Uncovering the secrets of a productive work environment

A journey through the impact of plants and colour

Iris Bakker

For Olaf, who already has endured me for many years.


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Das Gefühl der
Wasserwaage und
des Perpendikels ist
die Grundlage
unseres Menschseins
Goethe

Uncovering the secrets of a productive work environment

A journey through the impact of plants and colour

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The whip may be effective in slavery or to make the horse run faster but for knowledge productivity it is not an effective tool.

Preface

The slaves who were forced to row on Greek or Roman galleys were whipped to achieve higher productivity. To increase knowledge productivity the whip is no effective tool. Knowledge productivity has to do with willing, curiosity, enthusiasm and the intrinsic drive of people. An environment that invites the knowledge worker to curiosity and enthusiasm and helps him to fulfil his drives, can be conceived as a knowledge productive environment.

This thesis presents a thorough search for the characteristics of that knowledge productive environment. It was not an easy one way walking trail with red coloured markers but merely a discovery tour with complicated junctions radiating to the east, west, south or north. First the knowledge worker appeared to be an original and unique person who could not be framed in a simple short list of definitions. Secondly, the physical environment shows an endless and dynamic variety that changes over time. In this thesis is focused on the influences of plants and colour and both fascinating topics show this dynamic complexity.

Hence, during this quest pitfalls were found, but also elegant mountaintops that provide a fascinating view across the colourful nature.

Iris Bakker

Efficient standard workstation design
with extra comfort for the manager.

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Summary

Introduction
This PhD concerns the relationship between the physical environment and knowledge productivity. To create an optimal environment it is important to study the needs of knowledge workers in connection to the characteristics of the physical environment. Two components of the physical environment have been analysed: plants and colour. The effects of plants on productivity are studied by a critical assessment of the literature. The impact of colour has been studied by an extensive review of the literature and a comparison of human responses to a red and blue painted meeting room, in a real life setting. In addition, questionnaires have been disseminated to measure peoples' colour preferences on different topics. The choice for plants and colour is based on personal interest and because it is relatively easy to add and change plants and colours in real life settings. In the reviews of the literature particular attention has been paid to the research methods applied by other researchers, in particular in the field of environmental psychology, in order to understand the mechanisms behind the interaction between people and their environment and how this interaction affects their productivity. Based on these insights, a new framework has been developed to measure the perception of the built environment

Chapter 2 discusses the relationship between productivity of the knowledge worker, his networks, and knowledge, in connection to the physical environment. To ensure that the knowledge worker will be both productive and happy, it is hypothesized that it is important that he can fulfil all his needs. The psychologists Ryan and Deci (2000, 2001) mention three psychological needs: competences, relatedness and autonomy. Pink (2010) added two other needs: purpose and mastery. In knowledge work a distinction can be made between four types of work moods that not only matches with insights of modern Western psychologists, but also with ancient Eastern wisdom: social observation, collectiveness, contemplation and awareness. It is concluded that four characteristics of the physical environment can contribute to knowledge productivity: structure, variety, psychological safety and identity. These four factors have been elaborated into practical guidelines how to support the energy and different moods of the knowledge worker.

Chapter 3 presents a critical assessment on the effects of plants on productivity, based on an review of the literature. Next to effects on indoor air quality and relative air humidity, plants have in general a positive effect on productivity. The reactions of people can be physical/physiological, affective, or cognitive. Due to the huge variety in research methods and research settings, the research findings are not well comparable. For this reason, an overview of test aspects and a list of plant characteristics is presented that should be taken into account in conducting new research. In this thesis will be focused on the totality of the environment. After a review on a component that easily can be isolated, the next component is integrated in context and can only be approached in totality.

Chapter 4 presents the real life test whether different coloured meeting rooms (red, blue and a reference room) had any effect on self-reported productivity. No significant effects were found in the responses to the questionnaires. It is assumed that the participants were fully occupied by the meetings so that they didn't experience consciously the surrounding colours. A relatively large number of subjects responded that colour did not matter related to productivity (65%), collaboration (58%) and wellbeing (33%).

Chapter 5 provides an overview of colour preferences of 1077 Dutch people who were asked to fill out a questionnaire. Gender, age and education and some personality characteristics were significantly related to colour preferences. The overall favourite colour was blue although differences exist between males

and females: especially males prefer blue. The overall colour preference for clothing is black: females preferred this colour a bit more than males. The most preferred colour for the interior of buildings is white. Regarding states of mind most people prefer white to be quiet or being able to concentrate, and red to be energetic. Regarding being creative, they stated to have no colour preference. Remarkably most people choose for the physical environment the colour white (30 till 40%) and a substantial percentage (16 till 22%) stated to have no colour preference. Based on this analysis of colour preferences, people seem to be less interested in the application of particular colours in their environment.

Chapter 6 presents an in-depth analysis of the experience of colour in order to shed more light on how colour affects people physiologically, affectively and cognitively. This analysis is based on theoretical knowledge found in the literature. This literature shows that scientists, philosophers, artists and architects are rather sceptical about the often rational and scientific approach to understand colour. Theoretically, twelve colour characteristics can be discerned how colour appears in nature which can be linked to the twelve senses that were mentioned by Rudolf Steiner and to twelve colour contrasts. Both in practice and science, the HSI values (hue, saturation and intensity) are used to define colour, which is limited to only three colour contrasts. It is concluded that in order to understand the experience of colour in its totality, all twelve colour contrasts should be taken into account that can be related to the twelve senses.

Chapter 7 discusses possible pitfalls in conducting colour research by using questionnaires. By means of accurate observations during the colour test of Chapter 4 it turned out that the responses to the questionnaires could not always clearly be related to the research topics and did not always reflect the actual views of the subjects. For this reason additional personal interviews have been conducted with a number of subjects after the test. Contextual, personal and psychological factors showed to influence the responses of the subjects, including well-known phenomena such as the impact of personal interest, social desirability and cognitive dissonance reduction.

Chapter 8 reflects on the often applied three dimensions arousal, pleasure and dominance, that were developed by Mehrabian and Russell (1974) to measure people's environmental experiences and are still widely used in environmental psychology research. The many studies on people-environment interactions are hard to compare due to the different interpretations of these dimensions and the use of a huge variety of related adjectives. In this PhD research an attempt has been made to explore the connections between pleasure, arousal and dominance, the ABC model of attitude with the factors Affect, Behaviour and Cognition, and the three functions of the soul, feeling, acting and thinking, that were mentioned by Plato. It can be concluded that the dimensions of arousal, pleasure and dominance as Mehrabian and Russell originally have meant to be, are still appropriate to be used to describe peoples' experience of the physical environment, provided that the dimensions are well defined and operationalised in valid adjectives. In particular the often neglected third dimension 'dominance' deserves a rehabilitation.

Based on the discrepancies and the flaws that were found in research using pleasure, arousal and dominance to measure the experience and perceptual qualities of the built environment, **chapter 9** presents a new framework with bipolar adjectives to describe the experience of the physical environment. This framework refers to the twelve senses that were mentioned by Rudolf Steiner. By linking sensory information of the twelve senses to specific parts of the environment, it is possible to define people's experience of the physical environment in a more clear and objective way. The framework has been tested with practitioners from the field of housing and care and with designers. It showed to be applicable to get a sound understanding of the qualities of the physical environment, why people respond differently to the same environment, and how to improve this environment. Further testing of the framework with different samples and in different settings is needed to validate the framework.

The thesis ends with **chapter 10** that presents the overall conclusions and recommendations and reflects on the limitations of the research and next steps. This study tried to disentangle the complex concept productivity into four different work moods (contemplation, social observation, collectiveness, and awareness) and mentions four important elements of the physical environment: structure, variety, psychological safety and identity. The review on the effects of plants on productivity showed that plants in general have positive effects. Based on the research on colour, this relationship could not clearly be defined due to the complexity of both the concepts colour and productivity. However, the effects of colour on mood are definable. Because productivity can be conceived as a phenomenon existing of four types of work moods, future researchers can approach productivity more concrete. The developed framework to value and assess the totality of the environment can be helpful.

A good glass of wine can be helpful for creating a cosy atmosphere where people can think freely and creatively (Peter Vink).

How can we make an environment that supports the knowledge worker to be productive? Not a simple question because the knowledge worker is not a mechanical robot, knowledge and knowledge productivity are complex concepts and the environment has a large number of appearances.

Chapter

Introduction

The influence of the physical environment on knowledge productivity

1.1 Definitions and explanations

In order to facilitate a healthy knowledge economy, a productive work environment is of great importance. Since the physical environment influences people, this will also affect peoples' productivity (Kastelein, 2014). To be able to create a physical environment that supports the productivity of knowledge workers in an optimal way, it is necessary to know how the physical environment affects productivity: what is the magnitude of its influence, and which factors in the environment are influencing productivity? At least three elements are interesting: the physical environment, people working in this environment, and the outcome: productivity. This thesis aims to explore the complex relationships between all three elements.

1.1.1 The physical environment

The physical environment consists of a number of areas which are interrelated and both individually and in combination contribute to how humans experience the environment. Colour and materials for instance show a wide variety of manifestations that could affect humans. To understand how the physical environment affects people and their productivity, it is necessary to focus on some specific aspects that could be of importance for productivity (Figure 1).

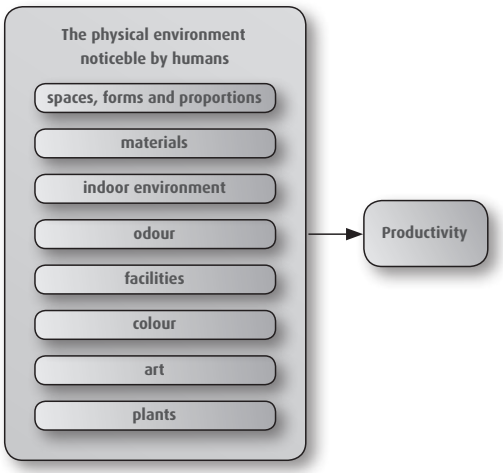

Figure 1: Areas of the physical environment

Figure 1 illustrates the areas which are most often mentioned in the literature as influencing factors.

- Spaces, forms and proportion influence feelings of spaciousness (Sadalla and Oxley, 1984; Stamps, 2009) and openness and enclosure (Hayward and Franklin, 1974; Fried, 1990; Stamps, 2009) which for instance affect feelings of freedom and the way products are valued (Meyers-Levy and Zhu, 2007).
- Materials provide meaning (Csikszentmihalyi and Rochberg-Halton, 1982; Rapoport, 1990; Sadalla and Sheets, 1993; Stedman, 2003) and influence health and comfort (Wargocki and Fanger, 1997; Jaakkola et al, 2006, Uhde and Salthammer, 2007).
- Indoor environment effects health, comfort and satisfaction (Seppänen and Fisk, 2005; Pejtersen et al, 2006; Van der Linden et al, 2007; Bluyssen, 2011).
- Odour influences (social) behaviour (Knasko, 1989; Zemke and Shoemaker, 2008; Morrisson et al, 2011) and mood (Diego et al, 1998) and contributes to the total experience of products (Fiore et al, 2000).
- Facilities influence behaviour (Devlin, 1992, Baldwin, 1985), health (Smith et al, 2000; Dowel et al, 2001; Groenesteijn et al, 2009), comfort (Wilder et al, 1994, Robertson et al, 2009), social support (Ulrich, 1991), mood and satisfaction (Leather et al, 2003).
- Colour effects wellbeing and mood (Goethe, 1981; Mahnke, 1996; Kaya and Epps, 2004) behaviour(Bellizi et al, 1983; Crowley, 1993; Elliot and Maier, 2007), time estimation (Caldwell and Jones, 1984; Van Hagen et al, 2009), the perception of form (Claessen, 1995) and flavour of food (Christensen, 1983).
- Art influences feelings of health (Argyle and Bolton, 2005, Fraser, 2011) and feelings of quality of life (Miles, 1994).
- Plants effects health (Ulrich, 1984, Kaplan and Kaplan, 1989, Fjeld et al, 1998, Van den Berg, 2005) and behaviour (Wolf, 2002).

1.1.2 The way people experience the environment

People usually experience the environment as a whole and experience this environment as pleasant or disgusting , beautiful or ugly, attractive or repulsive. In general, we are not aware of the environmental characteristics which cause this experience (Vonk, 2003; Dijksterhuis, 2007). Information from the environment enters the human body by the senses. Based on this input humans generate an experience. The human senses work closely together (Schneider, 1987; Soesman, 2005). Observing and experiencing colours for instance occurs by the sense of sight, together with touch, temperature and taste. We speak for instance of bright colors, soft colours, warm colours and sweet colours. People have their own individual way of experiencing their environment (Osgood, 1964; Küller, 1973; Mehrabian and Russell, 1974; Feldman, 1995; Mehrabian, 1996; Hansen, 2005; Ishikawa and Montello, 2006; Kim and Moon, 2009). This is not only caused by the different sensory sensitivities of the individuals, for example for sight, hearing, smell (Lundström et al, 2003) or taste (Kim and Drayna, 2004), but also by personal characteristics and personal experiences (Schneider, 1997; Vonk, 2003; Zajonc, 1996). People react on the environment at different levels. There could be a physiological, affective and cognitive reaction. Stimuli in the environment cause for example changes in energetic processes such as changes in brain waves, heart rate, skin conductance and eye blinking. These processes influence each other. Cognitive aspects such as thoughts and opinions influence energetic processes. This is demonstrated in the Michigan model (1981) made by Kahn which shows that not the objective environmental conditions, but the subjective interpretation of it, affects the well-being of human beings (Scheuerle, 1984; Vonk, 2003; Gaillard, 2003; Dijksterhuis, 2007; Bendin, 2008).

1.1.3 Productivity

The way humans experience the environment also influences productivity. To determine how the environment influences productivity we need a clear definition of productivity. As Frazelle (1992) stated: "Productivity must be understood before it is effectively measured" and therefore a good description with its related items is essential. After understanding productivity an attempt can be made to relate this to the characteristics of the physical environment. Defining the concept of productivity is difficult because productivity has a multitude of nuances and there can be confusion with related concepts such as 'performance' and 'profitability'. In addition, productivity has a close connection with the frequently used terms efficiency and effectiveness. Due to the need for transparency of these terms and their coherence, it makes sense to reflect on these concepts.

Performance concerns a broader concept and includes output factors such as an increase of market share, introduction of new products and social objectives (Sardina and Vrat, 1987).
Profitability is a financial term that is used for and by shareholders. Profitability is generally defined as the ratio of business's results to overall expenses. The Triple P model of Tangen (2005) clarifies the relationship between Performance, Profitability and Productivity (Figure 2):

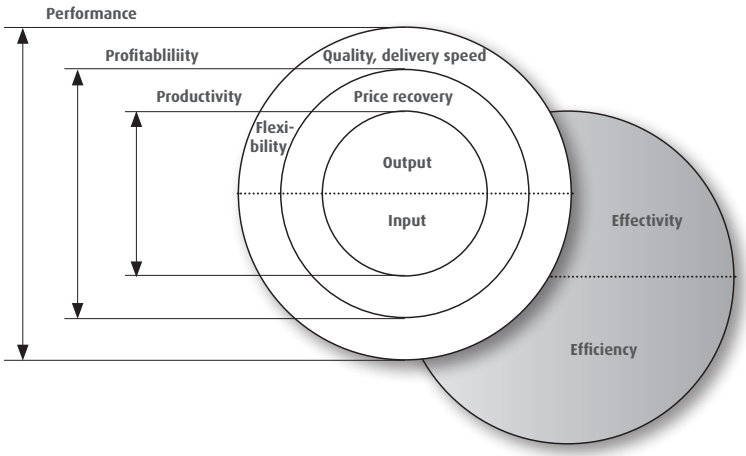

Figure 2: The Triple P- model of Tangen, 2005

Productivity, profitability and performance have a mutual quantitative and qualitative relationship. Studies for instance by Watson Wyatt (2000) among 7,500 employees who worked at various levels within the industry, revealed a clear relationship between organisational success (profitability and productivity) and the management style that is focused on increasing the involvement of the employee i.e. a performance indicator (Whitener, 2001).

Between productivity, effectiveness and efficiency also a close relationship exists. Effectiveness can be conceived as the ratio between actual results and expected results (In 't Veld, 1975) and is mainly related to the outputs i.e. the results. Effectiveness is often described as "doing the right things" (Van der Voordt, 2003a). Efficiency can be conceived as the ratio between the actual input and the expected input (In 't Veld, 1975) and is related to the input or the means. Efficiency can be understood as "doing things right (Van der Voordt, 2003a). Weggeman (2007) sees productivity as the product of effectiveness and efficiency. Drucker appoints the relationship between productivity, effectiveness and efficiency as follows: A business converts economic resources into something else. At this level, productivity is the balance between all production factors that will give the greatest return for the least effort (Drucker, 1973).

It is the optimal balance between output and input. De Waal (2001) sees the productivity ratio as a quantitative measure of the production results achieved in relation to the means of production employed such as labour, capital (goods), materials, energy and information. In the literature, productivity is also defined as output / input ratio (Van der Voordt, 2003b; Freeman, 2008). A common definition is: Productivity is strictly a relationship between resources that come into an organisational system over a given period of time and output generated with those resources over the same period of time (Sink and De Vries, 1984).

1.1.4 Knowledge productivity

In the knowledge economy knowledge productivity is a central issue. Knowledge sharing, creation, deepening and broadening can be interpreted as labour. Knowledge productivity is therefore a specific type of labour productivity (Belderbos et al, 2004). In definitions of 'knowledge productivity', the emphasis can be on the outcome or the process. Weggeman (2001) puts the emphasis on results and defines knowledge productivity as "the extent to which knowledge is used effectively and efficiently to develop, share and apply knowledge'. Kessels (1996, 2001) emphasises the process and defines knowledge productivity as 'a process of identifying, gathering and interpreting relevant information, developing new skills using this information and applying these new skills for a stepwise improvement and radically renewing of work processes, products and services'. Due to the prerequisite for the knowledge organisation in the knowledge economy, to continuously improve and to develop, with a prominent position for the ability to learn, it makes sense according to the definition of Kessels, to accentuate the character of improvement and innovation.

In the manufacturing industry it is possible to define and measure the ratio between output and input quantitatively. This is more difficult in the information sector with knowledge processes as input and information as output because it is difficult both to quantify the work processes for generating this information output and to quantify the output itself. In practice, therefore, knowledge productivity is not only measured quantitatively, but also qualitatively by adding quality criteria in the output measurement. Knowledge production has not a routine nature. It is a complex process that varies by individual, has many dependencies within the organisation and is intertwined with external partnerships. For these reasons, the application of standards to measure knowledge work quantitatively and to make quantitative evaluations, is difficult. Also, the qualitative aspect is less transparent due to the complexity of unambiguously qualitative criteria to define and measure the complex processes of knowledge broadening, knowledge deepening and new competencies. The time factor plays a difficult role as well. In the knowledge industry, the effect of developed knowledge can take place later than within a certain predetermined period of time. Moreover, it is often impossible to ascribe an increase of productivity of an knowledge organisation to the various individual contributions of its employees. Knowledge productivity is in fact the result of individual efforts and close cooperation between people and groups over time. In the text below, productivity refers to knowledge productivity that can be understood as a specific form of labour productivity.

1.1.5 Productivity: what do we know? Existing models and researches

Given the importance to optimise productivity several researchers developed models with a diversity of components that influence productivity. These models often distinguish personal, organisational, social and physical factors (Sutermeister, 1969; Ten Horn, 1999; Clements Croome, 2000; Kessels, 2001; Keursten et al, 2006; Batenburg and Van der Voordt, 2007; Stam, 2007). Personal factors include intrinsic motivation, attitude, personal skills and expectations. Organisational aspects are structure, enterprise

culture, organisational strategy, systems and leadership style. Social aspects include the atmosphere, the way people interact, social cohesion and communication. Physical factors are mentioned such as indoor climate, spaces and facilities. In his book 'Costs and benefits of innovative workplace design' Van der Voordt discusses (2003a) various models. The model of Sutermeister (1969) shows a detailed list of influencing factors such as the relationship with supervisors and managers, autocratic leadership, the way how someone has been introduced in a new job, training and cultural background of the employee. The model of Hackman and Oldman (1980) puts emphasis on job characteristics such as autonomy and feedback that are fundamental for critical psychological states such as responsibility and knowledge of the results. These in turn are important to achieve the optimal outcomes such as satisfaction and work effectiveness (Figure 3).

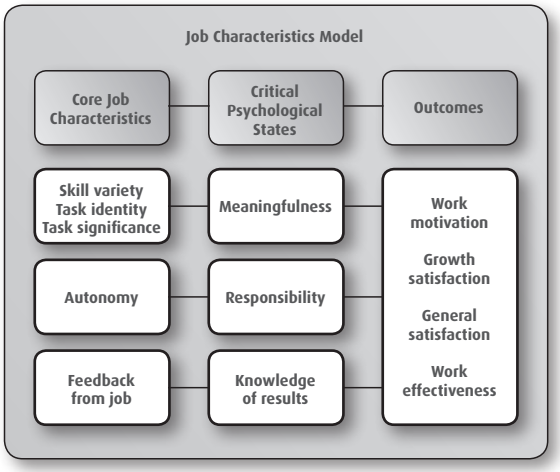

Figure 3: Job Characteristics Model of Hackman and Oldman (1980)

Herzberg (1959) makes a distinction between motivation factors (satisfiers) and hygiene factors (dissatisfiers). Satisfiers contribute to job satisfaction and encourage performance, such as growth opportunities, the nature of work and responsibility; dissatisfiers do not contribute to satisfaction, but if they fail cause dissatisfaction such as salary and status. For the personal factors, Woods (2001) distinguishes social factors and motivation factors. Also, in the Burke-Litwin model (Burke, 1994) motivation is an important issue in the balance between job demands, existing competencies and individual needs (Figure 4).

Porter and Lawler (1968) show how motivation leads to satisfaction in relation to effort and reward. In his ERI model (Effort Reward Imbalance) Siegrist (1996) mentions the necessary balance between effort and reward. The model of CIBSE (Oseland, 1999) pays - next to physical conditions such as aesthetics and climate issues - also attention to the distinction between extrinsic and intrinsic rewards. Extrinsic and intrinsic factors both contribute to job satisfaction.

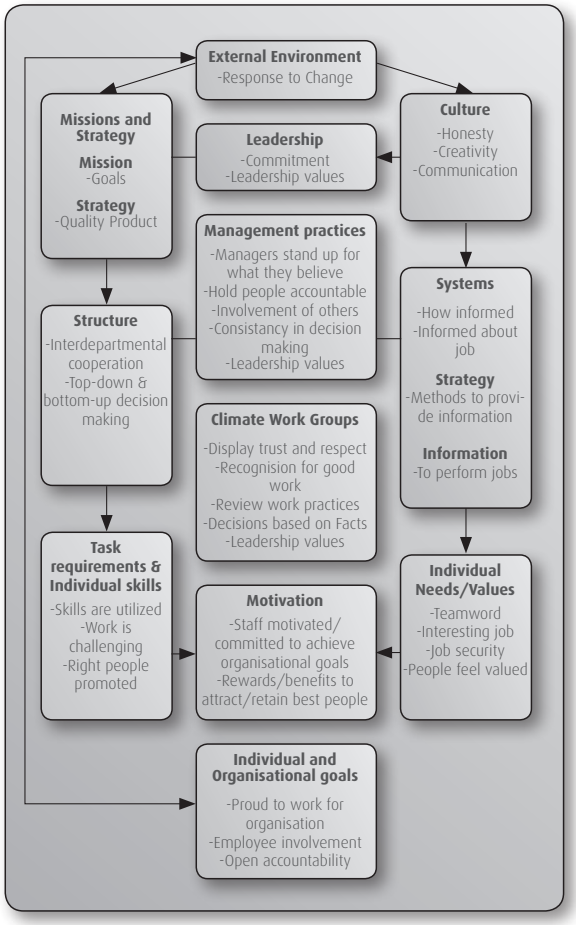

Figure 4: Burke-Litwin model (1994)

It's an interesting question how productivity is related to job satisfaction. Various models identify factors that contribute to job satisfaction such as the model of Sundstrøm (1986) with factors such as colleagues, career opportunities, company policies and characteristics of the physical environment. Latham and Locke (2007) point out the importance of sufficient challenges in work in their model. The model of Judge et al (2001) shows the factors that play a role in this context such as autonomy and progress in achieving goals. It would be expected that people who are more satisfied in their work will be more productive. After all, people are busy with activities they experience as positive. Nevertheless, it is not true that satisfaction is directly related to productivity. For instance, dissatisfaction with an excessive workload and insufficient autonomy (temporarily), can go together with a high productivity even though there is an unhealthy and unpleasant work situation. To establish the relationship between productivity and job satisfaction, further research is needed (Van der Voordt, 2003a) especially longitudinal research related to sustainable productivity taking into account the happiness and the health of the employee.

The different models show a multitude of factors which together contribute to job satisfaction and productivity. This multitude, the nuances of the factors themselves and the interaction and balance, make it difficult to discern clearly under which personal, organisational, social and physical conditions, productivity can be optimised. Assessing the impact of the physical environment on productivity, one has to take into account the personal, organisational and social aspects as these factors also influence the final result. The model of Van der Voordt and De Been offers an integral picture of these factors (figure 5).

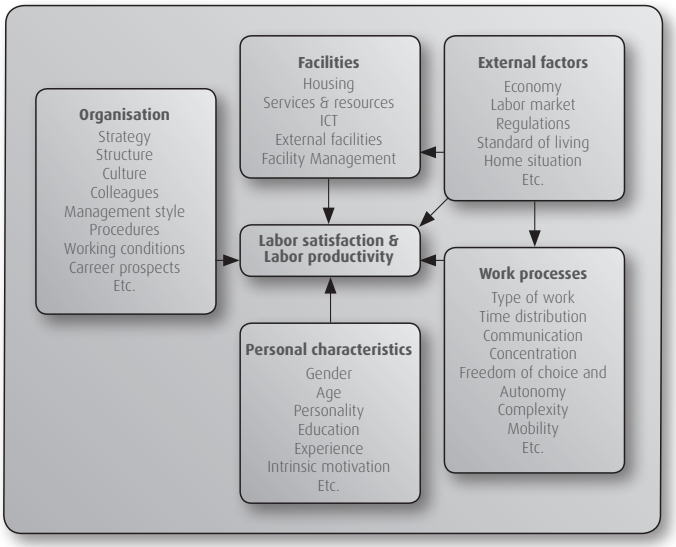

Figure 5: Factors that influence labour satisfaction and labour productivity (Van der Voordt and De Been, 2010)

Several studies have been performed on the influence of the different aspects of the physical environment on the productivity of the employees. The main findings are summarized below, separately for each aspect.

• *Spaces, forms and proportions*

Research shows a mix of findings. The office concept has significant influences on productivity (Blok et al, 2009) and employee satisfaction (Oldham and Brass, 1979; Brennan et al, 2002). Also less clear relationships are shown: reviews of De Croon et al, 2005 and Haynes (2008 a +b) show a mix of results depending on type of work activities. In addition studies focusing on more detailed elements that create space, such as panels, Brand and Smith (2005) show no clear effects on productivity.

• *Materials*

Several studies show the advantage of healthy materials (Gutnick, 2007) and the risks of applying indoor pollution sources (Bakó-Biro, 2004). McCoy and Evans (2002) show evidence that natural and less manufactured materials have positive effects on creativity.

• *Indoor environment*

Several studies have shown that elements of the indoor climate affect productivity: temperature (Vasmatzidis et al, 2002; Seppänen et al, 2004; Tanabe et al, 2007), air quality (Wargocki et al, 2000; Wyon, 2004), ventilation rate (Wargocki et al, 2000), light qualities and quantities (Hedge et al, 1995), sound/ noise (Smith-Jackson and Klein, 2009) and relative humidity (Wargocki et al, 2000).

• *Odour*

The effects of odours in buildings on performances vary from negative (Danuser et al, 2003), neutral (Knasko and Gilbert et al, 1990) to positive (Baron and Bronfen, 1994). Effects appear to depend on the type of task and the degree in which odours cause distraction (Danuser et al, 2003; Gaygen and Hedge, 2009), but also are influenced by individual preferences and exposure duration (Warm et al, 1991; Best et al, 2005).

• *Facilities*

For many types of facilities influences have been demonstrated on productivity: adjustable work surfaces (Hedge, 2004), laptop stations (Berkhout et al, 2004) and stand sit-stand workstations (Robertson et al, 2013). However, these influences are more of an instrumental character. They concern primarily bodily aspects like reduction of muscle tension and not affective processes related to concepts like motivation and emotion. An ergonomically optimal setting contributes to optimalisation of productivity: Dainoff (1990) showed an increase of 17.5% productivity compared to a situation which was ergonomically suboptimal.

• *Colour*

Studies mainly show no significant effects (Ainsworth et al,1993; Kwallek et al, 1996; Küller et al, 2008), on performance tasks. Significant relations primarily can be found when colour effects are studied using test materials such as computer screens (Mehta and Zhu, 2009) or paper forms (Elliot et al, 2007).

• *Art*

No studies are found that art significantly influences productivity, only hypotheses about the expected positive effects on awareness and collaboration (Heerwagen et al, 2004) and identity and confidence (Spring, 2001; Gesler et al, 2004; Meghisan and Meghisan, 2006).

• *Plants*

Indoor plants have a positive effect on productivity (Srivens, 1980; Marchant, 1982; Shibata and Suzuki, 2002) although the choice for type of plant, number and location needs attention (Bakker and Van der Voordt, 2010).

The relationships between physical environmental characteristics and productivity found in the literature can be summarised as follows:

a Of most elements in the environment influences were found on different types of work such as routine work, concentration work and creativity tasks. For several elements (e.g. colour) mixed results were found. Although some studies showed significant relationships, others could not find significant effects.
b The research into the relationships is complex as the areas influence each other. For example, colour and light are inextricably connected to each other (Küller, 1986). Odour and music also influence each other (Mattila and Wirtz, 2001; Morrison et al, 2011), as well as colour and odour (Zellner and Kautz, 1990), visual pictures and scent (Sakai et al, 2005), facilities and space (Imamoglu, 1973), colour and space (Stamps, 2011) and colour and shape (Claessen, 1995).
c People react differently to their environment due to their personal characteristics and experiences (Schneider, 1997; Vonk, 2003; Zajonc, 1996), their attention, personal preferences (Alter and Balcetis, 2011) and interest and knowledge (Distel and Hudson, 2001).

1.2 Knowledge gaps

The existing research on the impact of the physical environment on productivity shows three core problems:

a The studies focus on a separated part of the environment and simplify both the physical environment and the context in an artificial and simplified context like a laboratory environment. The question is whether the results accurately reflect reality of the real world, which is much more complex.
b Respondents are different individuals, with different motivations, interpretations and interests. The question is whether responses from the respondents are sufficiently valid and reliable to draw conclusions about the actual effects of the environment. Often students are asked to perform tasks in test situations. However these students react differently on the environmental test conditions than employees as they are not involved in organisational or social context.

c To approach a complex topic such as productivity, often used methods such as filling out questionnaires might not be sufficiently valid. An analysis of the pitfalls and risks of using questionnaires can shed light on the complexity of a sound research design and may contribute to minimise the pitfalls and risks in research.

The present research aims to improve the methods and to enhance the insight into the complex interactions that are relevant for reliable and valid interpretations of the research findings. The societal relevance is to show how environmental research can be improved so that research results can be used in a meaningful way to optimise the productive work environment.

1.3 Research questions

Productivity is difficult to measure, because the physical environment has many elements that may interact with each other and the perception of the physical environment shows a large individual variability. To be able to optimise the work environment, it is essential for engineers, architects and industrial designers to know how the physical environment can be improved. Also for the employees it is important to know of which factors their productivity is dependent, and thus their success. It is too complex to focus on all elements in a PhD. To learn more about causes and relationships, in this thesis two elements of the work environment are examined: plants and colour.

Plants is a physical element that simply can be separated from other elements and it is easy to change an interior using plants. The personal preference of the author for nature has contributed to the choice to have a closer look at plants. Plants can have a positive influence on people. Philosophers such as Nietzsche, Seneca, Aristotle and Voltaire, scientists like Leonardo da Vinci and Einstein and artists such as Van Gogh, Beethoven and Liszt provide various ways of how overwhelming the influence of nature is on our thoughts and actions.

Colour is a very popular issue in the physical environment: everyone has an opinion on colour, talks about colour and is concerned about colours for their clothes, cars, cell phones and different rooms, but which statements about colour are true and which are not? In this broad field with lots of opinions and speculations, it is interesting to know more precisely how colour actually has an effect on people and their productivity. Moreover, colour is an intriguing topic as it changes by the type of light, it could influence our moods and is a complex phenomenon according to different approaches such as physical, psychological, neurological and philosophical views. Colour cannot be separated from other elements because it communicates directly with other adjacent colours, and reflects in conjunction with other features such as lighting conditions, spaces and forms. Learning more about colour and its effects in the physical environment, may give insight how colour influences people.

By analysing and comparing two types of elements: plants that easily can be separated and colour that cannot be separated from its context, this thesis contributes to understanding the relationship between the environment and productivity and explores the following research questions.

1 What is the influence of colours and plants in the physical environment on knowledge productivity?
To understand the effects of the physical environment and to understand the complexity of the context, two areas will be analysed. The first area, the effects of plants on productivity are analysed on the basis of a review of researches that are conducted in lab environments. The second area concerns an in-depth research on the effect of colour on human experience and productivity. A test is conducted in a real work environment, which is a complex context. To get more insight into people's opinions colour preferences of people are also examined.

2 Which research methods do lead to valid and reliable results?
As described above research methods influence the outcomes and can even lead to conflicting findings. Therefore the applied methods of researches on plants and colour are further analysed. The key question is whether the results are sufficiently valid and reliable to conceive them as indicators for the real world. In addition, research methods and measurements which are regularly used within the field of environmental psychology will be examined for validity, reliability, and practical relevance.

1.4 Outline of this PhD

To answer the research questions, a number of different aspects will be examined (see Figure 6). In this dissertation evidence found in scientific research will be combined with theoretical insights of philosophers and psychologists. The topics show much complexity and deserve a broader view including philosophical and psychological theories. The next chapter explores the meaning of knowledge productivity, knowledge and the knowledge worker based on a review of the literature. The focus is on the demand site i.e. the knowledge worker and the requirements for a productive physical environment. The knowledge worker discussed here is not only conceived as an individual with his own needs and drives but also as a participant in knowledge networks.

Chapters 3 – 6 concern the physical environment i.e. the supply side. The effects of plants on productivity are assessed by a review of research papers. The next three chapters concern colour. First a test of the effects of colour on productivity in a real work environment, i.e. three meeting rooms in a government organisation will be described. Next, because the literature often mentions colour preferences, and various studies show conflicting results, 1,095 people were asked about their personal colour preferences, either on-line or face-to-face. Then the physiological, affective and cognitive effects of colour based on literature will be described and some recommendations will be given on how the effects of colour can be measured. Finally, in chapter 7-9 methods will be discussed that commonly are used to determine how the physical environment influences people and how people experience the environment. Looking at methods that are applied in general to describe environmental experience, the method of Mehrabian and Russell (1974) will be analysed and the way how adjectives are applied to describe peoples' experience of the built environment will be criticised. Chapter 9 ends with a proposal for a new framework with well-argued adjectives, that has been tested in a pilot study. In Chapter 10, reflection, conclusions and recommendations, the main findings will be presented and some concluding remarks will be made. Recommendations will be given for future research. The epilogue gives a view on the entire research process, the struggles and the triumphs.

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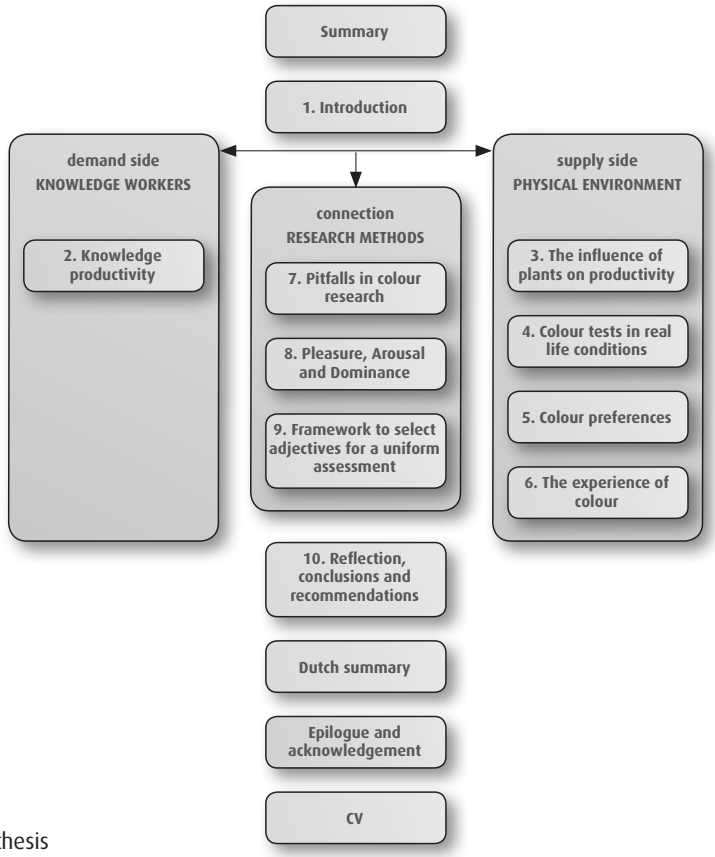


Figure 6: Outline of the thesis

1.5 References

Ainsworth, R.A., Simpson, L., Cassell, D. (1993), Effects of three Colors in an Office Interior on Mood and Performance, Perceptual and Motor Skills, Vol. 76(1), 235-241.

Alter, A.L., Balcetis, E. (2011), Fondness makes the distance grow shorter: Desired locations seem closer because they seem more vivid, Journal of Experimental Social Psychology, Vol. 47 (1), 16–21.

Argyle, E.,Bolton, G. (2005), Art in the community for potentially vulnerable mental health groups, Health Education, Vol. 105 (5), 340 – 354.

Bakker I.C., Van der Voordt, D.J.M. (2010), The influence of plants on productivity: a critical assessment of research findings and test methods. Facilities, 28(9/10), 416-439.

Bakó- Biró. Z. (2004), Human Perception, SBS Symptoms and Performance of Office Work during Exposure to Air Polluted by Building Materials and Personal Computers, PhD-thesis, International Centre for Indoor Environment and Energy, Technical University of Denmark.

Baldwin, S. (1985), Effects of furniture rearrangement on the atmosphere of wards in a maximum-security hospital, Hospital and Community Psychiatry, 36, 525-529.

Baron, R., Bronfen, M. (1994), A whiff of reality: empirical evidence concerning the effects of pleasant fragrances on work-related behavior, Journal of Applied Social Psychology, 24, 1179–1203.

Batenburg, R., Van der Voordt, D.J.M. (2007), Invloed van facilitybeleving op arbeidsproductiviteit (2), Facility Management Magazine 156, 45-48.

Belderbos, R., Carree, M., Lokshin, B. (2004), Cooperative R&D and firm performance, Research Policy, Vol. 33(10), 1477-1492.

Bellizi, J.A., Crowley, A.E., Hasty, R.W. (1983), The effects of colour in store design, Journal of Retailing, Vol. 59(1) 21-45.

Bendin, E. (2008), Individuelle Stereotypen-Beobachtungen zur Präferenzfrage, III, Internazionales Dresdner Architektursymposium “Lehren, Gestalten, Lernen”. Dresden.

Berkhout, A. L., Hendriksson-Larsén, K., Bongers, P. (2004), The effect of using a laptopstation compared to using a standard laptop PC on the cervical spine torque, perceived strain and productivity. Applied ergonomics, 35(2), 147-152.

Best, A. R., Thompson, J. V., Fletcher, M. L., Wilson, D. A. (2005), Cortical metabotropic glutamate receptors contribute to habituation of a simple odor-evoked behavior. The Journal of neuroscience, 25(10), 2513-2517.

Blok, M., De Korte, E., Groenesteijn, L., Formanoy, M., Vink, P. (2009), The effects of a task facilitating working environment on office space use, communication, concentration, collaboration, privacy and distraction. Proceedings of the 17th World Congress on Ergonomics, Beijing, 2009.

Bluyssen, P. M., Aries, M., Van Dommelen, P. (2011), Comfort of workers in office buildings: the European HOPE project. Building and Environment, 46(1), 280-288.

Brand, J.L., Smith, Th.J. (2005), Effects of Reducing Enclosure on Perceptions of Occupancy Quality, Job Satisfaction, and Job Performance in Open-Plan Offices, Proceedings of the Human Factors and Ergonomics Society Annual Meeting September 2005, Vol. 49 (8), 818-820.

Brennan, A., Chugh, J.S., Kline, Th. (2002), Traditional versus Open Office Design: A Longitudinal Field Study. Environment & Behavior, Vol. 34(3), 279-299.

Burke, W.W. (1994), Diagnosis for Organizational Change, Ch. 3, Guidford Press, New York.

Caldwell, J. A., Jones, G. E. (1984), The effects of exposure to red and blue light on physiological indices and time estimation. Doctoral dissertation, University of Southern Mississippi.

Christensen, C.M. (1983), Effects of Color on Aroma, Flavor and Texture Judgments of Foods, Journal of Food Science, Vol. 48(3), 787–790.

Claessen, J.P. (1995), Shaped by Colour, a Study on the Effect of Colour on the Perceived Shape of Objects. PhD diss., Technical University Delft.

Clements- Croome, D. (2000), Creating the Productive Workplace, Taylor & Francis, New York, USA.

Crowley, A.E. (1993), The Two Dimensional Impact of Color on Shopping. Marketing Letters, 4 (1), 59–69.

Csikszentmihalyi, M., Rochberg-Halton, E. (1981), The meaning of things: Domestic Symbols and the self. Cambridge, Cambridge University Press.

Dainoff, M. J. 1990. "Ergonomic Improvements in VDT Workstations: Health and Performance Effects." in DeRango, K., Amick, B.C., Robertson, M, Rooney, T, Moore, A. (2003), The Productivity Consequences of Two Ergonomic Interventions, Upjohn Institute Working Paper No. 03-95.

Danuser, B., Moser D., Vitale-Sethre T., Hirsig R., Krueger H. (2003), Performance in a complex task and breathing under odor exposure, Hum Factors. 5, 549–562.

de Croon, E., Sluiter,J., Kuijer, P.P., Frings-Dresen, M. (2005), The effect of office concepts on worker health and performance: a systematic review of the literature, Ergonomics, Vol. 48(2), 119-134.

DeRango, K., Amick, B.C., Robertson, M, Rooney, T, Moore, A. (2003), The Productivity Consequences of Two Ergonomic Interventions, Upjohn Institute Working Paper No. 03-95.

Devlin, A.C. (1992), Psychiatric ward renovation staff perception and patient behavior. Environment and Behavior, 24(1), 66-84.

de Waal, A. (2001), Presteren is mensenwerk, het streven naar een persoonlijke balanced scorecard, Kluwer, 35, 172.

Diego, M., Aaron Jones, N., Field, T., Hernandez-Reif, M., Schanberg, S., Kuhn, C., McAdam, V., Galamaga, R., Galamaga, M. (1998), Aromatherapy positively affects mood, EEG patterns of alertness and math computations, International Journal of Neuroscience, 96, 217–224.

Dijksterhuis, A. (2007), Het slimme onbewuste, denken met gevoel, Uitgeverij Bert Bakker, Amsterdam.

Distel, H., Hudson R. (2001), Judgment of odor intensity is influenced by subjects' knowledge of the odor source, Chem Senses. 26:247–251.

Dowell, W.R., Yuan, F., Green, B.H. (2001), Office seating behaviors: an investigation of posture, task and job type. Proceedings of the Human Factors and Ergonomc Society, 1245-1248.

Drucker, P. F. (1973), Management : Tasks, Responsibilities, Practices, Harper & Row, New York.

Elliot, A., Maier, M.A. (2007), Color and psychological functioning, Psychological Science, Vol. 16(5), 250-4.

Elliot, A.J., Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J. (2007), Color and psychological functioning: the effect of red on performance attainment, Journal of Experimental Psychology, Vol. 136 (1), 154-68.

Fanger, P.P. (1970), Thermal Comfort, McGraw-Hill, New York.

Feldman, L.A. (1995), Valence focus and arousal focus: Individual differences in the structure of affective experience. Journal of Personality and Social Psychology, Vol. 69(1), 153-166.

Fiore, A.M. , Yah, X., Yoh, E. (2000), Effects of a Product Display and Environmental Fragrancing on Approach Responses and Pleasurable Experiences, Psychology & Marketing, Vol. 17(1), 27-54.

