates and colour differences (CIE, 2004), or use images from digital cameras or manipulated pictures. Images from digital cameras have been used to measure landscape colours (Oleksiichenko et al., 2018), vegetation cover (Liu et al., 2011), and plant leaf and flower colour (Kendal et al., 2013).

According to Fridell Anter (2000), methods measuring colour radiation with colour measurement instruments (spectrometer, digital camera) give no direct relationship between the radiation in the physical measurement and the colours humans perceive. Methods that measure colour radiation were excluded from this research, since the main objective was to study human colour perception.

Various methods have been used to assess personal colour experiences, with the aim of generating knowledge and improving understanding about perceived colours in the outdoor environment. A recent study describes and systematically analyses personal subjective experiences of light in the landscape using a self-reflecting writing method (autoethnographic approache) (Edensor, 2017). Some studies use photograph-based methods (Polat & Akay 2015) or on-site questionnaires (Hoyle et al., 2018), while others have used phenomenological colour approaches in relation to architecture (Pernão, 2017) as well as in relation to observed colour effects in experimental rooms (Billger, 1999). The phenomenological model can gather perceptual characteristics of an environment and focus on expectations, interpretations and individual subjective experiences (Pernão, 2017; Daniel & Vining, 1983).

Another frequently used measurement technique is the portable colour-measuring instrument, where the assessed colour is given a code that is related to a specific colour in a portable colour chart. Methods like this have regularly been used in outdoor colour determination studies, where colour perception is at its core. Examples are the Royal Horticultural Society (RHS) Colour Chart and the Natural Color System (NCS) Color Atlas (Grose 2016; Levinsson et al., 2015; Nilsson, 2013; Fridell Anter, 2000). These types of tool have advantages, since the result can be calculated in statistical programs and they are easy to implement and understand.

Royal Horticultural Society (RHS) Colour Chart

The RHS colour chart devised for determining colours for botanical and horticultural purposes and descriptions (Voss & Hale 1998; Voss, 1992; Tucker et al., 1991) was used in all three empirical studies. The respondents were given three minutes to assess each colour situation from a general point of view (the respondents assessed the three most dominant colours), in each study respectively. All colour assessments were done between 10 a.m. and 2 p.m. to avoid excessive differences in colour temperature. In Papers I and II, all colour assessments were done in overcast weather, to avoid the glitter and reflective surfaces associated with direct sunlight. The study described in Paper III consisted of two main parts, firstly a questionnaire and secondly a colour assessment. As the seasonal weather varied from sunny to partly sunny, the following colour assessment was used under the same weather conditions to ensure a consistent result.

In Papers I and II, the respondents used the RHS04 system (Mini Colour Chart), containing 244 RHS colour samples, representing a wide spectrum of colour samples found in the RHS Large Colour Chart (Royal Horticultural Society, 2017). In Paper III, the main author, with professional qualifications in fine art, used the large colour chart system (RHS 6th edition) containing 920 colour samples. The RHS Colour Chart system derives from Albert Munsell's colour space system (Austin 1998; Voss, 1991), and is based on human visual responses to colour (Landa & Fairchild, 2005). Munsell's colour system specifies colours on the basis of three colour dimensions: hue, value and chroma (Kuehni, 2002, Munsell, 1905) and forms the basis for models such as CIELAB ($L^*a^*b^*$) colour space (Landa & Fairchild, 2005).

4.3 Selection of hues of applied artefacts

To improve understanding of human perceived colours, artefacts with yellow, red, blue (Paper II) and orange (Paper III) hues were incorporated in various green surroundings. The colours were chosen to reflect today's common practice of placing colourful intense red, orange, yellow and, to some extent, blue artefacts in urban green spaces. The green hue with its calming and relaxing character (Clark & Costall, 2008; Mikellides, 1989) forms the context in all papers included in this thesis.

Links between viewing red and orange hues and activation on the arousal level has been observed in experiments (e.g. Costa et al., 2018; Al-Ayash et al., 2016), where the red hues in relation to levels of arousal are well investigated while the orange hues have received less attention (Elliot, 2018). Since orange hues are used on artefacts in today's landscape architecture, and are not so well investigated in relation to human levels of arousal (Elliot, 2018), the orange hue was used in Paper III. In Paper II, the active primary colours red and yellow, as well as the passive blue primary colour, were used on the artefacts. Red hue has flexible effects, where red on green is a loud and rash intruder and yellow is associated with reflections and light, while the passive blue hue has a calming and humble character (Al-Ayash et al., 2016; Itten, 2003).

4.4 Selected methods for environmental assessments

In this thesis, assessment studies of perceived colours are combined with methods from environmental assessment measurements (Papers I and III). The following sections describe the methods used in relation to the aims.

4.4.1 Self-completion questionnaires

To evaluate human-environmental assessment in relation to colourful objects in an urban green context, I used self-completion questionnaires (Robson, 2011) as a method. In Paper III, the semantic environmental description developed by Küller (1973) was used. The semantic environmental description, which in Swedish is called Semantisk Miljöbeskrivning (SMB), is a standardised quantitative method intended for use as a tool in systematic descriptions of interior, exterior or simulated environments (Küller, 1991). The method has shown documented reliability and high stability over time (Laike, 1990). The SMB method has been used in, for example, different studies of colour space (Mikellides, 1989), and in measurement of visual aspects and variations along forest trails (Axelson Lindgren & Sorte, 1987), as well as comparing outdoor environments at nursing homes (Bengtsson et al., 2015) and influence of environmental features at daycare centres (Laike, 1997). The SMB model includes eight dimensions: pleasantness, complexity, unity, enclosedness, potency, social status, affection and originality. See Paper III for descriptions of the eight dimensions and adjectives included in each dimension.