Fjeld, T., Veiersted, B., Sandvik L. Riise G. Levy, F. (1998), The Effect of Indoor Foliage Plants on Health and Discomfort Symptoms among Office Workers, Indoor and Built Environment, Vol. 7(4), 204–209.

Fraser, K.D. (2011), Arts-based methods in health research: A systematic review of the literature, Arts & Health: An International Journal for Research, Policy and Practice, Vol. 3(20),110-145.

Frazelle, S.J. (1992), A Process for Process Improvement in a White Collar Environment, Productivity and Quality Improvement, in Government, edited by Fargher, J.S.W., Institute of Industrial Engineers, 02/92, 347-350 in Thomas, B.E., Baron, J.P. (1994), Evaluating Knowledge Worker Productivity: Literature Review, US Army Corps of Engineers, AD-A283-866, USACERL Interim Report FF44/27, Research Laboratories.

Freeman, R. (2008), Labour productivity indicators, comparison of two OECD databases, Productivity Differentials and the Balassa-Samualson effect, OECD.

Fried, Y. (1990), Workspace Characteristics, Behavioral Interferences, and Screening Ability as Joint Predictors of Employee Reactions: An Examination of the Intensification Approach, Journal of Organizational Behavior, Vol. 11(4), 267-280.

Gaillard, A.W.K. (2003), Stress, Productiviteit en Gezondheid, Uitgeverij Nieuwezijds, Amsterdam.

Gaygen, D.E., Hedge, A. (2009), Effect of Acute Exposure to a Complex Fragrance on Lexical Decision Performance, Chem. Senses, 34 (1): 85-91.

Gesler, W., Bell, M., Curtis, S., Hubbard, P., Francis, S. (2004), Therapy by design: evaluating the UK hospital building program, Health & Place, 10(2), 117-128.

Gilbert, A., Knasko, S., Sabini, J. (1997), Sex differences in task performance associated with attention to ambient odor, Arch. Environ. Health, 52, 195–199.

Goethe, J.W. (1981), Kleurenleer, eerste editie, Uitgeverij Vrij Geestesleven, Zeist.

Groenesteijn, L. ,Vink, P., de Looze, M., Krause, F . (2009), Effects of differences in office chair controls, seat and backrest angle design in relation to tasks, Applied ergonomics, Vol. 40(3) 362–37.

Gutnick, L. (2007), A Workplace Design That Reduces Employee Stress and Increases Employee Productivity Using Environmentally Responsible Materials. Dissertation, Eastern Michigan University, Michigan.

Hackman, J.R., Oldham (1980), Work redesign. Addison-Wesley Publishing Company. Philippies in Van der Voordt, D.J.M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

Hansen, T. (2005), Understanding consumer perception of food quality: the cases of shrimps and cheese. British Food Journal 107 (7), 500–525.

Harrington, S.S., Walker, B.L. (2004), The effects of ergonomics training on the knowledge, attitudes, and practices of teleworkers. Journal of Safety Research 35, 13-22.

Haynes, B.P. (2008a), The impact of office layout on productivity. Journal of Facilities Management, Vol. 6 (3), 189 – 201.

Haynes, B.P. (2008b), Impact of workplace connectivity on office productivity. Journal of Corporate Real Estate, Vol. 10(4), 286 – 302.

Hayward, C.S., Franklin, S.S. (1974), Perceived openness-enclosure of architectural space. Environment and Behavior, 6, 37-52.

Hedge, A., SIMS JR, W. R., & Becker, F. D. (1995), Effects of lensed-indirect and parabolic lighting on the satisfaction, visual health, and productivity of office workers. Ergonomics, 38(2), 260-290.

Hedge, A. (2004), Effects of an electric height-adjustable worksurface on self-assessed musculoskeletal discomfort and productivity in computer workers. METHODS, 8, 9.

Heerwagen, J.A., Kampschroer K., Powell K.M., Loftness V. (2004), Collaborative knowledge work environments. Building Research and Information, 32(6): 510–28.

Herzberg, F. (1959), Mausner,B., Snyderman, B., The Motivation to Work. in Van der Voordt, D,J,M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

Imamoglu, V. (1973), The effect of furniture on the subjective evaluation of spaciousness and estimation of size of rooms. In R. Küller (Ed.), Architectural psychology, page 314-352, Stroudsburg, PA: Dowden, Hutchinson & Ross.

In 't Veld, (1975), Analyse van Organisatieproblemen – Een Toepassing van denken in Systemen en Processen, AGON Elsevier, Amsterdam / Brussel.

Ishikawa, T., Montello, D. R. (2006), Spatial knowledge acquisition from direct experience in the environment: Individual differences in the development of metric knowledge and the integration of separately learned places. Cognitive psychology, 52(2), 93-129.

Jaakkola, J.J.K., Ieromnimon, A., Jaakkola, M.S. (2006), Interior Surface Materials and Asthma in Adults: A Population-based Incident Case-Control Study. Am. J. Epidemiol. , Vol. 164 (8), 742-749.

Judge, T. A., Thoresen, C. J., Bono, J. E. and Patton, G. K. (2001), The Job Satisfaction-Job Performance Relationship: A Qualitative and Quantitative Review. Psychological Bulletin, 127, 367 – 407.

Kahn, R.L. (1981), Work and Health, New York, Wiley, in Gaillard, A.W.K. (2003), Stress, Productiviteit en Gezondheid, Uitgeverij Nieuwezijds, Amsterdam.

Kaplan, R., Kaplan, S. (1989), The Experience of Nature: A Psychological Perspective, Cambridge University Press, New York, NY.

Kastelein, J.P. (2014), Space meets knowledge : the impact of workplace design on knowledge sharing. Dissertation, Nyenrode Business University, Breukelen.

Kaya, N. ,Epps, H.H. (2004), Relationship between color and emotion, a study of college students. College Student Journal, 396-405.

Kessels, J.W.M. (1996), Het Corporate Curriculum. Oratie. Leiden: Rijksuniversiteit Leiden.

Kessels, J.W.M. (2001), Verleiden tot kennisproductiviteit. Oratie. Universiteit Twente, Enschede.

Keursten, P., Verdonschot, S., Kessels, J., Kwakman, K, (2006), Relating learning, knowledge creation and innovation: case studies into knowledge productivity, Int. J. Learning and Intellectual Capital, Vol. 3, No. 4,, 405-420.

Kim, UK, Drayna, D. (2004), Genetics of individual differences in bitter taste perception: lessons from the PTC gene, Clinical Genetics, Vol. 67 (4),275–280.

Kim, W.G., Moon, Y.J. (2009), Customers' cognitive, emotional, and actionable response to the servicescape: A test of the moderating effect of the restaurant type. International Journal of Hospitality Management 28, 144–156.

Knasko, S. (1989), Ambient odor and shopping behavior. Chemical Senses, 14 (5), 719.

Knasko, S.C., Gilbert A.N. (1990), Emotional state, physical well-being, and performance in the presence of feigned ambient odor. J Appl Soc Psychol. 20, 1345–1357.

Küller, R. (1973), Beyond Semantic Measurement. In Architectural Psychology. Proceedings of the Lund Conference, Dowden, Hutchinson & Ross, Stroudsburg, PA, 181–197.

Küller, R. (1986), Physiological and psychological effects of illumination and color in the interior environment. Journal of Light and Visual Environment, 10, 33-37.

Küller, R., Mikellides, B., Janssens, J. (2008), Color, arousal, and performance—A comparison of three experiments. Color Research & Application, 34(2), 141-152.

Kwallek, N., C.M. Lewis, J.W. Lin-Hsiao, Woodson, H. (1996), Effects of Nine Monochromatic Office Interior Colors on Clerical Tasks and Worker Mood. Color Research and Application, Vol. 21(6), 448–458.

Latham, G. P., Locke, E. A. (2007), New Developments in and Directions for Goal-Setting Research, European Psychologist, Vol. 12(4), 290-300.

Leather, P., Beale, D., Santos, A., Watts, J., Lee, L. (2003), Outcomes of environmental appraisal of different hospital waiting areas. Environment and Behavior, 35, 842-869.

Lundström, J.N., Hummel. Th. , Olsson, M.J. (2003), Individual Differences in Sensitivity to the Odor of 4,16-Androstadien-3-one, Chem. Senses, Vol. 28 (7), 643-650.

Mahnke, F. (1996), Color, Environment, Human Response. New York: Van Nostrand Reinhold.

Marchant, B.(1982), A look at the industry-dimensions and prospects. American Nurseryman, Vol 156(10): 30-49.

Mattila, A.S., Wirtz, J. (2001), Congruency of scent and music as a driver of in-store evaluations and behavior, Journal of Retailing, 77, 273–289.

McCoy, J.M., Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity, Creativity Research Journal , Vol. 14(3 & 4), 409–426.

Meghisan, G, Meghisan, F. (2006), Aesthetics confers value to the firm, Management & Marketing Craiova (Management & Marketing Craiova), 1, 69- 72.

Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, 30. Cambridge, MA: MIT Press.

Mehrabian, A. (1996), Pleasure-Arousal-Dominance: A General Framework for Describing and Measuring Individual Differences in Temperament. Current Psychology, (14).4 ,261- 292.

Mehta, R. and Zhu, R.J. (2009), Blue or red? Exploring the effect of color on cognitive task performances Science Express, Vol.. 323, (5918), 1226-9.

Meyers-Levy, J, Zhu, R, (2007), The Influence of Ceiling Height: The Effect of Priming on the Type of Processing That People Use, Journal of Consumer Research, Vol. 34, 174-186.

Miles, M. (1994), Art in hospital: does it work? A survey of evaluation of arts projects in the NHS. Journal of the Royal Society of Medicine, 87(3), 161–16.

Morrison, M., Gan, S., Dubelaar, Ch., Oppewal, H. (2011), In-store music and aroma influences on shopper behavior and satisfaction, Journal of Business Research, 64, 558–564.

Oldham, G.R., Brass, D.J. (1979), Employee Reactions to an Open-Plan Office: A Naturally Occurring Quasi-Experiment. Administrative Science Quarterly, Vol. 24(2), 267-284.

Oseland, N. (1999), Environmental factors affecting office worker performance: A review of evidence, CIBSE Technical Memoranda TM24, CIBSE.

Osgood, Ch. E. (1964), Part four, Psychological approaches, Semantic Differential Technique in the Comparative Study of Cultures, American Anthropologist, Vol. 66 (3), 171-200.

Pejtersen, J., Allerman, L., Kristensen, T.S., Sjostrom, M. (2006), Indoor climate, psychosocial work environment and symptoms in open-plan offices, Indoor Air, 16(5), 392-401.

Porter, L. W., Lawler, E. E. (1968), Managerial attitudes and performance. Homewood, Illinois: Irwin-Dorsey.

Rapoport, A. (1990), The meaning of the built environment: A nonverbal communication approach. Tucson. University of Arizona Press.

Robertson, M., Amick, B.C., Derango, K., Roony, T., Bazzani, L., Harrist, R., Moore, A. (2009), The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. Applied Ergonomics, Vol. 40(1), 124–135.

Robertson, M. M., Ciriello, V. M., Garabet, A. M. (2013), Office ergonomics training and a sit-stand workstation: Effects on musculoskeletal and visual symptoms and performance of office workers. Applied ergonomics, 44(1), 73-85.

Sadalla, E. K., Oxley, D. (1984), The perception of room size: The rectangularity illusion. Environment and Behavior, 16, 291-306.

Sadalla, E.K., Sheets, V.L. (1993), Symbolism in Building Materials, Self-presentational and Cognitive Components, Environment and Behavior , Vol. 25(2), 155-180.

Sakai, N., Imada, S., Saito, S., Kobayakawa, T., Deguchi, Y. (2005), The effect of visual images on perception of odors. Chem Senses. 30: i244–i245.

Sardina, G.D., Vrat, P. (1987), A Model for Productivity Measurement in a Multi-Product Organization Using Programming and Multi-Attribute Utility Theory, Productivity Management Frontiers I, New York in Thomas, B.E., Baron. J.P. (1994), Evaluating Knowledge Worker Productivity: Literature Review, US Army Corps of Engineers, AD-A283-866, USACERL Interim Report FF44/27, Research Laboratories.

Scheuerle, H.J. (1984), Die Gesamt-Sinnes-Organisation. Überwindung der Subjekt-Objekt-Spaltung in der Sinneslehre, 2. neubearb. A. Thieme, Stuttgart.

Schneider, W. (1987), Sinn und Un-Sinn, Umweltt sinnlich erlebbar gestalten in Architektur und Design, Wiesbaden und Berlin: Bauverlag GMBH, 43, 106.

Seppänen, O., Fisk, W. J., Faulkner, D. (2004), Control of temperature for health and productivity in offices. Lawrence Berkeley National Laboratory.

Seppänen, O., Fisk, W. (2005), Some quantitative relations between indoor environment, performace and health. Proceedings of the International conference on Indoor Air Quality and Climate. Beijing. Plenary lecture.

Shibata, S., Suzuki, N. (2002), Effects of an indoor plant on creative task performance and mood, Journal of Environmental Psychology, Vol. 22 (3) 265-72.

Siegrist, J. (1996), Adverse health effects of high-effort. low-reward conditions, Journal of Occupational Health Psychology, 1, 27-41 in Gaillard, A.W.K. (2003), Stress, Productiviteit en Gezondheid, Uitgeverij Nieuwezijds, Amsterdam.

Sink, D. S., Vries, de S.J. (1984), An In-Depth Study and Review of 'State-of-the-Art and Practice Productivity Measurement Techniques, Conference Spring Proceedings, Institute of Industrial Engineers , 01.

Smith, C.A., Mirka, G.A., Myers, K.A. (2000), Ergonomic hand tool interventions for the furniture manufacturing industry. Proceedings of the IEA/HFES 2000 Congress, 99–104.

Smith-Jackson, T. L., Klein, K. W. (2009), Open-plan offices: Task performance and mental workload. Journal of Environmental Psychology, 29(2), 279-289.

Soesman, A. (2005), De Twaalf zintuigen, 4e druk, Vrij Geestesleven, Zeist.

Spring, M. (2001), Art surgery. Building, 36-41.

Srivens, S (1980), Interior Planting in large Buildings, London: The Architectural Press.

Stam, Ch. (2007), Knowledge Productivity, Designing and testing a method to diagnose knowledge productivity and plan enhancement, Dissertation University Twente, The Netherlands.

Stamps, A.E. (2009), On space and spaciousness. Environment and Behavior, Vol. 41(4), 526-548.

Stamps, A.E. (2011), Effects of Area, Height, Elongation, and Color on Perceived Spaciousness. Environment and Behavior, 43(2) 252–273.

Stedman, R.C. (2003), Is It Really Just a Social Construction?: The Contribution of the Physical Environment to Sense of Place. Society & Natural Resources: An International Journal, Vol. 16(8), 671-685.

Sundstrøm, E.D. (1986), Workplaces, The psychology of the physical environment in offices and factories. Cambridge University Press in Van der Voordt, D.J.M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

Sutermeister, R.A. (1969), People and Productivity. McGraw Hill, New York, 2nd edition in Van der Voordt, D.J.M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

Tanabe, S. I., Nishihara, N., Haneda, M. (2007), Indoor temperature, productivity, and fatigue in office tasks. HVAC&R Research, 13(4), 623-633.

Tangen, S. (2005), Demystifying productivity and performance, International Journal of Productivity and Performance Management, Vol. 54 (1), 34-46.

Ten Horn, L.A (red)(1999), Psychologische aspecten van de organisatie. Samson, Alphen aan de Rijn, 5de druk in Van de Voordt, D.J.M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

Thomas, B.E., Baron. J.P. (1994), Evaluating Knowledge Worker Productivity: Literature Review, US Army Corps of Engineers, AD-A283-866, USACERL Interim Report FF44/27, Research Laboratories.

Uhde, E., Salthammer, T. (2007), Impact of reaction products from building materials and furnishings on indoor air quality—A review of recent advances in indoor chemistry. Atmospheric Environment
Vol. 41 (15), 3111–3128. Indoor Air 2005 - 10th International Conference on Indoor Air Quality and Climate (Part I).

Ulrich, R.S. (1984), View through a window may influence recovery from surgery Science,
No. 224, 420-1.

Ulrich, R.S. (1991), Effects of interior design on wellness: theory and recent scientific research
Journal of health care interior design, Vol. 3(1), 97-109.

Vasmatzidis, I., Schlegel, R. E., Hancock, P. A. (2002), An investigation of heat stress effects on time-sharing performance. Ergonomics, 45(3), 218-239.

Van den Berg, A.E. (2005), Health impacts of healing environments: A review of the benefits of nature, daylight, fresh air and quiet in healthcare settings. Groningen: Foundation 200 years University Hospital Groningen.

Van der Linden, A.C., Kurvers, S.R., Raue, A.K. Boerstra, A.C. (2007), Indoor climate guidelines in The Netherlands: Developments towards adaptive thermal comfort Construction Innovation: Information, Process, Management, Vol. 7(1),72 – 84.

Van der Voordt, D,J,M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

Van der Voordt, D.J.M. (2003b), Productivity and employee satisfaction in flexible workplaces, Journal of Corporate Real Estate, Vol. 6 (2), 133-148.

Van der Voordt, D.J.M., de Been, I. (2010), Werkomgeving: Breinbreker of tevredenheidsgenerator in Bakker, I.C. (2010), De Breinwerker, Uitgeverij FMN, 67-86.

Van Hagen, M., Galetzka, M., Pruyn, A., Peters, J. (2009), Effects of colour and light on customer experience and time perception at a virtual railway station, Proceedings Experiencing Light 2009, International Conference on the Effects of Light on Wellbeing, 137-45.

Vonk, R. (2003), Cognitieve sociale psychologie. Uitgeverij Lemma BV, Utrecht, 375-380.

Wargocki, P., Fanger, P.O. (1997), Impact of changing the floor material on air quality in an office building. Proc. of Healthy Buildings/IAQ '97,243-248. Technical University of Denmark.

Wargocki, P., Wyon, D. P., & Fanger, P. O. (2000), Productivity is affected by the air quality in offices. In Proceedings of Healthy Buildings (Vol. 1, No. 1, pp. 635-40).

Warm, J.S., Dember, W.N., Parasuraman, R. (1991), Effects of olfactory stimulation on performance and stress in a visual sustained attention task, J Soc Cosmet Chem., 42(3),199–210.

Wilder, D., Magnusson, M.L., Pope, M. (1994), The effect of posture and seat suspension design on discomfort and back muscle fatigue during simulated truck driving. Appl.Ergon.,25, 66–76, in Wargocki, P., Fanger, P.O. (1997), Impact of changing the floor material on air quality in an office building. Proc. of Healthy Buildings/IAQ '97,243-248. Technical University of Denmark.

Weggeman, M. (2001), Kennismanagement, inrichting en besturing van kennisintensieve organisaties, Scriptum 4e druk., Schiedam.

Weggeman, M. (2007), Leiding geven aan professionals? Niet doen, Scriptum Schiedam.

Whitener, E.M. (2001), Do "high commitment" human resource practices affect employee commitment? A cross-level analysis using hierarchical linear modeling, Journal of Management, 17, 515-535.

Wolf, K.L. (2002), The impact of nature in and around shop areas; creation of an environment specifically suited to a consumer. Paper presented at the People/Plant Symposium, Amsterdam.

Woods, P.E. (2001), What is Productivity and How it is measured. in Van der Voordt, D.J.M. (2003a), Kosten en baten van Wekplekinnovatie, Een definitie- en programmeringsstudie, Stichting kenniscentum Center for People and Buildings, Delft.

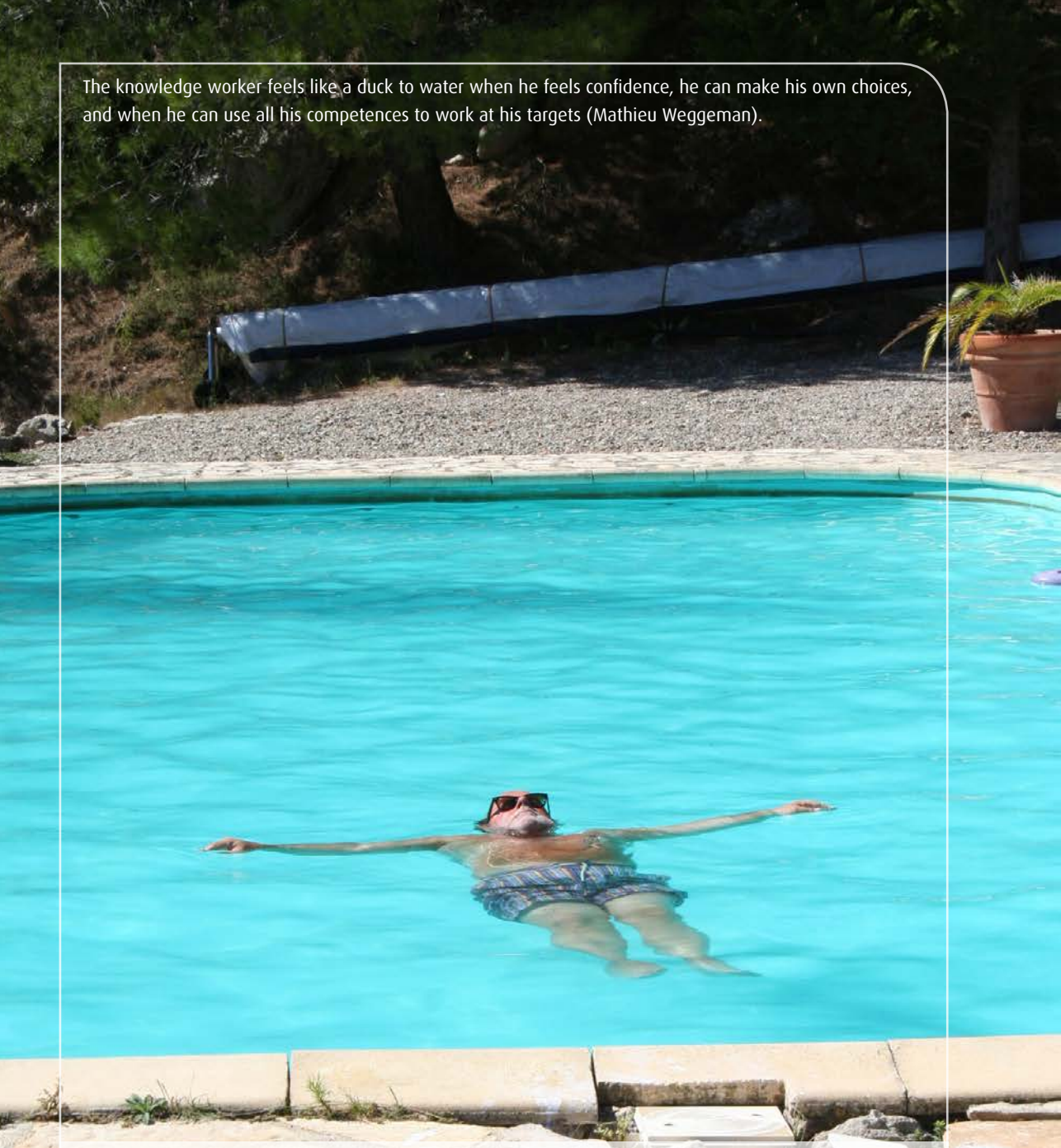
Wyon, D. P. (2004), The effects of indoor air quality on performance and productivity. Indoor air, 14(s7), 92-101.

Zajonc, A. (1996), Het licht zien, Het verbonden bestaan van licht en bewustzijn, Uitgeverij Vrij Geestesleven, Zeist.

Zellner, D.A., Kautz, M.A. (1990), Color affects perceived odor intensity, J Exp Psychol Hum Percept Perform., 16, 391–397.

Zemke, D.M., Shoemaker, S. (2008), A Sociable Atmosphere: Ambient Scent's Effect on Social Interaction, Cornell Hospitality Quarterly, Vol. 49(3), 317-329.

Knowledge productivity is less measurable than productivity of the manual worker.



The knowledge worker feels like a duck to water when he feels confidence, he can make his own choices, and when he can use all his competences to work at his targets (Mathieu Weggeman).

Many researches on the physical environment directly focus on technical solutions to create better environments However, buildings exist due to the existence of people. It is the knowledge worker who deserves attention and after this acquaintance with him, it is practical to have a look how the physical environment best fit. First a closer look at this knowledge worker.

Chapter Two
Knowledge productivity: in search for deeper need

The focus in this chapter is on the demand side and has a theoretical character as it is based on visions presented in textbooks: what is needed for the knowledge worker to perform best? Based on the five intrinsic needs as mentioned by Ryan and Deci (2001, 2002) and Pink (2102): competences, autonomy, relatedness, mastery and purpose, four key factors of the physical environment will be presented that might contribute to the environment, which stimulates productivity. Because the knowledge worker is not a stand-alone person but is working in networks to share knowledge and to develop knowledge by collaboration and social interactions, also attention is paid to these networks and knowledge.

abstract

As knowledge productivity is a complex topic an approach is presented based on insights from different knowledge disciplines. The knowledge worker has the central position. There will be focused on the needs of the knowledge worker finding the optimal conditions of the physical environment in which he can flourish. Next to these needs the mental energy of the knowledge worker asks attention as thinking is the central process within knowledge productivity. It appears that four work moods of the knowledge worker exist which are determining for the quality of his activities. These four work moods namely contemplation, awareness, collectiveness and social observation can be supported by appropriate environmental design. It appears that four environmental key factors are important to support optimal knowledge productivity. After collecting a huge amount of conditions which all support the knowledge worker, these four key factors turned to be structure, variety, psychological safety and identity. Some practical solutions based on a literature review show how these four key factors can be used in design to facilitate the four work moods of the productive knowledge worker.

2.1 Introduction

Drucker stated in 1999 that the biggest challenge for the knowledge economy was to use knowledge effectively to increase the knowledge productivity (Zegveld and Hartigh, 2007). In contrast to the productivity of the manual worker, Drucker characterised the productivity of the knowledge worker in terms of autonomy, responsibility for innovation, continuously learning, quality next to quantity and the treatment of the knowledge worker as an asset rather than a cost. It appears that specific personal needs and characteristics such as being able to make autonomous decisions or being curious are important preconditions to excel as a knowledge worker (Csikszentmihalyi, 1999b; Senge et al, 2001, 2008; Gaillard, 2003).

This chapter focuses on the question which key factors in the physical environment facilitate the knowledge worker to optimise his productivity. To find out in what environment the knowledge worker will be optimally productive his deeper needs will be observed, his energy, his work moods and his individual goals such as development of personal competences on his way to productivity. It is this focus which merely concerns a hypothesis rather than clear evidence although much literature of among others psychologists and physiologist supports the view of valid relationships between productivity and

concepts such as happiness and health. To elaborate this hypothesis frequently authors are cited such as Csikszentmihalyi, Covey, Pink and Goleman primarily referring to their views and in less extent to scientific research with evidence based statements. To find the key factors which are fundamental for a productive physical environment in which the knowledge worker can flourish, fully understanding of his intrinsic needs is necessary. People perform best when they are more motivated to act (Csikszentmihalyi, 1999b). Intrinsic motivators such as individual purposes have more influence on performances than extrinsic motivators such as salary (Amabile, 1996; Amabile et al, 2005; Csikszentmihalyi, 1998; Pink, 2010). As such, to understand the knowledge worker primarily insight is needed in his intrinsic needs. The first part of this chapter will focus on these intrinsic needs. In their self-determination theory Ryan and Deci (2000) mentioned three intrinsic needs as fundamental motivators, that are highly connected with the pyramid of Maslow: competences, autonomy and relatedness. The often mentioned pyramid of Maslow (1943) shows the hierarchical levels of human needs ranging from physiological and safety needs to needs of belonging, esteem and self-actualization. In the current knowledge area in which the physiological needs and safety needs (such as shelter, security and freedom from fear), in general are fulfilled, especially the higher levels of a sense of belonging, esteem and self-actualisation ask for attention. Ryan and Deci (2000) conceived competence as the need to succeed at tasks and to control the outcomes. The need for autonomy concerns experiencing choice and feelings of being the initiator of one's owns actions (Deci et al, 2001). Relatedness is the universal need to interact with others and to be connected with them. Pink (2010) mentioned two supplementary intrinsic needs: mastery and purpose. Mastery is the desire to improve and to get better in doing things which make sense. Purpose refers to the fact that people who find their activities serving a particular purpose are connected with feelings of meaning (Csikszentmihalyi, 1999b). If the activities of the knowledge worker match with his personal needs and drives he will be more eager and passionate to perform optimally in both quantitative and qualitative way. The underlying assumption of this chapter is that a knowledge worker performs best if he is able to fulfil his own needs and drives and he can use his energy efficiently. In knowledge productivity the central activity is 'thinking' and 'thinking' can be conceived as ordering of mental energy (Csikszentmihalyi, 1999b). If the knowledge worker is able to use his energy appropriately he will flourish which contributes to his happiness. What counts for all types of energy, is that energy optimally streams when the resistance is lowest. To provide this lowest resistance, a work environment is needed in which the energy of the knowledge worker can easily flow with energies from other knowledge workers.

It is not the knowledge worker as standalone individual who performs best getting optimal success, but the cooperation and coherence between knowledge workers in knowledge networks. As such, not only the knowledge worker as an individual deserves attention, but also the networks of knowledge workers to explore how mental energy can be used in the optimal way. What applies to the knowledge worker, also applies to the network: as thinking is the central process in networks, this mental energy process has to be optimally facilitated. After the acquaintance with the knowledge worker and networks of knowledge workers, attention will be paid to the product, i.e. knowledge. Knowledge as the product of the knowledge economy can be conceived as a complex phenomenon with a diversity of data that are more or less approachable, transparent and understandable (Weggeman, 2001). Different types of knowledge exist such as codified knowledge that can be conceived as quantitative date and can be stored in computer databases and tacit knowledge that is less approachable than knowledge being in one's head.
The knowledge worker as an individual, networks of knowledge workers and knowledge, all three make demands on the physical environment. In the next paragraphs, the conditions will be mentioned at the end of each paragraph. It appears that all healthy and productive environments meet the same basic

key factors. Introducing these key factors is a first step to be able to connect the needs of the knowledge worker with the physical environment, and as such with Place.
These key factors have to be translated to make them workable and practical. This happens in the next step that concerns the connection with Time. The knowledge worker cannot be conceived as a rigid and continuous producer of the same activities, but needs to be able to choose carefully how to conduct his work activities depending on his mood. Of course, the knowledge worker has to keep to the schedules within the organisation, his personal responsibilities, appointments with others and times for group meetings. Next to these conditions, the knowledge worker, however, needs to plan his activities as much as possible so that they suit his mood. Mood is time related. One time he prefers to work alone deeply concentrated, another time he prefers to be in discussion with colleagues. In the last paragraph a translation will be made from the more general key factors into time related solutions as guidelines for work environmental design to be able to create work areas where the knowledge worker depending on his mood and energy can flourish.

Sustainable productivity can be reached by adapting environments to human and organisational characteristics.
To stimulate optimal human performance, discomfort should be prevented. The tram cabin should in fact be built around the driver to accommodate his performance. The same applies to the environment of the assembly worker and the software system of the office worker. Optimal human performance is needed to stay ahead of competitors and reducing discomfort can be of great support (Peter Vink, 2013).

Due to a huge number of influencing factors on our productivity it is hardly possible to isolate the impact of one single factor and measure its effects in a reliable and valid way. But let's not be lazy and only investigate easy topics. When one loses his keys at a dark place it does not make sense to search at a place elsewhere with more light. We have to search at the right place and find ways to let more light shine at the dark spot (Theo Van der Voordt, 2014).

Figure 1 shows the path that is used to explore the conditions of a productive physical environment.

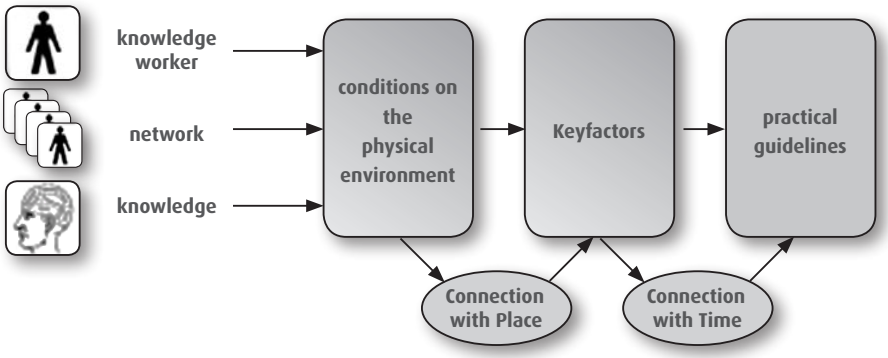


Figure 1: How to translate the needs of the knowledge worker, networks and knowledge into physical conditions and practical guidelines

2.2 The intrinsic needs and drives of knowledge workers

The more the knowledge worker is intrinsically motivated, the better his performances (Haywood and Burke, 1977; Benware and Deci, 1984; Lloyd and Barenblatt, 1984; Gottfried, 1985, 1990; Grolnick et al, 1987; Deci et al, 1991). As such it is interesting to know which needs strengthen the intrinsic motivation of the knowledge worker. In the next paragraphs these needs as mentioned by Ryan and Deci (2000) and Pink (2010) will be elaborated to get insight in the conditions for the productive physical environment (Table 1).

Table 1: the five needs of the knowledge worker

table

Needs	Definition
Competences	Succeeding at tasks and controlling the outcomes.
Autonomy	Experiencing choice and feelings of being the initiator of one's owns actions.
Relatedness	Interacting with others and being connected with them.
Mastery	Striving to improve someone's performances.
Purpose	Doing activities which make sense for someone and which are connected with feelings of meaning.

2.2.1 Competences

Rogers (1982) believed in one central human motive, the self-actualisation tendency: naturally, people strive to explore their competences during life span and fulfil their potentials to achieve the highest levels of development. Feeling competent is correlated with enhanced wellbeing (McGregor and Little, 1998; Carver and Scheier 1999). Being competent concerns a huge amount of capacities varying from being social, sensitive till being a great musician (Gardner, 1999). Covey (2005) made an interesting distinction between four kinds of competences:

a mental competence (mentioned by Covey as IQ), which stands for Intelligence Quotient, that is connected with the mind;
b emotional competence (EQ), that is connected with the heart;
c physical competence (PQ) that is related to the body;
d spiritual competence (SQ) that is related to the spirit.

Contrary to the common perception of IQ as the dominant factor of performance and success, according to Covey (2005), it is the balance between the four competences. The integration of the four competences is a necessary precondition for the development process of the knowledge worker combining thinking and doing by head, heart and hands (Kessels et al, 2011). These four competences are further elaborated below.

a. Mental competence

The mental competence (IQ) is the ability to analyse, rationalise, think abstractly, visualise and comprehend and shows itself by having vision (Goleman, 1996; Covey, 2005). These mental competences express themselves in conscious and unconscious thinking processes. Although the conscious thinking processes are fundamental for all work activities, Leonardo Da Vinci already recognised the richness of unconscious thinking processes rather than the more limited conscious thinking processes

(Dijksterhuis, 2007). Work that asks for creativity and innovation needs both phases for conscious thinking and periods in which the unconscious thinking can develop freely (Rogers, 1954, Amabile and Gryskiewicz, 1988; Amabile and Conti, 1999; Claxton, 2000). By retaining the conscious thinking patterns, possibilities can be created for these richer unconscious processes. To create these chances and give room to unconscious thinking, one can plan some activities that not directly require serious conscious thinking processes. Such activities are for instance simple routine or common daily activities or a break for walking without any conscious focus on the topics to think about. An example of a company that organised free thinking time for the employees is Google. Google allowed employees to take one day a week just available for thinking creatively about real and innovative products and services connected with Google, provided that this had something to do with their formal tasks.This idea appeared to be the most important source for the most profitable ideas (Pink, 2010).

If companies really are convinced about the importance of innovation and creativity, then these phenomena have to be highly valued, and room has to be created to show that innovation and creativity are key factors which finally determine the success.

With my colleagues we begin in the morning at my room and after an hour we take a walk and after another hour we take some coffee. Every time another environment gives a boost to our thinking processes. For us changes of places is very important (Robbert Dijkgraaf, 2012).

b. Emotional competence

The emotional competence (EQ) concerns self-knowledge, self-awareness and the capacity to communicate with others, to feel empathy for them and to behave appropriately in the social context. Based on neurological and psychological research of among others Arnold (1992), Mischel et al (1992), Damasio (1994) and Nowicki and Duke(1994), Goleman (1996) concluded that for a successful career and succeeding in tasks the emotional competences have twice as more influence rather than the mental competences. Additionally, neurological evidence shows that for decision making emotion plays a prominent role (Goleman, 1996). The emotional competences have determining effects on the quality of cooperation and coherence within a group. The social harmony as the result of the emotional competences of the group members determines the mental group competences that on their turn highly contribute to performance (Goleman, 1996). Due to the importance of the emotional processes within groups, the quality and the quantity of the interactions between the group members need to be supported, both formal and informal. To optimise these interactions certain preconditions are requested: the feelings of psychological safety of the knowledge worker need to be nurtured (Edmondson, 1999) and the direct eye contacts between knowledge workers belonging to one's own knowledge discipline and other knowledge disciplines need to be stimulated (Ramachandran and Brakeslee, 1998; Hatfield et al, 1993; Ekman, 2008; Miles et al, 2009).

c. Physical competence

The physical competence (PQ) concerns all bodily capacities of running appropriately processes such as respiration and the processes of the nervous system. In accordance with the phrase 'Mens sana in corpore sano' (A healthy mind in a healthy body), the physical competences are essential for the knowledge worker. In the time of the ancient Greece, people already were convinced of the influence of their physical state. They realised for instance that walking had positive influences on their thinking patterns.
In accordance with their so-called peripathetic method, Greek philosophers used to walk through the

gardens of the Academia with their students (Csikszentmihalyi, 1998). Walking improved the quality of their thinking processes. In line with this, it was Nietzsche who said 'All truly great thoughts are conceived by walking'. Conscious thinking processes while focusing on a specific topic or target follow common thinking patterns (de Bono, 1997; Kessels et al, 2011). However, during a walk, a part of our brains has the freedom to make unconsciously new connections less linear and less predictable, that leads to more creative and innovative ideas (de Bono, 1997; Csikszentmihalyi, 1998). Active movement inside or outside appears a vital condition for learning processes (Gregory, 1998; James, 2010). A close relationship exists between physical, mental and psychological processes (Goleman, 1996; Gaillard, 2003). Negative emotions have negative effects on health. Events with a psychological load such as a dissatisfied manager or dismissal, cause physiological effects such as high blood pressure, and vice versa physiological indicators such as heartbeats can induce psychological effects such as anxiety (Gaillard, 2003). Stress as a result of an unbalance between psychological load and existing competences causes changes in neural and neuroendocrine systems (McEwen and Stellar, 1993) and divergent physical diseases such as weaknesses of the immune system (McEwen and Stellar, 1993; Vingerhoets, 1995), heart diseases (Krantz and Manuck 1984; Karasek and Theorell 1990; Kamarck and Jennings, 1991), cold (Sheldon et al, 1998) or cancer (Goleman, 1996). It is important to take care for the vitality and bodily condition of the knowledge worker, as wellbeing on both short term and long term has a positive effect on performances (Fredrickson and Losada, 2005; Kessels et al, 2011).

d. Spiritual competence

The spiritual competence or spiritual quotient (SQ) concerns the ability to recognise meaning and the quality of making sense. It represents itself by consciousness and the sense what is right and what is wrong. This competence determines the directions of attention of the other three kinds of competences (Covey, 2005) and can be conceived as a guidance of how to use and to develop them during lifetime (Zohar and Marshall, 2000). By breeding awareness, intuition can be increased (Krishnakumar and Neck, 2002), that stimulates creativity (Freshman, 1999; Krishnakumar and Neck, 2002; Neck and Milliman, 1994). Intuition seems to be based on unconsciously consulting of all relevant information (Kessels et al, 2011) and can be conceived as a personal provider of knowledge (Nonaka and Takeuchi, 1995; Weggeman, 2001). The knowledge worker needs time to be alone for free thinking, making contact with his unconsciousness to develop ideas and to find creative solutions (Korpela, 1989; Claxton, 2000; Heerwagen et al, 2004). Spirituality brings benefits for the employees such as feelings of fulfilment (Burack, 1999; Krishnakumar and Neck, 2002), wellbeing, happiness and satisfaction (Naylor et al, 1996; Turner, 1999). It supports organisational factors such as connectivity (Neck and Milliman, 1994; Ashmos and Duchon, 2000;) and a growing involvement and commitment to organisational goals (Neck and Milliman, 1994; Leigh, 1997; Delbecq, 1999; Mitroff and Denton, 1999; Turner, 1999; Krishnakumar and Neck, 2002). Brefczynski-Lewis et al (2007) showed neurological evidence that meditation can strengthen concentration, an important condition to focus on the job. Central issues that support spirituality at the workplace, are establishing a trustful climate (Burack, 1999), attention and respect for personal fulfilment (Freshman, 1999) and an organisational attitude to show honesty as the prime focus towards employees, customers and suppliers (Wagner-Marsh and Conely, 1999).

The knowledge worker needs rest to achieve ways of thinking that are deeper (Kessels, 2011).

Regarding the four competences as described above the physical work environment can be supportive by offering the next conditions:

Table 2: Physical conditions that support the four competences:

- stimulating the unconscious thinking processes
- supporting feelings of psychological safety
- supporting the quality and quantity of interactions between knowledge workers both formal and informal
- offering a variety of spaces from shelter till openness
- providing direct eye contacts between knowledge workers belonging to the same knowledge discipline and other knowledge disciplines
- stimulating movement inside and outside
- creating a variety of possibilities for supporting the vitality and bodily condition of the knowledge worker
- giving room for meditating and musing

2.2.2 Autonomy

In the Self-determination Theory of Ryan and Deci (2000) and as one of the core values of intrinsic motivation according to Pink (2010), autonomy is an important psychological need. People need self-control concerning their personal goals (Csikszentmihalyi, 1999b) and the freedom to choose how to achieve their goals (Gaillard, 2003; Covey, 2005). The degree of autonomy influences the physiological and psychological state and feelings of happiness (Covey, 1995; Gaillard, 2003). If someone has the feeling of too little control, the cortisol level in his blood will arise which negatively influences the emotional state (Gaillard, 2003). On the contrary, feelings of control have positive effects: Reim et al (1971) for instance showed that people are less irritated by sound when they have the ability to control the sound level. Also for the knowledge worker counts that autonomy regarding the individually determined goals leads to happiness and productivity (Pink, 2010). If people are able to do the things they prefer and perform best, for the organisation this leads to productivity and success (Kessels et al, 2011; Clifton and Buckingham, 2003). Companies that stimulate autonomy among the employees perform better demonstrating higher growth and lower staff turnover (Pink, 2010). Employees need to feel free to move and to act (Amabile and Gryskiewicz, 1988; Amabile and Conti, 1999; Csikszentmihaly, 2003). This freedom however is not without any boundaries but is connected within the responsibilities and agreements in the organisational context. A clear structure is necessary with clearness of tasks, that enables people to work autonomously and creatively (Senge et al, 2008; Collins, 2005). Being an autonomous individual does not only mean to be a person who is able to act the way he wants, but also to conceive oneself as a unique person, with a unique identity. The feelings of being a unique individual contributes to feelings of being an autonomous person. To stimulate these emotional feelings of autonomy, the physical environment needs to support these feelings by providing surroundings with identity applying to that specific individual (de Croon et al, 2005; Millward et al, 2007). Regarding this identity two factors are important. First, the knowledge worker needs an inner circle with a unique group identity due to his psychological need for relatedness to belong to a group of people (Alexander et al, 1977; Kessels et al, 2011). Second, the individual needs an identity of the network as outer circle he wants to belong to due to his individual preferences regarding meaning, culture and image. These common preferences for the network are essential for feelings of involvement (Kessels et al, 2011).

People appreciate if they can spend a small amount of money or take some personal things to create their own personal atmosphere. I remember the fractious comments on the new built town hall of The Hague by architect Richard Meier who used his principle: Everything is allowed, provided that it is white colour. On the occasion of every simple office plant placed in the windowsill his lawyer from New York called. This is experienced as a too hard direction (Rinnooy Kan, 2010),

Regarding the four competences as described above the physical work environment can be supportive by offering the next conditions:

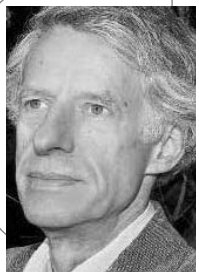
Table 3: Physical conditions that support autonomy:

table

- providing employees with self-control in choosing their own ways of working
- experiencing the physical environment as informal rather than controlling
- facilitating identity on group level in order to support social feelings of belonging and experiencing the groups identity and on network level to support feelings of recognition, affect and proudness.

2.2.3 Relatedness

According to Senge et al (2001) working together contributes to productivity and success. As such relatedness is an important psychological need that supports productivity. In the work situation positive social interactions have positive effects on one's functioning and increases one's energy levels (Warr, 1994; Gaillard, 2003). Social contacts lead to feelings of identity (Gaillard, 2003; Millward et al, 2007) and are highly correlated with experiencing support (Gaillard, 2003). This support reduces feelings of stress, (Gaillard, 2003). Rogers mentioned that what people really need is esteem of other people (Franzen, 2004). This esteem can be recognised in positive feedback. In the work conditions positive, relevant and personal feedback is of great importance (Deci, 1971; Vallerand and Reid, 1984; Csikszentmihalyi, 1999a, Gaillard, 2003; Giancola, 2011) that increases intrinsic motivation because it enhances perceived competence (Vallerand, 1983; Vallerand and Reid, 1984; Blanck et al, 1984; Harackiewicz and Larson, 1986; Deci, et al, 1991). As such feedback is essential for learning processes (Kessels et al, 2011). Relatedness is positive correlated to feelings of happiness (Argyle, 1987, Haidt, 2006; Myers, 1999 in Ryan and Deci, 2000; Ryan and Deci, 2001), wellbeing (Carstensen, 1998) and social contacts and social cohesion influence psychological and physiological processes. It can be concluded that relatedness strongly is intertwined in concepts such as productivity, happiness and wellbeing. The importance people attach to relatedness can be recognised in old languages such as Latin. The original expression for 'to live' is 'inter hominem esse' that means to be among men (Csikszentmihalyi, 1999a).



It appears that interactions with a matey character most strongly correlate with experienced support....The minimum thing someone wants is being part of a team (Tony Gaillard, 2009).

The most successful creatures on earth are according to Senge (2001) those who work together in teams. Effective collaboration is essential to perform successfully. The quality of collaboration is directly proportional to the quality of the products or services (Brockman and Morgan, 2006; Kessels et al, 2011). Etymologically, the company is by definition a place where people share their energies. The word 'company' is deduced from the Latin combination 'com panis' that means 'sharing of bread' (Senge et al, 2008). Even more than arts, science is founded on collectivity with an exchange of ideas and building on each other's opinions (Csikszentmihalyi, 1998). This collectivity contributes to a common identity and a common organisational culture (Kessels et al, 2011). It positively related to knowledge development (Brockman and Morgan, 2006), productivity and affect among employees (Landers et al, 1982; Wolfe and Box, 1987; Greene, 1989; Alkahafaji and Tompkins, 1990).
Zajonc (1968) showed that the frequency of interactions contributes to the fact that people like each other more. To increase affect in the organisation, it is recommendable to support informal interactions and their frequency (Hagstrom, 1965). Informal communication may happen by coincidence during walking through corridors, sections and facilities in the work environment and during coffee and lunch breaks (Hagstrom, 1965; Kraut et al, 1988). An increase of the affective feelings towards the networks enlarges the energy of the knowledge worker (Weggeman, 2001).
There are two types of networks. The informal collaboration networks are essential in many respects to easily solving unforeseen problems (Kraut et al, 1988; Kelley and Caplan, 1993; Goleman, 1996; Kessels et al, 2011), and in general strengthening social cohesion. However, also formal networks with a planned character are necessary to discuss for instance the mission statements. People have to know these mission statements and also seriously believe these statements (Drucker, 2000). Knowing the mission statements and personal goals, one is able to recognise the shared values, the common values for the organisation and the individual. These shared values as common goals are essential for the collective ambition and involvement (Warr, 1994; Gaillard, 2003). Recognition of the shared values strengthens the feelings of relatedness.

For a high quality communication it is important that people have direct eye contact and are able to see each other's facial expressions and body language and to hear each other's voice (Ramachandran and Brakeslee, 1998; Hatfield et al, 1993; Ekman, 2008; Miles et al, 2009). Words are representations of emotions (Ekman, 2008). Communication research shows that approximately 90% of an emotional message is nonverbal (Goleman, 1996). By means of the so called mirror neurons which are known since 1996, knowledge can be processed about each other's behaviour, thoughts and emotions to make them understandable for others (Gallesea et al, 2004; Oberman and Ramachandran, 2007). Mirror neurons are essential for learning processes and to understand and behave in social contexts (Oberman et al,2007; Kessels et al, 2011; Ramsey and Hamilton, 2012). High quality communication with direct eye contact, makes basic communication concepts possible such as synchrony, imitation and mindreading. Synchrony concerns simultaneous behaviour which confirms each other's understanding. Imitation of facial expressions, body language and behaviour supports mutual understanding and respect. Mindreading can also be conceived as a sign of understanding and commitment (Hatfield et al, 1993; Goleman, 1996; Miles et al, 2009). Mindreading is the ability to make a representation of the mental states of others and to adjust responses appropriately (Gallese and Goldman, 1998). In addition, neurologically it can be established that in interactions between people the amygdala as emotional centre reacts on information concerning facial expression and viewing direction, essential information to receive mutual understanding during communication.

In a knowledge economy employees have to learn permanently to stay economically attractive and to obtain maximum employability (Kessels, 2011).

This coordination of interactions elicits feelings of connectedness and interpersonal support (Miles et al, 2009). For the knowledge worker it is essential to understand exactly what other knowledge workers mean. As such, direct communication is necessary.
Proximity increases the frequency of communication, its quality and chances for collaboration (Hagstrom, 1965; Mayer, 1976; Allen, 1977; Eveland and Bikson, 1987; Kraut et al, 1988; Appel-Meulenbroek, 2014; Kastelein, 2014). Proximity positively influences communication and collaboration. However in many offices people working together are housed at different floors. Alexander et al (1977) showed that the number of people knowing each other decreases depending on the number of floors between each other's work place. A staircase between floors creates a distance of approximately 30 meters (Alexander et al, 1977).

Regarding relatedness as described above the physical work environment can be supportive by offering the next conditions:

Table 4: Physical conditions that support relatedness:

- generating feelings of identity to support recognition of roles, connectedness and cohesion and uniqueness in social interactions
- facilitating teamwork in which people experience esteem and receive positive feedback
- stimulating informal contacts and social interactions
- stimulating formal contacts
- offering a variety of spaces where knowledge workers observe and meet each other in different circumstances and during different activities
- stimulating direct eye contact in communication
- creating proximity

2.2.4 Mastery

Intrinsic motivation and enjoyment in knowledge work are forces to mastery (Csikszentmihalyi, 1998). To reach the level of mastery, one is never finished with the learning process and one needs continuously education (Drucker, 1999; Drucker, 2000; Kessels et al, 2011). This asks for an attitude of being curious, perseverance with discipline, accepting responsibilities and dedication (Collins, 2005). Creativity can be supported by an creativity fostering environment (Rogers, 1954; Harrington, 1987) to challenge people such as the ability of interactions with different knowledge disciplines or physical objects such as books and old instruments. It is striking that according to Collins also the successful G2G companies are characterised with the same adjectives such as persevering, focused and responsible. Learning and working are strongly connected with each other (Kessels et al, 2011). To stimulate mastery and support

curiosity, the knowledge worker needs to meet – next to knowledge - different knowledge workers from different knowledge disciplines, with different backgrounds, views and insights by coincidence or in formal systems.

Regarding mastery as described above the physical work environment can be supportive by offering the next conditions:

Table 5: Physical conditions that support mastery:

table

- creating and establishing an atmosphere to feed a culture of discipline and responsibilities
- stimulating the curiosity degree making knowledge touchable, visible and accessible
- stimulating the curiosity degree among knowledge workers during social interactions
- creating a close connection between the learning and work environment

2.2.5 Purpose

People yearn to find their individual purposes that generate personal meaning and that contribute to the world around them (Covey, 2005). They have the expectation that all goals they try to achieve contribute to their happiness (Csikszentmihalyi, 1999a; Csikszentmihalyi, 1999b). During lifetime, people try to use and explore their competences to come closer to their purposes (Csikszentmihalyi, 1999b; Kessels et al, 2011). Knowing the individual purposes and working at these purposes generate positive feelings of self-esteem (Csikszentmihalyi, 1999b), physical wellbeing (Brunstein, 1993) and positive mood (Csikszentmihalyi, 1999b). Working towards personal goals not only brings positive effects for the knowledge worker, but also for the network. Peters and Waterman (1982) found that a target driven culture in organisations leads to success (Weggeman, 2001; Kessels et al, 2011). To perform successfully as a knowledge worker, one has to focus on the common goals of individual and organisation, i.e. the shared values. It is important to stimulate an atmosphere of psychological safety in which the knowledge worker feels free to speak openly about his personal objectives to find chances in making connections between personal and organisational goals.

Regarding purposes as described above the physical work environment can be supportive by offering the next conditions:

Table 6: Physical conditions that support purposes:

table

- providing a psychologically safe environment where people feel free to speak openly about their personal objectives and connectedness with the network
- stimulating awareness of both networks goals and personal goals and drives by showing individual, group and organisational goals

2.2.6 Relationships between different needs

In the extensive literature many relationships are mentioned between the characteristics of the knowledge worker, his performances and the network. Feelings of being competent, relatedness to others, focus on purpose and being able to work towards purposes all contribute to feelings of happiness and wellbeing (Baumeister and Leary ,1995; Deci et al, 1991; McGregor and Little, 1998; Carver

and Scheier, 1999; Csikszentmihaly, 2003; Collins, 2005). These feelings of happiness and wellbeing are connected with the degree of intrinsic motivation of the knowledge worker. This in turn shows relationships with his performances. Organisational aspects are interrelated as well: the degree in which organisational goals are accepted by the employees, cohesion, team effectiveness and organisational performance are mutually related (Landers et al, 1982; Wolfe and Box, 1987; Greene, 1989). The conclusion is that the characteristics of the knowledge worker and organisational aspects have many relationships. Both the knowledge worker and the network flourish when their mutual commitment strengthen each other. This happens when the energy of the knowledge worker in the network can easily flow.

2.3 Energy of the knowledge worker and the knowledge network

2.3.1 Energy of the knowledge worker

It was Aristotle who said 2300 years ago that people primarily strive to happiness. An interesting linkage exists between working towards individual goals and striving to happiness (Figure 2): when people devote their energy at their personal goal, they will experience happiness (Csikszentmihalyi, 1999a; Csikszentmihalyi, 1999b; Covey, 2005). Due to the feelings of happiness, the people are intrinsically motivated to use all their competences and energy working towards their individual goals.

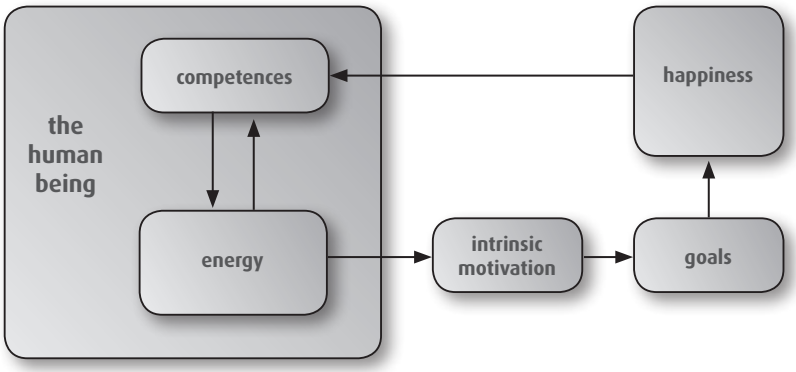


Figure 2: working at the personal target leads to happiness

The knowledge worker is primarily a thinker. Csikszentmihalyi (1999b) conceives thinking as ordering of mental energy. For thinking all four competences are important (IQ, FQ, EQ and SQ), as they all contribute to the thinking process. The knowledge worker is intrinsically motivated to use all his competences and mental energy to realise his goal which can be conceived as his personal added value and which leads to happiness (Rogers, 1982). In organisations, the concept of added value per employee is used to measure productivity (Belderbos et al, 2004). In those cases when the knowledge worker can devote his mental energy to his work that has the same direction as his personal goal, the knowledge worker experiences happiness in his work (Figure 3) and the organisation will flourish because the personal added value fits optimally within the organisational added value.

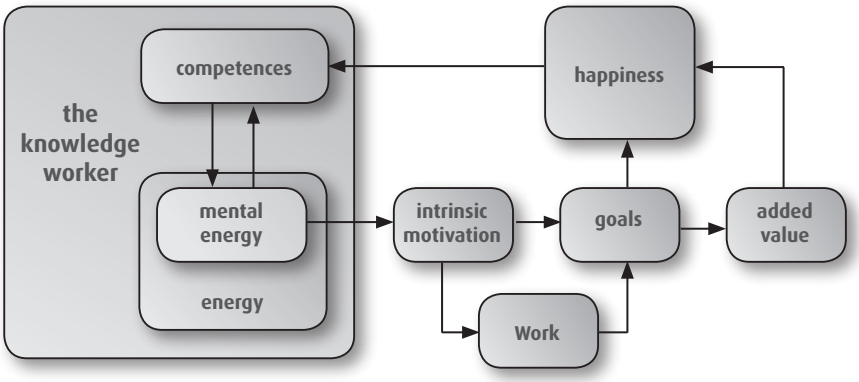


Figure 3:
work that is in accordance with personal objectives contributes to happiness

To optimise the performances of the knowledge worker, it is important that he can use his mental energy efficiently and effectively. This is only possible when this mental energy can optimally flow in the network where he works.

2.3.2 The mood of the knowledge worker

Considering the aspect of time, the preferences for the type of activities the knowledge worker wants to do, change over time. Depending on his mood and energy level, he will choose the activity that best fit, taking in account the organisational schedules, appointments and times for group meetings. The one time he wants to be alone and draws back for musing with a focus inside and the other time he is interested in the opinion of other knowledge workers with a focus outside to others and wants to cooperate with them. He chooses his activities related to his workmoods. In thinking processes two types of polarities can be discerned. Csikszentmihalyi (2003) mentioned the polarity that is necessary to fulfil one's potentials, as being together as an inextricably part of the wholeness at the one hand and at the other hand being alone as a unique person (vertical axe, Figure 4).
The second polarity concerns the direction of attention, (horizontal axe, Figure 4) by focusing at the one hand on the inner self with the individual stated meanings and at the other hand focusing on the surrounding world as compilation of extern meanings (Steiner, 1909). These meanings enable people to learn from others and to learn actually at the long last about their own ego and possibly to adjust their own individual meanings. The two axes, the vertical axe of Csikszentmihalyi accentuating the wholeness of being together and the awareness of being a unique person and the horizontal axe as mentioned by Steiner focusing inwards or outwards, result in a diagram showing four foci of thinking. These four foci of thinking are contemplation, awareness, collectiveness and social observation and all have to be nurtured by the physical environment.

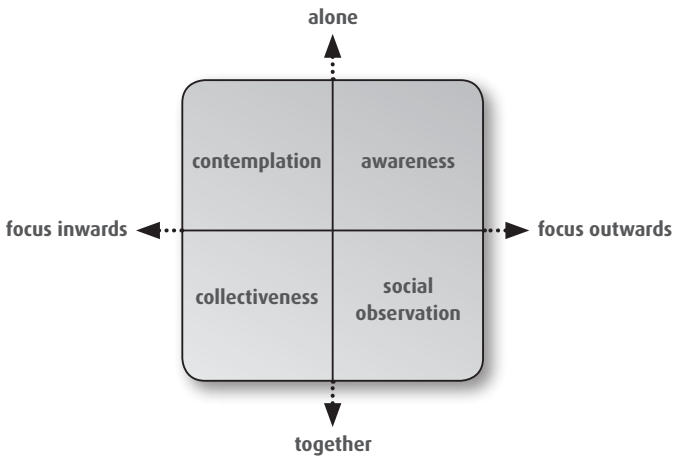


Figure 4:
the four foci of thinking for the knowledge worker

These four foci of thinking, are described below:
Contemplation is the state of preference for being alone and even being hidden while one can think on his own and listen to his intuition with the focus inside. Buchmann (1989) conceives contemplation as the freedom of thinking without the domination of the will, rules or learnt ideas.
Murdoch (1985) described contemplation as a ' devoted thinking, a refined and honest perception of what is really the case, a patient and just discernment of what confronts one, which is the result not simply of opening one's eyes but of a certainly perfectly familiar kind of moral discipline'. Haezrahi (1956) conceived contemplation as an attitude of pure attention and an act of unselfish almost impersonal concentration. Contemplation contributes to a growing sense of order and direction, further development and human flourishing (Buchmann, 1989).
Awareness is the state (Buss and Scheier,1976) of being alone and being awake for the surrounding context with the focus outside. Awareness is knowing what is happening and understanding the opinions of others (Heerwagen et al, 2004) which generates an understandable context (Dourish and Bellotti, 1992). The physical environment is part of this context (Dey et al, 1999). People have to be challenged to listen to their sensory information system to support feelings of awakeness and awareness. The sensory information system can be stimulated by an inspiring environment showing different types of contrasts.

Collectiveness is the state of being together and searching for the common shared values related to one's own individual goals with the focus inside. Organisations can be conceived as a collective that accommodates individual differences (Kavada, 2010). Despite of these differences, focusing on shared values strengthens the collectiveness. Minzberg speaks about the collective intention: 'how an organisation composed of many people makes up its mind' (Mintzberg, 1989). The degree in which an employee identifies himself with the organisational values and goals, determines the affective connectedness (Verbruggen, 1994).

Social observation is the state of being together with the focus outside, purely as observation, to collect external information about others, their behaviour, attitude and their activities. The already mentioned mirror neurons play an important role to learn during this social observation.

These four foci of thinking can be compared with the four competences mentioned by Covey, the IQ, EQ, PQ and SQ. Social observation without judgement concerns observing other people, their plans, behaviour and ways of working that is related to the IQ as IQ tells about among other things structure and strategies. Collectiveness asks for the focus on the shared values as a common good of knowledge worker and organisation and is as such connected with the EQ. Awareness is the state of being conscious of what is happening in contemporaneity experiencing all sensory information. Awareness is mostly connected with the PQ as sensory information strengthens awareness. Contemplation can be reached by listening to one's intuition that is connected with the SQ. The four thinking foci and their relation with the competences IQ, EQ, PQ and SQ, are showed in the next figure (Figure 5). These four types of competences as mentioned by the modern western psychologist Covey correspond with the Vipasyana or Insight Meditation according to the Mahayana tradition that started in the first century AD in the North West of India as the mainstream in Buddhism. In the ninth chapter of Shantideva's Bodhicaryavatara the four types of mindfulness are mentioned: Citta, Vedana, Kaya and Dharma (Negi and Choglamsar, 2012). Citta, citta-smritupasthāna, is related to the mind or the IQ. Vedana, vedanā smrityopsthāna, is connected to feelings, or the EQ. Kaya, kayasmrityupasthāna stands for the body or the PQ. The Dharma, dharma-smritupasthāna, is related spirituality or the SQ. Old Eastern insights of Buddhism meet modern western psychology.

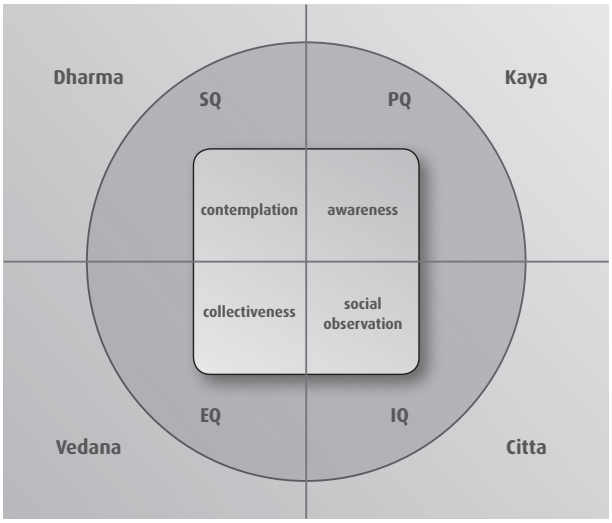


Figure 5: The four foci of thinking related to the four competences of Covey and the four types of mindfulness in the Buddhism

The four competences are combined with the four thinking foci giving these competences a description of the mood of the knowledge worker at a certain moment.

2.3.3 Energy of the knowledge network

The knowledge worker uses all his individual strengths to a knowledge network or organisational network which just like the knowledge worker himself can be conceived as a living creature, that autonomously functions with competences and with relatedness to other networks and companies in the surrounding market and its economic circumstances (de Waal, 2001). The focus on the organisational goals as described in the mission statements functions– like the goals of the knowledge worker- as intrinsic motivator (Figure 6). Just like the knowledge worker, also the organisation shows the four types of competences, the IQ, the EQ, the PQ and the SQ. The IQ of the organisation can be conceived as the structure, methods and the strategy (Nieuwenhuis, 2002). The EQ of an organisation is comparable with the culture. The PQ is comparable with all resources (financial, physical and informational resources). The SQ can be conceived as the inner intuition that is composed by all employees together (Figure 6). All these competences together can be conceived as the organisational strengths. In case of for instance a low organisational EQ, the culture shows a low degree of willingness to cooperate and a limited coherence. This has a negative influence on flowing energy to create output together. However, when an organisation functions as a social system with a high EQ and without waste of energy of the employees because employees are working together, the effectiveness is highest (Georgopoulos and Tannenbaum, 1957). To optimise the productivity of the knowledge worker concerning his thinking processes, it is important that the mental energy of the knowledge worker can easily flow in the network. In the force field of the network, which can be both virtual or non-virtual, all energies of the knowledge workers come together. All added values of the knowledge workers together can be conceived as the added value of the organisation and concern the total knowledge productivity. Under the conditions that the employees cooperate with each other, and goals of the individuals have the same direction as the company's objectives, the shared value will be optimal which contributes to knowledge productivity. For the knowledge worker the added value contributes to his happiness. For the organisation the added value contributes to its success (Chernatony and Harris, 2000).

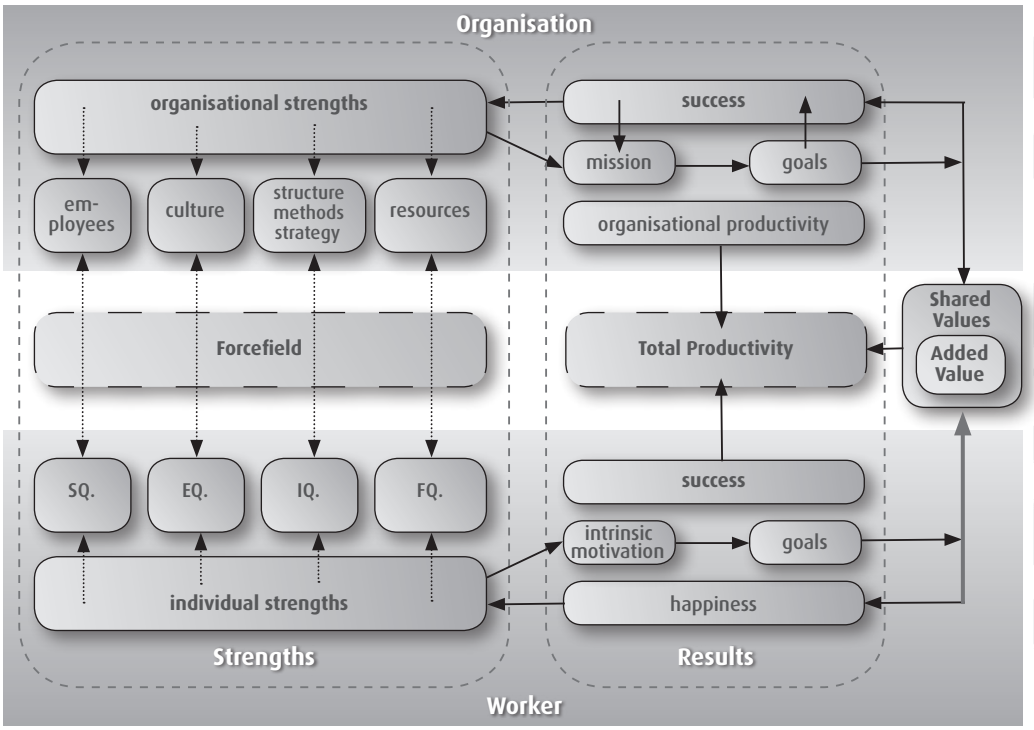


Figure 6: knowledge worker and knowledge organisation:
Flowing energy between the knowledge worker and the organisation

Regarding the energy and the work moods of the knowledge worker as described above the physical work environment can be supportive by offering the next conditions:

Table 7: Physical conditions that support the energy and the work moods of the knowledge worker

table

- offering a variety of spaces, in inner and outer areas to be able to make choices for being alone or among others
- providing a variety of spaces to concentrate with the focus inside (inners self) or to observe or communicate with others with the focus outside (outer world with others)
- optimising and facilitating the mental energy of the knowledge worker with attention for unconscious thinking processes and free ways of thinking
- facilitating a variety of mental, emotional, physical and spiritual processes with variations related to work moods and energy levels
- protecting and strengthening the synergy between knowledge worker and knowledge organisation by supporting mutual attractiveness
- creating places where one can think on his own
- creating places that are challenging as contextual sensing supports awareness
- creating places that invite to look for shared values and synergy
- creating an atmosphere where people feel psychologically safe
- designing sightlines to be able to observe others during different activities
- making areas providing psychological safety where people feel free to think and act
- providing identity contributing to feelings of coherence of the knowledge worker and the network

2.4 Knowledge

In this knowledge economy it is a challenge to create new knowledge and to broaden, deepen and integrate existing knowledge into new knowledge. This process shows various activities, from rationalizing with quantitative data, collecting and searching existing data, combining data till musing and day dreaming. Finding intelligent integration of knowledge asks for creative thinking. Collecting and searching data ask for an open mind to other knowledge workers, the extern networks and markets. Discussing data asks for social integration. Scrutinizing data asks for concentration. It is this mix of moods, attitudes and work processes that has to be nurtured by the physical environment.

In the literature, four knowledge related terms are interesting: codified knowledge, tacit-knowledge and implicit knowledge and information redundancy. Knowledge is divided into codified knowledge of quantitative and measurable data that can be stored in among other things, (E-) books and computer data networks, and tacit knowledge that is less sizable and less measurable such as a mixture of skills, experiences and data located in the head of the knowledge worker. In discussions people can express their tacit knowledge that helps to broaden and deepen the analyses, a serious reason why people prefer to work together and not separated at home (Becker and Sims, 2000). Working at a distance from colleagues reduces the 'tacit learning processes' (Becker and Sims, 2000). Regarding tacit knowledge, additionally the term 'implicit knowledge' is applied (Weggeman, 2001) with the subtle difference that implicit knowledge yet possibly partly can be codified, while tacit knowledge cannot be codified at all. Implicit learning can produce tacit knowledge that is acquired independently of conscious thinking patterns and strongly connected with intuition (Reber, 1989). Implicit knowledge is always richer and more sophisticated than explicit knowledge (Reber, 1989) and due to this quality it needs to be nurtured in the work environment. Sharing implicit knowledge takes place where people feel free and are challenged (Danner and Lonky, 1981; Amabile and Gryskiewicz, 1988; Amabile and Conti, 1999; Gagné and Deci, 2005) to think and discuss about divergent topics with other knowledge workers coming from different knowledge disciplines (Kessels et al, 2011). The shared values play an important role: the degree on which employees share their implicit knowledge depends on the collective ambition (Weggeman, 2001). Next to the implicit learning processes, information redundancy contributes to broadening and deepening of knowledge topics. Redundant information, apparently data that don't play any role of importance, contributes to the generation of ideas by creating connections of thoughts by coincidence. As such, it stimulates dialogue and communication (Nonake and Takeuchi, 1995; Weggeman, 2001). It is assumed that physically showing knowledge by for instance touchable antique or new books, rewards (knowledge workers are proud of the achieved results) or recently published articles, can stimulate the knowledge worker.

Regarding knowledge as described above the physical work environment can be supportive by offering the next conditions:

Table 8: Physical conditions that support knowledge

table
• supporting the share of implicit and tacit knowledge by stimulating informal meetings in an atmosphere where people feel free and psychologically feel safe • creating a not too efficient building and efficient facilities to enlarge the chance of information redundancy • creating an atmosphere where people feel challenged by meeting other knowledge workers and their products • maximising contacts with knowledge in different ways varying from visible antique books, till scientific rewards, achieved milestones and recently published articles • making knowledge easily visible and touchable

2.5 Key factors related to space

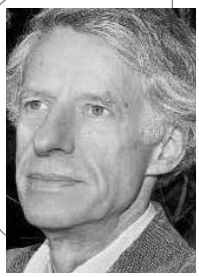
After collecting all elements in the previous chapters (Tables 2 till 8) that contribute to the productivity of the knowledge worker, a categorization is necessary in the huge amount of conditions in order to manage the physical environment. Looking at all conditions, it appears that they can be assigned into four key factors which characterise the productive environment. These key factors are structure and variety (two building aspects) and psychological safety and identity (both building aspects and user applications)(Table 9).

Table 9: Four key factors to support the demand side

structure	environmental cue	Structure, the logistic scheme inclusive, is determinant for order, clearness, movement and the chance on meeting
variety	environmental cue	Different thinking processes, activities, moods and energy levels of the knowledge workers ask for variety. A variety in spaces, climat-aspects, expression and atmosphere: from open till shuttered or hid-den, movement till quietness, inside and outside, cosy till industrial
psychological safety	both environmental cue and user application	To think and act freely and to speak openly, one needs to feel psychologically safe. This is basic for undertaking initiative and feel free to work at one's own targets as integrative part of the organisational targets
identity	both environmental cue and user application	A mix of organisational expression, group identity, individual identity and identity of place contribute to feelings of involvement, coherence and confidence.

Structure and variety

The first two key factors structure and variety are building characteristics which are in accordance how people experience both nature and culture (Plotinus, 1969; Berlyne, 1972; de Jong, 1995).
Structure and variety are recognisable in nature. Due to structure people recognise natural elements such as an oak, a rose or a zebra. Every oak, rose or zebra shows the same characteristics in its structure, so that people recognise these natural elements. However nature is lively and shows a huge variety. No oak, rose or zebra ever appears in the same way. Every oak differs from another oak, which is the same for the rose and the zebra. Exactly the same phenomenon is recognisable in culture. People recognise for instance the culture of the old Egypt or the Islam while every old Egyptian pyramid or image and every Islamite mosque is different and shows variety. Structure and variety are the basic natural characteristics which make the environment recognisable and causes feelings of safety at the one hand and which makes it lively and interesting at the other hand. The knowledge worker is defined as someone who shows many types of activities varying from analysing, discussing and collaborating till developing (Bosch-Sijtsema et al, 2010) and imposes a variety of conditions on the physical environment. Depending on his mood and the type of activity the knowledge worker wants to do, the physical environment has to offer a variety of spaces and atmospheres. In addition, next to variety the knowledge worker needs structure to understand where he is and where he has to go. Conditions such as stimulating physical contacts between knowledge workers, supporting meetings by coincidence, proximity and sight lines, are primarily based on the structure of the building as the structure determines the logistics of the building. Conditions such as a variety of sheltered and open places, a mix of inside and outside, different places to meet and to think alone, facilitating a variety of mental, emotional, physical and spiritual processes and different places to stay for a while or areas for movement, concern the need for variety in the building.



Like music, people need variety but only with a constant theme (Gaillard, 2009)

For me personally, the most positive influence of the work environment is variety (Weggeman, 2007).

Psychological safety and Identity

Next to the two key factors structure and variety, the mentioned conditions concern two other characteristics that are important for the knowledge worker i.e. psychologically safety and identity. In an environment that feels psychologically safe, people feel free to speak to mention their personal goals and to feel free to make their own choices (Edmondson, 1999). An environment that facilitates identity supports feelings of individuality, social feelings of belonging to groups or the organisation and proudness for the organisation where someone works. Psychological safety and identity are characteristics inside and outside the building that partly are created by the building itself, as for instance the proportions of spaces, and partly are created by the users of the building. If applied colours, furnishing and decorations are carefully chosen and make sense in relation to the organisational goals, culture and the context, this feeds feelings of psychological safety and identity. The environment asks for homogeneous language: the language of the management, their style and the culture, correspond to the language of the building. This language, or identity forms the sense of place, with individual, group and organisational identity to stimulate feelings of belonging and coherence. It provides the environment with sense, people want to belong to.

Psychological safety

I think that creativity strongly is stimulated when you feel safe. If a situation is not safe, your thoughts are in the here and now. To dare to let go and feeling safe, is a necessary precondition for a creative process. It is important to stimulate people to think freely

Identity

To be honest, it is important for me to have my own place, it is a type of anchor, it makes you feel free. ....It is important that buildings are recognisable, that strengthens your identity. I like for instance a statue of Einstein. Something generic tells nothing about who you are. ...It is important that a building something shows about what happens. You want to have the feeling that you are at a place with sense that coincides with your identity.... (Robbert Dijkgraaf, 2012).

In the text above attention has been paid to mental energy and the exchange of information among knowledge workers. The central processes in the knowledge economy are thinking and interacting. The knowledge worker as individual, groups of knowledge workers and knowledge, all contribute to these processes. In the building of knowledge (Figure 7) a thoughtful interpretation of structure, variety, psychological safety and identity , contribute to optimal performance.

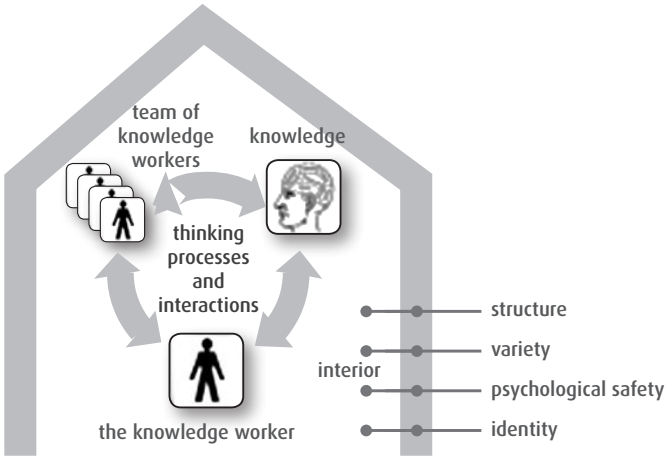


Figure 7:
The building of the knowledge organisation

For a better understanding of the content of these four key factors, all conditions mentioned in the text before are allocated to the four key factors in Table 10). This allocation is practical in design processes. Structure in the first place directly followed by variety deserve attention in the very beginning of the design process when an architect is finding out the optimal basic principles of the structure and logistics in his first building design. In an early phase he has to make choices concerning the structure and it is practical to have insight in existing conditions on structure and variety to make the right choices at the beginning of the design process. Psychological safety and identity come to the fore in the next phase as the more ambient factors receive attention in the interior architecture. Due to their different roles of importance, it is practical to have separately insight in the allocation to the four key factors.

Table 10: the four key factors with their physical conditions

table

structure	supporting the quality and quantity of interactions between knowledge workers both formal and informal
	creating an atmosphere where people feel challenged by meeting other kowledge worders and their products
	providing direct eye contacts between knowledge workers belonging to the same knowledge discipline and other knowledge disciplines
	optimising and facilitating the mental energy of the knowledge worker with attention for unconscious thinking processes and free ways of thinking
	creating a close connection between the learning and work environment
	stimulating the unconscious thinking processes
	giving room for meditating and musing and one can think on his own
	stimulating movement inside and outside
	designing sightlines to be able to observe others during different activities
	creating proximity
	stimulating direct eye contact in communication

	creating a not too efficient building and efficient facilities to enlarge the change of information redundancy
variety	offering a variety of spaces, in inner and outer areas to be able to make choices for being alone or among others facilitating a variety of mental, emotional, physical and spiritual processes with variations related to moods and energy levels providing a variety of spaces to concentrate with the focus inside (inners self) or to observe or communicate with others with the focus outside (outer world with others) offering a variety of spaces where knowledge workers observe and meet each other in different circumstances and during different activities providing employees with self-control in choosing their own ways of working offering a variety of spaces from shelter till openness creating a variety of possibilities for supporting the vitality and bodily condition of the knowledge worker
psychological safety	creating an atmosphere where people feel psychologically safe making areas providing psychological safety where people feel free to think and act providing a psychologically safe environment where people feel free to speak openly about their personal goals and connectedness with the network supporting the share of implicit and tacit knowledge by stimulating informal meetings in an atmosphere where people feel free and psychologically feel safe
identity	generating feelings of identity to support recognition of roles, connectedness and cohesion and uniqueness in social interactions facilitating identity on group level in order to support social feelings of belonging and experiencing the groups identity and on network level to support feelings fo recognition, affect and proudness stimulating awareness of both networks goals and personal goals and drives by showing individual, group and organisational goals creating places that are challenging as contextual sensing supports awareness creating places that invite to look for shared values and synergy protecting and strengthening the synergy between knowledge worker and knowledge organisation by supporting mutual attractiveness facilitating teamwork in which people experience esteem and receive positive feedback stimulating the curiosity degree among knowledge workers during social interactions creating and establishing an atmosphere to feed a culture of discipline and responsibilities stimulating the curiosity degree making knowledge touchable, visible and accessible maximising contacts with knowledge in different ways varying from visible antique books, till scientific rewards, achieved milestones and recently published articles making knowledge easily visible and touchable experiencing the physical environment as informal rather than controlling

2.6 Key factors related to mood and time

The above mentioned conditions don't play continuously their roles in the same way but this depends on the mood of the knowledge worker.

Science is a special mix of individual and social. I myself am more fond of the social side. I like to have the opportunity to meet other people, talk to them, but in my own research I recognise converging and diverging periods. In the diverging periods I often read and look around and maybe I go not so deeply. But at other times suddenly I only focus on two maybe three topics and I need rest for longer period to think deeply and concentrated (Robbert Dijkgraaf, 2012).

One time he prefers to discuss with other knowledge workers in teams and the other time he wants to remain hidden in solitude to deepen a certain topic. As such a knowledge worker does not prefer at the same time a space where he can meet others and a space to be alone for musing and to be concentrated. The physical environment has to facilitate different work moods and different activities that change over time. In paragraph 2.3.2 the four types of work mood were presented: contemplation, awareness, collectiveness and social observation. These moods have to be nurtured and as such the content of the four key factors have to be interpreted depending on these specified moods. To translate the content of the key factors into some practical guidelines to be able to design work areas that support a specified mood, a literature review is conducted. The mentioned conditions above are rather abstract and it may be helpful to recognise more concrete examples from different researches, such as applying a variety of house plants, being able to observe symbols (Cooper, 1974; Ashforth and Mael,1989) or concrete descriptions of restorative environments (Kaplan, 1983). Next it is interesting that this merely hypothetical view on knowledge productivity with new insights in work moods and energy of the knowledge worker can be supported by many serious scientific environmental researches. In Table 11 these guidelines are presented that can be helpful to design a physical work environment where the knowledge worker and groups of knowledge workers can flourish.

Table 11: Practical guidelines how to support the work moods of the knowledge worker

table

Contemplation

Contemplation: a sense of things being under control, feeling free to choose the place that's fits as an environmental self regulation creating and maintaing on's self, enjoying nature

Structure	Variety	Psychological Safety	Identity
clearness, constance and stability (Mead, 1934; Erikson,1950; Rosenberg, 1979; Proshansky et al, 1983)	different types of spaces and environments (Alexander et al, 1977)	places where people feel comfortable and psychologically safe (Rogers, 1954; Vischer, 2005; Knight & Haslam, 2010b)	self involvement by personal belongings (Bettelheim, 1969; Tuan, 1974, 1980; Relph, 1976; Godkin, 1980; Rowles, 1983; Rochberg-Halton's,1986; Korpela, 1989; Elsbach, 2003; de Croon et al, 2005; Elsbach & Bechky, 2007; Millward et al, 2007)
structure, logic and coherence (Ellemers et al, 2004; Kaplan, 1983; Korpela, 1989)	seperated, hidden places and places to be alone inclusive (Lukashok & Lynch,1956; Ladd, 1977; Cooper-Marcus, 1978, 1979; Hester,1979; Baum & Davis, 1980; Wyman, 1985; Korpela, 1989; Csikszentmihalyi, 2003; Heerwagen et al, 2004; Vischer, 2005)	informal rather than a controlling atmosphere (Dickinson, 1995)	restorative environments (Kaplan, 1983)

Contemplation - continued	logistic with hidden spaces (Lukashok & Lynch,1956; Ladd, 1977; Cooper-Marcus, 1978, 1979; Hester,1979; Baum & Davis, 1980; Wyman, 1985; Korpela, 1989; Vischer, 2005; Heerwagen et al, 2004)	differents routes and spaces inside and outside (Kaplan & Kaplan, 1989; McCoy & Evans, 2002)	control of favourite place (Kaplan, 1983; Dickinson, 1985; Korpela, 1989)	spatial/place identity (Proshansky et al, 1983; Fried, 1963)
	structure that stimulates to go outside (Kaplan & Kaplan, 1989; Csikszentmihalyi, 1998)	a variety of nature, inside houseplants and outside a variety of green (Kaplan & Kaplan, 1989; Ackerman, 1991; Ulrich, 1993; Csikszentmihalyi,1998; McCoy & Evans, 2002; Senge, 2008)	place belonginess (Proshansky et al, 1983)	symbols (Cooper, 1974; Ashforth & Mael,1989) and meaning (Ellemers et al, 2004)

Social observation

Social observation: observing people in different conditions and during a diversity of activities

Structure	Variety	Psychological Safety	Identity
visibility and sight into corridors, staircases, junctions and space, inside and outside (Hagstrom, 1965; Heerwagen et al, 2004)	different spaces and environments, inside and outside with sight on different functionalities where people act and behave in different ways (Kaplan & Kaplan, 1989; McCoy & Evans, 2002)	places where people feel comfortable and psychologically safe (Rogers, 1954; Visscher, 2005; Knight & Haslam, 2010b)	individual identity and group identity (Sani et al, 2008; Knight & Haslam, 2010)
logistic accentuating the common places for inspiration, informal meeting, coffee breaks, lunches (Hagstrom, 1965; Mayer, 1976; Allen, 1977; Eveland & Bikson, 1987; Kraut et al, 1988)	a variety of nature, inside houseplants and outside a variety of green (Kaplan & Kaplan, 1989; Ackerman, 1991; Ulrich, 1993; Csikszentmihalyi,1998; McCoy & Evans, 2002; Senge, 2008)	possibilities to observe from shuttered places till open and crowded areas (Jacobs, 1993)	

Collectiveness

Collectiveness: experiencing (from the perspective of one's own drives and targets) in the other individuals and groups in different qualities in relation to their personal drives and targets

Structure	Variety	Psychological Safety	Identity
movement patterns stimulating daily informal contacts facilitating face-to-face communication (Hagstrom, 1965; Mayer, 1976; Allen, 1977; Backhouse & Drew, 1992;Eveland & Bikson, 1987; Kraut et al, 1988)	shuttered meeting places both formal and informal (Hagstrom, 1965; Kraut et al, 1988)	places where people feel comfortable and psychologically safe (Rogers, 1954; Visscher, 2005; Knight & Haslam, 2010b)	intertwining of personal place (Elsbach, 2003; Zeisel, 2006) and organisational identity (Knight and Haslam, 2010a/b; Knight et al, 2010)
structure with well planned and interesting junctions (Kraut et al, 1988)	hidden places, or places not directly located in sight, inside and outside for small confidential talks (Csikszentmihalyi; 2003)		identity of being connected by place identity, organisational identity, group identity and symbols (Cooper, 1974; Proshansky et al, 1983; Ashforth & Mael, 1989; Korpela, 1989; Knight & Haslam, 2010 a/b)

	Structure	Variety	Psychological Safety	Identity
Awareness	sight and visibility inside and outside	showing variety in spaces, forms, aesthetics, textures, light, colours, temperature to make an inspiring and challenging environment (Danner & Lonky, 1981; Amabile and Gryskiewicz, 1988; Kaplan and Kaplan, 1989; Amabile and Conti, 1999; McCoy and Evans, 2002))	places where people feel comfortable and psychologically safe (Rogers, 1954; Visscher, 2005; Knight & Haslam, 2010b)	sense of place asking for attention (Fried, 1963; Proshansky et al, 1983; Knight and Haslam, 2010a)
	visibility and sight on movements, nature (waving trees inclusive) outside (Kaplan & Kaplan, 1989; Ulrich, 1993)	nature using a variety of houseplants and green outside (Kaplan & Kaplan, 1989; Ackerman, 1991; Ulrich, 1993; Csikszentmihalyi,1998; McCoy & Evans, 2002; Senge, 2008)Csikszentmihalyi,1998; McCoy & Evans, 2002; Senge, 2008)		personal identity (Elsbach, 2003; Zeisel, 2006)
	visibility and sight on aesthetics (Brill, 1984 ; Knight & Haslam, 2010b)	activating sensory information (Schneider, 1987)		organisational identity (Ashforth & Mael, 1989; Dickinson, 1995)
	complexity (McCoy & Evans, 2002; Kaplan& Kaplan, 1989)			group identity (Ashforth & Mael, 1989; Millward et al, 2007; Sani et al, 2008)

2.7 Reflections and conclusions

This view on knowledge productivity is based on a hypothetical approach making use of less measurable topics that all show many mutual relationships. This approach shows a combination of views from neurological, spiritual, economical till philosophical knowledge disciplines as knowledge productivity shows many aspects. The central question 'How can the knowledge worker be a productive worker?' leads to the energy efficiency and effectivity of this knowledge worker as mental energy is the main source in knowledge productivity. Insights from the West meet insights from the East and together they show that the physical work environment needs to support four work moods with different types of energy. These four work moods are contemplation, awareness, collectiveness and social observation. Especially four environmental features facilitate these four work moods, namely structure, variety, psychological safety and identity. In this hypothetical view the knowledge worker is not a data robot translating and combining facts and figures and is approached as a human doing, but this knowledge worker is conceived as a unique individual, actually as a human being.