In Paper I, the respondents measured their instant and spontaneous response (Lothian, 1999) through self-completion questionnaires. Written reflections of the perceived colours was the main evaluation method, and the respondents reflected on and described (in their own words) the ways in which they were aroused by the perceived colours (Sivik, 1995). The use of descriptive words was encouraged and some examples, e.g. ‘beautiful’, ‘pleasing’, ‘ugly’, ‘desolated’, were given in the questionnaires.

The methods used in Paper I and Paper III do not connect the assessed results to visual aspects such as design elements (Karlsson et al., 2003; Küller, 1991), so it is valuable to include an interpretation step to validate the results in relation to other methods (Küller, 1973). In Papers I and III, the results from the environmental assessment studies are connected to physical elements in the environment, to ensure a connection between human psychological responses and experienced colours.

4.5 Respondents in Paper I, II and III

Table 1 show the numbers of respondents in Papers I-III, as well as the distribution between expert, non-expert, female and male participants. The participants in Papers I-II consisted of students (second- and third-year students) trained in landscape design and enrolled on the Garden Design specialisation programme at the Swedish University of Agricultural Sciences, Alnarp. Employees in the field of landscape design and management at SLU, Alnarp, constituted a small number of respondents in Paper I. Four respondents from the group of employees can be categorised as non-expert, since they were not trained in landscape design or art.

The participating student groups in Papers I and II were all trained in colour theory and in colour determination, which increased the stability and credibility of the results (Sivik & Hård, 1979). In Paper III, the respondents were selected from a pre-survey of the average park visitors in terms of gender and age. One professional respondent evaluated the colour environment. The group of respondents in Paper III were park visitors, and were categorised as belonging to the group of non-experts.

Table 1. Respondents in the studies in Papers (I-III); distribution between experts and non-experts and between female and male respondents

	Number of respondents	Experts	Non- experts	Female	Male
Paper I	23	19	4	18	5
Paper II	27	27	0	23	4
Paper III	103	1	102	66	37

4.5.1 Ethical considerations

All studies included in this thesis followed the ethical declaration from the European Science Foundation, and were performed in line with the guidelines in the document 'The European Code of Conduct for Research Integrity' (ESF & ALLEA, 2017).

The respondents were informed about the aims and objectives of the research projects. The overall set-up was described before the colour assessments and completion of the questionnaires. All participation in the studies was voluntary, and involvement in each individual research phase could be discontinued at any time during the process. To motivate the student groups, it was explained that participation in the studies contributed to know-how concerning design principles in the field of landscape architecture. They were also informed that all participation in the research project was voluntary, and that non-participation in the studies would not affect their examination results. To protect the individuals, the raw data was anonymised and coded.

4.6 Analysis and interpretation of data

In Paper I, the primary sources of data were colours determined according to the RHS04 system and written reflections in relation to the preferred colour situation. The analysis of the perceived colours focused on the perceptual attributes of hue and Munsell value and chroma (Munsell, 1905). The hue was systematically organised in distinct characteristics, e.g. green hues from blue, red, yellow etc., and the perceived values and chroma were categorised according to the value and chroma scale according to Edwards (2004). The written reflections of the experienced colours were categorised in relation to hedonic values according to Berlyne (1971). The reflections were counted and grouped into positive and negative associations. When a balance occurred between a positive and negative reflection, the association was classified as indifferent.

In Paper II, the perceived colours were converted from the RHS04 colour chart system into the CIE ($L^*a^*b^*$[1]) space using a Konica Minolta Chroma Meter CR-400, and the perceived colour differences between the colour situations were tested by analysis of variance. To compare different colour situations, PROC MIXED in SAS software was used, with colour situation as fixed factor and respondents as random block factor. The analysis was run

[1] L^* represents lightness of the colour; a^* represents a spectrum from green to magenta; b^* represents a spectrum from blue to yellow (Kendal et al., 2013).

separately for L^*, a^* and b^*. To visualise the effect of the colour situations, scatter plots of the mean values of the variables L^* versus b^*, L^* versus a^*, and b^* versus a^* were created.

To statistically analyse the respondents' assessments of the SMB dimensions in Paper III, an analysis of variance was used, with a 3x2 factorial design, with the factors artefacts and character, and the interaction between character and artefacts. Using the same 3x2 factorial design, the 36 adjectives were measured separately. When analysing the marginal effects of character and artefacts, LSMEANS with SLICE in PROC MIXED was used. The perceived colours in Paper III were analysed and ranked by their dominance in the environment according to the 6th edition of the RHS colour chart system. The colour assessment was analysed using a qualitative comparative analysis, with tables as a technique.

The main results from each individual paper (Paper I-III) are analysed according to Johannes Itten's colour contrasts: complementary, light-dark and cold-warm contrast and summarised in the next section.

5 Papers I-III – Summary of the main results

This chapter provides a summary of the results of each of the three papers included in this thesis. For a detailed description of the papers, see the method description and the theoretical chapters, as well as the printed version of the Papers I-III, included as appendices.

5.1 Results of Paper I: Experience of vegetation-borne colours

The results from Paper I demonstrate how the perceived colours change their characters primarily due to changes in the investigated viewing distances (inside the stand, and at distances of 7 metres and 20 metres from the stand) and the seasons (winter, spring, summer, autumn).