This theory on the knowledge worker, knowledge networks and knowledge gave insight in four factors of the physical environment that could contribute to a productive physical environment. Based on empirical findings the key factors are structure, variety, psychological safety and identity. After this in-depth analysis of the demand side, the next chapters will explore the supply side i.e. the physical environment.

2.8 References

Ackerman, D. (1991), A natural history of the senses. New York: Vintage in McCoy, J.M. and Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity, Creativity Research Journal, 14:3-4, 409-426.
Alexander, Ch., Ishikawa, S., Silverstein, M. (1977), A Pattern Language, Towns, Buildings, Construction, Oxford University Press, New York.

Alkahafaji, A.,Tompkins, D. (1990), Determinants and impact of organisational Commitment. Management Challenges. in Weggeman, M. (2001), Kennismanagement, Inrichting en besturing van kennisintensieve organisaties, Scriptum Management, Schiedam.

Allen, T.J. (1977), Managing the flow of technology. Cambridge, MA: MIT Press in Kraut, R., Egido, C., Galegher, J. (1988), Patterns of Contact and Communication in Scientific Research Collaboration, Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 1-12.

Amabile, T.S. (1996), Creativity in Context: Update to the social psychology of creativity. Boulder, Colourado, West view Press in Pink, D. H. (2010), Drive, De verrassende waarheid over wat ons motiveert, Uitgeverij Business Contact Amsterdam-Antwerpen, original tittle Drive, The Surprising Truth About What Motivates Us, 16, 95, 110, 121.

Amabile, T M., Gryskiewicz, S.S. (1988), User's manual for the content analysis of creativity interviews. Greensboro, NC: Center for Creative Leadership in McCoy, J.M., Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity, Creativity Research Journal, 14:3-4, 409-426.

Amabile, T.M., Conti, R. (1999), Changes in the Work Environment for Creativity during Downsizing, The Academy of Management Journal, Vol. 42 (6), 630-640.

Amabile, T. M., Barsade, S. G., Mueller, J. S., Staw, B. M. (2005), Affect and creativity at work. Administrative science quarterly, 50(3), 367-403.

Appel-Meulenbroek, R. (2013), How to measure added value of corporate real estate and building design. Dissertation, Bouwstenen 191, Technical University Eindhoven.

Argyle, M. (1987), The Psychology of Happiness. London: Methuen in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Arnold, K. (1992), Research conducted with T. Denny, University Illinois, cited in The Chicago Tribune 29 may in Goleman, D. (1996), Emotionele intelligentie, Uitgeverij Contact, Amsterdam/Antwerpen, 31, 32, 38-45, 142, 166, 222, 229, 233-236, 239.

Ashforth, B.E., Meal, F. (1989), Social Identity Theory and the Organisation, The Academy of Management Review, Vol 14(1), 20-39.

Ashmos, B.P., Duchon, D. (2000), Spirituality at work: A conceptualization and measure,
Journal of Management Inquiry, Vol 9 (2), 134-145 in Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace, Journal of Managerial psychology, Vol 17(3), 153-164.

Backhouse, A., Drew, P. (1992), The design implications of social interaction in a workplace setting, Environment and Planning B: Planning and Design, 19, 573–584 in Heerwagen, J.H., Kampschroer, K., Powell, K.M., Loftness, V. (2004), Collaborative knowledge work environments, Building Research and Information, 32 (6), 510-528.
Baum, A. , Davis, G.E. (1980), Reducing the stress of high-density living: an architectural intervention, Journal of Personality and Social Psychology 38, 471-481.

Baumeister, R., Leary M.R. (1995), The need to belong: desire for interpersonal attachments as a fundamental human motivation, Psychol. Bull. 117:497–529 in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Bakker, I.C. (2007), Productiviteit en kennisontwikkeling, Interview with Mathieu Weggeman, Facility Management Informatie, nov, 44-45.

Bakker, I.C. (2009), Gezond werken en de waan van de dag, Interview with prof Tony Gaillard, Facility Management Informatie, Vol 5, 24-27.

Bakker, I.C., Van der Voordt, D.J.M. (2010), Huisvesting als middel tot sociaal-economische vitaliteit, Interview with Alexander Rinnooy Kan, Facility Management Informatie 5, 32-35.

Bakker, I.C., Van der Voordt, D.J.M. (2011), Niet managen maar faciliteren, Het beste in kenniswerkers naar boven halen, Interview with Joseph Kessels, Facility Management Magazine 192, 55-58.

Bakker, I.C., Van der Voordt, D.J.M. (2012), Een plek die ons stimuleert zo vrij mogelijk te denken, Interview with Robbert Dijkgraaf, Facility Management Informatie 1, 32-37.

Becker, F., Sims, W. (2000), Offices That Work: Balancing Cost, Flexibility, and Communication, Corporate Publication, Cornell University.

Belderbos, R., Carree, M., Lokshin, B. (2004), Cooperative R&D and firm performance , Research Policy, Vol 33(10), 1477-1492.

Benware, C., Deci, E. L. (1984), Quality of learning with an active versus passive motivational set, American Educational Research Journal, 21, 755-765 in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.

Berlyne, D. E. (1972), Uniformity in variety: Extension to three-element visual patterns and non-verbal measures. Canadian Journal of Psychology 26(3), 277-291.

Bettelheim, B. (1969), The Children of the Dream. London: Thames and Hudson in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Blanck, P. D., Reis, H. T., Jackson, L. (1984), The effects of verbal reinforcement on intrinsic motivation for sex-linked tasks, Sex Roles, 10, 369-387 in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.

Bosch-Sijtsema, P.M., Ruohomäki, V., Vartiainen, M. (2010), Multi-locational knowledge workers in the office: navigation, disturbances and effectiveness, New Technology, Work and Employment, 25:3, 183-195.

Brefczynski-Lewis, J.A., Lutz, A., Schaefer, H.S., Levinson. D.B., Davidson, R.J. (2007), Neural correlates of attentional expertise in long-term meditation practitioners, PNAS , Current Issue, Vol 104 (27), 11483-11488.

Brill, M., Margulis, S.T., Konar, E.,(1984), Using OÐce Design to Increase Productivity. New York: Workplace Design and Productivity, The BuÐalo Organisation for Social and Technological Innovation in Knight, C. Haslam, S.A.(2010b),Your Place or Mine? Organisational Identification and Comfort as Mediators of Relationships Between the Managerial Control of Workspace and Employees' Satisfaction and Well-being, British Journal of Management, Vol. 21, 717–735.

Brockman, B.K., Morgan, R,M. (2006), The Moderating Effect of Organisational Cohesiveness in Knowledge Use and New Product Development, Journal of the Academy of Marketing Science, vol. 34 (3), 295-307.

Brunstein, J. C. (1993), Personal goals and subjective well-being: a longitudinal study, J. Pers. Soc. Psychol. 65: 1061–70 in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Buchmann, M.(1989), The Careful Vision: How Practical Is Contemplation in Teaching? American Journal of Education, Vol 98(1), 35-61.

Burack, E.H. (1999), Spirituality in the work place, Journal of organisational change management, Vol 12 (4), 280-291 in Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace, Journal of Managerial psychology, Vol 17(3), 153-164.

Buss, D.M., Scheier, M.F.(1976), Self-Consciousness, Self-Awareness, and Self-Attribution, Journal of research in personality, 10, 463-468.

Carver, C.S., Scheier, M.F. (1999), Themes and issues in the self-regulation of behaviour. In Perspectives on Behavioural Self-Regulation: Advances in Social Cognition, ed. RS Wyer Jr, XII:1–105. Mahwah, N.J.: Erlbaum in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Carstensen, L.L. (1998), A life-span approach to social motivation. in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Chernatony, L. de, Harris, F. (2000), Added value: its nature, roles and sustainability, European Journal of Marketing, Vol. 34 (½) 39-56.

Claxton, G. (2000), Hare Brain, Tortoise Mind: How Intelligence Increases When You Think Less. HarperCollins, New York in Heerwagen, J.H., Kampschroer, K., Powell, K.M., Loftness, V. (2004), Collaborative knowledge work environments, Building Research & Information, 32 (6), 510-528.

Clifton, D.O., Buckingham, M.(2003), Ontdek je sterke punten (2003) Spectrum, Utrecht in Kessels, J. Poell, J., Poell, R., (2011), Handboek human resource development, Organiseren van het leren, Bohn Stafleu Van Loghum; Houten.

Collins, J. (2005), Good to Great , Uitgeverij Business Contact Amsterdam/Antwerpen, 58.

Cooper, C. (1974), The house as symbol of the self in Proshansky, H.M., Fabian, A.K., Kaminoff, R. (1983), Place-identity: Physical world socialization of the self, Journal of Environmental Psychology, 3, 57-83.

Cooper-Marcus, C. (1978), Remembrance of landscapes past, Landscape, 22, 35-43 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Cooper-Marcus, C. (1979), Environmental autobiography. Institute of Urban & Regional Development. University of California, Berkeley. Working paper 301 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Covey, S. R. (2005), De 8e eigenschap, van het effectief leiderschap, Uitgeverij Business Contact Amsterdam/Antwerpen, page 15, 46.

Csikszentmihalyi, M. (1998), Creativiteit, Uitgeverij Boom, Amsterdam, 59, 140-142, 147, 149, 150.

Csikszentmihalyi, M. (1999b), De weg naar Flow, Uitgeverij Boom Amsterdam, 34, 42, 160.

Csikszentmihalyi, M. (1999a), Flow, psychologie van de optimale ervaring, Uitgeverij Boom Amsterdam, 21, 23, 84, 219, 220.

Csikszentmihalyi, M. (2003), Flow in zaken, over leiderschap en betekenisgeving, Uitgeverij Boom Amsterdam, 34, 71,72,110.

Damasio, A.R. (1994), Descartes'Error: Emotion, Reason and the Human Brain. New York: Grosset/ Putman in Goleman, D. (1996), Emotionele intelligentie, Uitgeverij Contact, Amsterdam/Antwerpen, 31, 32, 38-45, 142, 166, 222, 229, 233-236, 239.

Danner, F. W., Lonky, E. (1981), A cognitive-developmental approach to the effects of rewards on intrinsic motivation, Child Development, 52, 1043–1052 in Gagné, M, Deci, E.L. (2005), Self-determination theory and work motivation, Journal of Organisational Behaviour 26, 331–362.

Davidson, J.R., Kabat-Zin, J., Shumacher, J., Rosenkranz, M., Muller, D., Santorelli, S.F., Urbanowski, F.,Harrington, A. Bonus, K., Sheridan, J.F. (2003), Alterations in Brain and Immune Function Produced by Mindfulness Meditation, Psychosomatic Medicine, 65:564–570.

Davidson, R.J. (2007), Neural correlates of attentional expertise in long-term meditation practitioners, PNAS , Current Issue, Vol 104 (27), 11483-11488.

De Bono, E. (1997), Over wijsheid, Nieuwe Zijds BV, Amsterdam.
Deci, E. L. (1971), Effects of externally mediated rewards on intrinsic motivation, Journal of Personality and Social Psychology, 18, 105–115 in Gagné, M, Deci, E.L.(2005), Self-determination theory and work motivation, Journal of Organisational Behaviour 26, 331–362.

Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.

Deci, E.L., Ryan, R.M. , Gagné, M.G., Leone, D.R., Usunov, J., Kornazheva, B.P. (2001), Need Satisfaction, Motivation, and Well-Being in the Work Organisations of a Former Eastern Bloc Country: A Cross-Cultural Study of Self-Determination, Personality and Social Psychology Bulletin, Vol 27(8), 930- 942.

de Croon, E.M., Sluiter, J. K., Kuijer, P.P.F M., Frings-Dresen, M.H.W. (2005), The effect of office concepts on worker health and performance: A systematic review of the literature, Ergonomics, 48,
119 –134 in Knight, C., Haslam, S.A.(2010a), The Relative Merits of Lean, Enriched, and Empowered Offices: An Experimental Examination of the Impact of Workspace Management Strategies on Well-Being and Productivity, Journal of Experimental Psychology: Applied, Vol. 16 (2), 158 –172.

de Jong, T.M. (1995), Systematische transformaties in het getekende ontwerp en hun effect, 153e Dies Natalis, TU Delft.

Dey, A.K., Abowd, G.D., Brown, P.J., Davies, N., Smith, M., Steggles, P. (1999), Towards a Better Understanding of Context and Context-Awareness. H.W. Gellersen, (Ed.): HUC (99), LNCS 1707, 304-307, Springer-Verlag Berlin-Heidelberg.

Delbecq, L.A. (1999), Christian spirituality and contemporary business leadership, Journal of Organisational Change Management, Vol 12 (4), 345-349 in Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace, Journal of Managerial psychology, Vol 17(3), 153-164.

de Waal, A. (2001), Presteren is mensenwerk, het streven naar een persoonlijke balanced scorecard, Kluwer, 35, 172.
Dickinson, L. (1995), Autonomy and Motivation, A literature review, System, Vol. 23 (2), 165-174.
Dijksterhuis, A. (2007), Het slimme onderbewuste, denken met gevoel, Uitgeverij Bert Bakker Amsterdam, 25, 26, 128, 129, 130.

Dijkgraaf, R. (2012), in Bakker, I.C., Van der Voordt, D.J.M. (2012), Een plek die ons stimuleert zo vrij mogelijk te denken, Interview with Robbert Dijkgraaf, Facility Management Informatie 1, 32-37.

Dourish, P., Bellotti, V. (1992), Awareness and Coordination in Shared Workspaces. CSCW Proceedings of the 1992 ACM conference on Computer-supported cooperative work, 107-114. Awareness of individual and group activities is critical to successful collaboration.

Drucker, P.F. (1999), Knowledge-Worker Productivity: The Biggest Challenge; California Management Review, Vol 41 (2), reprint series, 79-94.

Drucker, P. (2000), Management, uitdagingen in de 21e eeuw, Uitgeverij Business Contact, Amsterdam/Antwerpen.
Edmondson, A. (1999), Psychological safety and learning behaviour in work teams. Administrative science quarterly, 44(2), 350-383.

Ekman, P. (2008), Gegrepen door emoties, Wat gezichten zeggen, Uitgeverij Nieuwezijds; Amsterdam, 29,30.

Ellemers, N., de Gilder, D., Haslam, S. A. (2004), Motivating individuals and groups at work: a social identity perspective on leadership and group performance, Academy of Management Review, 29 (4) 459–78 in Knight, C., Haslam, S.A., Haslam, C. (2010), In home or at home? How collective decision making in a new care facility enhances social interaction and wellbeing amongst older adults, Ageing & Society 30, 1393–1418.

Elsbach, K.D. (2003), Relating physical environment to selfcategorizations: Identity threat and affirmation in a non-territorial office space. Administrative Science Quarterly, 48, 622– 654 in Knight, C., Haslam, S.A. (2010a), The Relative Merits of Lean, Enriched, and Empowered Offices:
An Experimental Examination of the Impact of Workspace Management Strategies on Well-Being and Productivity, Journal of Experimental Psychology: Applied, Vol. 16 (2), 158 –172.

Elsbach, K.D., Bechky, B.A. (2007), It's more than a desk: Working smarter through leveraged office design, California Management Review, 49, 80 – 87 in Knight, C., Haslam, S.A. (2010a), The Relative Merits of Lean, Enriched, and Empowered Offices: An Experimental Examination of the Impact of Workspace Management Strategies on Well-Being and Productivity, Journal of Experimental Psychology: Applied, Vol. 16 (2), 158 –172.

Erikson, E.H. (1950), Childhood and Society. New York: W.W. Norton in Proshansky, H.M., Fabian, A.K., Kaminoff, R. (1983), Place-identity: Physical world socialization of the self, Journal of Environmental Psychology, 3, 57-83.
Eveland, J., Bikson, T. (1987), Evolving electronic communication networks: An empirical assessment. Office: Technology and people, 3, 103-128 in Kraut, R., Egido, C., Galegher, J. (1988), Patterns of Contact and Communication in Scientific Research Collaboration, Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 1-12.

Franzen, G. (2004), Wat drijft ons? Denken over motivatie sinds Darwin, Boom Lemma uitgevers, Den Haag.

Fredrickson, B. L., Losada, M. F. (2005), Positive affect and the complex dynamics of human flourishing. American Psychologist, 60(7), 678-686.

Freshman, B. (1999), An exploratory analysis of definitions and applications of spirituality in the workplace, Journal of Organisational Change Management, Vol 12(4), 318-327 in Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace Journal of Managerial psychology, Vol 17(3), 153-164.

Fried, M. (1963), Grieving for a lost home, in Proshansky, H.M., Fabian, A.K., Kaminoff, R. (1983), Place-identity: Physical world socialization of the self, Journal of Environmental Psychology, 3, 57-83.

Gagné, M, Deci, E.L. (2005), Self-determination theory and work motivation, Journal of Organisational Behaviour 26, 331–362.
Gaillard, A.W.K. (2003), Stress, Productiviteit en gezondheid, Uitgeverij Nieuwezijds, 2e druk.

Gaillard, A.W.K. (2009) in Bakker, I.C. (2009), Gezond werken en de waan van de dag, Interview with prof Tony Gaillard, Facility Management Informatie, Vol 5, 24-27.

Gallese, V., Goldman, A. (1998), Mirror neurons and the simulation theory of mind-reading, Trends in Cognitive Sciences, Vol 2(12), 493-501.

Gallesea, V., Keysers, Ch., Rizzolatti, G. (2004), A unifying view of the basis of social cognition, TRENDS in Cognitive Sciences, Vol.8(9), 396–403.

Gardner, H. (1999), Intelligence reframed, Basic Books, New York, 4.

Georgopoulos, B.S., Tannenbaum, A.S.(1957), A Study of Organisational Effectiveness, American Sociological Review, Vol 22(5), 534-540.

Giancola, F.L. (2011), Examining the Job Itself as a Source of Employee Motivation, Compensation & Benefits Review, 43(1) 23–29.

Godkin, M.A. (1980), Identity and place: clinical applications based on notions of rootedness and uprootedness in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.
Goleman, D. (1996), Emotionele intelligentie. Uitgeverij Contact, Amsterdam/Antwerpen, 31, 32, 38-45, 142, 166, 222, 229, 233-236, 239.

Gottfried, A.E. (1985), Academic intrinsic motivation in elementary and junior high school students, Journal of Educational Psychology, 20, 205-215 in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.

Gottfried, A.E. (1990), Academic intrinsic motivation in young elementary school children, Journal of Educational Psychology, 82, 525-538 in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.

Greene, Ch. N. (1989), Cohesion and Productivity in Work Groups, Small Group Research , Vol. 20. no. 1, 70-86.

Gregory, R.L. (1998), Eye and the brain; Oxford University Press, Oxford Tokyo, 143.
Grolnick, W.S.,Ryan, R.M., Deci, E.L.(1987), The inner resources for school achievement: Motivational mediators of children's perceptions of their parents, Journal of Educational Psychology in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.
Guay, F., Boggiano, A.K., Vallerand, R.J. (2001), Autonomy Support, Intrinsic Motivation, and Perceived Competence: Conceptual and Empirical Linkages, Personality and Social Psychology Bulletin, Vol. 27 No. 6, 643-650.

Hagstrom, W.O. (1965), The scientific community. Carbondale, Ill: Southern Illinois University Press in Kraut, R., Egido, C., Galegher, J.(1988), Patterns of Contact and Communication in Scientific Research Collaboration, Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 1-12.

Harackiewicz, J.M., Larson., J.R. (1986), Managing motivation: The impact of supervisor feedback on subordinate taskinterest, Journal of Personality and Social Psychology, Vol 51, 547-556 in Guay, F., Boggiano, A.K., Vallerand, R.J. (2001), Autonomy Support, Intrinsic Motivation, and Perceived Competence: Conceptual and Empirical Linkages, Personality and Social Psychology Bulletin, Vol. 27 No. 6, 643-650.

Haidt, J. (2006), De gelukshypothese, de balans tussen oude wijsheid en moderne wetenschap, Uitgeverij Het Spectrum; Utrecht, 1e druk, 114, 250.

Harrington, D. M., Block, J. H., Block, J. (1987), Testing aspects of Carl Rogers's theory of creative environments: child-rearing antecedents of creative potential in young adolescents. Journal of Personality and Social Psychology,52(4), 851.

Hatfield, E., Cacioppo, J. L., Rapson, R. L. (1993), Emotional contagion, Current Directions in Psychological Sciences, 2, 96-99.

Haywood, H. C., Burke, W. P. (1977), Development of individual differences in intrinsic motivation. in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 & 4), 325-346.

Haezrahi, P. (1956), The Contemplative Activity: A Study of Aesthetics. New York: Abelard-Schuman, in Buchmann, M. (1989), The Careful Vision: How Practical Is Contemplation in Teaching? American Journal of Education, Vol 98(1), 35-61.

Heerwagen, J.H., Kampschroer, K., Powell, K.M., Loftness, V. (2004), Collaborative knowledge work environments, Building Research & Information, 32 (6), 510-528.

Hester, R. (1979), A womb with a view. How spatial nostalgia affects the designer, Landscape Architecture, 475-482 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Jacobs, A. B. (1993), Great streets, ACCESS Magazine, 1(3), 23 - 27. UC Berkeley: University of California.

James, K.H. (2010), Sensori-motor experience leads to changes in visual processing in the developing brain, Developmental Science, 13 (), 279–288.

Kamarck, T. , Jennings, J.R. (1991), Biobehavioural factors in sudden cardial death, Psychological Bulletin, 109, 42-75 in Gaillard, A.W.K. (2003), Stress, Productiviteit en gezondheid, Uitgeverij Nieuwezijds, 2e druk.

Kaplan, S. (1983), A model of person-environment compatibility, Environment & Behaviour, 15, 311-332 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Kaplan, R., Kaplan, S. (1989), The experience of nature: A psychological perspective. New York: Cambridge University Press in McCoy, J.M. and Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity, Creativity Research Journal, 14:3-4, 409-426.

Karasek, R., Theorell, T. (1990), Healthy work. New York, Basic Books in Gaillard, A.W.K. (2003), Stress, Productiviteit en gezondheid, Uitgeverij Nieuwezijds, 2e druk.

Kastelein, J.P.(2014), Space meets knowledge : the impact of workplace design on knowledge sharing. Dissertation, Nyenrode Business University, Breukelen.

Kavada, A. (2010), Between Individuality and Collectiveness: Email Lists and Face-to-Face Contact in the Global Justice Movement, International Journal of E-Politics (IJEP), Vol 1(1), 41-56.

Kelley, R., Caplan, J. (1993), How Bell labs creates star performers; Harvard business Review, Vol 71(4), 128-39 in Goleman, D. (1996), Emotionele intelligentie. Uitgeverij Contact, Amsterdam/Antwerpen, 31, 32, 38-45, 142, 166, 222, 229, 233-236, 239.

Kessels, J., Poell, J., Poell, R., (2011), Handboek human resource development, Organiseren van het leren, Bohn Stafleu Van Loghum; Houten, 31, 32, 35; 39, 41; 78, 92; 95; 96; 101; 139; 184; 186; 187;255; 256; 358.

Kessels, J. (2011), in Bakker, I.C., Van der Voordt, D.J.M. (2011), Niet managen maar faciliteren, Het beste in kenniswerkers naar boven halen, Interview with Joseph Kessels, Facility Management Magazine 192, 55-58.

Knight, C., Haslam, S.A., Haslam, C. (2010), In home or at home? How collective decision making in a new care facility enhances social interaction and wellbeing amongst older adults, Ageing & Society 30, 1393–1418.

Knight, C. ,Haslam, S.A. (2010a), The Relative Merits of Lean, Enriched, and Empowered Offices:
An Experimental Examination of the Impact of Workspace Management Strategies on Well-Being and Productivity, Journal of Experimental Psychology: Applied, Vol. 16 (2), 158 –172.

Knight, C., Haslam, S.A. (2010b), Your Place or Mine? Organisational Identification and Comfort as Mediators of Relationships Between the Managerial Control of Workspace and Employees'
Satisfaction and Well-being, British Journal of Management, Vol. 21, 717–735.

Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Krantz, D.S., Manuck, S.B. (1984), Acute psychophysiological reactivity and risk of cardiovascular disease: A review and methodological critique, Psychological Bulletin, 96, 435-464 in Gaillard, A.W.K. (2003), Stress, Productiviteit en gezondheid, Uitgeverij Nieuwezijds, 2e druk.

Kraut, R., Egido, C., Galegher, J. (1988), Patterns of Contact and Communication in Scientific Research Collaboration, Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 1-12.

Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace, Journal of Managerial psychology, Vol 17(3), 153-164.

Ladd, F. C. (1977), Residential history. You can go home again. Landscape, 21, 15-20 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Landers, D. M., Wilkinson, M.O., Hatfield, B. D., Barber, H. (1982), Causality and the cohesion–performance relationship, Journal of Sport Psychology, Vol 4(2),170-183.

Leigh, P. (1997), The new spirit at work. Training and Development, Vol 51 (3), 26-34 in Krishnakumar, S., Neck, Ch.P.

(2002), The 'what', 'why' and 'how' of spirituality in the workplace. Journal of Managerial psychology, Vol 17(3), 153-164.

Lloyd, J., Barenblatt, L. (1984), Intrinsic intellectuality: Its relation to social class, intelligence, arid achievement, Journal of Personality and Social Psychology, 46, 646-654 in Deci, E.L., Vallerand, R.J., Pelletier, L.G., Ryan, R.M. (1991), Motivation and Education: The Self-Determination Perspective, Educational Psychologist, 26(3 and 4), 325-346.

Lukashok, A. K., Lynch, K. (1956), Some childhood memories of the city, Journal of the American Institute of Planners, 22, 142-152 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation. Journal of Environmental Psychology, Vol 9 (3), 241–256.

Mawson, A. (2002), The workplace and his impact on productivity; Advanced Workplace Associates.

Mayer, M. (1976), The telephone and the uses of time. In Pool, Ithiel. (1977), (Ed.) The Social Impact of the Telephone. Cambridge, Massachusetts: MIT Press in Kraut, R., Egido, C., Galegher, J.(1988), Patterns of Contact and Communication in Scientific Research Collaboration, Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 1-12.

McEwen, B.S., Stellar, E. (1993), Stress and the Individual Mechanisms Leading to Disease, Arch Intern Med. 153(18), 2093-2101.

McGregor, I., Little, B.R. (1998), Personal projects, happiness, and meaning: on doing well and being yourself, J. Pers. Soc. Psychol. 74:494–512 in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

McCoy, J.M., Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity Creativity Research Journal, 14:3-4, 409-426.

Mead, G. H. (1934), Mind, Self and Society from the Standpoint of a Social Behaviourist. Chicago: University of Chicago Press in Proshansky, H.M., Fabian, A.K., Kaminoff, R. (1983), Place-identity: Physical world socialization of the self, Journal of Environmental Psychology, 3, 57-83.

Miles, L.K., Nind, L.K., Macrae, C.N. (2009), The rhythm of rapport: Interpersonal synchrony and social perception, Journal of Experimental Social Psychology, 45, 585–589.

Millward, L.J., Haslam, S.S., Postmes, T. (2007), Putting Employees in Their Place: The Impact of Hot Desking on Organisational and Team Identification, Organisation Science, Vol 18 (4), 547-559.

Mintzberg, H. (1989), Minzberg on Management, inside our strategy world of organisations, The free press, New York, London, 25.
Mischel, W., Shoda, Y. ,Rodigruez, M.L. (1992), Delay of Gratification in Children in Loewenstein, G. and Elster, J. (1992), Choice over Time, Russell Sage Foundation, New York,147-164.

Mitroff, I.I., Denton, E.A. (1999), A Spiritual Audit of Corporate America; Jossey-Bass publishers, San Francisco, CA in Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace, Journal of Managerial psychology, Vol 17(3), 153-164.

Murdoch, I. (1985), The Sovereignty of Good. London: ARK, in Buchmann, M.(1989), The Careful Vision: How Practical Is Contemplation in Teaching? American Journal of Education, Vol 98(1), 35-61.

Myers, D.G. (1999), Close relationships and quality of life. See Kahneman et al 1999, 374– 91 in Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Naylor, T.H., Willimon, W.H., Osterberg, R. (1996), The Search for Meaning in the Workplace. Abington Press, Nashville, TN in Krishnakumar, S.Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace, Journal of Managerial psychology, Vol 17(3), 153-164.

Neck, Ch.P., Milliman, J.F. (1994), Thought Self-leadership, Finding Spiritual Fulfilment in Organisational Life, Journal of Managerial Psychology, Vol. 9 (6), 9-16.

Negi, W. D. , Choglamsar, L.L.(2012), Buddhist Meditation Practices. Buddhist Philosophy and Meditation Practice: Second IABU Conference Thailand, Mahachulalongkornrajavidyalaya University (MCU), 370-377.

Nieuwenhuis, M. (2002), The Art of Management, Nieuwenhuis, 10-15.

Nonaka, I. ,Takeuchi (1995), The Knowledge-Creating Company. Oxford University Press, New York in Weggeman, M. (2001), Kennismanagement, inrichting en besturing van kennisintensieve organisaties, Scriptum 4e druk., Schiedam.

Nowicki, S. Jr, Duke, M.P. (1994), Individual differences in the nonverbal communication of affect: The diagnostic analysis of nonverbal accuracy scale Journal of Nonverbal Behaviour 18(I), Human Sciences Press, Inc. 9-35.

Oberman, L.M., Pineda, J.A., Ramachandran, V.S. (2007), The human mirror neuron system: A link between action observation and social skills, Soc Cogn Affect Neurosci, 2(1): 62-66.

Oberman, L.M., Ramachandran, V.S. (2007), The simulating social mind: The role of the mirror neuron system and simulation in the social and communicative deficits of autism spectrum disorders Psychological Bulletin, Vol 133(2), Mar 2007, 310-327.

Peters, T., Waterman, R. (1982), In search of excellence. Harper & Row, New York in Weggeman, M. (2001), Kennismanagement, inrichting en besturing van kennisintensieve organisaties, Scriptum 4e druk., Schiedam.

Pink, D. H. (2010), Drive, De verrassende waarheid over wat ons motiveert, Uitgeverij Business Contact Amsterdam-Antwerpen, Original title, Drive,The Surprising Truth About What Motivates Us, 16, 95, 110, 121.

Plotinus, (1969), The Enneads, S. MacKenna Trans, New York: Faber and Faber.

Proshansky, H.M., Fabian, A.K. ,Kaminoff, R. (1983), Place-identity: Physical world socialization of the self, Journal of Environmental Psychology, 3, 57-83.

Ramachandran, V., Blakeslee, S. (1998), Het bizarre brein, Wat fouten in de hersenen ons leren over de werking ervan, Kosmos-Z&K Uitgevers, Utrecht/Antwerpen, 197-198.

Ramsey, R., Hamilton A.F. de C. (2012), How does your own knowledge influence the perception of another person's action in the human brain?, Soc Cogn Affect Neurosci. 7(2), 242–251.

Reber, A.S. (1989), Implicit Learning and Tacit Knowledge, Journal of Experimental Psychology: General, Vol. 118 (3), 219-235.

Reim, B., Glass, D.C., Singer. J.E. (1971), Behavioural Consequences of Exposure to Uncontrollable and Unpredictable Noise, Journal of Applied Social Psychology, Vol 1 (1), 44-56.

Relph, E. (1976), Place and Placelessness. London: Pion in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Kan, R. (2010), in Bakker, I.C., Van der Voordt, D.J.M. (2010), Huisvesting als middel tot sociaal-economische vitaliteit, Interview with Alexander Rinnooy Kan, Facility Management Informatie 5, 32-35.

Rinpoche, S. (2006), presentation Rinpoche, Conference Dalai Lama, Antwerpen.

Rochberg-Halton, E. (1984), Object relations, role models, and cultivation of the self, Environment & Behaviour, 16, 335-368 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation. Journal of Environmental Psychology, Vol 9 (3), 241–256.

Rogers, C. (1982), Over mens zijn, een perspectief. Uitgeverij de toorts, Haarlem, 279-281, Original Title: A way of being.

Rogers, C.R. (1954), Toward a theory of creativity. American Psychological Association, Vol 11, 249-260 in McCoy, J.M. and Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity, Creativity Research Journal, 14:3-4, 409-426.

Rosenberg, M. (1979), Conceiving the Self. New York: Basic Books in Proshansky, H.M., Fabian, A.K. , Kaminoff, R. (1983), Place-identity: Physical world socialization of the self, Journal of Environmental Psychology, 3, 57-83.

Rowles, G. D. (1983), Place and personal identity in old age: observations from Appalachia. Journal of Environmental Psychology, 3, 299-313 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation, Journal of Environmental Psychology, Vol 9 (3), 241–256.

Ryan, R.M., Deci, E.L. (2000), Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions, Contemporary Educational Psychology 25, 54–67.

Ryan, R.M., Deci, E.L. (2001), On happiness and human potentials, A Review of Research on Hedonic and Eudaimonic Well-Being, Annu. Rev. Psychol. 52:141–66.

Sani, F., Bowe, M., Herrera, M. (2008), Perceived collective continuity and social well-being: exploring the connections. European Journal of Social Psychology, 38, 4,365–74.

Schneider, W. (1987), Sinn und Un-Sinn, Bauverlag GMBH Wiesbaden und Berlin.

Senge, P., Cambron- Mc Cabe, N., Lucas, Th. , Smith, B., Dutton, J., Kleiner, A. (2001), Lerende scholen een vijfde discipline boek, Academic Service, Schoonhoven, 38, 42.

Senge, P., Kruschwitz, N., Laur, J.,Schley, S. (2008), De noodzakelijke revolutie, Hoe organisaties en individuen een duurzame wereld creëren, Sdu Uitgevers bv Den Haag; First published in Great Britain by Nicholas Brealey Publishing London 2008; original title The Necessary Revolution. 134; 215, 322, 271, 346-369.

Sheldon, C., Frank, E., Doyle, W.J., Skoner, D. P., Rabin, B.S., Gwaltney Jr., Jack M. (1998), Types of stressors that increase susceptibility to the common cold in healthy adults. Health Psychology, Vol 17(3), 214-223.

Steiner, R, (1909), Zur Sinneslehre, 8 Vorträge, Thermen aus dem Gesamtwerk 3, 'Antroposophie. Die Sinnen des Menschen'. Herausgegeben von Christoph Lindenberg (1981), Verlag Freies Geistesleben, Stuttgart, 48-67.

Tuan, Y-F. (1974), Topophilia: A Study of Environmental Perception, Attitudes and Values.
Englewood Cliffs, New Jersey: Prentice-Hall in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation. Journal of Environmental Psychology, Vol 9 (3), 241–256.

Tuan, Y. F. (1980), Rootedness versus sense of place. Landscape, 24(1), 3-8.

Turner, J. (1999), Spirituality in the workspace, CA Magazine, Vol 132 (10), 41-421 in Krishnakumar, S., Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace. Journal of Managerial psychology, Vol 17(3), 153-164.

Ulrich, R. S. (1993), Biophilia, biophobia, and nature landscapes in McCoy, J.M. and Evans, G.W. (2002), The Potential Role of the Physical Environment in Fostering Creativity. Creativity Research Journal, 14:3-4, 409-426.

Vallerand, R. J. (1983), Effect of differential amounts of positive verbal feedback on the intrinsic motivation of male hockey players. Journal of Sport Psychology, 5, 100-107.
Vallerand, R., Reid, G. (1984), On the causal effects of perceived competence on intrinsic motivation: A test of cognitive evaluation theory. Journal of Sport Psychology, Vol 6(1), 94-102.

Verbruggen, M. (1994), Soleren en samenspelen: Kan dat? Twijnstra Gudde Management Consultants, Amersfoort, in Weggeman, M. (2001), Kennismanagement, Inrichting en besturing van kennisintensieve organisaties, Scriptum Management, Schiedam, 154.

Vingerhoets, A.J.J.M. (1995), Psychosociale belastingen immuniteit in Gaillard, A.W.K. (2003), Stress, Productiviteit en gezondheid, Uitgeverij Nieuwezijds, 2e druk.

Vischer, J. C. (2005), Space Meets Status. Abingdon: Routledge.

Wagner-Marsh, F., Conely, J. (1999), The fourth wave: The spirituality based firm, Journal of Organisational Change Management, Vol. 12 (4), 292-301, in Krishnakumar, S. and Neck, Ch.P. (2002), The 'what', 'why' and 'how' of spirituality in the workplace. Journal of Managerial psychology, Vol 17(3), 153-164.

Warr, P. (1994), A conceptual framework for the study of work and mental health. Work and Stress, 8, 84-97 in Gaillard, A.(2003), Stress, productiviteit en gezondheid, Uitgeverij Nieuwezijds, Amsterdam.

Weggeman, M. (2001), Kennismanagement, inrichting en besturing van kennisintensieve organisaties, Scriptum 4e druk, Schiedam.

Weggeman, M. (2007) in Bakker, I.C. (2007), Productiviteit en kennisontwikkeling, Interview with Mathieu Weggeman, Facility Management Informatie, nov, 44-45.

Wolfe, J., Box, Th.M. (1987), Team cohesion effects on business game performance, Developments in Business Simulation & Experiential Exercises, Volume 14, 250 -255.

Wyman, M. (1985), Nature experience and outdoor recreation planning. Leisure studies, 4, 175-188 in Korpela, K.M. (1989), Place-identity as a product of environmental self-regulation. Journal of Environmental Psychology, Vol 9 (3), 241–256.

Zegveld, M., den Hartigh, E. (2007), De winst van productiviteit Sturen op resultaat in dienstverlening Stichting Management Studies (SMS), Van Gorcum, 13.

Zajonc, R. B. (1968), Attitudinal effects of mere exposure. Journal of Personality and Social Psychology, (Monograph Supplement, Part 2), l-27 in Kraut, R., Egido, C., Galegher, J. (1988), Patterns of Contact and Communication in Scientific Research Collaboration, Proceedings of the 1988 ACM conference on Computer-supported cooperative work, 1-12.

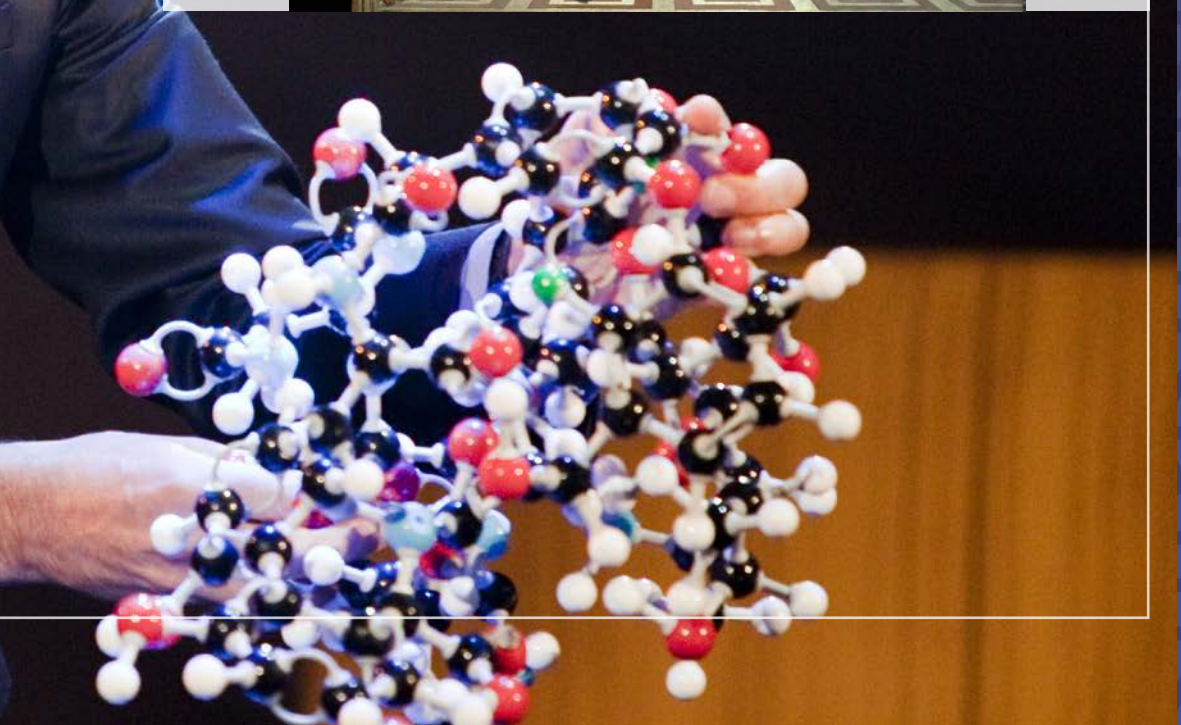
Zeisel, J. (2006), Inquiry by design. New York, NY: Newton in Knight, C. ,Haslam, S.A. (2010a), The Relative Merits of Lean, Enriched, and Empowered Offices: An Experimental Examination of the Impact of Workspace Management Strategies on Well-Being and Productivity. Journal of Experimental Psychology: Applied, Vol. 16 (2), 158 –172.

Zohar, D and Marshall, I. (2000), Connecting with our spiritual intelligence. Bloomsburry, New York in Covey, S. R. (2005), De 8e eigenschap van het effectief leiderschap, Uitgeverij Business Contact Amsterdam/Antwerpen, 15, 46.

The happy knowledge worker with daylight, natural materials and a green environment.

Robbert Dijkgraaf

In this digital era we only touch the buttons of keyboards, sweep rapidly across the touchscreen, make fleeting photos of reality and even strike virtual dogs with tiny plastic touch screen pens. We design brick stone walls by touching one button, without the feeling of the brick stone itself, without handling it, even without drawing some stones by hand. However, materials and real things stimulate imagination and experience and support comprehension for complex and abstract topics, as behaviour of electromagnetic fields or the expanding cosmos. It is professor Robbert Dijkgraaf who is able to make extremely complicated topics understandable so that they even seem to be rather simple, just by showing physical things such as balls and umbrella's. Also in the old times, the Italian painter Raphael painted Ptolemy in the School of Athens in exactly the same way giving this astronomer a ball in his hands to be able to explain about the complex cosmos.



As Einstein said ‘Look into Nature, and then you will understand everything better’, Nature is our teacher in learning processes and offers a helping hand to be a productive, healthy and happy knowledge worker (Marc van den Tweel, Algemeen Directeur Natuurmonumenten).

To analyse the effects of the physical environment, the first focus will be on plants. In general plants have a positive effect on productivity. But what is the mechanism and are researches on the interaction between plants and productivity comparable?

Chapter Three

The influence of plants on productivity
A critical assessment of research findings and test methods

Bakker I.C., Van der Voordt, D.J.M. (2010), The influence of plants on productivity: a critical assessment of research findings and test methods. Facilities,28(9/10), 416-439

People are often not aware of the environment and do not distinguish the influence of individual parts, but experience the environment as a totality. To learn how to assess and understand the complex relationship between this totality and the complex topic of productivity, we first focus on plants. The choice to have a closer look at plants is made because plants can easily be added to and removed from the environment and can be isolated from the context. There are also indications that plants influence productivity. Because of this reason, it is interesting to study the relationship between this component and productivity.

abstract

This paper aims to review available research into the impact of plants on people and labour productivity in order to test a number of hypotheses and the reliability and validity of "evidence based" statements. An extended literature review has been conducted of research concerning the potential impacts of plants on people and labour productivity. In order to be able to compare the findings of different researchers, an analysis was made of similarities and dissimilarities with regard to the research context, starting-points and test methods. The paper identifies a lack of precise descriptions of the research design and poor comparability between different researches with regard to the characteristics of the plant, test persons, test procedures, surrounding conditions and contents of the reports. Although we can be concluded that plants have a positive impact on the productivity of human beings, it is remarkable that in research reports and research papers the properties of the plant itself are only mentioned by exception. The condition of the plant - whether it is healthy or not – is not described at all. Only 17 studies and underlying papers have been investigated and no new research has been conducted with the proposed improvements. The findings can be used by managers to legitimate investments in plants and by researchers to improve (the comparability of) research into plants. In addition to the review of the impact of plants on different types of productivity a vision is presented about the impact of the vitality of plants. Furthermore recommendations are given on how to cope with the methodological problem of poor comparability of research.

Keywords *plants; productivity rate, research methods; work psychology, work place*

3.1 Introduction

In order to be able to design the optimal working environment where people can flourish in their work and organisations will be successful, it is important to know how the physical environment affects people and productivity. One of the variables is the presence of plants. In search of evidence-based knowledge about the impact of plants on labour productivity it turned out that the existing literature is not always clear on what the impact exactly is. It is needed to define this impact more exactly. Second we observed a large variety of research methods and test conditions. As a consequence, the comparability of different research projects and the conclusions that came out of the research is limited. And third, the first scan

of a number of studies and included references showed that in particular information about the plants themselves is often lacking. This is an omission, because probably nobody will be more productive by seeing a faded or dead plant. Apart from the appearance, the type of the plant may be an important issue too. It may be expected that people respond differently when seeing a cactus or a rose plant. These observations have lead to three main questions for a more extensive literature review on the impact of plants on productivity:

1. What is the influence of plants on productivity?
2. Are different researches sufficiently comparable to draw sound conclusions?
3. What is the impact of the appearance and vitality of the plant?

These questions have been rephrased into three hypotheses:

Hypothesis 1: Plants have a different impact on different types of productivity.

Productivity covers a diversity of activities such as routine work and creativity. Creativity tasks and complex knowledge work need inspiration and deepening. Through history many statements of famous philosophers, writers and artists such as Nietzsche or Liszt refer to the inspiring and deepening effect of nature. Our hypothesis is that in case of routine work plants might help to support wellbeing and as such keep people going on, whereas in case of creativity work a positive effect is expected in relation to inspiration and deepening.

Hypothesis 2: Research concerning the impact of plants on productivity is not well comparable.

Research is rather complex. Even when the focus is just on one "dependant" variable, plants, many "independent" variables can influence the results. It is expected that research so far does not use standardised research methods.

Hypothesis 3: Both the appearance, type and vitality of the plant have an impact on productivity.

One of the wonders of nature is its infinite variation combined within certain patterns and structures. Each variety has its own characteristics. As a consequence one might expect different effects of different plants. In particularly the vitality of a plant is expected to be important. Probably a healthy plant has a more positive impact on people than a plant that is not vital. In addition it is important that a plant lives in an environment with healthy conditions that support the plant and conditions people need.

3.2 Research methods and conceptual model

Initially, 17 research studies from renowned researchers and research institutes were collected (see the Appendix A).These documents have been scanned on possible effects of plants on people and labour productivity, relevant variables and references for further reading (see list of references). Without any exception all studies make a significant contribution to the field. Together an incredible amount of data has been collected on many different effects. Second, in order to enlarge the knowledge that came out of the documents - both technical and psychological – discussions with specialists of the knowledge institutes TNO and Fytagoras/TNO have taken place as well. Third, because of the many different phenomena that are being mentioned in the studies and additional references, the need came up to develop a conceptual model that visualises the different types of impact of plants on human beings (Figure 1). Two different mechanisms have been traced:

1. Evolutionary influence.

Since our genesis we have been surrounded by green plants and trees. From this point of view it is generally assumed that seeing plants has, in general, a restful effect (Ulrich, 1984; Kaplan and Kaplan, 1989).

2. Healthy indoor climate.

Plants have an impact on the indoor climate; this indoor climate in turn affects people and their productivity (Wolverton, 1989; Wood et al, 2004).

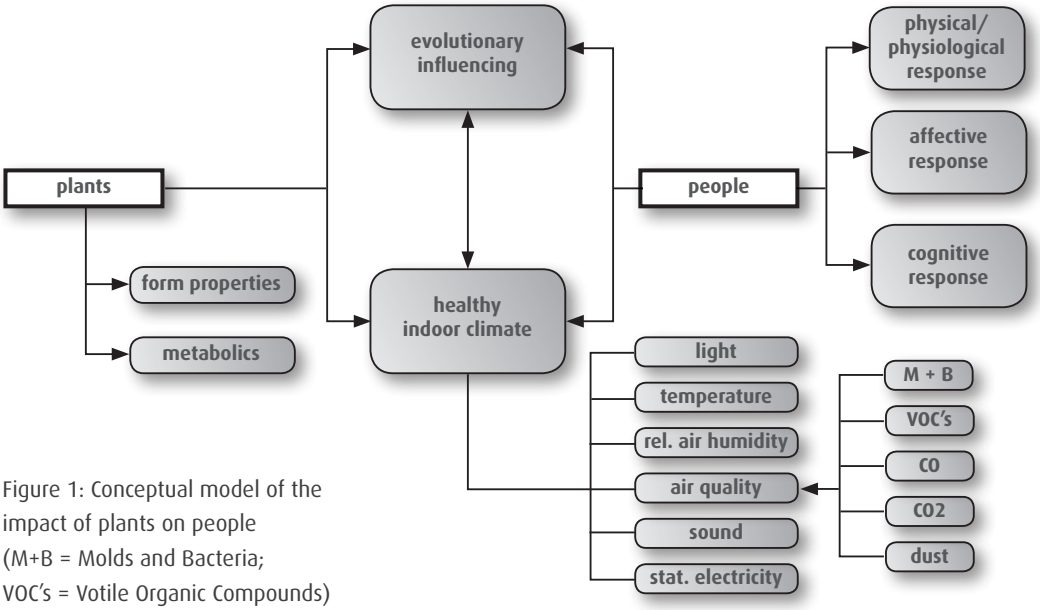


Figure 1: Conceptual model of the impact of plants on people (M+B = Molds and Bacteria; VOC's = Votile Organic Compounds)

The evolution of human beings and a healthy indoor climate affect people in three ways: plants evoke a physical/physiological response, an affective response and/or a cognitive response. In the literature six components of the indoor climate are being mentioned in relation to the impact of plants: light, temperature, relative air humidity, air quality, sound and static electricity. Another point of attention is the characteristics of plants themselves, including form properties and metabolics. The latter are hardly mentioned in the literature.

This conceptual model has been used as a guiding principle to analyse and discuss the collected data to examine the research findings and conclusions in the studies more closely. In a cyclic process of reading, reflecting, discussing, further reading etc. a list of items has been traced with regard to the test conditions (Table 1). This list includes six main aspects:

1. characteristics of the plant;
2. the test surroundings;
3. the test persons;
4. the test process;
5. test strategies; and
6. methods and variables.

Table 2 shows the variables that have been investigated in each research.

table

Table 1: Overview of items to compare different researches on plants

Plants	Test surroundings	Testsubjects	Testproces	Test	Methods and Variables
spot · position in space · height of view · indoor/outdoor · view **sort** **variety** **intensity** · dimension/ number per square m **number** **size** **cleanliness order** **maintenance situation** **pot ground/ hydroponics** **pot size** **form pot** **artificial plant** **image plants** **flower** **micro-organism**	**institute** · outdoor area · laboratory · education · office · shop · hospital/care **space type** · *one person space* · *two persons space* · *multi persons space* · *various* **space characteristics** · number of windows · size of windows · size of space **relation to temperature** **light level** **relation lighting** · fluorescent broad spectrum · neon light **day light** **Relative Air Humidity** **ventilation system** · natural ventilation · mechanical ventilation · air treatment · airco **quantity ventilation** · design ventilation quantity · real ventilation quantity **sound** **static electricity** **colour space** **fragrance** **interior elements** **smoke** **specification and VOC's** **parts and value parts of dust** **CO2 and value CO2** **CO and value CO** **moulds** **pathological micro-org.** **time** · link to seasons · link day/night **one cell organism** **weather**	**testsubjects** **men** **women** **children** **patients** **students** **employees** **age** **number** **sort of work** **concentration** **creativity** **routine** **commitment** **testpersons** · relevance · seriousness of participation · to participate own choice · involvement final result · preference for plants	**reduction** **hawthorne-effect** · attention **habituation proces** · attention **test surrounding** · clear information at the beginning · intensive accompaniment · acceptation management **test aspects** · placebo	**observation** · observation by testsubject · observation researcher · technical supporting measurements · data semantic questionnaire · data standard interview · data interview/ survey · data question conversation · questionnaire · computer program **biofysical observation** · hartbeat · syst bloodpressure · muscle tension · skin conductance · electr brain activity **number measurements** **test duration** · hours · days · weeks · months · years **objectifying** · knowledge structure questionnaire **effects** · affective feeling · affective mood · affective behaviour · physical primary · physical secondary · phygological effects · cognitive · cognitive concentration · cognitive memory · cognitive reaction time · cognitive discipline **other mentioned effects** · productivity/performance · sound · ecologically/reduction energy · staff keeping and recruitment · on working environment · on plants **start conditions** · single plant · many plants	**information** · observation · by testsubject · by researcher · biofysical · questionnaires · standard · scoremodel · quantative · qualitive · interview method · guidance question conversation · no guidance · computer program · ZIPER test **fee** · credit **task** · association task · key typing task VDT · computertask · sortingtask · concentration task **technology** · air/ventilationsystems · lightsystems · measurement · airquality **concept** · position plants · number plants

table

Table 2: Aspects that have been mentioned in 17 studies

Studies (numbers according to Appendix A)

Component	aspect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Sum
Plants																			
spot	position in space	X	X	X		X		X							X	X		X	8
	height of view		X	X		X		X											4
	indoor/outdoor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	17
	view		X	X									X						3
	sort		X	X		X	X	X			X		X	X	X		X	X	11
	variety			X		X	X	X			X			X	X		X	X	9
intensity	dimension/number per square m			X		X		X			X			X	X				6
number			X	X		X	X	X					X	X	X	X		X	10
size				X		X		X			X	X						X	6
cleanliness order		X											X			X			3
maintenance situation				X		X							X					X	4
pot ground/hydroponics		X				X									X		X		4
pot size													X					X	2
form pot				X		X							X		X				4
artificial plant		X			X														2
image plants		X											X						2
flower					X								X						2
micro-organism						X													1
Test surroundings																			
type of environment	outdoor area	X						X					X			X			4
	laboratory							X						X	X				3
	education		X																1
	office		X			X	X											X	4
	shop															X			1
	hospital/care	X	X										X						3
space type	one person space		X			X	X											X	4
	two persons space																		0
	multi persons space							X											1
	various																		0
space characteristics	number of windows		X				X	X			X	X							5
	size of windows		X																1
	size of space		X			X	X	X		X	X			X	X			X	8
temperature	known					X		X		X				X				X	5
light level	known		X			X		X											3
type of light	fluorescent broad spectrum		X																1
	neon light		X					X						X					3
	unknown		X														X		2
day light	known	X	X	X				X								X			5
Relative Air Humidity	known		X	X		X		X		X				X				X	7
ventilation system	natural ventilation					X												X	2
	mechanical ventilation		X			X								X					2
	air treatment					X													1
	airco			X														X	2
quantity of ventilation	designed ventilation quantity													X	X			X	3
	real ventilation quantity					X													1
sound	known			X		X								X					3
static electricity						X													1
colour space	known						X	X											2
fragrance	known			X									X						2
interior elements				X		X					X	X							4
smoke				X		X							X	X					4
specification VOC's						X								X	X		X	X	5
value VOC's						X								X			X	X	4
parts of dust			X			X								X					3
value parts of dust						X													1
CO2						X								X				X	3
value CO2						X								X				X	3
CO			X			X												X	3
value CO						X												X	2
moulds			X			X													2
path micro-org.				X		X													2
time	which season(s)									X									1
	day/night																		0
one cell organismn						X													1

Studies (numbers according to Appendix A) - continued -

Component	aspect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Sum
Test persons																			
test persons	no distinction	X	X										X			X			4
	men				X	X	X	X			X	X							6
	women				X	X	X	X			X	X							6
	children		X																1
	patients	X											X						2
	students					X	X	X			X	X							5
	employees		X		X	X	X	X										X	6
	age			X			X												2
	number				X	X		X					X						4
type of work	concentration					X	X	X				X							4
	creativity											X							1
	routine					X	X					X							3
commitment	relevance						X				X	X							3
testpersons	seriousness of participation																		0
	to participate is own choice				X		X	X			X	X						X	6
	involvement in final result																		0
	preference for plants							X											1
Testproces																			
reduction hawthorne-effect	attention		X																1
habituation proces	attention		X			X	X					X						X	5
	clear information at the beginning						X												1
test surrounding	intensive accompaniment						X									X			2
	acceptation management																		0
test aspects	placebo																		0
Test strategies																			
observation	observation by test person				X			X					X					X	4
	observation researcher							X					X						2
	tecnical measurements																		0
	data semantic questionnaire																		0
	data standard interview																		0
	data interview/ survey												X			X			2
	data question conversation															X			1
	questionnaire		X		X	X	X				X		X						6
	computer programme							X											1
biofysical observation	hartbeat	X						X					X						3
	syst bloodpressure	X						X					X						3
	muscle tension												X						1
	skin conductance												X						1
	electr brain activity												X						1
number of measurements	known							X						X				X	3
test period	ours		X				X					X	X						4
	days					X								X			X		3
	weeks																		0
	months		X			X									X			X	3
	years		X			X													2
objectivity	knowledge structure questionnaire																		0
effects	affective feeling	X	X	X		X		X			X		X			X			8
	affective mood	X	X	X		X		X					X			X			7
	affective behaviour	X		X												X			3
	physiologically primary	X	X	X		X		X					X				X		7
	physiologically secondary	X	X	X		X		X					X						6
	cognitive	X	X				X	X			X		X						6
other mentioned effects	productivity/performance							X								X	X		3
	sound																		0
	ecological / reduction of energy															X			1
	staff retaining and recruitment												X						1
	impact on working environment		X		X						X						X		4
	impact on plants					X													1
	other				X											X			2
start conditions	single plant																		0
	many plants					X													1
Total mentioned aspects		19	38	23	13	54	24	41	1	4	18	14	32	20	13	18	11	28	371

3.3 Research findings

3.3.1 Effects of plants on human beings: physical, physiological, affective and cognitive response

The next responses are mentioned rather often:

- *physical/physiological:*
  primary physical responses are effects on blood pressure and heart beat and physiological decrease of complaints of headache; secondary responses are physiological phenomena like faster recovery (all documents excl. no 9, 6, 10, 13, 14)
- *affective:*
  positive affective response on mood and affective behaviour like self-confidence, alertness or less aggression and positive feelings like pleasure (all documents, excl. no 9, 13, 14, 16 and 17)
- *cognitive:*
  positive cognitive responses are better concentration capacity and higher response speed (all documents excl. no. 9, 13 and 14).

Ulrich (1984), Fjeld et al (1998) and Lohr et all (1996) showed significant statistical correlations between seeing plants and physical/physiological, affective and cognitive responses. These researchers use different methods like questionnaires, the Zipertest (Zuckerman Inventory or Personal Reactions), interviews and observation of behaviour. Unfortunately a clear explanation of the set-up of these methods is often missing.

In most research also quantitative effects were also mentioned, be it quite underexposed. The following quantitative data are interesting:

- Wolf (2002) mentions in her research at shops an increase of sale concerning all products of 12% when plants are present;
- Lohr et all (1996) appoint an increase of the response speed of 12% at simple recognition tests;
- Fjeld (1995) shows a decrease of symptomatic physical complaints of 23% at 51 office employees;
- Research of Fjeld et al (1998) among 48 employees of an X-ray division showed a 25% decrease of health complaints by using plants; and
- In 2001-2002 Fjeld revealed an average 24% reduction of physical complaints among different groups of 48 bank employees after the introduction of plants and light with a broad spectrum.

When the results are analysed more closely, a uniform effect on physical/physiological, affective and cognitive responses comes up. This confirms the statements of many famous people that emphasise the positive effects of nature on human beings. Greek philosophers used the so called 'peri-pathetic method: walking through the academy garden, to discuss their ideas (Csikszentmihalyi,1996,1998). Based on studies such as presented above, it can be concluded that a relation exists between seeing and experiencing plants and physical/physiological, affective and cognitive responses. This relation however is merely qualitatively described and to a lesser extent quantitatively defined. The exact effect of plants on human being is still not clear. In accordance with the model, three explanatory options are possible. The effect can be evolutionary: during centuries of development of human beings, plants have always been an important part of nature and a strong foundation in our existence. A second effect is the improvement of the indoor climate. Many aspects of the indoor climate are strongly connected to the presence of plants. Third, metabolics may have an influence on people. Plants form metabolics, chemical compounds with amongst other things fragrances and colour properties. These substances may be expected to influence people, but this has not been proven by research so far. Little attention has been paid to the impact of intermediary variables such as research conditions and test persons. So, although

the positive effects of plants on human beings are widely accepted and supported by research, we have to interpret the research findings carefully.

3.3.2 Effects of plants on the indoor climate

Plants and indoor climate affect one another. To be able to interpret research findings on the impact of plants correctly, detailed information is needed about the indoor climate in the test situation. But due to differences in descriptions and lack of essential information concerning technical data that might affect the process and the impact of plants it is rather difficult to draw clear conclusions. Nevertheless some interesting results have been found with regard to the six components of indoor climate that are included in the conceptual model: light, temperature, relative air humidity, air quality, sound and static electricity.

Light

With regard to photosynthesis the blue and red part of the spectrum are necessary for healthy plants. In many buildings light with a broad spectrum is absent, so probably insufficient blue and red light will be available for the plant. This obstructs the growth and also the processes of photosynthesis and metabolism. It is striking that in the examined studies both light colours (spectrum) and light intensity are usually not mentioned at all, in spite of its importance for the health of the plant. Vice versa the reflection of light on the leafs of plants affect the variation on light colours in the physical surrounding.

Temperature

Stec et al (2005) revealed that an outside awning of plants is more effective than a regular awning. Schempp (2002) mentions a difference of two up to three degrees with regard to outside temperature by application of an outside awning with plants in combination with plants inside.

Relative air humidity

Research of Costa and James (1995) and Strickler (1994) showed that the relative air humidity of a space without air treatment increases with approximately 5% when plants are used. It is necessary to use a quite large number of plants. Lohr et al (1996) mentions an increase from zero to 15% if a space is not ventilated; in a ventilated room there is an increase of 3 to 5%. Applying plants means that you have to take care for them. When for instance the value of relative air humidity is too low, the stomata at the base of leafs will close.

Air quality

In the air volatile organic compounds (VOC's) occur, such as small dust particles, moulds, bacteria, metabolics, CO and CO2. Air quality is expressed by the VOC's concentration which is quantified in parts per million (ppm) value. Based on the experiments of Wolverton (1989) it is known that a synergetic process between plant and micro organisms that attaches themselves to the root structure of the plant contributes to the reduction of the VOC's-value. Van der Wal and Hoogeveen (1993) proved that unrealistic amounts of plants are needed to reach a sufficient reduction of the VOC's value. Quite often the indoor climate in buildings is not optimal for plants and therefore also not optimal for the process of VOC's reduction. Plants also have a positive influence on the reduction of dust accumulation. Research of Lohr et all (1996) showed that plants in optimal conditions can cause a dust reduction of 20%. Plants are selected in buildings in such a way that they will not grow too rapidly, because rapid growth increases the exploitation costs too much. It may be concluded that a positive effect of plants is not the right argument to use of plants as a means to control or improve the indoor air quality. Ventilation is much more effective.

Sound

Research of Costa and James (1995) shows that the reverberation time of sounds with a high frequency is shortened when plants are used, and as such the space will be quieter. At low frequencies more inflection of the sound takes place. Dependent of the exact location and the spreading, sound absorption takes place.

Static electricity

Employees working at least four hours at screens undergo less inconvenience of static electricity, when plants are in their workspace, then other employees without plants in their rooms (Dortmont and Bergs, 2001).

Overall we may conclude that in real working environments the influence of plants on the indoor climate is rather small. So this can not be a convincing argument to apply plants in working environment.

3.3.3 Effects of plants on productivity

According to the studies that have been analysed, the question of whether plants have an impact on the functioning and productivity of people can be answered in a positive way (Table 3). Most studies mention the positive qualities of plants. However, it is hardly possible to compare the studies in a systematic way because of the lack of clear definitions of productivity and performance and a lack of clear information about which activities have been measured, what exactly has been measured, what the characteristics were of the test persons and in which way the measured results were achieved. Because of the large amount of variables it is impossible to establish clear conclusions.

Table 3: Effects of plants on labour productivity

Research	Conclusions	Doc. number (appendix A)
Asami et al (1989)	indoor plants reduce the fatigue of the eye when working with screens	10
Conklin (1974-1978); Isen (1990-1993); Knez (1995);	plants in offices lead to higher employee morale and higher effectiveness	7, 11
Isen (1990, 1993); Isen & Shalker (1982)	if people are in a positive mood, their creativity raises	6, 11
	positive phenomena stimulate the brain for recalling more information and they initiate more cognitive manipulation that causes a higher level of creativity	6
Larsen(1998)	a larger number of plants improves the mood, but reduces concentration; the perceived productivity increases in connection to the number of plants	1, 6
Lohr et al (1996)	plants lead to 12% increase of the response speed and reduce the number of mistakes	5, 8
Mayer et al (2006)	plants strengthen the capacity to think about life problems	1
Mayer & Frantz (2004)	plants evoke a positive feeling of alliance and increase problem solving capacity	1
Srivens (1980) & Marchant (1982)	With plants increase of productivity 10 – 15%	7
Ottoson & Grahn (2005)	staying one hour in a green space improves concentration	1
Shibata & Suzuki (2002)	Plants have a larger impact on performances related to females than to males. In spaces with a plant men performed better: conducting a sorting and association task men performed on a lower level than women in case of no plants in the room, but when a plant was placed in front of them, men performed better than women. The impact of plants was larger at the association task, than at the sorting task. Plants had a negative effect on women in sorting tasks.	1, 5, 11
Shibata & Suzuki (2002)	the presence of plants increases the performance score of women; in general the presence of a plant increases the mood and the appreciation of the space	11
Shoemaker (1992)	plants have no impact on work satisfaction	5
Stone (1998)	Plants have a negative impact on performance and task perception	11

In spite of the methodological shortcomings we can discern a common red thread:

- Plants bring people in a better mood and improve confidence and openness of the mind to the surrounding world. Plants have also a positive social effect in relation to alliance and morality.
- If people are in a better mood, the perceived productivity increases, whereas the measured ('real') productivity score decreased.
- The amount of plants plays a role.
- The presence of a plant stimulates people in different ways.
- The effect of plants can be different depending on the activities.
- With regard to productivity of creative work, a clear positive relation is evident on the basis of the research above.

3.4 Reflections on the attention paid to five test items

As has been said before, to improve the comparability of research on plants, a test structure has been developed with five test characteristics that should be described very clearly the plant; the test surroundings; the test persons; the test process; and the test itself. Furthermore standard items have been formulated per aspect. The collected studies have been examined on the attention paid to these five aspects and the components (Table 2).

3.4.1 The plant itself

Looking at the plant itself, most reports and papers only pay attention to its type, variety and number and sometimes the spot. Heights and sizes of pots are mentioned as well. The characteristics of the plant itself are usually not described at all. Several types of plants are used, with different varieties (Table 4). Particularly the Dracaena with the Spathiphyllum and the Epipremnum are often used. Because of the different plants that are involved in the investigations, the conclusions from the studies are not comparable.

table

Table 4: Names of plants appointed in the research documents **(numbers refer to the numbers of the documents in Appendix A)**

Plant species	Lohr (7)	Burchett Tarran (in 5)		Wood (16)	Larsen e.a. (6)	Van der Wal (13+14)	
		Strickler (in 5)	Klein Hesselink (5)		Wolverton (3)	Shabita & Suzuki (10+11)	
Aglaonema	X						X
Chamaedora	X						
Dracaena	X	X	X	X		X	X	
Epipremium	X		X	X				X
Homalomena	X							
Hoya	X							
Philodendron	X	X					X	
Sansevieria	X							
Scindapsus	X							
Syngonium	X							
Dizygotheca		X						
Ficus benjamina		X		X				X
Hedera		X						
Howea			X	X				
Spathiphyllum			X	X	X		X	
Schefflera			X	X				
orchidee					X			
bromelia achtigen					X			
Augusta								
Phycorapis							X	
Strelizia							X	

3.4.2 Test surrounding

Most studies mentioned whether the tests have taken place inside or outside. In all studies, the environment of the test is described, including offices, a laboratory, shops, care sector and education buildings. Most attention is paid to the size of the space and the relative air humidity. All other aspects of the test surroundings are mentioned only very briefly and to an insufficient degree. Colour specification is extremely limited, whereas this variable affects the light frequencies required for the photosynthesis of the plant.

3.4.3 Test persons

The test persons vary from children to students (graduates and undergraduates), clients and employees and include men and women in different sectors. Usually reports and papers do not give any information about the psychological and social psychological situation of test persons or personal characteristics (beside age and sex), personal conditions or mood specifications. So, no valid statements can be made about the impact of these issues. Sometimes attention is given to the willingness of people to participate in the experiment.

3.4.4 Test process

Processes are very complex; there are many factors playing a role and also influencing one another. No single study paid attention to psychological effects like the Hawthorne effect. In a number of cases attention was paid to habituation. However, the way which habituation has been defined and being measured is described insufficiently. It is possible that both the habituation of the test persons and the early effects of VOC'S-reduction of plants have affected the test results, but in which way is still not known.

3.4.5 Test methods and variables

Observations, measurements, impact and test duration are only comparable in a limited way. The observations vary from individual perceptions of the test persons to observations by research workers and standard questionnaires with scores and/or scales. Biophysical observation has taken place to a limited extent.

It may be concluded that because of the huge variety in test characteristics the comparability of the 17 analysed documents is limited. Testing phenomena like effects of plants on productivity is related to many variables, so it is a very complex process. As a consequence it is nearly impossible to draw sound and transparent conclusions. Many studies do not pay sufficient attention to important terms. Quite often terms have not been formulated consistently or accurately. At this moment, there is no standard research framework that can be used as a guideline to design research. A positive exception is study nr. 5 of TNO (Klein Hesselink et al, 2006). The appointment of 55 aspects is a relatively complete description. The analysis of Fjeld and Bonnevie (2002) scores also high with an appointment of 44 aspects. The more technical considerations of Wood et al (2004) and Van de Wal (1991) have high scores as well. They focus on a pure technical and well-defined input.

3.5 A closer look at the appearance and vitality of a plant

Table 5 shows an overview of relevant aspects with regard to appearance and vitality. Based on this scheme, all remarks about the appearance and vitality of plants have been collected and analysed. It is obvious that researchers do not pay sufficient attention to the appearance of plants or their health condition. Research with significant evidence of the impact of the appearance and health condition of a plant on human behaviour has not been found yet. It has been noted that plants with flowers

table

Table 5: Characteristics of plants and its application in 17 studies

Plant characteristics			17 studies (numbers refer to Appendix A)																
nr	**aspect**	**subaspect**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Total**
1	chemical activity	bioproces system																		
2		admission chem. compounds																		
3		quantity of transpiration									X									1
4	plants	plant type				X	X		X						X	X				5
5	differentiation	plant sort		X			X	X	X			X		X				X	X	8
6		plant variety					X	X	X			X						X		5
7	sizes	plant height			X		X		X			X	X						X	6
8		planten width			X															1
9		proportions			X															1
10	form	appel/pear form																		
11		fulness/mass																		
12		horizontally or straight																		
13	structure	structure plant			X															1
14		structure branches																		
15		structure leaf																		
16		mesophyll																		
17	leaf	number/ intensity				X		X				X			X	X			X	6
18		size			X												X		X	3
19		form																		
20		surface/tactility characteristic					X													1
21		colour mix			X															1
22		colour expression			X															1
23		structure			X															1
24		position																		
25		expression																		
26		brilliance																		
27		difference colour front/back																		
28		leaf edge																		
29	fragrance plant	nature			X	X														2
30	flower	mentioned				X								X						2
31		expression																		
32		form																		
33		structure																		
34		colour																		
35		colour differentiation																		
36		position																		
37		fragrance																		
38		number/ intensity																		
39		brilliance																		
40	seeds and	number																		
41	fructification	size																		
42		form																		
43		colour differentiation																		
44		colour expression																		
45		structure																		
46		position																		
47	dynamics	dynamics																		
48	external factors	pot form			X		X							X					X	5
49		pot ground/hydroponics	X				X									X		X		4
50		position		X					X											2
51		integration environment																		
52		care and carefulness	X				X							X			X		X	5
53		solitarily/group																		
54	performance	fine or grove structure																		
55	metabolics																			
56	health	degree of vitality			X															1
	total		**2**	**2**	**11**	**4**	**8**	**3**	**5**	**0**	**0**	**4**	**1**	**4**	**2**	**3**	**2**	**3**	**6**	**60**

give most entertainment (Nakamura and Fujii, 1992). Costa and James (1995) discuss the size of the leaf and/or the length of the little hairs in connection with admission of specks of dust and chemical substances. Only the study of Van Dortmont and Bergs (1997) discusses plant properties based on conversations with garden experts.

The comparative analysis shows that hardly any attention is being paid to the properties of the plant itself, like the shape of the leafs, colours and structures of the vascular bundle. One can imagine that a cactus has another effect on people than a rose plant, and that an unhealthy or nearly dead plant makes people feel less pleasantly than a strong and healthy plant. These considerations are missing in nowadays research.

3.6 Discussion and conclusions

Hypothesis 1: Plants have a different impact on different types of productivity.
Although a consistent positive influence of plants on creativity came out from the studies mentioned, the influence of plants on overall productivity varies. In general plants have a positive impact on the physical/ physiological and affective response of people. Through centuries people are aware of the impressive nature. Modern research supports the so-called "Biophilia Hypothesis" that refers to the biological basis for human values in nature (Kellert and Wilson, 1993). There is also a growing awareness of the importance of nature to children's development – intellectually, emotionally,
socially, spiritually, and physically (Kellert, 1995; Moore and Cooper Marcus, 2008). Plants support people in their feelings of safety, because all plants have a clear structure. Concerning cognition, the effects of plants are different for various reasons. Many factors are playing a role. Another issue is the infinite diversity of people, their way of being, living, doing, feeling and thinking. All people are completely different concerning Intelligence and Emotional, Spiritual and Physical Quotient. Their personal situations are also different. So one might question of it is really possible to measure the effects of plants on people.

Hypothesis 2: Research concerning the impact of plants on productivity is not well comparable.
Due to the lack of essential information and indistinct and incomplete data, the comparability of the analysed studies is limited. Accuracy concerning the various aspects playing a role in research is necessary to establish clear conclusions. Because of the complexity of this type of research and the lack of accurate information about the many aspects playing a role there is doubt about the validity of the posited conclusions from present research.

Hypothesis 3: Both the appearance, type and vitality of the plant have an impact on the influence of plants on productivity.
None of the analysed studies discussed the appearance of the plant on a scientific basis.
Only study 3 refers to the vitality of the plant, whereas, hypothetically it is assumed that the more healthy the plant, the more positive the impact on people. It is remarkable that researchers were looking for a physical environment that is healthy for human beings, without paying sincere attention to the plant itself. Plants are – like ourselves - living beings and are permanently changing their form, colours and fragrances. It is really important to treat plants with respect. Nowadays, they are cultivated in a world with emphasis on low costs and less time. So, it's really the question if the cheap pots and cheap potting soils are benefiting the plants it selves. Moreover, the spots where plants in buildings will be placed are often too windy, too dark without day light, or lack the blue and red light of the spectrum. When plants are unhappy, they can't make people feel happy. When more attention is paid to the plant itself and when the plant stays healthier, this stronger interaction between people and plant will generate positive effects in a more socialising way. An interesting example is a home for older people,

where the older men and women were allowed to take care for their own plants, which they had selected themselves. These elderly people were feeling better and had fewer complaints (Rodin and Langer, 1977). Just by bringing user involvement in the organisation, both plants and users of a building will be happier.

3.7 Recommendations

It is highly recommended to make the approach of future research less unambiguous in order to improve its comparability with other research and to support sound conclusions. For that purpose a more elaborated standard research approach is needed. The tables and schemes that came out of this paper may be helpful here, in particular in recording of the properties of plants in a structured way. It is also important to use unambiguous definitions without overlaps and to pay more attention to the appearance and vitality of plants. This will help to create a more complete picture. However, people have to be humble. Nature is so infinite in her expressions, that it is impossible to gather all variations of nature in a model made by human beings. Finally it is recommended to pay more attention to the health of the plants themselves. It is hypothesised that the happier the plant, the more positive effect the plant has on human beings. It is interesting to study this hypothesis more closely.

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The review of the effects of plants on productivity showed that plants can contribute to the four key factors of the physical environment: structure, variety, psychological safety and identity. Plants have a distinctive structure and show an endless variety. They also showed to support people's feelings of safety. The extensive overview of characteristics of plants that all contribute to its appearance, can be used to create uniqueness and as such to contribute to identity. Based on this review two lessons can be learnt. First, productivity is a complicated concept in which many interrelated aspects play a role such as employee morale and work satisfaction. The second lesson is that the research method can have influence on the research findings. Most research is conducted in laboratory settings. However, lab situations do not represent the complex real life situation and organisational context. These two lessons learned have been taken into account in the next step of this research. The study on plants will be not continued because a very interesting aspect, namely a possible influence of metabolics actually cannot clearly be measured. In addition, a closer look into a complex and integrated component of the physical environment is needed to understand the impact of particular components in connection to the totality of the environment. We have selected colour to include in the next step, both due to its complexity and also because colour just like plants can easily be adapted, added or removed.

3.8 References

Asami, D.K. (1995), Effects of ornamental foliage plants on visual fatigue caused by visual display terminal operation. Journal of Shita 7, 138-143.

Conklin, E. (1974), Interior plantings bring nature indoors. American Nurseryman, Vol 12-13, 105-112.

Conklin, E. (1978), Interior landscaping. Journal of Aboriculture, Vol 4, 73-79.

Costa, P., James, R.W. (1995), Constructive use of plants in office buildings. Lecture notes for the catalogue of the symposium Plants for People.

Csikszentmihalyi, M. (1998), Creativiteit, Boom Amsterdam.

Csikszentmihalyi, M. (1996), Creativity : Flow and the Psychology of Discovery and Invention. New York: Harper Perennial.

Fjeld, T. (1995), The effects of interior plants for offices, Report Symposium Plants for People .

Fjeld, T., Veiersted, B., Sandvik, L., Riise, G., Levy, F. (1998), The Effect of Indoor Foliage Plants on Health and Discomfort Symptoms Among Office Workers. Indoor and Built Environment, 7: 204-206.

Fjeld, T. and Bonnevie, C. (2002), Het effect van planten en kunstmatig daglicht op het welbevinden en de gezondheid van kantoorpersoneel, schoolkinderen en gezondheidsmedewerkers, (The effect of plants and artificial daylight on the well-being and the health of office workers, school children and health care personal), paper presented at the International Symposium, Floriade.

Isen, A.M., Shalker, T.E. (1982), The effect of feeling state on evaluation of positive, neutral and negative stimuli, Social Psychology Quarterly 45(1), 58-63.

Isen, A.M. (1990), The influence of positive and negative affect on cognitive organisation: Some implications for development. In N. Stein, B. Leventhal and Trabasso, T., (Eds), Psychological and biological approaches to emotion (75-94). Hillsdale N.J.: Lawrence Erlbaum.

Isen, A.M. (1993), Positive affect on decision making. In M. Lewis and Haviland, J.M. (Eds.) , Handbook of emotions, (261-277) New York: Guilford .

Kaplan, R., Kaplan, S. (1989), The experience of nature: A psychological perspective. New York: Cambridge University Press (doc 1, 2, 6, 10, 11).

Kellert, S. R. (1995). The biophilia hypothesis. Island Press.

Kellert, S. , Wilson, E.O. (1993), The biological basis for human values in nature, in Kellert, S. and Wilson, E.O. (Eds) (1995), The Biophilia Hypothesis, Island Press, Washington, DC.

Klein Hesselink, J. , Hopstaken, L. (1995), Planten op het werk (Plants in the Working Environment), NIA, Amsterdam.

Klein Hesselink, J., de Groot, E., Loomans, M., Kremer, A. (2006), Fysiologische en psychische en gezondheidseffecten van planten in de werksituatie op gezondheid en welbevinden van mensen (Physiological and Mental and Health Consequences of Plants in the Work Situation on Health and Well-being of People), TNO rapport 21573/018.10311, TNO Kwaliteit van Leven, Hoofddorp.

Knez, I. (1995), Effects of indoor lighting on mood and cognition. Journal of Environmental Psychology, Vol 15(1), 39–51.

Larsen, L., Adams, J., Deal, B., Kweon, B. ,Tyler, E. (1998), Plants in the workplace: the effect of plants density on productivity, attitudes and perceptions, Environment and Behaviour, Vol. 30 No. 3, 261-81.

Lohr, V.I., Pearson-Mims, C.H., Goodwin, G.K. (1996), Kamerplanten kunnen de arbeidsproductiviteit verbeteren en de hoeveelheid stress verminderen in een omgeving zonder ramen,(Interior plants may improve productivity and reduce stress in a windowless environment), Journal of Environment Horticulture, Vol. 14, 97-100.

Loomans, M. , Klein Hesselink, J. (2005), Het effect van planten op het werk, (The influence of plants in the working environment), Facility Management Magazine, 133, 17-21.

Marchant, B. (1982), A look at the industry- dimensions and prospects. American Nurseryman, Vol 156 (10): 30-49.

Mayer, F.S. , Frantz C.M. (2004), The Connectedness to Nature Scale: A Measure of individuals' feeling in community with nature. Journal of environmental Psychology, 24, 504-515.

Mayer, F.S., Frantz, C.M., Bruehlman-Senecal, E. and Dolliver, K. (2006), "Mayer F.S., Frantz, C.M., Bruehlman-Senecal, E., Why is nature beneficial? The role of connectedness to nature", Journal of Environmental Psychology, 28,192-9.

Moore, R.C., Cooper Marcus, C. (2008), Healthy planet, healthy children: designing nature into the daily spaces of childhood, in Kellert, S., Heerwagen, J. , Mador, M. (Eds), (2011)
Biophic Design: Theory, Science and Practice, John Wiley & Sons, Hoboken, NJ.

Nakamura, R. and E. Fujii (1992). A comparative study of the characteristics of the electroencephalogram when observing a hedge and a concrete block fence. Journal of the Japanese Institute of Landscape Architects, 55: 139-144. (In Japanese with English summary) .

Ottoson, J. , Grahn, P. (2005), A comparison of leisure time spent in a garden with leisure time spent indoors: on measures of restoration in residents of geriatric care, Landscape Research, Vol. 30(1), 23-55.

Rodin, J., Langer, E. J. (1977), Long-term effects of a control-relevant intervention with the institutionalized aged. Journal of personality and social psychology, 35(12), 897.

Schempp, D. (2002), Green architecture, plants in buildings; key massage plants for people, paper presented at the International Symposium, Floriade.

Shibata, S., Suzuki, N. (2001), Effects of indoor foliage plants on subjects' recovery from mental fatigue, North American Journal of Psychology, Vol. 3(3), 385.

Shibata, S. ,Suzuki, N. (2002), Effects of an indoor plant on creative task performance and mood, Journal of Environmental Psychology, Vol. 22 (3), 265-72.

Shoemaker, C.A. (1992), Relationships between plants, behaviour, and attitudes in an office environment, HortTechnology, Vol. 2(2), 205-6.

Srivens S. (1980), Interior Planting in Large Buildings, London: The Architectural Press (doc 7).

Stec, W.J., Van Paassen, A.H.C., Maziarz, A. (2005), Modelling the double skin facade with plant", Energy and Buildings, Vol. 37(5), 419-27.

Stone, N.J. (1998), Windows and environmental cues on performance and mood", Environment and Behaviour, Vol. 30(3), 306-21.

Strickler, B. (1994), Water evaporation of five common indoor plants under various climate conditions, AIVC, Vol. 1, 151-62.

Ulrich, R.S. (1984), View through a window may influence recovery from surger", Science, 224, 420-1.

Ulrich, R.S. (2002), The Consequences on Health of Plants in and around Hospitals on Patients and Nursing Staff, Center for Health Systems and Design, Texas A&M University College State, College Station, TX.

Van den Berg, A. , Winsum Westra, M. (2006), Ontwerpen met groen voor gezondheid, (Designing with plants creating health), Reeks Belevingsonderzoek, No. 14, Alterra rapport 1371.

Van der Wal, J.F. (1991), Oriënterend onderzoek naar de luchtzuiverende werking van potplanten in een mechanisch geventileerde proefruimte (Orientation Study Concerning the Air Cleansing Functioning of Pot Plants in a Mechanically Ventilated Test Space), TNO rapport, TNO Bouw, B-91-0137, TNO, Delft.

Van der Wal, J.F., Hoogeveen, A. (1993), Onderzoek naar de regeneratie van actieve kool door potplanten (Study Concerning the Regeneration of Active Cabbage by Pot Plants), TNO rapport, TNO Bouw, B-92-1155, TNO, Delft.

Wolf, K.L. (2002), Het effect van natuur in en rond winkelgebieden; creatie van een consument gerichte leefomgeving, (The impact of nature in and around shop areas; creation of an environment specifically suited to a consumer), paper presented at the People/Plant Symposium, Amsterdam.

Wolverton, B.C. (1989), Interior Landscape Plants for Indoor Air Pollution Abatement, NASA, John C, Space Center.

Wood, R., Orwell, R. and Tarran, J. (2004), Planten om de luchtkwaliteit van een kantoor te verbeteren (Plants to Improve Office Air Quality), Flower Council of Holland, Sydney, Final report of Office "On-Location" Study.

Wood, R.A., Burchet, M.D., Tarran, J., Torpy, F. (2002), Het vermogen van planten/aarde om schadelijke stoffen uit vervuilde lucht binnenskamers te verwijderen, (The capacity of plants/ground to remove indoor detrimental substances out of polluted air), Journal of Environment, Horticulture and Biotechnology, Vol. 77(1), 120-9.

Appendix A: list of the examined 17 research reports

1 Van den Berg, A., Winsum Westra , M. (2006), Ontwerpen met groen voor gezondheid, (Designing with plants creating health). Alterra rapport 1371, ISSN 1566-7197 Reeks Belevingsonderzoek nr 14, Wageningen, Alterra.

2 Fjeld, T., Bonnevie, C. (2002), Het effect van planten en kunstmatig daglicht op het welbevinden en de gezondheid van kantoorpersoneel, schoolkinderen en gezondheidsmedewerkers [The Effect of plants and artificial daylight on the well-being and the health of office workers, school children and health care Personal] International Symposium Floriade Netherlands.

3 Dortmont, J.F., Bergs J.A. (1997), Planten en productiviteit, (Plants and productivity), Leiden: Bloemenbureau Holland.

4 Klein Hesselink, J., Hopstaken, L. (1995), Planten op het werk, (Plants in the working environment), Amsterdam: NIA.

5 Klein Hesselink, J., de Groot, E., Loomans, M., Kremer, A. (2006), Fysiologische en psychische en gezondheidseffecten van planten in de werksituatie op gezondheid en welbevinden van mensen (Physiological and mental and health consequences of plants in the work situation on health and well-being of people). TNO rapport 21573/ 018.10311. Hoofddorp: TNO Kwaliteit van Leven.

6 Larsen, L., Adams, J.,Deal, B. , Kweon B, Tyler, E, (1998), Plants in the workplace: The effect of plants density on productivity, attitudes and perceptions. Environment and Behaviour, 30, 261- 281 Sage Publications, Inc. (US).

7 Lohr, V.I., Pearson-Mims, C.H., Goodwin, G.K. (1996), Kamerplanten kunnen de arbeidsproductiviteit verbeteren en de hoeveelheid stress verminderen in een omgeving zonder ramen, (Interior plants may improve productivity and reduce stress in a windowless environment). Journal of Environment Horticulture, 14, 97-100, Horticultural Research Institute, Washington.