In comparison the species mixture, from a monoculture of Quercus robur L., via a two-species mixture of Quercus robur L. and Prunus padus L., to a species-rich mixture with species such as Corylus avellana L. Fraxinus excelsior L., Quercus robur L., Tilia cordata Mill., and Prunus avium L. were less influential.

When viewed from a distance of 20 metres, colours could be discussed in terms of being a 'colour mass'. At that distance the colours are perceived as a uniform mass, sustained by a body of vegetation, ground surface colours and reflections from the sky, creating a united compound of light and colours. One observation was that least positive hedonic values (respondent's notations were dominated by negative associations, e.g. 'deserted', 'gloomy') were noted when the stands were viewed at 20 metres away from the forest stand, except for spring time, which shows predominantly positive hedonic values in relation to this distance. The result may depend on the visible variation with maximum complexity/novelty that a viewing distance of 20 metres generates. Colours from numerous sources are mixed together, creating a complex situation where the level of arousal can be expected to be in the lower end of the right-hand region (region C) in Figure 5.

In contrast, when the forest stands were viewed from a distance of 7 metres, the situation was perceived as having positive hedonic values (respondent's notations were dominated by positive associations e.g. 'warm', 'fresh'). This was particularly evident during the spring, summer and autumn seasons. At this distance, the perceived colours of the leaves were interlinked with the dark colours of the stems and branches of the species, as well as the surrounding light situation.

According to Itten (2003), a positive experienced arrangement can be created with a light-dark contrast composition in black, white and greys and with two to four main colours. Knowledge rooted in colour theory seems to support the results of this study. The light and dark contrast observed from a distance of 7 metres can therefore be described in terms of being architectural, and perceived as 'colour architecture'. The positive hedonic values from a distance of 7 metres can be a result of a contrast effect, and the probable scenario is that the arousal level is moderate, and the visible features have a moderate complexity and novelty (region B in Figure 5).

Inside the forest stands, the view was dominated by stem and branch structures, and the perceived colours were influenced by a more shaded condition. The light-dark contrast was not as obvious as the perception from a distance of 7 metres. Despite this, positive hedonic values were noted inside the stands.

5.2 Results of Paper II: The impact of the primary colours yellow, red and, blue on the perception of greenery

The results in Paper II show that artefacts (screen and patches) with yellow, red and blue colours influence the perceived green colours of 'light' green vegetation like Matteuccia struthiopteris (L.) Tod., 'average' green vegetation, such as Geranium macrorrhizum L. 'Spessard', and of 'dark' green vegetation like Hedera hibernica (G. Kirch.) Bean. The analyses of CIE ($L^*a^*b^*$) show that the values of the light spectrum L^* and the blue-yellow spectrum b^* were strongly correlated. The results demonstrated clear differences between the perceived green colours of the studied plant species, with the green colours being perceived as more 'light' or 'dark' green.

The statistical analysis showed a significant effect, mainly concerning the yellow and, to some extent, the blue and red primary colours placed on (patches) or behind (screen) the foliage of the studied plants, Hedera hibernica and Geranium macrorrhizum 'Spessard'. As an example, the yellow patches caused the green colours of Hedera hibernica to be perceived as significantly more 'dark green' in relation to the control, while the green colours of Geranium macrorrhizum 'Spessard' were perceived as significantly more 'light green'. The results partly relate to colour theory and colour theorists like Johannes Itten (2003), accentuating the importance of colour proportions and perceptions of distinct differences between colours for colour contrast.

Patch artefacts with primary colours in a combination with dark green vegetation (Hedera hibernica) seem to possess the correct proportions and colour combinations for a colour contrast to occur. The arrangement with 'dark green' vegetation and yellow, red and blue patches could therefore emphasise a perceivable colour contrast (complementary, light-dark and cold-warm contrast). In contrast, results from the study indicate that 'average' green vegetation, like Geranium macrorrhizum 'Spessard', may reduce such a contrast effect.

5.3 Results of Paper III: Perceived colours and visitor experiences of urban parks as influenced by colourful artefacts: An in-situ quasi-experiment

The results from Paper III show that orange artefacts placed in a public park dominated by buildings and paved areas, as well as in areas dominated by greenery, can influence levels of arousal and generate both positive and negative hedonic values. The orange hue in combination with the dominating green surrounding of vegetation formed an optimal situation for a colour contrast to occur. This suggests that orange artefacts incorporated in the area with high proportions of green (naturalistic character) had the right quantitative proportions of green and orange hues for a complementary and cold-warm contrast to arise. The results also show that environments containing green vegetation in combination with orange artefacts had a significantly higher value for the SMB dimension 'pleasantness', indicating that the respondents experienced moderate levels of complexity/novelty (arousal) (Figure 5, region B) and positive hedonic values (e.g. 'idyllic', 'good', 'pleasant').

In contrast, the area with a predominance of greyish colours (plaza character) and orange artefacts present, showed low values of pleasantness. This indicates that the plaza character with its predominantly grey environment in combination with orange artefacts influenced levels of arousal in the lower part of region C (maximum complexity/novelty) with negative hedonic values as a consequence (Figure 5).

The main results from the study show that a park environment can either limit or promote how coloured (orange) artefacts will be perceived and experienced. The results also indicate that a perceived complementary and cold-warm contrast in a naturalistic setting might affect levels of moderate complexity and novelty and thereby increase pleasantness.