8 Loomans, M., Klein Hesselink, J. (2005), Het effect van planten op het werk. [The influence of plants in the working environment] Facility Management Magazine 133, 17-21.

9 Schempp, D. (2002), Green Architecture, Plants in buildings; Key massage Plants for People, International Symposium Floriade, Netherlands.

10 Shibata, S., Suzuki, N. (2001), Effects of indoor foliage plants on subjects' recovery from mental fatigue, North American Journal of Psychology, Vol. 3 nr. 3, p 385.

11 Shibata, S., Suzuki, N. (2002), Effects of an indoor plant on creative task performance and mood. Journal of Environmental Psychology, 22, 265- 272.

12 Ulrich, R. S. (2002), De gezondheidseffecten van planten in en rond ziekenhuizen op patiënten en verplegende staf. (The consequences on health of plants in and around hospitals on patients and nursing staff), Center for Health Systems and Design, Texas A&M University College State.

13 Van der Wal, J.F. (1991), Oriënterend onderzoek naar de luchtzuiverende werking van potplanten in een mechanisch geventileerde proefruimte, (Orientation study concerning the air cleansing functioning of pot plants in a mechanically ventilated test space] TNO rapport, TNO Bouw, B-91-0137, TNO Delft.

14 Van der Wal, J.F., Hoogeveen, A. (1993), Onderzoek naar de regeneratie van actieve kool door potplanten (Study concerning the regeneration of active cabbage by pot plants), TNO rapport, TNO Bouw, B-92-1155, TNO Delft.

15 Wolf, K. L. (2002), Het effect van natuur in en rond winkelgebieden; creatie van een consument gerichte leefomgeving (The impact of nature in and around shop areas; creation of an environment specifically suited to a consumer), People/Plant Symposium Amsterdam, Netherlands.

16 Wood, R.A., Burchet, M.D., Tarran, J., Torpy, F. (2002), The capacity of plants/ground to remove indoor detrimental substances out of polluted air, J Environ. Hort. Biotechnol. 77 (1), 120- 129.

17 Wood, R., Orwell, R., Tarran, J. (2004), Planten om de luchtkwaliteit van een kantoor te verbeteren (Plants to improve office air quality), Final report of Office 'On-Location' study, Flower Council of Holland, Sydney.

Not a real life setting.

Your head high in the mountains and a small talk with your friends provides new thinking energy for the knowledge worker (Jan Walburg in the middle).

The effects of colour are always measured in lab conditions or real work environments when employees are asked to perform some tasks such as making anagrams. But how do people react on colours in their own work environment doing their regular tasks discussing with colleagues? Extremely difficult to measure as reality is unruly.

Chapter Four

Red or blue meeting rooms: does it matter?

The impact of colour on perceived productivity, social cohesion and wellbeing

Bakker I.C., Van der Voordt, D.J.M., De Boon, J., Vink, P. (2013), Red or blue meeting rooms: does it matter? The impact of colour on perceived productivity, social cohesion and wellbeing. Facilities, 31(1/2), 68-83.

Colour is an integrated component of the physical environment. It communicates immediately with other environmental cues. To assess productivity with sufficient attention to its complexity, it was decided to conduct a colour test in a real life setting. It is extremely difficult to find test locations in real life situations that meet the scientific requirements of measuring cause-effect relationships. Next, it is complex to test the effects of colour as a real life effect. At the one hand too much colour may cause an artificial effect. At the other hand in case of little colour the effects cannot be tested. Therefore a test situation has been created that optimally corresponds with a real life setting, i.e. testing the impact of colour on meetings in a regular meeting room compared to two similar meetings rooms, one with three walls painted in red and the other one with three walls painted in blue. The choice for red and blue was made because the main effects of colour concern the light/darkness polarity and the warmth-coldness polarity and red and blue are the strongest counterparts of the warmth-coldness polarity. In order to be able to test the qualitative experience of the environment, the warmth-coldness effects are strengthened. In the red coloured room warm illumination of 3500K is applied; in the blue situation cold illumination of 5300K is used. Next, the tables in the red room have a warm wooden top desk whereas in the blue room the top desk is grey coloured.

abstract

The purpose of this research is to establish the influences of the colours red and blue on perceived wellbeing, social cohesion and productivity in complex real life work conditions during regular meetings. In total, seven regular government teams held seven regular meetings in red, blue and reference meeting rooms. In literature it is often mentioned that red is a warm and blue a cool colour. To be able to test the warmth and coldness effects the warm and cold qualities are amplified with light colour and colour of the table top desk. The employees were asked to complete questionnaires concerning perceived wellbeing, social cohesion and productivity. In total, 52 subjects completed three questionnaires, at the start, the end and two or three days after the meeting. Data were analysed with SPSS 16.The findings did not show any effects of the red and blue environment on perceived wellbeing, social cohesion and productivity. It is assumed that the processes in real life work situations are too complex to measure influences. The research focuses on individual perceptions and did not measure actual wellbeing, social cohesion and productivity. Practical implications are that statements frequently mentioned in literature concerning influences of red and blue might be not valid in real life meeting settings. New ways of testing the impact of colours should be reconsidered. Because lab situations are too simplified and artificial, it is suggest testing influences of colour in an isolated setting in relation to art. The originality of this research concerns testing colour influences in complex real life work settings, such as meetings.

Keywords: *Individual perception, Rooms, Design, Colours, Meeting rooms, Colour influences, Red and blue, Perceived productivity, Wellbeing, Social cohesion, Employees productivity*

4.1 Introduction: Impact of colour on people

The physical environment has influence on how people function and experience the world with their senses (Schneider, 1987). People constantly interact with and reflect on their surroundings (Ford and Ford, 1987, in Franzen, 2004). Colour plays an important role in this interaction. Although many research projects have been accomplished in search of the physiological, affective and cognitive effects of colours on people, there is still a lack of knowledge about the exact effects of specific colours on human beings and their behaviour (Tofle et al, 2004; Elliot and Maier, 2007). A number of studies concern effects of healing environments in search of optimal environmental solutions to reduce pain, medication and length of stay (Dijkstra et al, 2008). In work environments, influences of colours on performance, productivity and mood have been investigated as well (Kwallek et al, 1997; Elliot and Maier, 2007; Stone, 2003; Mehta and Zhu, 2009). However, findings and conclusions are contradictory and not clear (Tofle et al, 2004). Different causes may play a role here. Researchers use different methods in different situations and also different colours even if those colours bear the same name. Moreover, different researches did not find any strong evidence about clear influences. Looking at colour is very complex. Goethe already mentioned that our eyes strive to totality (Goethe, 1810), a fact that has been confirmed nowadays neurologically and physiologically (Hubel, 1990). Without knowing in what way and how long a subject observes colour and due to the complex processes in the retina, we are not able to define quantitatively which colour information is sent from the retina to the visual cortex. The results of our visual system also depend on our personal experience and knowledge (Gregory, 1998), that Plotinus already claimed in the third century (Ferwerda, 2005). Furthermore, it is unknown in what way people really observe their environment on a conscious or unconscious level. Many people hardly take notice of their environment (Dijksterhuis, 2007) and do not know on a conscious level which colours surround them. So, it is unknown if and to what extent colour is experienced on a conscious or unconscious level.

Moreover, it is not clear yet which cognitive, affective and emotional processes take place in human brains and how these processes interact. At the same time many areas in the brain are active (Andreasen, 2002). Just for the treatment of visual information simultaneously 30 different areas play their specific role (Ramachandran, 2006). The thalamus filters information and coordinates the stimuli from sensory, emotional, higher cortical, motoric and memory areas (Andreasen, 2002). Each human being is a specific creature with his own associations, memories, constitution and emotion, which complicates a clear comprehension of our brain processes. In addition, people might react differently due to the moderating role of the stimulus screening ability: low screeners are more sensitive and react more intensely than high screeners who can easily screen out the sensation of the environment (Dijkstra et al, 2008). Also mood plays a role: when people are more anxious or dissatisfied they react more strongly to their environment, both physiologically as psychologically (Damasio, 2006). So, it is impossible to establish a clear interaction between colour and the influence on human beings.

Another interesting issue concerns the context dependent effects of colour. For instance "red" plays a different role in different contexts (Elliot and Maier, 2007). Regarding the construct of avoidance motivation (when people are aware of red they are more afraid to make mistakes) red can play a different role than in other cognitive tests (Mehta and Zhu, 2009). The way we use and experience the environment is mainly defined by our perceptions (Plotinus, ± 260, in Ferwerda, 2005; Kepler ±1620, in Lombardi, 2007). In colour research some tension fields can be observed. First we cannot separate colour from its form, texture and other surroundings. Secondly, testing colours in lab situations is risky because of the complexity of real life settings. Thirdly, the observation process of human beings is complicated by complex human variables such as constitution, attention, sensitivity and brain functions, which can differ per subject.

4.1.1 Testing effects of red and blue in a real life setting

In order to improve our understanding of the influence of colour we tested the impact of red and blue on perceived productivity of meetings in a real life situation. Working people spend a relatively large amount of time in meetings. In The Netherlands on average meetings take 25% of the working time (Vink, 2009). Therefore, it is important to know if and how colour affects people during meeting sessions. Because real life meetings are complex processes, with many interacting and intermediating social, emotional and rational variables, organisational influences, and different intrinsic motivations, testing in real working situations is preferable. Many colour tests have been conducted in labs, using students in artificial environments (for instance Guilford and Smith, 1959, Dijkstra et al, 2008; Mehta and Zhu, 2009; Moller and Maier, 2009; Rutchick et al, 2010; Roberts et al, 2010). But lab situations are simplified imitations of a complex world. Colour is an integrated part of the environment and influences of colour can only be observed in its context (Elliot and Maier, 2007). In lab situations applied test devices have their constraints and environmental aspects are artificially isolated, so testing colour effects in lab situations bears the risk of losing insight in the mutual and complex coherences between entities. Moreover, using students as test subjects does not correspond to the complexity of real work situations (Vonk, 2003). For this reason we conducted a colour test in a governmental organisation during regular meetings of regular teams. The main research question is: what are the effects of the colours red and blue in a real life meeting situation on perceived productivity, in connection to the intermediary constructs "social cohesion" and "wellbeing"?

4.1.2 Why red and blue?

In the literature the warm and cold effects of red and blue are mentioned quite frequently. Warm colours are believed to evoke more arousal than cool colours (Jacobs and Suess, 1975, Stone and English, 1998, Kaya and Epps, 2004, Yildirim et al, 2011). Warm colours are supposed to stimulate the senses, with cool colours showing the opposite effect (Mahnke, 1996). These different effects are often related to the differences in wavelength. Long wavelengths like red are connected to arousal, short ones like blue are supposed to calm down (Kaya and Epps, 2004; Adams and Osgood, 1973; Jacobs and Suess, 1975). On the contrary, brain research shows that in comparison with red light, blue light leads to more arousal, which is expressed by the results of AAC (alpha attenuation coefficient) and the mean power of the alpha band (Yoto et al, 2007). Also, wavelengths showed to influence humans' emotional state (Crowley, 1993; Kaya and Epps, 2004).

However, other researchers did not find evidence for a relation between colour effects and wavelengths (Fehrman and Fehrman, 2004; Mikkelides, 1990), nor evidence for the relationship between colours and mood (Ainsworth et al, 1993). Research findings regarding the effects of the colours red and blue on performance do not match as well (Elliot et al, 2007). Many researchers did not find any relation between colour and performance (Ainsworth et al, 1993; Etnier and Hardy, 1997), whereas other researchers pointed out that red enhances cognitive performance (Kwallek and Lewis, 1990) or, the opposite, reduces cognitive performance (Soldat et al, 1997). Blue was found to stimulate systematic thinking (Soldat et al, 1997) and being preferable in creativity tasks (Mehta and Zhu, 2009). Also blue light showed to improve cognitive performance (Lehrl et al, 2007). Red was found to stimulate avoidance motivation (Elliot and Maier, 2007; Elliot et al, 2007) and to improve cognitive performance concerning detail orientated tasks (Mehta and Zhu, 2009). On the contrary, red impairs performance on complex tasks (Elliot et al, 2007) and tasks that require exactness (Goldstein, 1942). Even the word "red" showed to undermine intellectual performance (Lichtenfeld et al, 2009). In addition to effects on intellectual performance, other effects have been investigated as well. In some sports, wearing red instead of blue clothes was found to enhance the chance of winning (Hill and Barton, 2005). Whereas red is related to avoidance motivation, blue is related

to approach motivation. But this issue seems to be context dependent as well, because in shops no relation was found between colour and approach orientation (Bellizi et al, 1983).

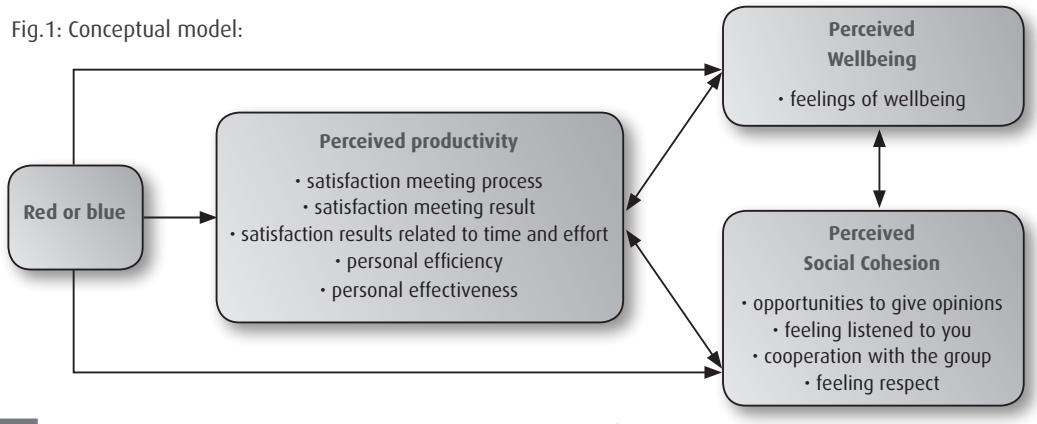
Cognitive, emotional and physiological processes are closely interacting. Blue light was found to reduce physiological arousal, blood pressure, galvanic skin response, respiration rate and eye blink frequency (Gerard, 1957), whereas warm colours showed to increase physiological and psychological arousal (Jacobs and Suezz, 1975). Seeing red leads to more right cortical activity in EEG's (Elliot and Maier, 2007). Blue was found to have an endocrine based strengthening effect on muscles (Ott, 1979). Other researchers did not find any different effects of red and blue illumination on physiological processes (Caldwell and Jones, 1985). Besides luminance perception varies from person to person (Conway, 2007). There might be various explanations why the results are rather conflicting. The effects of colour are highly context dependent (Elliot et al, 2007). Physiological influences are not universal (Van Cranenburgh, 1998). Screening ability may influence the reactions of people on colours as well. Office workers with a low screening ability performed worse in red in comparison to people with a high screening ability (Kwallek et al, 1997). Attention (Dijksterhuis, 2007) and motivation (Mehta and Zhu, 2009) also play a role. People differ in their sensitivity to the environment, which may depend on their constitution (Van Cranenburgh, 1998). For instance, when people easily loose balance, they probably will pay more attention to elements which support stability. Because it is difficult to measure differences in sensitivity and attention, it is also difficult to draw clear conclusions regarding the influences of colour.

Because of the conflicting findings of a considerable amount of research concerning the effects of red and blue on performance, a real life test situation is arranged with the possibility to observe the testing process in detail. The main research question is: what are the effects of the colours red and blue in a real meeting situation on perceived productivity, directly and in connection to wellbeing and social cohesion?

4.2 Conceptual model

In order to attain viability and continuity of organisations it is important to maximise productivity (Van der Voordt, 2003; Vink, 2009). An important function of meetings is to strengthen involvement and co-operation. Therefore, in addition to productivity, social cohesion is a second issue to be investigated. Thirdly, it is important employees feel comfortable, so perceived wellbeing is the third issue. Building on analyses of meeting processes in which productivity, social cohesion and wellbeing are discerned as important issues (Briggs et al, 2006; den Hengst et al, 2006; Post et al, 2008; Duivenvoorde et al, 2008), a conceptual model has been developed to be used as a starting point for data-collection and data-analysis (Figure 1). The model visualises the assumption that colour, i.e. red and blue has an influence on people's productivity, directly and in interaction with social cohesion and wellbeing.

Fig.1: Conceptual model:



4.3 Research design

4.3.1 Test environment

The test is accomplished in a governmental building in Rijswijk in The Netherlands. Three identical meeting rooms were used with a size of 3.300 x 6250 mm; height = 2,400 mm. Both long sides of the room have a window to the inner corridors(double corridor access), made of glass, 3300mm (width) x 1900mm (height). To measure the influence of red and blue and the related colour effects "warmth" and "coldness" two meeting rooms on the fifth floor were adapted (Figure 2). In each room, three walls were painted in a red or a blue colour, respectively. To strengthen the warmth and coldness effects of red and blue, also the colour temperature of the lighting and the top desks of the tables is modified. As such, the primary focus is on the warm and cold effects and not specifically on only the colours red and blue. On the third floor a neutral room, which was identical to the meeting room the respondents usually use, was used as a reference room. In the red meeting room warm illumination of 3,500 K was applied and a wooden top desk (beech print, Ahrend, code 61). In the blue meeting room was cold illumination of 5,300 K and a white/grey top desk (Ahrend, code 52). Colours of the reference room were greenish, codes S 1010-B70G (light greenish) and S 2020-B30G (dark greenish) (Figure 2). To prevent the room appearing too reddish or too bluish – which might cause an unnatural and disharmonious situation – a combination was made of the main colour and a grey supporting colour in each room. Also, by choosing a specific grey tone, it was attempted to enhance the effect of red and blue, respectively. In the red room the red code S 3560-Y80R was used on the long sides and one short side. The other short side (with a whiteboard), was coloured grey (code S 6502-R). In the blue meeting room, the blue code S 3560-R90B was used on the two long sides and one short side. The other short side had the grey code S 6502-B. The reference room had exactly the same features as the blue and the red room, apart from the table form. In the reference room the table was placed against the short side of the meeting room. This position was highly disapproved by the employees and also not standard in government meeting locations. To prevent that this fact would influence the coloured rooms in a too negative way, here a standard table form (with an extra bow) and standard location with free space around was applied.

Figure 2: The blue, red and reference meeting rooms

1: blue room 2: red room 3: reference room

Floor finish was dark grey carpet. Seat covers of the chairs were all black. The white ceiling was a modular system. Lighting consisted of three neon tubes (58 W) situated in the centre in one line above the table, incorporated in the ceiling. There was neither daylight, nor plants, nor art. The indoor climate was standard, with an estimated office temperature of 21-23 degrees Celsius and a standard relative air humidity. During seven regular meeting sessions of seven different teams (totally 49 sessions) the employees used the blue meeting room, the red one and the standard reference meeting room (Table

I). Team characteristics were: a permanent chairman and a meeting frequency that varied from one to three weeks. Each team had its own starting time and meeting time, which were both the same throughout the colour testing period. The time between two meetings was minimal a week. No order effects were expected, and the seven team sessions are tested in the same order: red, blue, reference, red, blue, reference and red room. The first session in the red room only served as a habituation process. The results of this first test meeting are not used in the statistical analyses and not included in the tables. Before starting the test, all subjects were informed about the test set up, the process, targets and period. During all 49 tests the researcher was present to observe the meeting process and to report anything out of ordinary. This made it possible to check the responses to the questionnaires against the data from observations. All subjects received a small gift after each meeting for their extra effort completing the questionnaires.

4.3.2 Participants and team sessions

The test subjects were all government employees, aged between 26 and 56 years. Education level varied between middle level vocational education and university. During the sessions totally 250 times opinions about all items were collected (Table I).

Table 1: Number of participants per team and per meeting; data from the first test were excluded

table

	meeting 2 Blue	meeting 3 Reference	meeting 4 Red	meeting 5 Blue	meeting 6 Reference	meeting 7 Red	Total excl. meeting 1
team 1	7	8	8	10	8	8	49
team 2	5	3	6	7	5	6	32
team 3	7	8	4	5	4	7	35
team 4	9	6	8	8	5	7	43
team 5	4	3	3	4	5	4	23
team 6	11	7	7	9	4	7	45
team 7	4	4	4	4	3	4	23
	47	**39**	**40**	**47**	**34**	**43**	**250**

4.3.3 Research methods

To collect employees' opinions four questionnaires (Q1-Q4) were used used (see for questionnaires Q1-4 appendix). Questions have been adopted from earlier research concerning the different variables playing a role in meetings – with productivity as the main topic - plus an additional questionnaire (Q5) to assess individual colour preferences regarding favourite colour and colour preferences for clothing, different types of rooms and different moods. The results of Q5 will be published in a separate paper. All questionnaires were first tested in a pilot and then adapted. The first questionnaire (Q1) was completed at the beginning of each meeting, the second one at the end (Q2), both inside the meeting room. The same questionnaire was again completed two or three days after the meeting session by e-mail (Q3). Based on research concerning meeting productivity (Briggs et al, 2006; den Hengst et al, 2006; Post et al, 2008; Duivenvoorde et al, 2008) for all three questionnaires the seven-points Likert scale is used. When all meeting were finished, a fourth questionnaire (Q4) was sent out by e-mail to probe personal opinions related to the colour testing process and to ask which aspect of the environment respondents find most important for a meeting room. Also during the process Q5 was sent out to collect individual colour preferences (Figure 3). Data were analysed with the statistical programme SPSS16. Furthermore we examined whether subjects filled out the questionnaires in a consistent way.

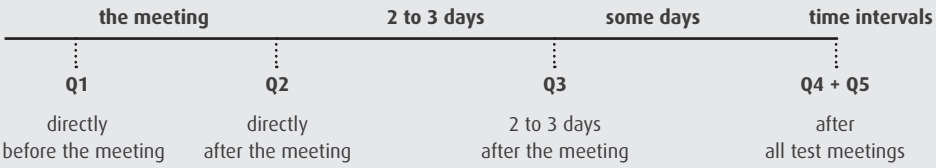


Figure 3: questionnaires Q1 to Q5, filled out in time intervals

4.4 Results

4.4.1 Impact of red and blue

Analyses of variance did not show any significant effect of the red and blue environment on perceived productivity (α =0.05; p = 0.673; F = 0.396), nor on the different items of productivity (α=0.05; p = 0.207 to 0.588 ; F = 0.533 to 1.587)nor on the different items of social cohesion (α=0.05; p= 0.358 to 0.658; F= 0.419 to 1.032), nor on wellbeing (α=0.05; p=0.656; F= 0.422).Also, no significant relation was found between the colour of the room and the judgements of the subjects regarding the meeting room (question: I experienced the meeting room as pleasant (Q2 and Q3) (α=0.05; p= 0.770; F= 0.262).

A consistent behaviour was observed regarding the answers in the questionnaires. Score 5 was mostly used. There were rather small differences between the results of the questionnaires which were completed immediately after the meeting and two to three days after the meeting. In all cases the scores in the last questionnaire (Q3) were lower. Judgements regarding meeting results and meeting productivity showed the largest reduction, namely 0.6 (Table 2); the employees showed to be most critical about meeting result and productivity. Regarding all productivity aspects the means were highest in the reference room and lowest in the red room. But the differences are all not significant.

Table 2:
Means and Standard deviations (S.D.) per productivity aspect mentioned in the questionnaires Q2 and Q3.

Productivty aspect	Questionnaire	Red Room		Blue Room		Reference Room	
		Means	S.D.	Means	S.D.	Means	S.D.
well being	Q2	4,6	1,4	4,7	1,3	4,8	1,0
	Q3	4,2	1,8	4,4	1,7	4,6	1,4
personal efficiency	Q2	4,5	1,3	4,8	1,3	5,1	0,8
	Q3	4,3	1,7	4,5	1,7	4,8	1,4
personal effectiveness	Q2	4,6	1,3	4,7	1,3	5,0	0,9
	Q3	4,1	1,8	4,5	1,7	4,8	1,4
giving opinions	Q2	5,0	1,3	5,1	1,3	5,4	0,9
	Q3	4,6	1,8	4,8	1,8	5,1	1,4
listening to you	Q2	4,9	1,3	4,9	1,3	5,3	0,9
	Q3	4,5	1,8	4,6	1,8	5,0	1,4
feeling respect	Q2	5,0	1,3	5,0	1,5	5,4	0,9
	Q3	4,6	1,8	4,7	1,8	5,0	1,6
cooperation	Q2	4,7	1,4	5,0	1,4	5,4	1,0
	Q3	4,4	1,9	4,5	1,8	4,8	1,6
meeting	Q2	4,7	1,4	4,9	1,4	5,1	1,0
	Q3	4,2	1,8	4,4	1,8	4,6	1,6
meeting process	Q2	4,6	1,4	4,9	1,4	5,0	1,1
	Q3	4,2	1,8	4,3	1,8	4,5	1,6
meeting result	Q2	4,6	1,4	4,8	1,4	5,0	1,1
	Q3	4,1	1,8	4,2	1,8	4,4	1,7
meeting productivity	Q2	4,6	1,5	4,7	1,4	5,0	1,1
	Q3	4,0	1,8	4,1	1,8	4,4	1,7

However, in the data base (Q2 and Q3) a strong cohesion was found between employees appraisals of the meeting room (question: The colour of the walls had a positive effect (Q2 and Q3)) and the appraisals of the wall colour during the test process (question: I experienced the meeting room as pleasant (Q2 and Q3) (Cronbach's Alpha= 0.789 (Q2) and 0.886 (Q3)). By contrast there was no cohesion between the judgement of the meeting room and the appraisal of temperature and air quality (question: I think the temperature was fine and I think the air quality was fine (Q2 and Q3).) Cronbach's Alpha= 0.385 and 0.402 respectively (Q2) and 0.588 and 0.564 respectively (Q3).
This is remarkable, because when the respondents were asked to mark the relative importance of twelve different interior aspects (in Q4, after all test sessions), the highest scores were assigned to air quality and temperature, while wall colour ranked rather low. Apparently, during the test process subjects combine their judgements regarding the meeting room with the knowledge about the test goals, which they wereaware of. Moreover, because the colour wall was anomalous from the situation subjects were accustomed to, they would be more critical of the coloured walls.

4.4.2 Perceived impact of colour and preferred colour

It is interesting that in response to questionnaire Q4, most respondents mention that colour doesn't matter with regard to a number of issues (see Table III). It is striking that the percentage is highest (65%) regarding productivity (question: in this meeting room, what we achieved was worth time and effort (Q4)) and lowest (31 and 33%) regarding judgement meeting room (question: I think the meeting room was pleasant (Q4)) and wellbeing (question: I felt good in the meeting room (Q4)). It makes sense that the percentage is rather low (31%) in relation to the judgement of the room, because we asked about the physical aspects. When we asked the subjects, who were convinced that colour indeed had influence, about their room preference, most of them prefer the blue and the reference room. The red room was least popular.

Table 3: percentages of subjects saying 'colour doesn't matter' and room preference from those saying colour has influence (Q4)

table

Themes	colour doesn't matter	Most marked room preference by those saying colour has influence
Meeting room	31 %	Red, blue or reference room
Wellbeing	33 %	Blue and reference room
Personal effectiveness	58 %	Blue room
Personal efficiency	54 %	Blue room
Cooperation	58 %	Reference room
Meeting	44 %	Reference room
Meeting process	52 %	Blue room
Meeting result	58 %	Blue room
Meeting productivity	65 %	Reference room

4.4.3 Favourite colour and preferred colour for a meeting room

We have asked the subjects about their favourite colour and their colour preferences for meeting rooms in general. Concerning the favourite colour, quite a high percentage prefers "blue" or respond with "doesn't matter (DM). The most preferred colour for a meeting room is "white" (Table 4).

Table 4: Favourite colours and colour preferences regarding meeting rooms in general in percentages

table

colour	favourite colour	general colour meeting room preference
blue	39%	8%
red	15%	14%
white	0%	36%
various colours	23%	17%
doesn't matter	21%	23%
missing	2%	2%
total	**100%**	**100%**

After all meeting sessions the subjects were asked about their preferred test room (Table 5). It is striking that most subjects (55%) do not have any preference for a specific meeting room.

Table 5: Preferred test room; in percentages

table

prefered test room	
blue room	17%
red room	12%
reference room	16%
doesn't matter	55%
total	**100%**

Next, subjects were asked about their preference in two different situations: a work situation with the subject having a strong position (case 1), and a situation (case 2) where the subject had a weak position. The preferences in different situations (strong versus weak position) had no relation with someone's favourite colour or preferred colour in the meeting room.

4.5 Discussion

The effects of the colours red and blue and specific their warmth and coldness effects, are tested in a real life work setting. No effects were found on perceived productivity, perceived social cohesion and perceived wellbeing. Some questions can be asked if certain phenomenon's have played a role to diminish the effects of colours. What can be said about the data: are the entities like "feeling respect" or "personal effectiveness" properly used in the constructs "social cohesion" respectively "productivity" and are the questionnaires completed in a serious way? And if no effects on perceived productivity, social cohesion and wellbeing can be seen, have the subjects told the truth? And has the phenomenon colour itself something to do with the difficulties to create a transparent research process? After working out these questions, an advice can be given which type of colour research can learn us more about colour effects.

4.5.1 Validation of the conceptual model

In the conceptual model, productivity is composed of six items: personal efficiency, personal effectiveness, meeting process, meeting result, the meeting and finally "meeting productivity". Regarding the statement: "What we have achieved it was worth the time and effort" the subjects are asked directly to value the meeting productivity. In this paper we consequently make a distinction between meeting productivity (concerning the statement mentioned above) and productivity (a more general estimation). The cohesion within the productivity construct has been checked with Cronbach's alpha (0.915). All six items contributed to the total concept productivity.

In the conceptual model, social cohesion is composed of four items: "sufficient opportunities to give opinions", "being convinced colleagues have listened to you", "co-operation" and "feeling respect". The Cronbach's alpha is 0.945, which indicates a high correlation. Besides important elements as the opinions concerning meeting, cooperation, feeling respect and wellbeing, also are strongly correlated with a Cronbach's alpha of 0.861. Combining the items of productivity with wellbeing, Cronbach's alpha = 0.918. The relation between personal entities (personal efficiency and effectiveness) and wellbeing showed to be stronger (Cronbach's alpha = 0.885) than the relation between wellbeing and meeting productivity (Cronbach's alpha = 0.666). The influence of productivity on wellbeing is mostly caused by satisfaction about the individual effort (personal efficiency and personal effectiveness). Regarding the relation between social cohesion and wellbeing, we found a significant cohesion with a Cronbach's alpha of 0.924. We may conclude that the conceptual model we used seems promising.

4.5.2 Attention, perception and process of completing the questionnaires

The test results pointed out that red or blue coloured walls in meeting rooms have no influence on perceived wellbeing, social cohesion or productivity. On a conscious level subjects did not experience different influences, assuming that they actually focused on their real feelings and experiences and not on learned cultural associations or organisational and social features. The process of completing questionnaires existing out of reading the questionnaire, thinking about the answers and completing the questionnaires, is not transparent, because it is based on an individual way of thinking, while emotions and cognitions are mixed together. The differences between emotions and cognitions are hard to make (Damasio, 2006). Moreover, attention is a crucial factor in the process of experiencing the environment. People do not experience their environment on a conscious manner (Dijksterhuis, 2007). Next, the subjects paid their attention to a complex meeting process with social, cognitive and psychological aspects that influence each other in a dynamic way (Den Hengst et al, 2006). So attention is focused on this process and not on the physical environment. During the test, the participants are observed while completing the questionnaires directly before and after the meeting. One third of the subjects looked around before completing the questionnaires, which means that these subjects needed visual information to define their opinions at that moment, information they apparently did not have in their minds before. Because of the questions in the questionnaire they started to look on a conscious level at the wall colour and the question can be asked if they just used their personally and culturally learned associations.

The questionnaires forced the participants to give their opinions. These opinions are based on personal perceptions which may differ from facts and actual measurements. Researches about the effects on productivity by plants for instance, have pointed out that when subjects think their productivity has increased, in reality this does not have to be true (Larsen et al, 1998). Moreover, subjects may give socially desirable answers corresponding to what they think people are expected from them (Vonk, 2003). So one may wonder if the responses actually indicate colour effects or should be seen as expressions of diffuse combinations of personal perceptions, social norms and values, cultural features and organisational characteristics. Besides, the fact that many people are convinced that colour has no to little effect, can be seen as a risk to estimate the value of colour as too low. No effects of colour on conscious level could be observed. This does not imply that colour did not have effect on unconscious level.

4.6 Concluding remarks

Based on the results, the next conclusions can be made:

- on conscious level no effects of colours could be found on perceived productivity, perceived social cohesion and perceived wellbeing;
- people were influenced by their awareness concerning the test process;

- a relative high number of the subjects had the opinion that colour does not matter; and
- no relations were found between personal colour preferences, preferences for colours of meeting rooms in general and preferences for a specific meeting test room.

When we really want to analyse the effects of colour, we have to distinguish the objective colour quality (Steiner, 1984) and the subjective colour feeling (Oegema Van der Wal, 1956). Colour judgement is not only effected by objective colour qualities; personal aspects like experience, memory and constitution play a big part. These aspects define our colour cognitions and associations. The objective colour quality has nothing to do with our culturally and personally constructed associations. It is much more interesting to relate the objective colour quality to our affect (Zajonc, 1980).
We have tried to test the influences of a red and blue meeting environment on perceived wellbeing, social cohesion and productivity during regular meetings in a real life work environment. In the data that have been collected according to the validated conceptual model, no evidence has been found that colour affects perceived wellbeing, social cohesion or productivity. This does not mean that colour has no effect. The only thing we can conclude is that reality and real working processes are too complex to be able to measure colour influences on a conscious level in a clear way The mutual influences of different interior components, group processes and last but not least human factors such as attention, observation, brain processing and consciousness, make it almost impossible to analyse the colour influences. Testing colours in a lab situation might give more clear results. However, the question is whether these results can be transferred to a real work situation. Colour "communicates" with its surroundings and people never experience the colour separately. So we may wonder whether it is possible at all to test the influences of colour. Only in particular circumstances it is possible to test colour in a solitary position without any influences of other aspects, material, textures, or form. As a solution to test the effects of colours in a way worthy to the topic, art will be introduced.

4.6.1 The colours of Turrell

A very interesting work of art from the colour- and light artist Turrell (Bridget's Bardo, Ganzfeld Piece) could give us the unique possibility to test the influences of colour on its own. Turrell designed a spatial construction with a "viewing space" and a "sensing space" where colour is disconnected from material and form (Figure 4). So we can experience colour here on its own without any influence of other aspects.

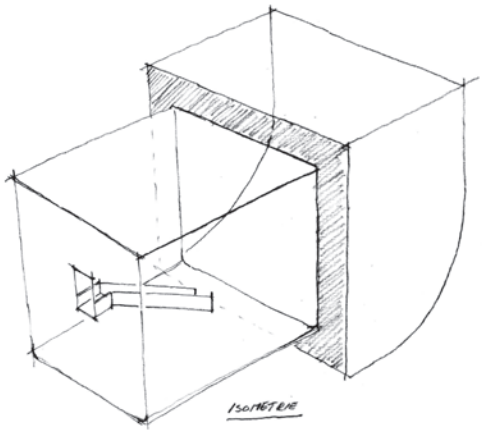


Figure 4:
Isometry of
Bridget's Bardo
(drawing: Jan de Boon)

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It would be challenging to test the psychological and physiological effects of colours in such an environment without the influences of other aspects of the environment. At the same time, testing colours this way would mean to testing a situation completely different from common reality. So what is actually needed is to design future colour research with integration of knowledge and parameters from cognitive and behaviouristic psychology, neurology, physiology, physics, biology and art. This colour test did not show any effects of the colours red and blue on perceived productivity, coherence and wellbeing. A relative high number of the participants responded that colour did not matter: 65% stated that colour was not of any importance concerning productivity. Most respondents mentioned not to have any colour preference regarding a meeting room. It is difficult to find data concerning colour preferences for the physical environment. To understand how people think about colour in the physical environment and to know their preferences it might be helpful to choose appropriate colours. For this reason data have been collected about colour preferences in connection to different topics and different environments. This is the subject of the next chapter.

4.7 References

Adams, F.M., Osgood, C.E. (1973) in Van Hagen, M. Galetzka, M, Pruyn, A., Peters J. (2009), Effects of Colour and Light on Customer Experience and Time Perception at a virtual Railway Station, Proceedings Experiencing Light 2009; International Conference on the Effects of Light on Wellbeing; 137-145.

Ainsworth, R. A., Simpson, L., Cassell, D. (1993), Effects of three colours in an office interior on mood and performance. Perceptual and Motor Skills, 76, 235–241.

Andreasen, N. C. (2002), Schitterend nieuw brein, Amsterdam, Uitgeverij Nieuwezijds, 75, Translation from Brave new Brain, 2001, Oxford: Oxford UP 2001.

Bellizi, J. A., Crowley, A.E., Hasty R.W. (1983), The effects of colour in store design, Journal of retailing, Vol 59, number 1, 1983; 21-45.

Briggs, R.O., Reinig, B.A., De Vreede, G.J.,(2006), Meeting Satisfaction for Technology-Supported Groups, Small Group Research, Vol 37(6), 585-611.

Caldwell, J.A. , Jones, G.E. (1985), The effects of exposure to red and blue light in physiological indices and time estimation, in Tofle, R. B., Schwartz, B., Yoon, S., Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, United States of America, The Coalition for Health Environments Research (CHER).

Conway, B.R. (2007), Colour Vision, Cones and Colour Coding in the cortex, The neuroscientist, Vol 15(3), 274-290.

Crowley, A.E. (1993), The two-dimensional impact of colour on shopping, in Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.H., 2008, Interior colour in healthcare environment. Conference paper 3 TU Symposium, Delft.

Damasio, A.R. (2006), De vergissing van Descartes, 6e druk Wereldbibliotheek, Amsterdam, 2006, original title: Descartes'Error-Emotion, Reason and the Human Brain.

Den Hengst, M., Kolfschoten, G, Dean, D.L., Chakrapani, A. (2006), Assessing the Quality of Collaborative Processes, HICSS '06 Proceedings of the 39th Annual Hawaii International Conference on System Sciences – Vol 01, IEEE Computer Society Washington.

Dijksterhuis, A. (2007), Het slimme onderbewuste, denken met gevoel, Amsterdam: Uitgeverij Bert Bakker, 33-42, 53, 64-73.
Dijkstra K, Pieterse M.E., Pruyn, A Th H. (2008), Individual differences in reactions towards colour in simulated healthcare environments: the role of stimulus screening ability, Journal of environmental Psychology, 28; 268- 277.

Dijkstra, K. (2009), Understanding healing environments, University of Twente Publications, Twente.

Dijkstra, P.D, Preenen, T.Y. (2008), No effects of blue on winning contests in judo, Proceedings of the Royal Society B 2008, 275, 1157-1162.

Duivenvoorde G.P.J., Kolfschoten G.L., Briggs R.O., De Vreede , G.J. (2008), Towards an instrument to measure Success-fulness of collaborative effort from a participant perspective, 42nd Hawaii International Conference on System Sciences.

Elliot, A.J., Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J.(2007), Colour and Psychological Functioning: The Effect of Red on Performance Attainment, Journal of Experimental Psychology, Vol 136(1), 154-168.

Elliot, A., Maier, M.A. (2007), Colour and psychological functioning, Current Direction in Psychological Science, Vol 16(5), 250-254.

Etnier, J.L., Hardy, C.J., 1997, The effects of environmental colour, Journal of Sport Behaviour, Vol 20(3), 299-312.

Fehrman, K. R., & Fehrman, C. (2004). Colour: The secret influence (2nd ed.). Upper Saddle River, NJ: Prentice Hall. in Elliot, A.J., Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J.(2007), Colour and Psychological Functioning: The Effect of Red on Performance Attainment, Journal of Experimental Psychology; Vol 136; no 1, 154-168.

Ferwerda, R.(2005), Enneaden, Porphyrius, Het leven van Plotinus, Budel: Damon B.V., 920.

Ford, M. E., Ford, D. H. (1987), Humans as self-constructing living systems: Putting the framework to work. Lawrence Erlbaum Associates, Inc.

Gerard, R. (1957), Differential effects of coloured lights on psychophysiological functions, in Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.H., 2008, Interior colour in healthcare environment, Conference paper 3 TU Symposium, Delft.

Goethe, J.W. (2004), Goethe, kleurenleer, Zeist, Uitgeverij Vrij Geestesleven (1e editie 1810), 134.

Goldstein, K. (1942), Some experimental observations concerning the influence of colours on the function of the organism. in Elliot, A.J., Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J. (2007), Colour and Psychological Functioning: The Effect of Red on Performance Attainment; Journal of Experimental Psychology, Vol 136(1), 154–168.

Gregory, R.L. (1998), Eye and brain, The Psychology of Seeing, Oxford, Oxford University Press, fifth edition.

Guilford, J.P, Smith, P.C. (1959), A system of colour preferences, in Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.(2008), Interior colour in healthcare environment., Conference paper 3 TU Symposium, Delft.

Hill, R.A. ,Barton, R.A. (2005), Red enhances human performance in contests, in Dijkstra, P.D, Preenen, T.Y. (2008), No effects of blue on winning contests in judo, Proceedings of the Royal Society B, 275, 1157-1162.

Hubel, D. (1990), Visuele informatie, schakelingen in onze hersenen, Natuur en techniek, Maastricht/Brussel, Original title: Eye, Brain, and Vision.

Jacobs, K.W. , Suess, J.F. (1975), Effects of four psychological primary colours on anxiety state, in Dijkstra, K. 2009, Understanding healing environments, University of Twente Publications, Twente.

Kaya, N., Epps, H.H. (2004), Relationship between colour and emotion, a study of college students, College Student Journal, Vol 38, 396-405.

Kwallek, N., Lewis, C.M. (1990), Effects of Environmental Colour on Males and Females: A Red or White or Green Office, Applied Ergonomics Vol 21(4): 275–278.

Kwallek, N., Woodson, H., Lewis, C. M., Sales, C. (1997), Impact of three interior colour schemes on worker mood and performance relative to individual environmental sensitivity. Colour Research and Application, 22, 121–132.

Larsen, L., Adams, J., Deal, B., Kweon, B., Tyler, E. (1998), Plants in the workplace: the effect
of plants density on productivity, attitudes and perceptions, Environment and Behaviour, Vol 30(3), 261-81.

Lehrl, S, Gerstmeyer, K., Jacob, J.H., Frieling, H., Henkel, A.W., Meyrer, R., Wiltfang, J., Kornhuber J, Bleich S. (2007) in O' Connor, Z. (2011), Colour psychology and colour therapy: Caveat emptor, Colour Research and Application; Volume 36, Issue 3, 229–234.
Lichtenfeld, S., Maier, M.A., Elliot, A.J., Pekrun, R. (2009), The semantic Red effect: Processing the word Red undermines intellectual performance, Journal of Experimental Social Psychology 25; 1273-1276.

Lombardi, A.M. (2007), Kepler, astronoom op zoek naar harmonie, Amsterdam, Van Veen Magazines.

Mahnke, F.H. (1996), Colour Environment & Human Response, Van Nostrand Reinhold, USA.

Mehta R., Zhu, R.J. (2009), Blue or Red? Exploring the Effect of Colour on Cognitive Task Performances, Science Express, Vol. 323. no. 5918, 1226-1229.

Mikkelides, B. (1990), Colour and psychological arousal, in O' Connor, Z., 2011, Colour psychology and colour therapy: Caveat emptor, Colour Research and Application; Volume 36(3), 229–234.

Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J. (2007), Colour and Psychological Functioning: The Effect of Red on Performance Attainment; Journal of Experimental Psychology, Vol 136(1), 154–168.

Moller, A.C. , A.J., Maier, M.A. (2009), Basic Hue Meaning associations, Emotion, Vol 9(6), 898-902.

Oegema van der Wal, Th. (1956), Practische kleurenpsychologie, Amsterdam: Wereldbibliotheek, 47.

Ott, J. W. (1979). The dual function of the eyes. Southern Journal of Optometry, 21, 8–13. in Elliot, A.J., Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J.(2007), Colour and Psychological Functioning: The Effect of Red on Performance Attainment, Journal of Experimental Psychology; Vol 136(1), 154-168.

Post, W.M., In't Veld, M.A.A., Van den Boogaard, S.A.A. (2008), Evaluating Meeting Support Tools, Personal and Ubiquitous Computing - Special Issue: Volume 12(3), 223-235.

Ramachandran, V.(2006), Het bewustzijn. Een korte inleiding, Pearson Education Benelux, 14.

Roberts S. G., Owen, R.C., Havlicek, J.(2010), Evolutionary Psychology Vol 8 (3); 350-364.