5.4 Overall results of Papers I-III

The overall results indicate that perceived characteristics of colour effects, such as colour contrast, in urban green spaces vary according to the conditions. A complementary and cold-warm contrast effect seems easier to achieve in areas with the presence of coloured artefacts placed in the vegetation, rather than when only vegetation is the design element. The result from Paper I shows that the distance between the viewer and the vegetation has a greater influence on the perceived colours than the species mixture. The light-dark contrast was the main contrast effect (Figure 7). In Paper II a complementary contrast and, to some extent, a light-dark and cold-warm contrast effect occurred in specific coloured situations, while in Paper III, a complementary and cold-warm contrast emerged in a green-orange surrounding (Figure 7).

5.4.1 Influence of viewing distance on perceived characteristics of colour effects in urban green contexts

The results from Papers I-III suggest that different colour contrast effects (complementary, light-dark and cold-warm contrast) can be produced at different viewing distances. This is particularly evident in Paper I, where the light-dark contrast in the vegetation was most noticeable from a distance of 7 metres (Figure 7). The light-dark contrast was also part of the colour experience inside the stand (0 metres), but was less noticeable. At 20 metres from the situation, no colour contrast occurred. A light-dark contrast was also noticeable in some of the studied situations in Paper II. Together with the results from Paper I, a conclusion can be drawn that light-dark contrast as manifested in the studies of Papers I and II may be perceived from a viewing distance of 0 to 7 metres (Figure 7). The results also show that the perceived colours vary according to conditions, such as altered distance to the perceived situation.

In Papers II and III, the light-dark contrast was less noticeable. Instead, a complementary and cold-warm contrast was the dominant contrast effect. In Papers II and III, the vegetation in focus was studied from viewing distances of 3 and 15 metres, and the contrast effect was maintained. The sustained contrast indicates that a complementary and cold-warm contrast can be a stable perceived colour contrast in public parks regardless of distance (Figure 7).

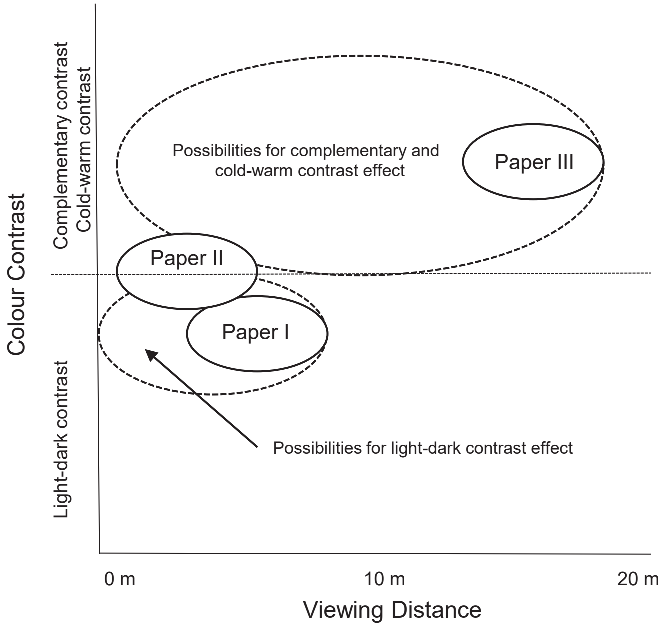

Figure 7. The ovals (Papers I-III) show the influence of viewing distance on perceived complementary, cold-warm and light dark contrast. The dotted ovals point suggest that light-dark, complementary and cold-warm contrasts may be perceivable.

5.4.2 Colour contrast and prerequisites of moderate arousal

Through the lens of Berlyne's arousal theory (1971), the results from Papers I and III indicate that perceived light-dark, complementary and cold-warm contrasts are possible to interconnect with moderate levels of arousal and positive experiences.

In Paper I, positive hedonic values were observed when the effects of light-dark contrast were present. This was most evident from a distance of 7 metres, and was reduced but still noticeable at distances down to 0 metres (inside the stand). This indicates that light-dark contrast might cause moderate arousal from a viewing distance of 0 to 7 metres, and offer opportunities for positive human experiences (Figure 8).

In Paper III, the environment dominated by green vegetation and incorporated orange artefacts gave rise to pleasurable experiences. This indicates that complementary and cold-warm contrasts have the possibility to generate moderate levels of arousal from a viewing distance of 15 metres. Together with the results from Paper II, this shows that complementary and cold-warm contrasts can be perceived from a viewing distance of 3 metres. The conclusion can be drawn that it is likely that the appearance of complementary and cold-warm contrasts varies widely, and consequently for moderate arousal to occur at distances of 3-15 metres (Figure 8).