Rutchick, A.M., Slepian, M.L., Ferris, B.D. (2010), The pen is mightier than the word: Object priming of evaluative standards, European Journal of Social Psychology 40, 704–708.

Schneider, W. (1987), Sinn und Un-Sinn, Umweltt sinnlich erlebbar gestalten in Architektur und Design, Wiesbaden und Berlin: Bauverlag GMBH, 31.

Soldat, A.S., Sinclair, R.C., Mark, M.M. (1997), Colour as an environmental processing cue: External affective cues can directly affect processing strategy without affecting mood, in Mehta R., Zhu, R.J., 2009, Blue or Red? Exploring the Effect of Colour on Cognitive Task Performances, Science Express, Vol 323(5918), 1226-1229.

Steiner, R. (1984), Grundlinien einer Erkenntnistheorie der Goetheschen Weltanschauung, Dornach: Rudolf Steiner-Nachlassverwaltung.

Stone, N.J. (2003), Environmental view and colour for a simulated telemarketing task, in Mehta R., Zhu, R.J., 2009, Blue or Red? Exploring the Effect of Colour on Cognitive Task Performances, Science Express, Vol 323(5918), 1226-1229.

Stone N.J., English, A.J. (1998), Task type, posters, and work space colour on mood satisfaction, and performance, in Dijkstra, K. (2009), Understanding healing environments, Enschede, University of Twente Publications.

Tofle, R. B., Schwartz, B., Yoon, S., Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, United States of America, The Coalition for Health Environments Research (CHER).

Van Cranenburgh, B. (1998), Neurowetenschappen. Deel 1 Toegepaste Neurowetenschappen, Maarssen: Elsevier/De Tijdstroom, 76-78.

Van der Voordt, D.J.M. (2003), Costs and benefits of innovative workplace design, Delft: Center for People and Buildings.

Van Hagen, M., Galetzka, M, Pruyn, A., Peters J. (2009), Effects of Colour and Light on Customer Experience and Time Perception at a virtual Railway Station, Proceedings Experiencing Light 2009; International Conference on the Effects of Light on Wellbeing; 137-145.

Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.H. (2008), Interior colour in healthcare environment, Conference paper 3 TU Symposium, Delft.

Vink, P. (2009), Aangetoonde effecten van het kantoorinterieur, Amsterdam: Kluwer.

Vonk, R. (2003), Cognitieve Sociale Psychologie, Lemma BV, Utrecht, 68-76.

Yildirim, K., Lutfi Hidayetoglu, M., Capanoglu, A. (2011), Effects of interior colours on mood and preference: comparisons of tow living rooms, Perceptual and Motor skills, Vol 112, 509-524.

Yoto, A., Shimomura, Y., Iwanaga, K., Katsuura, T.(2007), Effects of Object colour Stimuli on Human Brain Activities in Perception and Attention Referred to EEG Alpha Band Response, Journal of Physiological Anthropology, 26(3), 373-379.

Zajonc, R.B. (1980), Feeling and Thinking, Preferences Need No Inferences, American Psychologist, Vol 35(2), 151-175.

Meeting test: questionnaire before the meeting (= Q1)

Room	I think the meeting room is pleasant
	The colour of the walls has a positive effect
	I think the light colour is pleasant
	I think the intensity of the light is pleasant
	The effect of the colour of the table top is pleasant
	I think the temperature is fine
	I think he air quality is fine
	I don't mind there is no daylight
Person	I feel good

Meeting test: questionnaire directly after the meeting and exactly the same 2 to 3 days after the meeting (=Q2 and Q3)

Room	I have experienced the meeting room as pleasant
	The colour of the walls had a positive effect
	I have experienced the light colour as pleasant
	The intensity of the light felt pleasantly
	The effect of the colour of the table top was pleasant
	I think the temperature was fine
	I think he air quality was fine
	I didn't mind there was no daylight
Person	I felt good
	My contribution at the process was good
	My contribution at the results was good
Group	There were enough opportunities to give my opinions
	They listened to me well
	I felt respected by the others
	Our cooperation was good
Meeting	I think the meeting was pleasant
	The way the session went, was good
	I think the result of the meeting is good
	What we achieved was worth time and effort

Meeting test: questionnaire after all meetings (=Q4)

R = Red room; B = Blue room; Ref = Reference room
Please, put per rule in one of the columns (1 till 7) once a R (red), once a B (blue) and once a Ref (Reference).
One box contains maiximal one choice. When you don't have any preference, pleease put a cross in the column 'doesn't matter'.

Room	I think the meeting room was pleasant
Person	I felt good in the meeting room
	In this meeting room my contribution at the process was the best
	In this meeting room my contribution at the results was the best
Group	In this meeting room our cooperation was good.
Meeting	In this meeting room I think, the meeting was pleasant
	In this meeting room the way the session went was good
	In this meeting room I think we achieved the best results
	In this meeting room, what we achieved was worth time and effort.

What is your opinion about the importance of the different components of the room?
In the table below 12 components of the room are mentioned which all contribute to the quality of the meeting room
Please will you give each component a number 1 till 7, while 1= not important and 7= very important?

component

temperature	air quality	wall colour	table top colour
form table	comfortable chairs	acoustics	day light
intensity lighting	colour lighting	art	plants

Green meeting space refreshing our views.

Beach cabin, Oerol Terschelling.

Musing on the roof watching the clouds can bring the knowledge worker enlightening ideas (Paulien Cornelisse).

The colour preference for clothing for females is black. However, Paulien wears a red dress. Red is the preferred colour to get in a mood of energy. Which colours do people prefer as favourite colour, as preference for clothing, the physical environment or moods? And has a technical person different preferences than an emotional individual? These are interesting questions because colour preferences can have influence on how people perceive colour.

Chapter Five
Colour preferences for different topics in connection to personal characteristics

Bakker I.C., Van de Voordt, D.J.M.., Vink, P., De Boon, J., Bazley, C. (2013), Color preferences for different topics in connection to personal characteristics. Color Research & Application. DOI: 10.1002/col.21845.

A substantial body of literature is available on colour preferences. However only a limited number of studies pays attention to colour preferences regarding the physical environment. The next step in this research concerns an extensive analysis of colour preferences of 1077 Dutch people regarding different topics and environments. Also the relations with personal characteristics such as age, gender, education, and personality are studied. This broad approach might help to understand colour preferences for the physical environment from a broader perspective and can shed more light on the experience of colour.

abstract

Studies on colour preferences are dependent on the topic and the relationships with personal characteristics, particularly personality, but these are seldom studied in one population. Therefore a questionnaire was collected from 1095 Dutch people asking for colour preferences about different topics and relating them to personal characteristics.

Colour preferences regarding different topics show different patterns and significant differences were found between gender, age, education and personality such as being technical, being emotional or being a team player. Also different colours were mentioned when asked for colours that stimulate to be quiet, energetic and able to focus or creative. Probably, due to unconsciousness of contexts, many people had no colour preference, a result that in the literature seldom is mentioned.

Blue was the overall favourite colour, however most males chose for blue (25%) while most females had no colour preference (18%). Black was the overall favourite colour for clothing, mainly chosen by females (40%), while males primarily chose blue (27%). For building interiors subjects preferred white. For moods, subjects preferred white for being quiet or being able to focus, red for being energetic and had no colour preference for being creative.

It is concluded that colour preferences are dependent upon the topic, and personal characteristics. The findings are important for architects, interior designers, fashion designers and product designers to have a basic idea of preferred colours for different objects by different types of people.

Keywords *colour preference; personal characteristics, personality, mood*

5.1 Introduction

5.1.1 Many different viewpoints on colour preference

Since the end of the 19th century studies on colour preferences show many differences in human preferences (Cohn, 1894, Katz and Breed, 1922; Holden and Bosse, 1900). One of the earliest studies found no general order of preferences for colours. Cohn stated that individual taste largely determines someone's colour preferences. In 1933, a common range of colour preferences was observed, showing

first order of colour as blue, second or third as red or green and the fourth as yellow (Katz and Breed, 1922; Eysenck 1941; Mather et al, 1971; Valdez and Mehrabian, 1994; Dittmar, 2001) suggesting a biological cause of likes and dislikes of colours (Eysenck, 1941). These likes and dislikes can be interfered by human characteristics. While many studies established relationships between preferred colours and personal characteristics, including extensive studies of Eysenck who collected data of different researches concerning totally 21,060 subjects in 1941, a clear view on the relationships between colour preferences and personal characteristics is still lacking. In addition, authors discuss on the relationship between colour preferences and the characteristics of colour such as hue, value and chroma. According to Arnheim (1974) the relationship between colour preferences and the characteristics of colours is still unclear.

5.1.2 Determination of colour preferences for different topics

The determination of colour preferences varies in many studies. In most studies, colour preferences are studied by asking for an overall favourite colour. Other studies ask for particular colour preferences for clothing, the exterior and interior of buildings, food or cars. Schloss et al (2012) showed differences in colour preferences dependent on type of clothing. Gage (1995) states that black is the preferred colour for clothing. In the Renaissance, black was the colour of privilege and wealth. Nowadays, black clothing is worn by all levels of society and is often the preferred colour for clothing and is an appropriate colour for all occasions (Gage, 1995).. People are viewed as more attractive when dressed in black or red (Roberts et al, 2010). In addition, Choo and Kim (2003) indicate red and greyish tones as an elegant image. However, Vrij and Akehurts (1997) state that black clothing is seen as the stereo-type colour for criminals.
In studies concerning colour preferences for workspace environments, the focus is often on a specific colour. The primary colour preference for the workplace is white (Kwallek et al, 1996) or the low chroma colours of light blue, light aqua green and off white (Brill et al, 1985; Bakker et al, 2013). In addition, Schloss et al (2012) showed for walls a dependency with the lightness of colours.
In studies concerning food colour, Hutchings and Food (1999) stated that colour preferences are determined by evolution. Pangborn (1987) found that the relationship between colour and taste is strong and demonstrated that artificially coloured food products, such as white wine coloured with a red pigment tastes sweeter than the same white wine without the red pigment.
Colour preferences for non-food products are often based on the way people want to present themselves (Trinkaus, 1991) or as a marketing cue (Crozier, 2002). In these cases colour is linked to the product. For instance, according to Eysenck (1941), Katz (1922), Valdez & Mehrabian (1994), and Dittmar (2001), blue is generally the preferred overall colour. However, when purchasing a car, people do not prefer the colour blue at all (Crozier, 2002). Additionally, context plays a prominent role in colour preference (Schloss et al, 2012; Clarke and Costall, 2008; Cubukcu and Kahraman, 2008). Advertisements are driven by looking for eye catchers asking for instance specific qualities of the colour (Lee and Barnes, 1990). Yellow is often applied because it implies a radiating quality (Schindler, 1986), although the colour yellow is scarcely mentioned as favourite colour (Eysenck, 1941; Dittmar, 2001; Crozier, 2002).

5.1.3 Factors influencing colour preference

Researchers found differences in colour preferences related to gender (Jastrow, 1897; Eysenck 1941; Saito, 1996; Kwallek et al, 1996; Dittmar, 2001; Schloss et al, 2012,. For instance, Funk and Ndubisi (2006) mentioned that males prefer colours related to what the colour signifies, whereas females' colour preferences are related to the colours' attractiveness. However, Katz and Breed (1922) stressed that gender has no effect on colour preference. Additionally, Ou et al (2004) found no differences between males and females in colour emotions. Other researchers also found differences in colour preferences related to age (Katz and Breed, 1922; Child et al, 1968, Lind, 1993; Saito, 1996; Dittmar, 2001). Lind

(1993) reported biological and social factors as underlying factors for colour preferences and seasonal influences related to the three colour variables hue, value and chroma. Other factors are mentioned in the literature as well such as level of education (Garth, 1924; Garth and Collado, 1928), intellectual development (Katz and Breed, 1922), culture (Saito, 1996; Crozier, 2002; Park and Guerin, 2002), marital status and background (Whitfield, 1984), region (Saito, 1996) , lifestyles (Saito, 1996) and personality such as introvert versus extrovert (Radeloff, 1991).

5.1.4 Applied methods

The types of methods applied in studies could influence the resulting colour preferences. The way colour preferences are determined varies from analysing magazines (Lee and Barnes, 1990),watching facial expressions (Zentner, 2001), establishing the fixation time (Adams, 1987), counting the quantity of coloured toys, clothes and room colours (Pomerleau, 1990), selecting clothing samples (Radeloff, 1991) or selecting coloured squares on screens (Ou et al, 2004; Schloss et al, 2012) or photographs on screens (Cubukcu and Kahraman, 2008). . Additionally, the way the colour is presented differs and varies from coloured charts (Katz and Breed, 1922; Eysenck, 1941; Guilford and Smith, 1959), Milton Bradley coloured papers (Garth, 1924) till colour palettes (Park and Guerin, 2002) , coloured dolls (Burkitt et al, 2007, coloured chips (Brill et al, 1985), coloured rooms (Kwallek et al, 1996), coloured clothing samples (Radeloff, 1991) or screens (Ou et al, 2004; Schloss et al, 2012). The number of the colours presented varies from two (Child et al, 1968), four (Dittmar, 2001), five (Adams, 1987), six (Katz and Breed, 1922),nine (Whitfield, 1984) and ten (Eysenck 1941) or more (Guilford and Smith, 1959; Ou aet al, 2004; Schloss et al, 2012). Sometimes colours are applied to objects that are familiar to test subjects, i.e., Milton Bradley pencils (Garth and Porter, 1934 . In other studies, colours are presented using different levels of chroma and saturation (Guilford and Smith, 1959; Adams and Osgood, 1973; Valdez and Mehrabian, 1994; Kwallek et al, 1996; Ou et al, 2004; Manav, 2007; Cubukcu and Kahraman, 2008; Schloss et al, 2012). Different information models are used to measure the degree of attractiveness (Bellizi et al, 1983), the degree of pleasure, arousal, dominance and emotion that is, the model of Valdez and Mehrabian (Ou et al, 2004; Verhoeven et al, 2009) and models based on the Semantic Differential Scale of Osgood (Bellizi et al, 1983; Ou et al, 2004). Due to the differences in applied test materials, methods and models and different contexts, it is difficult to compare the outcomes. In addition, the qualities of the colour itself may have an influence as well. There have been many discussions about the influences of these qualities on colour preferences. The psychologist, Zajonc (1980) indicates that value and chroma do not play any role in the process of establishing colour preferences. Zajonc conceives colour as a phenomenon with colour groups such as blue group or the yellow group without any specifications. When colour preferences are related to topics such as cars or particular clothes, contexts like backgrounds, forms and spaces or emotions and connotations such as happiness or calmness, chroma and value influence the colour preference (Guilford and Smith, 1959; Wright and Rainwater, 1962; Beach et al, 1988; Camgöz et al, 2002; Manav, 2007; Cubukcu and Kahraman, 2008; Schloss et al, 2012). However, the findings of the different researchers concerning the influences of value and chroma are conflicting and do not show consistent patterns. Guilford and Smith (1959)for instance showed that people perceive colour as more pleasant when brightness is added while Eysenck (1941) indicates a colour preference that is inversely with the luminosity factor. Park and Guerin (2002) mention that both saturation and value determine the colour preference while Acking and Küller show no effect of these two factors (1972, 1976). In addition, individual differences among the test subjects may contribute to the conflicting findings. By combining different aspects in one study, this study provides additional information on colour preferences for different topics related to personal characteristics.

5.1.5 Research questions

Many colour studies focus on general colour preference. Because daily people experience the physical environment and are also concerned about their clothing every day, the present research investigates both the general favourite colour and colour preferences for the physical environment and clothing. These topics are regularly researched (Bellizi et al, 1983; Whitfield, 1984; Brill et al, 1985; Trinkaus, 1991; Radeloff, 1991; Lind, 1993; Kwallek et al, 1996; Saito, 1996; Vrij and Akehurts, 1997; Park and Guerin, 2002; Choo and Kim,2003; Cubukcu and Kahraman, 2008; Verhoeven et al, 2009; Roberts et al, 2010; Schloss et al, 2012; Bakker et al, 2013). Besides these physical topics it is interesting whether people have any colour preferences related to their moods. This could be relevant to the physical environment as well. The colour preference regarding a specific mood such as being creative might have added value related to the colour preferences for a meeting room in which creative sessions could be organised. Not only is colour a complex phenomenon, but so are people. A person is not only characterised by data such as age and education, but also by human characteristics. As such, this research focuses on two main research questions:

1 What are the colour preferences of adults and do they differ per topic?
2 Is there any relationship between colour preferences and personal characteristics, in particular personality?

5.2 Methods

For this study, 1095 subjects were asked to complete a colour preference questionnaire indicating a favourite colour in general, colour preferences for clothing, four types of rooms for example the living room and the office and colour preferences for certain moods for example being energetic. Eighteen subjects were excluded due to colour blindness leaving 1077 subjects in our study. In this research, it is assumed that a relationship exists between a colour name (such as blue) and the colour people have in their mind. So the colour name is conceived as a group of colours in the way Zajonc did, including differentiations concerning value and chroma. The demographics collected were: age, gender, education level, living area, type of company and size of company. On a 'Likert' seven point scale the participants were asked if they considered themselves to be: technical, artistic, rational, emotional, a soloist, like to be alone, a team player, messy, tidy, happy, prefer colours and require much light. All subjects live in the Netherlands which can be considered as European western culture. Only the names of the colours were mentioned in the questionnaire as primarily is focused on the personal image people have of colours such as for instance the group blue or the group yellow.

The questionnaires (Figure 1) were collected by email and distributed on-site during lectures at different educational institutions of higher education. All data was processed using SPSS 16 to analyse ratios and significant correlations.

figure

Figure 1: The questionnaire for colour preferences used in this study

personal characteristics (please complete or mark)		**lives in the area** (please mark the right option)		
date of birth:	.....	NH	Limburg	Friesland
gender	M/F	ZH	Gelderland	Groningen
are you colour blind	yes/no	Utrecht	Overijssel	Flevoland
do you use eye correction (lenses/glasses)	yes/no	Nrd Brabant	Drenthe	Zeeland

colour preferences (one cross per line)	nop	whi	lil	vio	dbl	blu	lbl	tur	gre	lgr	yel	ora	pin	red	dre	bro	gry	bla
what is your favourite colour?																		
what is your favourite colour for clothing?																		
what is your favourite colour for the living room?																		
what is your favourite colour for the bedroom?																		
what is your favourite colour for the office?																		
what is your favourite colour for the meeting room?																		
what is your favourite colour combination (max. 3)																		
colour and mood (one cross per line)																		
what colour makes you feel calm?																		
what colour makes you feel energised?																		
what color helps you focus?																		
what colour makes you most creative?																		

	not at all			average			very much
general questions (one cross per line)	1	2	3	4	5	6	7
are you technical?							
are you artistic?							
are you rational?							
are you emotional?							
are you a soloist?							
do you like to be alone?							
are you a team player?							
are you messy?							
are you tidy?							
are you happy?							
do you prefer many colours around you?							
do you prefer much day or artificial light around you?							

(please mark the right option)

school/education		**work**	
last received education		**type of company**	
primary school		government	
level		semi public	
lower vocational		public	
higher vocational		**size company**	
university		1-3 persons	
		4-9 persons	
		10-49 persons	
		50-99 persons	
		100-199 persons	
		200 or more	

nop = no preference
whi = white
lil = lilac
vio = violet
dbl = dark blue
blu = blue
lbl = light blue
tur = turquoise
gre = green
lgr = light green
yel = yellow
ora = orange
pin =pink
red = red
dre = dark red
bro = brown
gry = grey
bla = black

5.3 Results

5.3.1 Study population

The characteristics of the study population are shown in Table 1. The numbers of men and women are nearly the same. The age varies mainly from 19 to 65 years old. Most subjects are educated at the higher vocational level and most subjects are working in a business environment.

Table 1: Characteristics of the study population

table

Characteristics	number	percentages
gender		
male	548	50,9
female	524	48,7
missing	5	0,5
total	**1077**	**100,0**
age range		
till 18	11	1,0
19 till 25 incl.	279	25,9
26 till 35 incl.	185	17,2
36 till 45 incl.	228	21,2
46 till 55 incl.	204	18,9
56 till 65 incl.	111	10,3
66 and older	5	0,5
missing	54	5,0
total	**1077**	**100,0**

Characteristics	number	percentages
education		
university level	262	24,3
higher vocational level	644	59,8
lower vocational level	164	15,2
missing	7	0,6
total	**1077**	**100,0**
work		
government	164	15,2
semi government	185	17,2
business	583	54,1
other	145	13,5
missing	0	0,0
total	**1077**	**100,0**

5.3.2 Favourite colours in general

Table 2 shows the percentages of the favourite colours of the total population in this study. The colour blue was the favourite colour, showing the highest percentage of 19% and no colour preference was second at 16.1%. The majority of females in the study had no colour preference (17.7%) and blue was the second preferred colour choice (13%). Both female and male chose red as the third favourite colour.

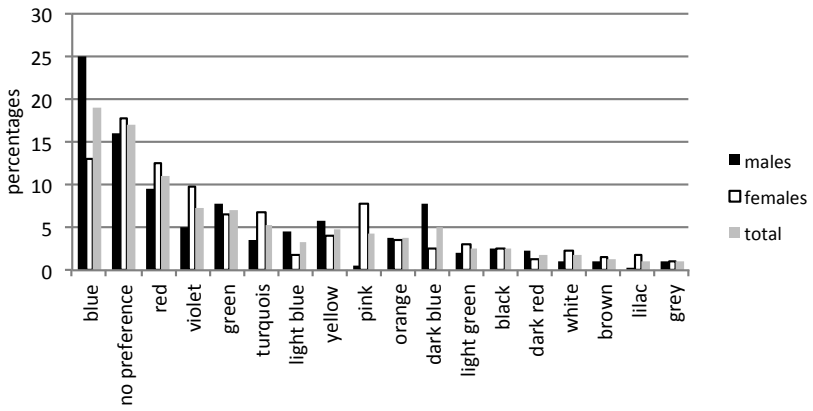


Figure 2: The favourite colours for males and females, and total group in percentage of this specific group

Significant correlations between favourite colours and gender (χ2= 101.19; p=0.00; α = 0.05), age (χ2= 121.3 p=0.000; α = 0.05) and education (χ2= 46.806; p=0.026; α = 0.05) are found. University level educated subjects chose blue more often and subjects of vocational level had a higher preference for light green and pink. Also significant relationships between favourite colours and the personality of the subject characterised by him or herself as 'being artistic' (One way ANOVA: F= 2.1092 p= 0.04; α=0.05) are found. People who said they were less artistic, more often chose for blue. Subjects who characterized themselves as 'very artistic' chose colours that were chosen at a lower percentage, such as turquoise. No significant relationships are found with living area, type of company and size of the company.

5.3.3 Colour preferences for clothing

Figure 3 shows the colour preferences for clothing for males and females. In the whole sample black is the most preferred colour for clothing (28%). It is especially favourite among females (40%). Males rated black at the fourth position (16%) after blue (27%), dark blue (18%) and the option 'no colour preference (17%). The choice for 'no colour preference' concerning clothing was rather high: women ranked 'no colour preference' as second (17%) and men with an almost equal percentage at the third place. Among all 1077 subjects, no one preferred yellow as favourite colour for clothing. Colour preferences for clothing were significantly related to gender (χ2 = 194.59; p=0.00; α = 0.05), age (χ2= 194.59 p=0.000; α = 0.05) and education (χ2= 62.831; p=0.000; α = 0.05). Subjects educated at university level chose blue for a preferred clothing colour and in lower extent for 'no colour preference' and black. Nearly one-third of both groups educated at higher vocational and lower vocational level chose black. Subjects with education at higher vocational level had a relative low preference for blue. The preference for blue increases with age: older people chose blue and dark blue. The youngest subjects preferred black while the oldest subjects chose black the least.

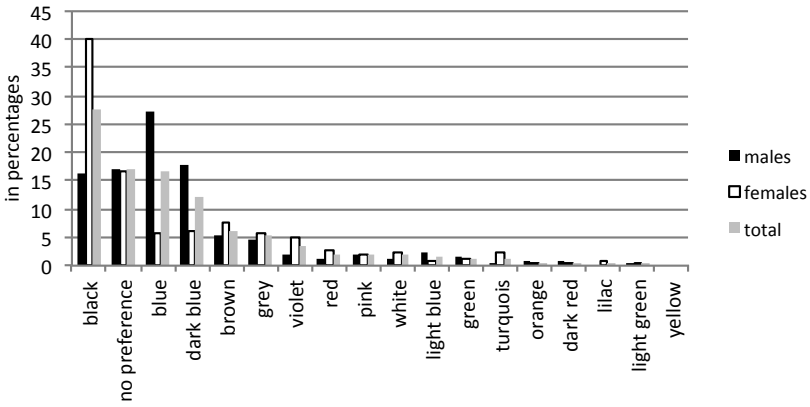


Figure 3: Colour preferences of males and females and total group for clothing in percentage of the total of the group

The colour preferences related to clothing were significantly related to personalities 'being technical' (One way ANOVA: F= 2.3973; p= 0.020; α=0.05) and 'being emotional' (One way ANOVA: F= 2.764; p= 0.0113; α=0.05). The more technical respondents preferred blue coloured clothing and the less technical preferred black clothing. The more emotional respondents preferred black clothing. Colour preferences were also significantly related to the degree people were liking colours around them (One way ANOVA: F= 2.482; p= 0.022; α=0.05). No significant relations are found with living area, type of company and size of company.

5.3.4 Colour preferences for the physical environment

Thirty to forty one percent of all subjects chose the colour white for a preferred colour in four types of physical environments, the highest percentage in office spaces. For all four types of rooms, male respondents preferred white over that of females. The choice for' no colour preference 'was highest for meeting rooms at 22%. The percentages concerning the colour preference for males and females for the physical environment are presented in Figure 4.

Figure 4 a to d: Colour preferences for the physical environment for males, females and the total group in percentage of that group. (a) The living room, (b) the bed room, (c) the meeting room, and (d) the office

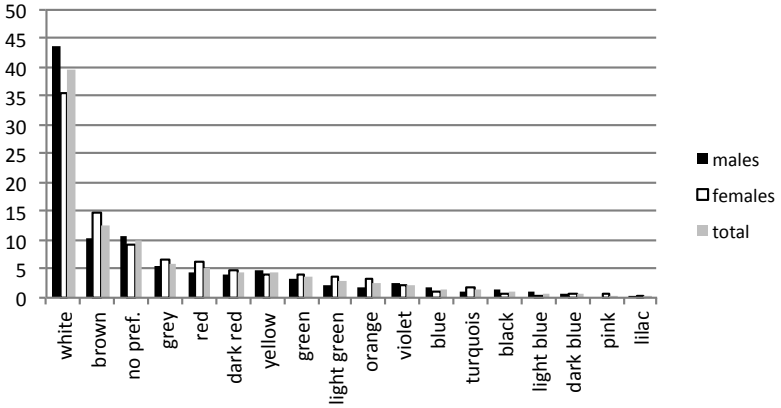


Figure 4a: The living room

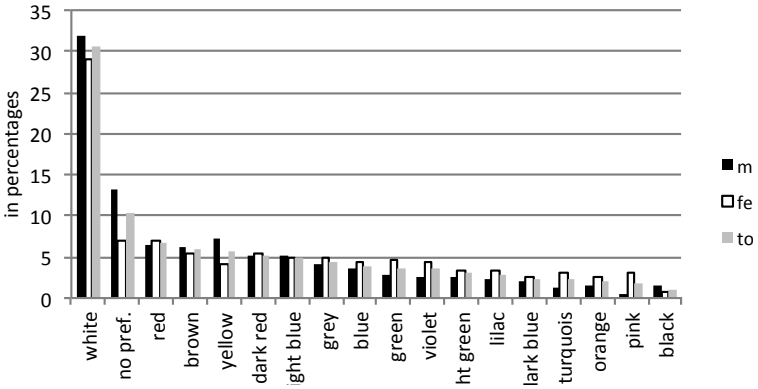


Figure 4b: The bed room

Colour preferences for the physical environment were significantly related to gender concerning the bed room (χ2=40.76, p=0.001, α=0.05) and the office space (χ2=28.81; p= 0.036; α= 0.05), age concerning the living room (χ2= 87.54; p= 0.000; α=0.05), the bed room (χ2= 101.83; p= 0.001; α=0.05) and the office space (χ2 office space = 49.47; p= 0.007; α=0.05) and education concerning the living room (χ2= 42.08; p= 0.000; α=0.05) and the meeting room (χ2 =35.41; p= 0.018; α=0.05).

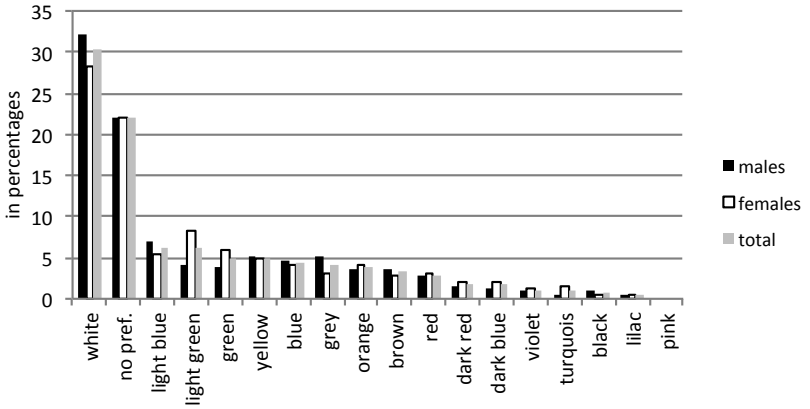


Figure 4c: The meeting room

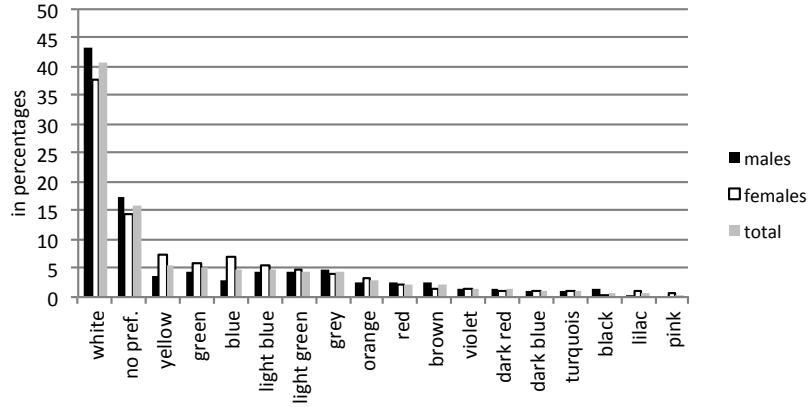


Figure 4d: The office

Colour preferences for the physical environment were significantly related to the personality of the subjects: for the bedroom, the colour preferences were significantly related to 'being a soloist' (One Way ANOVA: F=3.37; p= 0.003; α=0.05); the colour preferences for the office space (One Way ANOVA F=3.56; p= 0.001; α=0.05) and the meeting room (One Way ANOVA F= 2.23; p= 0.03; α=0.05) were statistically significant to 'being artistic'. No significant relations are found with living area, type of company and size of company.

5.3.5 Colour preferences related to moods

Subjects preferred white colours around them for "being quiet" (19% and for "being focused", 36% preferred white and 17% had no colour preference. Additionally, 30% preferred red for "being energetic" and 27% had no colour preference for being creative.

Figure 5 shows colour preferences for the moods for males, females and the total group in percentage of that group.

(a) Colour preference for the mood "quiet" in percentage of the group males, females and total.
(b) Colour preference for the mood "energetic" in percentage of the group males, females and total.
(c) Colour preference for the mood "concentrated" in percentage of the group males, females and total.
(d) Colour preference for the mood "creative" in percentage of the group males, females and total.

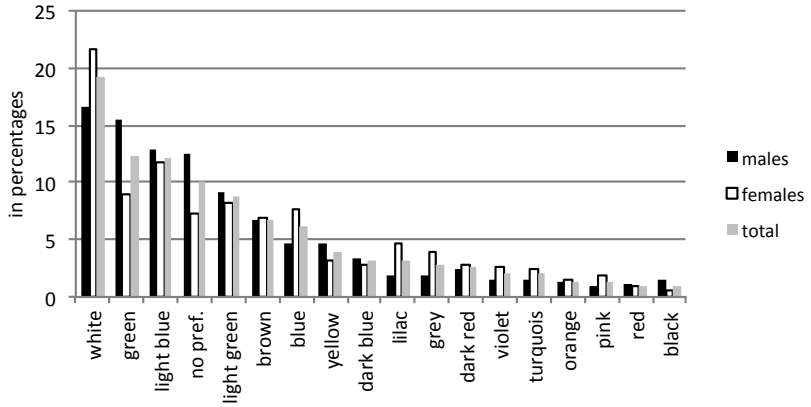


Figure 5a: Colour preference for the mood ' quiet' in percentage of the group males, females and total

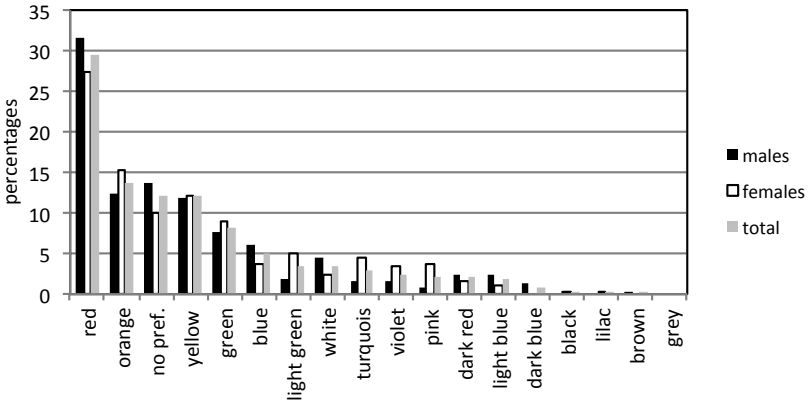


Figure 5b: Colour preference for the mood 'energetic' in percentage of the group males, females and total

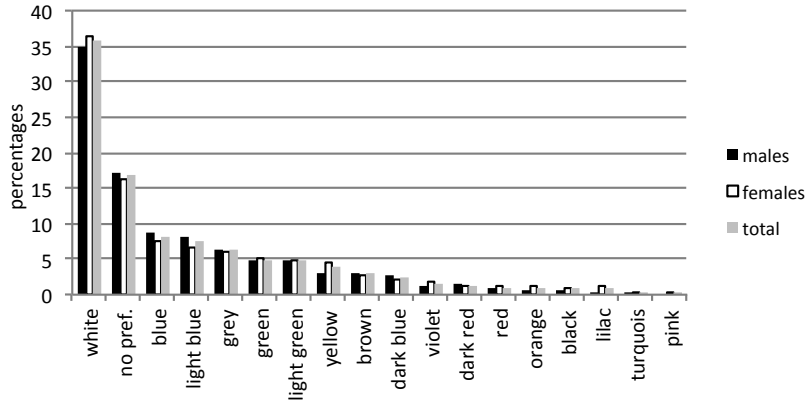


Figure 5c: Colour preference for the mood ' concentrated' in percentage of the group males, females and total

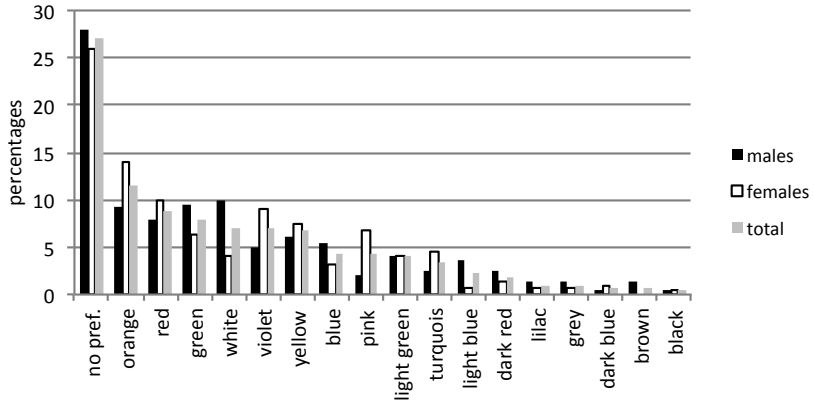


Figure 5d: Colour preference for the mood 'creative' in percentage of the group males, females and total

Colour preferences for moods (Figure 5) were significantly related to gender concerning 'being quiet (χ2 =44.66; p= 0.000; α=0.05), being energetic (χ2 = 60.1; p= 0.001; α=0.05) and 'being creative' (χ2 = 72.20; p= 0.000; α=0.05). For all moods significant relations exist with age (χ2 being quiet = 108.33; p= 0.000; α=0.05) (χ2 being energetic = 98.54; p= 0.000; α=0.05) (χ2 being focused = 76.39; p= 0.000; α=0.05) (χ2 being creative = 79.60; p= 0.003; α=0.05). Education was significantly related to 'being quiet (χ2 = 38.46; p= 0.016; α=0.05), being focused (χ2 = 34.45; p= 0.023; α=0.05) and being creative (χ2 = 47.14; p= 0.013; α=0.05).

The colour preferences for the moods were significantly related to personality:' being energetic' is significantly related to being artistic (One Way ANOVA: F= 2.14; p= 0.03; α=0.05) and 'being a team player' (One Way ANOVA: F= 3.54; p= 0.002; α=0.05). 'Being focused' is significantly related to 'being a soloist' (One Way ANOVA: F= 2.58; p= 0.017; α=0.05). 'Being creative' is significantly related to 'being artistic'(One Way ANOVA: F= 3.25; p= 0.002; α=0.05). No significant relations are found with living area, type of company and size of company.

5.3.6 Colour preferences and influencing factors

Personal characteristics such as gender, age and education showed to have a significant influence on colour preferences in different ways. The same holds true for personality such as 'being technical' or 'being a team player'. To the best of our knowledge this has never been discussed in the literature so extensive. Table 2 shows the significant relations.

Table 2: influencing factors on colour preferences

table

influencing factors	favourite colour in general	colour preference for clothing	colour preference for moods				colour preference for types of rooms			
			being quiet	being energetic	being able to concentrate	being creative	the living room	the bed room	the office	being creative
age	x	x	x	x	x	x	x	x	x	x
gender	x	x	x	x	no	x	no	x	x	no
education	x	x	x	no	x	x	x	no	no	x
personality	artistic	technical emotional liking colours	no	artistic teamplayer	soloist	artistic	no	soloist	artistic	artistic

Four types of colour preferences are analysed. For all colour preferences a significant relation exist with age, that is in accordance with the literature (Katz and Breed, 1922; Child et al, 1968; Lind, 1993; Dittmar, 2001; Funk and Ndubisi , 2006). The factor gender however did not show a significant relationship with colour preferences such as the mood 'being concentrated' and the colour preferences for the living room and the office. In these cases males and females showed no significant differences. These findings are in accordance with Katz (1922) and Ou et al (2004) who in addition did not find significant differences. The factor education has significant influence on the favourite colour in general (that is in accordance to Garth and Collado (1929) and Park and Guerin (2002) and the colour preference for clothing. The personalities showed a different pattern and due to the novelty of these factors, no comparison can be made with the existing literature. The personality 'being artistic' shows most significant relations and is significantly related to the favourite colour preference in general, the moods as 'being energetic' and 'being creative' and the colour preferences for the office and the meeting room. In addition the personalities as 'being technical', 'being emotional', 'liking colours', being a teamplayer' and 'being a soloist' all have – in different ways- significant influence on the analysed colour preferences.

5.4 Discussion

This research concerns a collection of different types of colour preferences based on using colour names such as blue. It is assumed that people use these colour names for a part of the spectrum belonging to a colour group (such as blue). The advantage of presenting colours by mentioning the names of these colours and not by showing pictures of specific colours is that colour preferences can be found for a colour as a group such as blue. Showing pictures of specific colours in a questionnaire has the disadvantage that someone can have a preference for a specific colour group such as blue but dislikes the presented blue due to the degrees of value and chroma. Another problem of showing pictures of colours is that the place where the questionnaire is completed influences the presented colours due to light reflections in the environment.

The first research question asks what the colour preferences of adults are and if they differ per topic. The research findings show that colour preferences of adults are dependent on the topic. The favourite colour choice coincides with the clothing colour preference. Twenty three percent of all subjects chose the same favourite colour in general and the colour preference for clothing. However, the colour black shows a different pattern. The colour preference for black clothing overall is at 28% whilst the total colour preference for black as favourite colour is 3%. No other relationships could be found between the four types of colour preferences that were studied here. The findings are in accordance with the data mentioned in the literature (Katz and Breed, 1922; Eysenck, 1941; Dittmar, 2001): the range for favourite colours in general shows the highest preference for the colour blue overall, the range for clothing shows the highest preference for black, and the range for the physical environment shows the colour white. For each type of colour preferences a specific pattern can be observed. There is a universal scale of colour preferences according to Eysenck (1941) for specific favourite colour preferences and these colour preferences seems to vary inversely with the luminosity factor of the colour.
That black is the preferred colour choice for clothing was also found in the literature. People tend to prefer dark colours for clothing, with high percentages for black, blue, dark blue and brown. The high percentage for the option of 'no colour preference' may attribute to the awareness of contexts. According to Kleeman (1981) and Kwallek et al (1996) white is the colour that creates a spacious feeling. This might explain the preference for white in residential and office environments that is in accordance with modern ways of architectural and interior design.

The colour preferences for the four type of moods correlate with the common associations such as red being an active colour (Gerard, 1957; Wilson, 1966; Birren, 1978; Bellizi et al, 1983; Kaya and Epps, 2004; Mahnke, 1996) and white representing a neutral colour (Kaya and Epps, 2004; Mahnke, 1996; Acking and Küller, 1972, 1976). The high percentage of 'no colour preference' (27%) regarding the preferred colour for the mood 'being creative' is striking. It seems that the subjects, in this case, were aware of context dependency in choosing a preferred colour for a particular mood.

The second research question asks if there is a relationship between colour preferences and personal characteristics such as gender, age, education and personality such as 'being technical' or 'being emotional'. This study showed significant influences on colour preferences (Table 2). No influences were found due to the type or size of the company. While the literature shows evidence concerning the influence of human characteristics on colour preferences (Jastrow, 1897; Katz and Breed, 1922; Garth, 1924; Garth and Collado, 1929; Garth and Porter, 1934; Eysenck, 1941; Child, 1968; Whitfield, 1984; Radeloff, 1991; Saito, 1996; Kwallek et al, 1996; Dittmar,2001; Crozier, 2002; Park and Guerin, 2002; Funk and Ndubisi, 2006; Schloss et al, 2012) it would be thinkable that in addition the character of the company could have any influence. This was not the case.

It can be concluded that in addition to characteristics often mentioned in the literature, such as age, gender and education, also personality, such as being technical, emotional, artistic, being a team player or being a soloist, influence the analysed types of colour preferences. However, while the factor 'age' consequently influences all types of colour preferences, all other analysed types of colour preferences are influenced in different ways. The colour preference for clothing is influenced by most factors and the colour preference for the living room by the least number of factors (table 2). It might be that subjects are aware of context factors. This could contribute to the percentages for the option 'no colour preference' for all types of colour preferences surveyed. These high percentages are remarkable because these results are scarcely mentioned or found in the literature.
Another interesting point to mention is that the influence of factors is in agreement with the existing literature, such as with growing age people choose more for blue (Katz and Breed, 1922; Child et al, 1968; Adams, 1987) and the higher the education the more people choose for blue Garth, 1924; Mercer, 1925; Garth and Collado, 1929).To recapitulate the main points it is notable that this study confirmed previous findings that the colour blue is the overall favourite colour and for this study mainly chosen by males at 25 percent, whereas females primarily chose ' no colour preference' at 18%. Also notable in the literature is that the colour black is often mentioned as the favourite colour for clothing and for this study mainly chosen by females at 40%, while males primarily chose the colour blue at 27%. A drawback to this study is that the data collection occurred on different days, where people could have different moods, for instance influenced by weather conditions. These variations could have influenced the way participants answered as we have shown that there are relationships between colour preference and mood. On the other hand, in real life, conditions vary as well and having a large population these influences could be limited. Another drawback to this study is that participants had to imagine which colour they prefer without seeing an actual object. Other studies use coloured charts (Katz and Breed, 1922; Eysenck, 1941) or colour palettes (Whitfield, 1984). The advantage of visual tools is that no verbalisation phase is needed to describe the colours. On the other hand, the object itself, its meaning, texture or form might influence the outcome. Showing coloured clothing samples (Radeloff, 1991) for instance, has a disadvantage that the product and its features, such as texture might influence the colour preference. In fact, there is no ideal way of studying colour preference. In this study part of the solution to the problem is tackled by asking for colour preferences of different topics. This in turn makes it clear that the general colour preferences differ dependent on the topic.