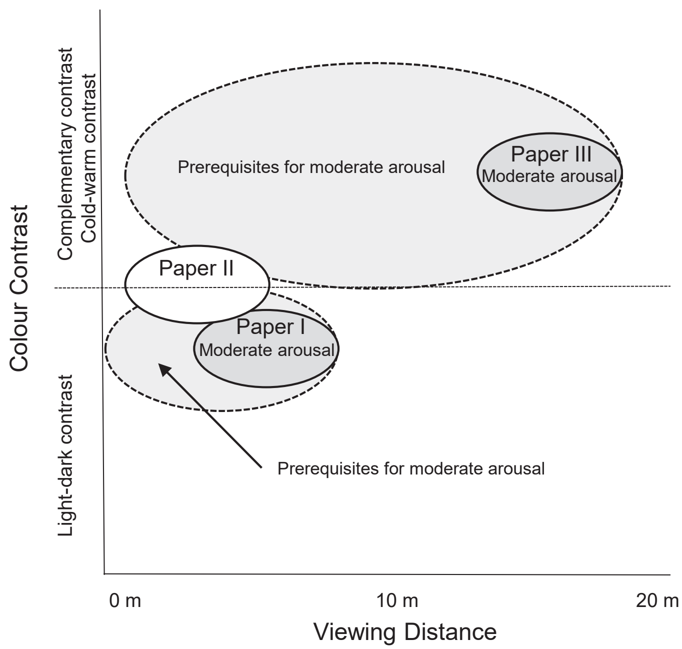

Figure 8. The dark grey areas show the connection between perceived colour contrast and moderate arousal. The dotted and light grey areas indicate possibilities for experiences of moderate arousal from 0 metres up to 7 metres for light-dark contrast and from 3 metres up to 15 metres for complementary and cold-warm contrast.

6 Discussion and reflections

In contemporary landscape architecture there is a tendency for vegetation structures to be complemented with, and at times even replaced by, intensely coloured artefacts. An in-depth understanding of the effects on human colour perception and linked experiences should be an important issue, both within research and in landscape design practice.
In the discussion, the four following aspects will be mainly considered, and related to the current knowledge base, as well as in relation to urban design practice:

- Effect of viewing distance on perceived characteristics of colour effects
- Transient and sustainable colour contrast effects
- Impact of perceived colour contrast on levels of arousal
- Methodological considerations and constrains

6.1 Influence of viewing distance on perceived characteristics of colour effects

The studies included in the thesis involve a viewing distance of 20 metres down to a more close-up plant border perspective. This makes it possible to present both a specific and a more general picture of perceived colours in relation to distance. The approach using various viewing distances also contributes to the overall understanding about perceived colour contrast in the outdoor environment. This is especially important, since the effects of viewing distance on colour perception and perceived colour contrast have not been investigated in detail and published studies show inconsistent results. As examples, Arriaza et al. (2004) showed a significant correlation between viewed scale and perceived colour contrast, unlike a study by Wang et al. (2016) that showed no such effect.

In each of the studies, the viewing position was fixed at a given distance. This entailed some limitations to the results, since human experience in a landscape context in most cases is not related to a static position of the viewer and a fixed viewing distance. Humans are mostly on the move and colour perception should therefore be explored in a variety of ways and situations. Although relatively few viewing distances were used in these studies, the fixed position in the studies could be compared with the view from benches placed in woodland situations or in urban park environments. This makes the results useful in cases when decisions are to be made about, for example, the placement of brightly coloured playground equipment, street furniture or vegetation structures. The results also give some indications about placement of, for example, waiting zones (e.g. bus stop, train station) and walking routes in relation to viewing distance and seasonal colour variations.

6.2 Colour contrast in outdoor environments – transient or sustainable effects

The effect of colour contrast in outdoor environments has proved to be an important parameter in the assessment of visual beauty (e.g. Oleksiichenko et al., 2018; Eroğlu et al., 2012; Arriaza et al., 2004). However only a small number of studies have referred to detailed contrast effects and shown the connection between, for example, complementary and light-dark contrast and related positive experiences (Huang & Lin, 2019; Polat & Akay, 2015; Eroğlu et al., 2012). The perceived colour contrast effects generated in the studies (Papers I-III) complement previous research and provide an opportunity to incorporate this knowledge into planning processes.

In relation to previous studies, the work presented in this thesis connects detailed experiences of characteristics of colour effects, like complementary, light-dark and cold-warm contrasts, with the effect of changing viewing distances on the overall experience. The studies (Paper I-III) show that the complementary colour contrast effects might be an even more positive factor if the coloured artefacts are combined with, for example, evergreen structures. The colour contrast can then remain stable throughout the year, unlike when intense coloured artefacts are embedded in deciduous vegetation. The effect of colour contrast in such situations will be reduced during the rest period in wintertime, when the positive impact of the contrast effects will be reduced or even lost.

A complementary contrast seems harder to achieve in situations where vegetation is the main design element, compared to environments where the colours are easier to control and keep stable through the year. In situations where greenery dominates, using mainly light-dark contrast effects appears to be a good course of action. However, results from the studies included in this thesis give the impression that a light-dark contrast effect has a more transient character than the effects of complementary contrast. The studies (Papers I-II) indicate that perceivable light-dark contrast effects occur when the viewing distance from the perceived situations is relatively short and the situation is clearly visible in close-up. In contrast, a complementary and cold-warm contrast effect perceived in an unchanging and relatively stable context seems to have a longer viewing range and sustainable perceivable effects.

6.3 New conditions and perceived colour changes

The coloured artefacts in the studies can be associated with common colourful artefacts found in our surroundings, such as street furniture (Figure 9, left; Figure 10, right), and fitness equipment (Figure 13, right) or contemporary landscape architecture (Figure 9, right; Figure 12, left/right). The placing of bright coloured artefacts in urban green spaces creates new conditions and perceived colour changes. As stated in this thesis and related literature, a perceived colour contrast in outdoor environments can generate positive values and experiences for humans (e.g. Oleksiichenko et al., 2018; Arriaza et al., 2004), which can be regarded as a clear quality in urban green spaces.

Intense and bright colours can influence levels of arousal and thereby generate perceived positive or negative aesthetic pleasure (Wilms & Oberfeld, 2018; Al-Ayash et al., 2016; Berlyne, 1971). Knowledge of how human perception changes in relation to integrated colourful artefacts is important, and leads to the conclusion that coloured artefacts create new conditions and can transform the perceived colours and related experiences.

Figure 9. Left: yellow and orange street furniture in a public square in Bollnäs, Sweden, designed by Karavan landskapsarkitekter, 2016. *Photo:* Johan Fowelin. Used with permission. Right: contemporary landscape architecture in bright orange hue in “Rigets have” at Rigshospitalet, Copenhagen, Denmark, designed by LAND+, 2008.

Figure 10. Left: playground in central Lund, Sweden. Right: blue street furniture in a public park (Stadsparken) in central Lund, Sweden.

Figure 11. Left: playground in central Copenhagen, Denmark. Right: red seating places and contemporary landscape architecture designed by Kongjian Yu, Turenscape, 2010, at Shanghai Houtan Park, Shanghai, China, used with permission.

Figure 12. Left: contemporary landscape architecture in a bright yellow hue on Amir Avenue, Hadera, Israel, 2017, designed by BO Landscape Architecture. Used with permission. Right: contemporary landscape architecture in Copenhagen designed by 1:1 landskab 2015, at Gulbergs plads, Denmark.

6.3.1 Transformed experiences and potential changes in arousal level

The frequent use of active colours on today's artefacts in urban green spaces might be traced back to colour theory publications emphasising active/passive (red-orange/blue-green) combinations as complementary pairs and with a high rate of cold-warm contrast. However, the right proportions and distinct differences are crucial in creating a contrast effect (Itten, 2003). In some situations in today's urban landscape, it can be hard to achieve such a contrast effect or, conversely, a strong and stable colour contrast need not necessarily be a positive factor in all regards. Examples are the use of primarily active colours on, for example, playground equipment in relation to surrounding coloured ground surfaces (Figure 10, left), entire neighbourhoods 'painted' in red, orange and pink colours, like the 'Red Square' in Superkilen, Copenhagen (Figure 13, left) or the use of coloured hard materials in combination with fitness equipment in a contemporary residential park in Uppsala, Sweden (Figure 13, right). The use of many bright colours concentrated in a limited area could lead to maximum levels of complexity/novelty and raised levels of arousal, and consequently unpleasant areas. It is most likely that artefacts that are easy to understand and with a clear purpose, such as playground and fitness equipment, are easier for humans to understand and thereby easier to accept as a novel element in the outdoor environment.

The choice of colours on incorporated artefacts and the surrounding colour schemes has been found to be important for perceived colour contrast and thereby for potential changes in arousal level. In Paper III, the results indicate that an orange artefact inserted in a predominant grey environment generated less pleasurable experiences compared to when the orange artefacts were incorporated in a dominated green environment. According to Berlyne (1971), distressing stimuli or excessively novel and complex environments distract and overwhelm humans. This can lead to a rapid drop of arousal level and changes in pleasantness. The results from Paper III might be a result of a biological evolution in line with the reasoning that human responses to colours are innate and biological reactions (Crozier, 1999; Humphrey, 1976), evolved for finding food/bright berries among green leaves (Yantis & Abrams, 2016; Mather, 2016). This could apply to the results from the green-orange scene in Paper III. The generated pleasurable experiences in the scene with dominance of green hues together with an orange hue could be associated with a colour contrast showing where to find edible fruits in nature.

The above reasoning shows that it is important to be aware of the distinct differences between colours humans perceive in the outdoor environment. The introduction of permanent intense and bright colours in urban green spaces might lead to unpleasant experiences while, in other cases, being a positive contributor. Knowledge about how different colours interact with the surrounding environment can be seen as important knowledge for the landscape design practice, providing valuable information for the design processes. Therefore the trend of using intense colours on introduced artefacts should be discussed at planning process levels.

Figure 13. Left: a large-scale ‘painted’ neighbourhood in Copenhagen. The “Red Square” was designed by the landscape architecture office BIG, 2012, Denmark. Used with permission. Right: outdoor fitness equipment in a residential park (Solvallsparken) in Uppsala, Sweden, designed by Karavan landskapsarkitekter, 2016. Photo Alex Giacomini. Used with permission.

6.4 Method reflection – strengths and limitations

A main strength of this thesis as compared to many other closely related studies within the field of colour assessment is that all three empirical studies were performed in situ in common outdoor situations. The results therefore give an indication about the perceived colour contrast in relation to a living and complex reality, which means an everyday life context.

All three studies (Paper I-III) were implemented in a specific geographical context using participants with shared cultural backgrounds. This can be seen as a limitation, making it more difficult to generalise the results. Nevertheless, studies have showed a consistent response across cultures regarding colour notation for single colours and the scales warm/cool and active/passive (Ou et al., 2012; Gao et al., 2007). The assumption that colour is innate and a general ability for humans, and thereby influenced by perceptual differences (Kuehni, 2003), together with studies showing that colour assessment goes beyond cultural boundaries, indicates that the results presented in this thesis could be part of a widespread context and might be generalised across geographical and cultural borders.

The studies of human colour perception are based on the colour reference system, the RHS colour chart. The method enables quantification of the results through statistical analyses and categorisation of the colours according to dominance or through value or chroma scales. The use of the RHS colour chart as an analysis tool makes the perceived 'average' colour in the outdoor environment visible, and makes it possible to relate to other findings in the studies. The method and analyses also enabled possibilities for visual representation, where visual communication through colourful tables and diagrams permits a broad presentation of the results.

The studies were based on repetition and, since all studies were performed outdoors, the research had to be carried out during days of 'right' weather conditions. The study design in Paper I was multifaceted and involved four seasons. This caused difficulties in the recurrent use of the same participants during days of optimal conditions. Papers II and III were not based on a long-time repetition, but the studies used a study design where weather conditions as similar as possible were desirable.

Colour vision is personal and depends on perceptual colour differences, for example related to age. According to Werner et al. (1990), the eye starts to change after approximately the age of 45. In Paper II, all participants were between the ages of 20 and 40. In Paper I, one participant was more than 45 at the time of the study. This can be seen as a minor limitation in the study design, but no obvious colour differences were seen in the analysis of the assessed colours in Paper I.

The respondents used for colour determination all had connections to the Swedish University of Agricultural Sciences, Alnarp, as students or employees. The use of respondents connected to the campus area generated limitations in the choice of researchable areas (Paper I-II) – due to time constraints, the studies had to be within walking distance of the campus. The location of the university campus in an old park with surrounding areas of experimental woodland zones could be regarded as a strength, giving opportunities for suitable researchable areas, but limited to a specific context in southern Sweden.

6.4.1 Expert and non-expert respondents

Recent studies involving colour determination in a landscape context using RHS or NCS colour charts as measurement tools have used the individual observation of an expert and skilled observer (Grose, 2016; Nilsson, 2013; Fridell Anter, 2000). The strength in such approach is that a skilled observer can, in a professional manner, evaluate the perceived colours and give a 'correct' representation of the perceived reality. According to Fridell Ander (2000), a trained and interested participant can see colours in a more differentiated way than non-experts, where studies using trained respondents in colour determination show stability and reliability in reporting of colours (Sivik & Hård, 1979). The use of experts and respondents trained in colour theory and colour determination can be seen as a positive factor. The participating students were also part of a design course with a focus on colour aspects in outdoor environments at the time of the investigations, so the use of 47 skilled respondents (total number in Papers I-III) might give a representative outcome of the observed mean values of the perceived colours.
However, no far-reaching conclusions can be drawn from the results, as there has been no comparative study between the expert group and non-experts. Nevertheless, a previous study evaluating perceived biodiversity showed no significant difference in the rating between experts and novices (Pihel at al., 2015), indicating that the results from the studies can give an indication of how the places were perceived in relation to the colour aspect.

Among humans with normal colour vision, the range of variation in response to colour stimuli varies (Lloyd, 2007). Males and females differ in terms of normal colour vision by a factor of 22.1 (Mather, 2016). The respondents in Paper I and Paper II were not screened for defective colour vision, which can be seen as a limitation. However, women were overrepresented in the studies and the student group was trained for the task, and no participant (women or male) verbally indicated colour blindness. In Paper III, one professional respondent (the main author with a background as an artist and landscape planner) evaluated the colours in the environment concerned. To ensure reliability, the Ishihara colour blindness test was carried out before the colour assessment.

A strength in Paper III is the combination of using colour assessment studies with a method from a psychological approach. The average park visitor, which in this perspective constituted a non-expert group, was asked to evaluate the experienced environment in relation to the SMB scale. The respondents were Swedish citizens aged 20 to 73, but most were over the age of 64. The investigated area (a public park) is situated in one of the most affluent neighbourhoods in southern Sweden. This limited the possibility to generalise the result, but the result does provide knowledge about comparable socio-economic areas and age in relation to a colourful artefact.

6.4.1 Determination of outdoor colours

Studies examining colour differences in park landscapes, plant colours or seasonal changes have mostly been carried out in controlled laboratory settings (e.g. Huang & Lin, 2019; Oleksiichenko et al., 2018; Eroğlu et al., 2012), using manipulated images (Paddle & Gilliland, 2016), or photographs from real environments (Wang et al., 2016) as a scene. A limitation when using such methods is often the variation in colour measurements produced by different digital cameras (Kendal et al., 2013). Also, the artificial illumination in the investigation room and the colour settings (e.g. contrast, brightness, saturation) of projectors or computers could be seen as a limitation. In contrast, a strength in such studies is the fully organised situation and the control over, for example, reflections of sunlight and indirect illumination. Another limitation of using digital cameras is that a single moment (a snapshot with the camera) represents the reality at that point in time.

All studies performed in this thesis involved direct interaction with the outdoor environment, where each colour determination averaged three minutes. This enables a more straightforward evaluation process and gives a more realistic picture of the perceived reality than a snap-shot with a digital camera. Another strength is that outdoor studies do not have problems with technical issues such as indoor and projector illumination, but weather and light issues are sometimes a crucial problem for outdoor studies. Despite difficulties with performing outdoor studies, the results are a product of perceived reality and indicate how humans relate to and experience the world around them.

In Papers I and II, the RHS04 system (Mini Colour Chart) was used and in Paper III, the RHS Large Colour Chart (RHS 6th edition) was used. The RHS Large Colour Chart contains more than three times as many colour samples, so allows a more precise evaluation than the RHS04 system. A strength with the RHS04 system is that it comprises only one fan, which is a positive parameter out in the field with limited time and sometimes unfavourable weather. In contrast, the RHS Large Colour Chart comprises four fans, so might be unwieldy and bulky out in the field. However, the RHS Large Colour Chart contains considerably more choices of colour samples, which can be seen as a positive parameter. From another perspective, too many choices can also be seen as a limitation, where restrictions of time can accentuate stress and lead to hasty selection of the perceived colours.

6.4.2 Quantitative approach against determination of outdoor experiences

The method used for colour determination with colour charts and selected methods for environmental assessments relates to a positivistic approach, with empirical knowledge and logic as a frame. All three studies are based on quantitative approaches, and one criticism of the approach used is that I may have missed some fundamental layers and information about the observed reality (Alvesson & Sköldberg, 2009), information that could have helped to increase knowledge and understanding.

A limitation in the method is therefore that personal interpretations of the perceived colours were not studied. A complement with, for example, an open-ended process could have broadened the results and expanded the understanding of the experienced situation. It would have been interesting to supplement the methods with, for example, a phenomenological approach involving interviews. The research method would then have involved personal explanations and involvement (van den Brink et al., 2017). A combination of the two approaches (quantitative and qualitative) would have expanded and broadened the understanding of the overall colour experience.

6.5 Conclusion and proposals for future studies

Urban green spaces are undergoing a process of transformation, in which colourful artefacts are playing an important role. In this thesis the effect of colours has been interpreted using the arousal theory as a lens. The results show that perceived effects of complementary, light-dark and cold-warm contrast can be related to experienced pleasantness, which in turn relates to various viewing distances and perceived landscape situations. Complementary contrasts seem to be easier to achieve than a light-dark contrast in areas with the presence of a stable intense colour, such as a colourful artefact. Cold-warm contrasts can emerge in such situations. In areas where vegetation is the only design element, it appears that a light-dark contrast has the prominent role, but this depends on the species composition and seasonal variation. An emerged clear perceivable contrast effect seems to link to positive experiences and moderate levels of complexity/novelty (arousal), and perceived complementary and cold-warm contrasts have a wider range of perceivable attraction than a perceived light-dark contrast.

The studies show that landscape architects and related professions should consider the surrounding colours of vegetation and the built environment, as well as how the colours of integrated artefacts influence the perceived colours and the overall colour experience. Awareness of colour aspects, such as colour contrasts in the outdoor environment, deserve to be addressed in the planning and design of urban environment processes. This knowledge can support designers and planners in their work to develop outdoor environments that are attractive and supportable for humans.

To verify the outcome found in this thesis, more of the same types of studies are needed to broaden the understanding of human experiences in relation to perceived colours in urban green space. Repeatable studies could give indications about the stability of the results and directions for the future, which would deepen the understanding of human experiences and perceived colour contrasts. Colour vision is only one part of landscape perception, and the research presented in this thesis gives no indications about perceived colours compared to other perceptual aspects, although the studies demonstrate that colour perception influence human's experiences (arousal). It would be relevant to implement a multi-sensory approach to future studies, including smell, sound and sense of touch.

The methods used in this thesis could be complemented with phenomenological or autoethnographic approaches. Balancing quantitative methods with personal subjective experiences could provide useful information for comprehensive planning of public areas. It would also be interesting to further develop an approach of free reproduction of human colour experiences. A freer interpretation of perceived colours could provide information about proportions and internal relations of perceived colours and about human experiences in relation to perceived characteristics of colour effects. Extended studies of the impact of viewing distances on perceived colour contrast would improve understanding about how and when various colour contrasts occur. Initial repeated studies in Strandparken, Lomma (Paper III) using the same colours as tested in Paper II, could be a start.

In-depth studies of human reactions in relation to active or passive colours in outdoor environments might enable knowledge and understanding of the effect of incorporated colours on human experiences. Testing the differences between experienced red, yellow or orange hues in outdoor settings could enable a detailed understanding of the impact of active colours on human levels of arousal. Studies of human reactions in relation to passive colours, e.g. blue or violet hues, could also provide valuable insights. Comparable studies between active/passive colours and experienced levels of arousal might give directions to the planning process of coloured artefacts in urban green spaces.

A deeper understanding about colour proportions in various environmental settings during different seasons and light conditions in relation to incorporated coloured artefacts could help ensure a balanced choice of plants, plant mixtures and planting design principles concerning the background vegetation. This could also help identify optimal placement of artefacts in relation to the surroundings.

The growing frequency of colourful artefacts, together with a larger number of coloured artefacts at each site, generates ideas for exploring the perceived colour effect of the extent and appearances of the artefacts, e.g. size, shape, and number in relation to the surrounding environment. This would increase knowledge about the impact of colourful artefacts on human colour perception and related experiences. Comparing studies of human experiences and perceived colours of flowers, leaves and artefacts might enable an understanding of similarities and differences between natural and artificial colours in outdoor environments.

In the context of discussing colours of incorporated artefacts, cross-cultural studies would increase the understanding of cultural impact on artefact experiences in outdoor environments. Longitudinal studies of the effects of incorporated artefacts on human experiences would increase understanding of the perceived effects of colourful artefacts on a daily basis. Such studies could give some indication about fluctuations in the arousal level and contribute to a more comprehensive understanding of the impact of coloured artefacts on long-term human experiences.

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This thesis explores outdoor colour influences on human perception and related experiences in urban green spaces. The studies were performed in situ in southern Sweden, employing a quasi-experimental approach with combined studies of colour perception and environmental assessment methods. The results show that perceived effects of colour contrast can be related to experienced pleasantness, which in turn relates to various viewing distances and perceived landscape situations.

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