Regarding the practical implications cautiousness is needed in transferring preferred colours to physical products. For the clothing industry it is useful to know the colour preferences and the differences of colour preferences between males and females to respond on these preferences in their collections. For architects and interior architects is it practical to know that most people prefer light colours. However, the real effects of colours depend on the colour qualities and its context.

5.5 Conclusion

Adults show different colour preferences dependent on the topic. There seems to be a correlation between a favourite colour in general and a preferred colour for clothing: overall 23% of all subjects chose the same colour for their favourite colour and for their clothing. The order of overall favourite colours, mentioned in the literature of past colour studies, is blue, red or green, followed by yellow. This is confirmed by the results found in this study. The results from past studies showed black being the preferred colour for clothing. This study also found that in total the colour black was mostly preferred for clothing. However, the colour preference of black was at a higher percentage for women (40%) than men (16%). Men preferred blue (27%) , followed by dark blue and 'no colour preference'. This is a new insight in the colour preferences for clothing distributed throughout gender. The colour preference for the physical environment was white which might be influenced by modern ways of decorating the interiors of the built environment, particularly in the Netherlands. Additionally, the colour preferences of the four moods, being quiet, being energetic, being able to focus and being creative, indicated learned associations. In this study the high percentages for the choice of 'no colour preference' for being creative is striking and scarcely mentioned in previous studies.

Due to the high number of subjects and the multiplicity of data, the findings are important for architects and interior designers designing interiors for different types of moods, fashion designers selecting colours for cloths for different types of people and products designers choosing colours for different types of products.

Acknowledgements

The authors wish to thank the 1095 subjects who completed the colour questionnaire and the Association for Facility Management Netherlands (FMN) for collecting them and a special thanks to Leo Faasen, colour specialist at PPG, for his colour advise and questionnaire collecting during his colour lectures.

This extensive overview of colour preferences has contributed to a better insight in the colour preferences for the physical environment. Many relationships were found between colour preference and age, gender, education and personality. Remarkably, between 30 to 40% of the participants preferred the colour white and 16-22% mentioned that they had no colour preference. In normal circumstances people do not consciously experience their physical environment. As a consequence, asking people about their colour preferences may not provide clear indications what colours should be applied in different environmental conditions. Because the colour test described in chapter 4 did not show any evidence about the impact of colour and the data collection of colour preferences in this chapter clearly shows that people are not very interested in environmental colours, an additional extensive review of the literature has been conducted to understand more about colour experience. This review which will presented in the next chapter.

5.6 References

Acking, C. A., Küller, R. (1972), The perception of an interior as a function of its colour, Ergonomics, 15, 645-654.

Adams, R. J. (1987), An evaluation of colour preference in early infancy. Infant Behaviour and Development, 10(2), 143-150.

Adams, F.M., Osgood, Ch.E., (1973), A Cross-Cultural Study of the Affective Meanings of Colour, Journal of Cross-Cultural Psychology, Vol 4(2), 135-156.

Acking, C. A., Küller, R. (1976), Interior space and colour. Colour for architecture, 120-122.

Arnheim, R. (1974), Art and visual perception: The psychology of the creative eye. The new version. Berkeley and Los Angeles, CA: University of California Press. in Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Bakker I.C., Van der Voordt, D.J.M. De Boon, J. de, Vink, P. (2013a), Red or blue meeting rooms: does it matter? The impact of colour on perceived productivity, social cohesion and wellbeing, Facilities, Vol. 31(1/2), 68 – 83.

Beach, L., Wise, B. K., Wise, J. A. (1988), The Human Factors of Colour in Environmental Design: a critical review. Moffet Field, CA.: National Aeronautics and Space Administration, Ames Research. in Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Bellizi, J.A., Crowley, A.E., Hasty, R.W. (1983), The effects of colour in store design, Journal of Retailing, Vol. 59(1), 21-45.

Birren, F. (1978), Colour & human response: aspects of light and colour bearing on the reactions of living things and the welfare of human beings. Van Nostrand Reinhold Company.

Brill, M., Margulis, S.T., Konar E. (1984), BOSTI: Using Office Design to Increase Productivity. Vol. I. in Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments:A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Burkitt, E., Tala, K, Low, J. (2007), Finnish and English children's colour use to depict affectively characterized figures. International Journal of Behavioural Development,; Vol 31(1), 59–64.

Camgöz,N., Yener, C., Guvenc, D. (2003), Effects of hue, saturation, and brightness: Part 2. Colour Research and Application, 29, 20–28.

Child, I. L., Hansen, J. A., Hornbeck, F. W. (1968), Age and sex differences in children's colour preferences. Child development, 237-247.

Choo, S., Kim, Y. (2003), Effect of colour on fashion fabric image. Colour Research & Application, 28(3), 221-226.

Clarke, T., Costall, A. (2008), The emotional connotations of colour: A qualitative investigation. Colour Research & Application, 33(5), 406-410.

Cohn, J. (1894), Experimental investigation of colours. Philosophical Studies, 10: 562-602. in: Eysenck, H.J. (1941), A critical and experimental study of colour-preferences. The American Journal of Psychology; 54, 385- 394.

Crozier, W.R. (2002), De psychologie van kleurenvoorkeuren, in Kleur. Veenman drukkers, Ede; 75, 77.

Cubukcu, E., & Kahraman, I. (2008), Hue, saturation, lightness, and building exterior preference: An empirical study in Turkey comparing architects' and nonarchitects' evaluative and cognitive judgments. Colour Research & Application, 33(5), 395-405.

Dittmar, M. (2001), Changing colour preferences with ageing: A comparative study on younger and older native Germans aged 19–90 years. Gerontology, 47(4), 219-226.

Eysenck, H.J. (1941), A critical and experimental study of colour-preferences. The American Journal of Psychology; 54, 385-394.

Funk, D., Ndubisi, N. O. (2006), Colour and product choice: a study of gender roles. Management research news, 29(1/2), 41-52.

Gage, J.(1995), Colour and Culture, in Lamb, T., Bourriau, J. (1995), Colour, Art and Science, Cambridge University Press, Cambridge.

Garth, T. R. (1924), A Colour Preference Scale for One Thousand White Children. Journal of experimental psychology, 7(3), 233.

Garth, T. R., Collado, I. R. (1929), The colour preferences of Filipino children. Journal of comparative psychology, 9(6), 397.

Garth, T. R. and Porter, E. P. (1934), The colour preferences of 1032 young children. The American Journal of Psychology: Vol 46, 448-451.

Gerard, R. (1958), Differential effects of coloured lights on psycho-physiological functions. Unpublished doctoral dissertation, University of California, Los Angeles.

Guilford, J.P, Smith, P.C. (1959), A system of colour preferences, in Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.H., 2008, Interior colour in healthcare environment., Conference paper 3 TU Symposium, Delft.

Holden, W.A., Bosse, K.K. (1900), in Hayne, W., Reese, H.W., Lipsitt, L.P.(1978), Advances in child development and behaviour. Academic Press, Inc; United States of America: Vol 12, 158.

Hutchings, J. B. (1999), Food, Colour and Appearance. Aspen publishers Inc. 2nd edition, Maryland; 2-3.

Jastrow, J. (1897), The popular aesthetics of colour. Popular Science Monthly, 50: 361–368.

Katz, S. E., Breed, F. S. (1922), The Colour Preferences of Children. Journal of Applied Psychology, 6(3), 255.

Kaya, N., Epps, H.H. (2004), Relationship between colour and emotion, a study of college students, College Student Journal, 396-405.

Kleeman, W.(1981), The Challenge of Interior Design. Boston: CBI Publishing Company, Inc. in Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Kwallek, N., C.M. Lewis, J.W. Lin-Hsiao, Woodson, H. (1996), Effects of Nine Monochromatic Office Interior Colours on Clerical Tasks and Worker Mood. Colour Research and Application, Vol. 21(6), 448–458.

Lee, S., Barnes, J.H.(1990), Using colour preferences in magazine advertising. Journal of Advertising Research: Vol 29(6), 25-30.

Lind, C. (1993), Psychology of colour: Similarities between abstract and clothing colour preferences. Clothing and Textiles Research Journal, 12(1), 57-65.

Mahnke, F. (1996), Colour, Environment, and Human Response. New York: Van Nostrand Reinhold.

Manav, B. (2007). ColourÐemotion associations and colour preferences: A case study for residences. Colour Research & Application, 32(2), 144-150.

Mather, J., Stare, C., Breinin, S. (1971), Colour preferences in a geriatric population. The Gerontologist, 11 (4 Part 1), 311-313.

Mercer, F. M. (1925), Colour preferences of one thousand and six negroes. Journal of Comparative Psychology, 5(2), 109.

Ou, L. C., Luo, M. R., Woodcock, A., Wright, A. (2004), A study of colour emotion and colour preference. Part I: Colour emotions for single colours. Colour Research & Application, 29(3), 232-240.

Pangborn, R. M. (1987), Selected factors influencing sensory perception of sweetness. In Sweetness (49-66). Springer London.

Park, Y. ,Guerin, D.A. (2002), Meaning and preference of interior colour palettes among four cultures. Journal Interior Des; 28:27–39.

Pomerleau, A., Bolduc, D., Malcuit, G., Cossette, L. (1990), Pink or blue: Environmental gender stereotypes in the first two years of life. Sex Roles, 22(5-6), 359-367.

Radeloff, D.J. (1991), Psychological Types, Colour Attributes, and Colour Preferences of Clothing, Textiles, and Design Students. Clothing and Textiles Research Journal; Vol 9(3), 59-67.

Roberts, S. C., Owen, R. C., Havlicek, J. (2010), Distinguishing between perceiver and wearer effects in clothing colour-associated attributions. Evolutionary psychology: 8(3), 350-364.

Saito, M. (1996), Comparative studies on colour preference in Japan and other Asian regions, with special emphasis on the preference for white. Colour Research & Application, 21(1), 35-49.

Schindler, P.(1986), Colour and contrast in magazine advertising. Psychology and Marketing; Vol 3(2), 69–78.

Schloss, K. B., Strauss, E. D., Palmer, S. E. (2012), Object colour preferences. Journal of Vision, 12(9), 66-66.

Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Trinkaus, J. (1991), Colour preference in sport shoes: An informal look. Perceptual and motor skills, 73(2), 613-614.

Valdez, P., Mehrabian, A. (1994), Effects of colour on emotions. Journal of Experimental Psychology: General, 123, 394–409.

Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.H. (2008), Interior colour in healthcare environment, Conference paper 3 TU Symposium, Delft.

Vrij, A., Akehurts, L. (1997), The existence of a black clothing stereotype: The impact of a victim' black clothing on impression formation. Psychology Crime & Law; 2.3: 227-237.

Walton, W.E., Guilford, R.B., Guilford, J.P. (1933), Minor studies from the psychological laboratory of the university of Nebraska. in: Eysenck H.J. A critical and experimental study of colour preferences. The American Journal of Psychology; 54: 385–391.

Whitfield, T.W.A. (1984), Individual differences in the evaluation of architectural colour: Categorisation effects. Percept Mot Sk; Vol 59, 183–186.

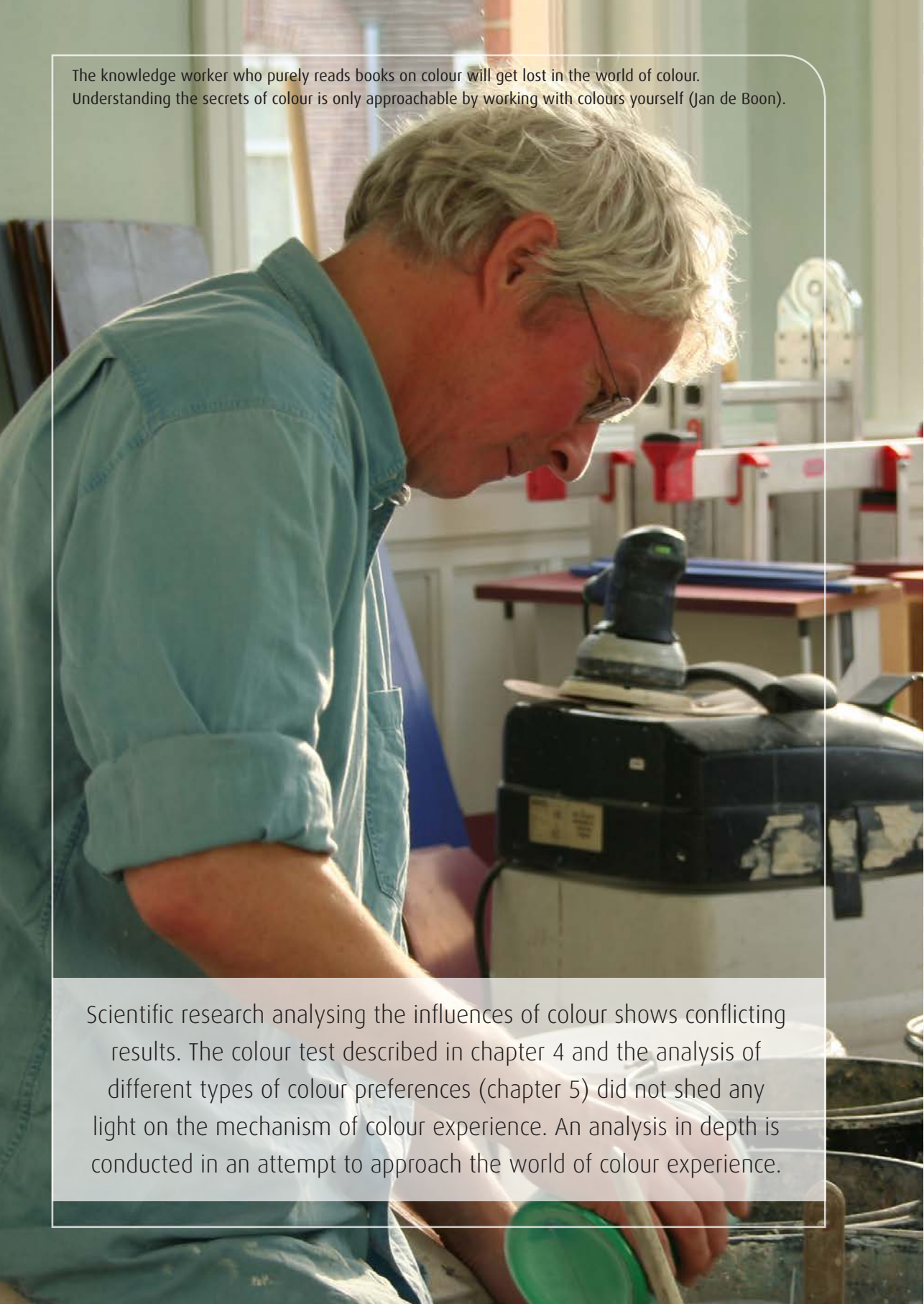
Wilson, G.D.(1966), Arousal properties of red versus green, Perceptual and Motor Skills, 23, 947-949.

Wright B, Rainwater L. (1962), The meanings of colour. J Gen Psychol; 67:89 –99 in Ou, L. C., Luo, M. R., Woodcock, A., Wright, A. (2004), A study of colour emotion and colour preference. Part I: Colour emotions for single colours. Colour Research & Application, 29(3), 232-240.

Zajonc, R.B. (1980), Feeling and Thinking, Preferences Need No Inferences, American Psychologist, Vol 35(2), 151-175.

Zentner, M.R. (2001), Preferences for colours and colour emotion combinations in early childhood. Developmental Science, 4(4), 389-398.

Façade architecture in the mysterious pinewood.



The knowledge worker who purely reads books on colour will get lost in the world of colour. Understanding the secrets of colour is only approachable by working with colours yourself (Jan de Boon).

Scientific research analysing the influences of colour shows conflicting results. The colour test described in chapter 4 and the analysis of different types of colour preferences (chapter 5) did not shed any light on the mechanism of colour experience. An analysis in depth is conducted in an attempt to approach the world of colour experience.

Chapter Six
The experience of colour

To understand how colour influences people and how colour is experienced, it is necessary to make an in-depth analysis how colour influences people physiologically, affectively and cognitively. Because people experience the environment, colour inclusive, with all their senses, the sensory information system will be introduced. This sensory information system could provide a solution for how to measure the experience colour in its totality and is studied in this chapter.

abstract

The experience of colour is a complex phenomenon that it is difficult to define and to measure the influences on people. In the current paint industry three indicators are used to define the qualities of colour: hue, saturation and intensity (HSI) (Castleman, 1998). Colour studies use these terms to define colour qualities. However, it appears that these three colour qualities are too limited to describe colour experience in its totality. The research findings show large differences. People experience their environment, including colour, at different processing levels: physiological, affective and cognitive. A framework with these perspectives is used to learn about the background of colour. Humans experience the coloured environment with all their senses as the human sensory information system is the only system that is responsible for transporting data concerning the connection between the outer environment and the inner human. Each sense focuses on a specific colour characteristic as it appears in nature. As these colour characteristics represent themselves as polarities such as warmth and coldness, harmony and disharmony and light and darkness, they appeal to specific colour contrasts. In their turn these colour contrasts appeal to specified senses. For example, the sense of temperature is sensitive for the warmth-coldness contrast. The connection between twelve natural phenomena, twelve senses and twelve colour contrasts explain the colour experience in its totality. This view shows that the HSI method is too limited, since it only uses three types of colour contrasts. Relying solely on the HSI method may be one of the causes why colour research shows ambiguous results.

6.1 Introduction

Previous research described in the chapters 4 and 5 shows the difficulties of establishing effects of colour on productivity. Colour appears to be a complex and versatile phenomenon that influences people via physiological, affective and cognitive processes and thereby may affect productivity. The goal of the present research is to examine how colour influences people and their productivity and to specify the optimal physical conditions for enhancing productivity. For this reason, an exploration is carried out within three knowledge areas to be able to define the total colour experience. The following questions have been a guide for this search:

1. Physiological level: Which evolutionary developed systems and physiological mechanisms in the eye can be traced determining the way how we see and experience colours?
2. Affective level: Does colour influence emotional and motivational processes and feelings?

3. Cognitive level: How does colour influence the mind and how we think about colour. Can we learn about the mechanism by looking at ancient cultures and applied languages on colour?
   As the focus is purely on seeing and experiencing colours, no attention will be paid to the capacities of recognizing of movement and changes, although this is a fundamental functionality of the human eye. Also colour is a dynamic phenomenon in nature and the human eye is a perfect instrument of vision with the focus on differences. The eye is extremely focused on signal movements. Even in stable situations without any changes in the environment, the eye is searching with so-called cascades for movements. In this chapter we focus on the influences of colour, although it is realised that vision concerns integrated functionalities. In fact colour analysis and coding cannot be isolated from analysis and coding of attributes such as form and motion (Gegenfurtner and Kiper, 2003). In addition, the eye is not developed to observe monochromatic colours, but is always searching for changes and variations in colour.

Due to the complex and elusive character of colour, in addition to experimental research, also other views will be examined to understand the influences of colour. The focus is on the influence of colours through the eye. It could be possible that in addition colours have effects through the human skin, although this has not been demonstrated by experimental research. Cojochen et al (2006) showed there was no acute elevation of body temperature or suppression of melatonin when light was administered to the skin in the popliteal area (Cajochen et al, 2005). In addition, Foster et al (1991), Eastman et al (2000), Lindblom et al (2000) and Wright and Czeisler (2002) showed no effects when bright light is lit behind the knee. In contrast, Campbell and Murphy (1998) found this effect.

As the environment influences people in their development, behaviour, their ways of thinking, also colour influences our behaviour, since colour is an integrated part of the environment. To understand how colour influences people, it is important to understand how colour is experienced. Colour research makes use of the HSI system, with Hue, Saturation and Intensity as features to define the exact colour. The HSI-system is often used in the paint industry (Castleman, 1998) and provides users practical information on what the colour looks like. Other systems used are physical and focus on wavelengths and number of quanta (Van Beek, 1983) or physiological with a focus on the number of red, blue and green photons as the receptors in the human eye are sensitive for these colours (Conway, 2009). The choice of system used in research determines the output. The system used to watch determines the results. In this paper the assumption is that when colour research is based on the three HSI-factors, significant facts can be found related to these factors (Tedford et al, 1977, Valdez and Mehrabian, 1994, Mahnke, 1996, Camgoz et al, 2003). If the HSI-factors are not the only indicators for human experience, conflicting results could be found in colour research and this is exactly the case: colour researches show in many cases conflicting results (Bakker, 2013b, 2013c).

People experience their environment on an unconscious level (Dijksterhuis, 2007). People generally focus on the activities they are doing and not on details in the environment. This is due to the efficient energy system of the human brain: the neurological processes are efficiently organised to minimize the need for energy consumption (Niven and Laughlin, 2008). Although the brain only accounts for 2% of the human bodyweight, it accounts for 20% of the resting metabolism (Attwell and Laughlin, 2001) with a relative high demand for the visual cortex (Wong-Riley, 2010). To minimize this need for energy, the human vision system has developed high efficiency methods to transport and manipulate visual data. James Grimes (1996) demonstrated that the eye registers far less details when subjects are showed nearly the same pictures. This example stresses the dominant role of mental representations in perception (in Gregory, 1998). Another efficiency measure is that looking at areas with the same brightness, the eye

mainly focuses on boundaries of those areas and not on the areas themselves (Fortner and Meyer, 1997; Gregory, 1998). The blind spot test, used by Gerritsen (1972), shows that the human eye completes images without testing exactly all details. The blind spot test shows not only the existence of the blind spot, but also that the human eye completes images which actually do not exist. Gerritsen used as background for the blind spot test a checkered pattern and it can be observed that exactly at the blind spot, the checkered pattern emerges and the eye completes the checkered pattern, which in fact the eye could not see.

People experience colour depending on context and their expectations. Detailed environmental information appears on a conscious level only in situations in which the environment does not fit to our expectations, or if we pay specific attention to it for other reasons. If a tree has violet colours, people are aware of this strange phenomenon because it differs from their expectations of a green tree that they are accustomed to (Vonk, 2003). People consciously pay attention to the violet tree because it is abnormal to their expectations. In hospitals for instance the colour white is often applied to hospital walls. If a wall is pink coloured in a hospital, it will be more striking than if found in a trendy clothing store where striking colours are often applied (Vonk, 2003). The representations stored in the human memory, are connected with contextual information.

The main question

The main question is whether any mechanism exists that more accurately defines the human experience of colour and how people physiologically, affectively and cognitively are influenced.
Related to the physiological processes, insight is needed on how the human eye functions (Figure 1). First, the evolutionary development of the human eye could be useful in understanding the working principles and learning more about colour experience. Next, it could be useful to learn about physiological insights. Related to the affective processes, insight is needed on how people psychologically experience and react on colour. Thirdly, related to the cognitive processes, cultural developments and etymological information about the development of colour words and original meanings are interesting.

The next guide will be followed to find the way how colour influences people (see Figure 1):

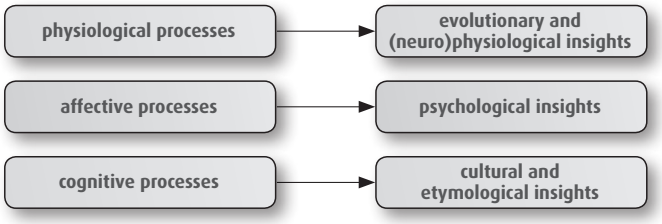


Figure 1: The view on colour: physiological, affective and cognitive view

In the next paragraphs the experience of colour will be discussed separately for the three mentioned views. Each paragraph begins with a question and ends with a conclusion. Lastly, a view is presented to define the human colour experience in a more appropriate way.

6.2 What is the influence of colour on physiological processes?

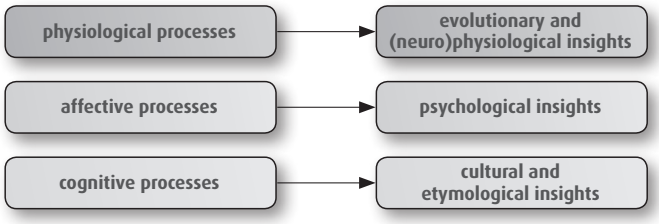


Figure 2: The view on physiological processes

The research question with respect to the physiological processes is: which evolutionary developed systems or (physiological mechanisms in the eye determine the way how we see and experience colours?

6.2.1. Are there any evolutionary developed systems in the human eye which physically influences colour experience?

More than 600 million years ago (Mya period) early organisms evolved with photoreceptors with a light sensitivity (Conway, 2009). These types of vision had purely a cardian and/or shadow detecting function (Lamb et al, 2007). Since they have only one type of photoreceptor these early organisms could not discern any colour. After a development of sensitivity for the yellow (middle waves) and the blue light (short waves) and a long period of dichromatic vision, about thirty million years ago, the trichromatic colour vision of today developed (Nathans, 1999). During this period a gen duplication and modification took place. After this gen duplication and modification, a comparison of the middle and long waves was possible thereby providing the early ancestors of people the ability to see the colour red (Conway, 2009). Scientists in the nineteenth century developed the hypothesis that the gen duplication is a co-evolutionary development connected with the appearance of yellow or orange coloured fruit of tropical trees. More recent ecological evidence shows that these trees such as several members of the family Sapotaceae, are exclusively dispersed by monkeys, with the same colour vision system of trichromacy (Mollon, 1995). The development of trichromacy and the ability to see the colour red was induced by the existence of ripe fruit. Evolutionary, the only reason to see colours is the ability to discern objects when the background is multi-coloured and vary in forms and lightness and to see in complex environments which elements belong together (Mollon, 1995). The early existence of being able to see the middle wavelengths (yellow) is probably due to the fact that these wavelengths had the lowest attenuation through saltwater (Conway, 2013). We hypothesize that the early existence of seeing blue is caused by the need for polarity of seeing yellow, due to the fact that all sensory systems are based on polarities in order to see and experience the world as a totality (Schneider,1987; Goethe, 1981; Bortoft, 2010; Bohm, 1985).

Conclusion

The hu*man* eye is not developed as an instrument to observe colours but to discern objects.

6.2.2 Physiology of the human eye

Which mechanisms in the eye determine the way how we see and experience colours?

All processes are strongly connected to each other and all the organs in the human body cooperate together, therefore it is difficult to separate them. The reason we focus on colour vision by means of different mechanisms and data streams, is to bring some clarity to the different functionalities and the way how mechanisms operate together. As Darwin states 'the eye, with all its inimitable contrivances... could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree...' (Lamb et al, 2007), it is impossible to describe all details of the human eye in a respectful

way. Many excellent researchers as Hering, Helmholtz, Land, Maxwell and Young have made enormous progress giving insight in how people observe colours. However, there are still many questions. After analysing data and mechanisms on the human eye (realizing that the functionality of the human will be simplified), it appears that for the experience of colours two mechanisms are fundamental in observing and experiencing colours. The first mechanism concerns discerning and recognizing objects by means of colour contrast and colour constancy respectively. Colour contrast enables people to discern objects and colour constancy contributes to the ability of recognition. The second mechanism concerns the cooperation between physiological, affective and cognitive processes and forms an intelligent exchange system of visual information located in the central part of the brain (Milner, 1974; Gegenfurtner and Kiper, 2003; Sarter et al, 2006).

Colour contrasts and colour constancy: making comparisons

In the process of seeing colours the ability of seeing distinction is based on detecting contrasts. The eye is extremely focused on detecting different types of contrasts. Even the basic organisation for transformation of information to the brain by neurons is a complex network of thousands or millions connections with other neurons, enabling the ability to discern contrasts. The communication between neurons happens by on and off cells, the so called excitatory and inhibitory cells: if signals of information are too small or too large, an inhibitory process begins, however if the signals are appropriate, excitatory processes forward the information (Hubel, 1990; Kandel et al, 2000). The human eye observes incoming wavelengths not as isolated signals, but observes data in their totality related to their spatial and temporal context (Grossberg, 1994; Grossberg et al, 1997; Conway, 2009). Complex networks of opponent cells, double opponent cells, bipolar cells and horizontal cells all contribute to find these contrasts related to context (Stockman and Brainard, 2010; Conway, 2009). In the retina and in the visual cortex processes of comparison take place of the cone activities to compute these colour contrasts (Conway, 2009). This theme of comparison is recognisable by observing colour in two ways. First, comparisons are made between objects and their context and background by making use of colour contrasts to discern objects. Different types of colour contrast exist, such as: dark-light contrast, colour contrast, warm-cold contrast, complementary contrast, simultaneous contrast, successive contrast, quality contrast and quantity contrast. It appears that these types of contrast enable us to see the nuances in colour. Secondly, the comparisons between new objects and objects in our memory, make use of colour constancy to facilitate recognition.

Colour constancy is achieved by local comparison of light reflections coming from the object and adjacent areas (Hurlbert and, Wolf, 2004; Danilova and Mollon, 2006). The result is that we observe well known coloured objects as the same colour while in reality the colours are different due to different illumination conditions. For example, while looking at a white paper under a tree with greenish light reflections through the green leaves, we just see a white paper. However, a camera makes use of the factual existence of middle wavelengths and registers a greenish coloured image. Under different light conditions objects appear the same and facilitate recognition. Factors, such as memory and learning are the critical and determining factors that contribute to colour constancy. Scientists have long searched for the mechanisms of colour constancy: Helmholtz (1867) wrote about human judgement of colours through the undefined process of the 'unconscious interference'. Hering (1877) emphasized the importance of memory (Zeki and Marini, 1998) and Land and McCann (1971) formulated his retinex theory. Zeki and Marini (1998) indicated the involvement of higher cognitive functions and the predominant role of the cerebral cortex. Recently computations with algorithms define how the primary visual cortex arranges colour constancy (Barnard et al, 2002; Finlayson and Trezzi, 2004; Van de Weijer et al, 2007).

Intelligent exchange of visual information connects physiological, affective and cognitive processes.
The colour information sent from the retina is translated into understandable images and is not transported through one simple stream of factual colour information directly to the visual cortex for decoding, but encounters mediating systems before reaching the visual cortex (Das et al, 2005; Sarter et al, 2006). Two basic pathways transport visual data and transform data into perceptual information: the optical pathway and the energetic pathway.

The optical pathway
In 1860 Helmholtz already argued 'it may often be rather hard to say how much of our perceptions (Anschauungen) as derived by the sense of sight is due directly to sensation, and how much of them, on the other hand, is due to experience and training' (Pollen, 1999). With the terms 'Vorstellung' or 'Idea' he meant all visual images people have in their mind without any present sensory impression and he applied the term 'Perzeption' for an awareness of a direct sensation (Pollen, 1999). Helmholtz believed in the existence of processes that permanently mix the ideas in our memory and present sensory impression. Neurological evidence research has found how neurological networks combine new sensory information with cognitive recognitions (Pollen, 1999). This combination solves the 'stability-plasticity-dilemma': new sensory data is compared to stable memories and learnt expectations but the brain remains flexible enough to process new sensory input (Pollen, 1999). To blend new sensory data with our memory and expectations, brain feedback loops exist between the different portions of the visual brain (V1 till V5 i.e. parts of the visual cortex) and the LGN (Lateral Geniculate Nucleus i.e. the centre relaying visual information from the retina to the visual cortex) in the thalamus (Milner, 1974) which functions as the primary relay centre for visual information (Figure 3).

In 1969 Gerald Schneider assumed an optical system with a separation in the brain of the localization of a stimulus (the 'where' pathway) and the identification of a stimulus (the 'what'- pathway). This assumption appeared to be true. The 'where' pathway appeared to be the so called dorsal pathway (Milner and Goodale, 1995) which sends retinal information concerning localization of a stimulus and goes from the tractus opticus, through the superior colliculus located in the mid brain to the posterior parterial cortex. It is interesting to understand perception and how we experience colour through the 'what-pathway'. The 'what' pathway appeared to be the ventral pathway (Milner and Goodale, 1995) which sends most of the retinal information through the tractus opticus and then through the lateral geniculate nucleus (dorsal part) (LGNd) - which is located in the thalamus - to the inferior temporal cortex (Mishkin et al, 1983; Goodale and Milner, 1992; Gegenfurtner and Kiper, 2003). This ventral pathway sends information concerning presentation, identification, recognition and perception inclusive. Due to our mental representations, objective colour characteristics such as data concerning wavelengths are transformed into labelled colour information. This information system unconsciously influences the psychological and physiological state of people. The centre of the psychological processes is the amygdala (Morris et al, 1996). The thalamus – in which the LGN is located- is directly connected to the amygdala (Das, 2005) and the reticular activating system (Sarter et al, 2006). In the thalamus an exchange of colour information takes place, and actually physiological, affective and cognitive processes cannot be entangled but work strongly together (Figure 3). Also in his book 'Descartes' Error: Emotion, Reason, and the Human Brain' Damasio (1994) indicates this strong connection between physiological, affective and cognitive processes.

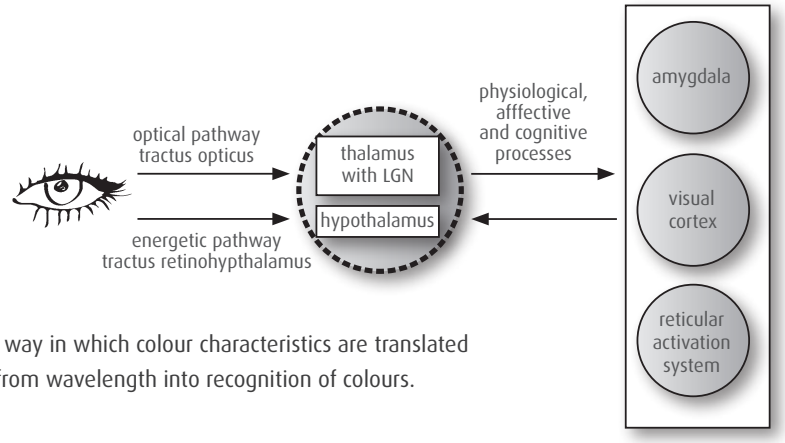


Figure 3: illustration of the way in which colour characteristics are translated into labelled information, from wavelength into recognition of colours.

The energetic pathway

In order to process retinal information very quickly, there is a second path, i.e. the energetic pathway that is stimulated by light. This second pathway was recently discovered in 1990s by researchers as Berson et al (2002, 2003), Foster (2005) and Hankins and Lucas (2002). It appeared that about 1% of the retinal ganglion cells have a specific light sensitivity. This system is not only responsible for the regulation of sleep and circadian rhythms, but in addition sends information, colour information inclusive, through the Reticular Formation- the most influential component of the Ras-system-, located in the brainstem to the ascending arousal system that is responsible for cortical arousal (Garcia-Rill, 2002; Saper et al, 2005; Walusinki, 2006). This rather small part of retinal information directly influences the physiological processes through the hypothalamus and the pituitary gland (Figure 3).

There is a maximum sensitivity for the blue part of the spectrum (420-480 nm) (Foster, 2005; Cajochen et al, 2005). Hankins and Lucas (2002) measured activities at the 576 nm wavelength, and also larger wavelengths that resulted in increased light response to the condition that the wavelengths are bright enough (Berson, 2013). Human unconscious responses to light (pupillary, circadian or neuroendocrine, etc.) are largely mediated by the ganglion-cell photoreceptors. These ganglion cells also draw information from the other photoreceptor types by way of indirect synaptic circuits. This means that these "reflexive" or "non-image-forming" visual responses are actually quite broad in their spectral (colour) tuning (Berson, 2013). Through the energetic pathway humans unconsciously experience colour characteristics.

Through the optical pathway and the energetic pathway objective retinal information is processed through loops encountering our memories – colour memories inclusive- and is transformed into labelled colour information. Due to our memory, objective colour information is transformed into labelled colour information. People do not experience colour in an objective way.

Conclusion:

Seeing colours helps people to discern and recognize objects by means of colour contrast and colour constancy. Neurological systems transform objective colour information into colour qualities, a process located in the visual cortex with strong interference of the amygdala and the reticular activating system. Intern loops blend colour information perceived by the ganglia in the eye with physical, cognitive and emotional memories into colour labels. Seeing and experiencing colours is a result in which physiological, affective and cognitive processes are closely intertwined. Due to our personal characteristics and memories, it is possible that personal reactions on colour stimuli differ.

6.3 Colour and the affective processes

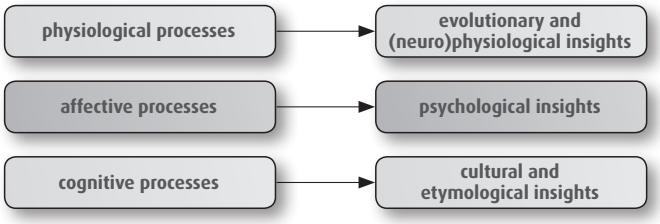


Figure 4: the view on affective processes

The research question with respect to affective processes: What are the effects of colour on affective processes?

Our brain probably encodes the external world by means of symbolic representations of things, creatures and events (Ramachandran, 2006) and therefor the world of colour seems to be extremely difficult to understand. Is it true that our own nature determines which story a colour will tell? Goethe (1810) indicated the central role of the soul in the phenomenological observation when the subjective colour feelings and objective colour quality meet; it is the soul that translates the language of colour. Steiner (1914) mentioned that 'Colour is the language of the soul of the universe'. Also Kandinsky relates the effects of colour directly to the soul. Albers (2006) indicated the fact that colour continuously deceives. Albers wrote: 'First, it should be learned that one and the same colour evokes innumerable readings. And experience teaches that in visual perception there is a discrepancy between physical fact and psychic effect. In visual perception a colour is almost never seen as it really is – as it physically is. This fact makes colour the most relative medium in art'. Birren (1982) writes 'Uniform illumination and uniform brightness in the field of vision may be ideal from an academic standpoint, but they are inconsistent with the natural properties and capabilities of human beings'. Itten (1961) distinguishes the real value of colour and the subjective colour quality as two different phenomena.

Colour directly influences the psyche as colour influences mood and affect (Goethe, 1810; Rosenstein, 1985; Kwallek et al, 1988; Küller et al, 2006, 2009). People do not observe the environment as a collection of objective facts, but rather experience spaces, climate aspects, things and colours subjectively depending on personal experiences, characteristics, mood and constitution. The so called mental representations, a mix of objective factual information and subjective personal interpretations determines our affect (Goethe, 1810; Zeylmans van Emmichoven, 1923; Scheuerle, 1984; Bendin, 2008; Vonk, 2003). Learnt associations and memories contribute to these subjective interpretations. The colour red for instance is associated with energy and blue is associated with calmness. Due to these learnt associations, red feels energetic and blue suggests calm.

Memories determine the way in which we perceive colour (Bendin, 2008). For instance, a person whose parents had a yellow carpet in the bedroom and as a young child the parents provided feelings of safety in the bedroom, the young child may have developed a learnt preference for the same colour of yellow as the carpet because that colour represents feelings of safety. So, mental representations permanently influence consciously or unconsciously the way how we perceive the environment, colours inclusive. This also exists during pre-conscious observation, the so-called subliminal observation - when a stimulus is shown in such a short period, that the observer hasn't been aware of the presentation- the information is being interpreted and judged and has an influence on the affect. When a phobia exists, such as being afraid of snakes and a person observes a picture of a snake subliminally, (i.e. the presentation of the image is so brief as to not see the snake on conscious level), the skin conductance of the person increases (Goleman, 1996). In addition, this happens, even when we say that we are not

afraid of a snake. Cognition – the snake is recognized by means of mental representations - influences the physiological processes while actually not being aware of any snake. In addition, when people experience colours on conscious level or on unconscious level, mental representations have influence how they experience colours. These mental representations can be genetically based mechanisms or innate learning systems. It is interesting to ask to what extent the intrinsic colour quality expresses itself in these mental representations.

Conclusion

Both at a conscious level and on an unconscious level the perception and experience of colour is modulated by psychological processes, both at an affective and cognitive level.

6.4 Colour and the cognitive processes: Ancient cultures and applied language on colours

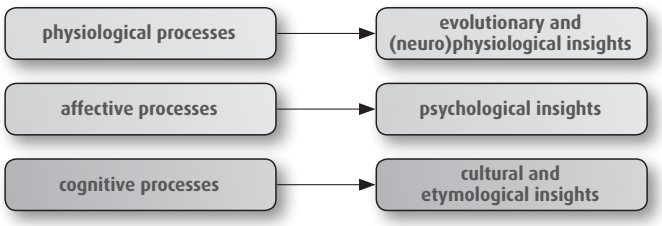


Figure 5: The view on cognitive processes

The research question concerning the cognitive processes is: How does colour influence cognitive processes and what can we learn by looking at ancient cultures and applied language on colour?

In 1836 Emerson wrote: 'Nature always wears the colours of the spirit'. Maxwell (1872) searched on an approach for the world of colour. He wrote: 'If the sensation which we call colour has any laws it must be something in our own nature that determines the form of these laws....The science of colour must therefore regarded as essentially a mental science' (in Zeki and Marini, 1998). Both a poet and a mathematical physicist indicate the role of the spirit and the mind in the relationship to colour. To learn about this role, a focus on the ancient cultures and the applied language is practical, because cultures and applied languages enfold information about mental development.

For ancient cultures, such as Ancient Greece or Mesopotamia, there was no separation between the inner world of thoughts and the outer worldly experience. The inner and outer worlds were combined and inner and environmental experience embraced each other. During the beginning of the 5th century A.D, the period of Saint Augustine, a modulation of thoughts appeared: people needed physical evidence for beliefs by seeing something in reality in the outer world. Inner and outer world became separated areas (Sennett, 1992). Additionally, in language the development of separatism developed: in the ancient Hebrew language the verb has the leading role with the accents on connection and the process. In modern languages the noun is accentuated which underlines the separatism between things (Bohm, 1985).

These characteristics of the old cultures show the two ways people looked at colour. In the old culture colour was not seen as a separated and standalone phenomenon, but was perceived as a broader description taking the process into account. For example, in ancient Egyptian the word 'green' (wadj) described the processes of growing, flourishing, or being fresh, unspoilt, raw, young or healthy. One word expresses different colours. The word 'red' (desjer) meant intense red (as blood) and yellow red as barley (Loose, 2010). Also in the ancient Greek time these processes were not described as separated aspects. The word 'chloros' for instance used in ancient Greek documents that modern Greek colour theorists translate as 'green', did not exactly define a colour but was used as connotations that can be related to green. In the Ilias honey is 'chloros', in de Odyssey a nightingale is 'chloros'. Pindaros

mentioned ‘chloros’ as dew and Euripides used ‘chloros’ to represent tears and blood. ‘Chloros’ was a term not used to define the colour green, but rather to describe conditions as fresh, wet and live and as such this term was used to describe processes. In Old Testament biblical or ancient traditional literature colour was not conceived as a standalone phenomenon. Often, the information given is not about a specific colour but the degrees of lightness and darkness (MacLaury, 2005). Only white, red and green are distinguished by name, whereas yellow and blue terms are wanting (see jewish encyclopedia). In primitive cultures colours were not accentuated with specific colour names, but related to the things and materials that represented the colour such as soil, bile or rendeer buck (MacLaury, 2005). Etymology shows this relationship such as the colour ‘brown’ coms from ‘bheros’ that means ‘dark animal’ or the Greek word ‘phrynos’ that also means brown animal.

In old cultures, people observed a colour not as a separated characteristic, but experienced the quality of the colour within their intense connection between the inner and outer world (Zajonc, 1993). In history the meeting between the inner human light and the outer light is a central theme. The Bhagavad-Gita, Homer, Empedocles, Plato and the evangelist Matthew, all speak about the meeting of the two lights as a mediating process between the inner world and the outer world (Zajonc, 1993). In ancient cultures light is a central issue that is expressed by the polarity of yellow and blue. It is intriguing how the colours yellow and blue are used in the ancient cultures. In the Odyssey Homer mentions the copper coloured sky and the sea coloured as wine. In the countless descriptions of Homer of the sky and the sea, linguists never found the name of the colour blue, but only found the iron or copper coloured sky and a black, white, grey, purple or wine coloured sea. The Greek word ‘kyanos’ is associated with the blue colour of lapis lazuli, but is only used to describe darkness. The Greek conceived blue as a quality of darkness (Zajonc, 1993). This is recognized in etymological data. Blue, induced from the Germanic word ‘blao’ is possibly related to the Latin ‘flavus’ that means yellow. The Old Saksich word for blue, blao, meant not only blue, but also yellow. In addition, ‘blao’ is connected to the old Greek word ‘mélas’ that means black. The old Norwegian word for blue ‘blār’ means both blue and black (Van der Sijs, 2010). It appears that in the ancient times the colour blue was not considered as this colour is today, but merely the colour of darkness. In addition, the appearance of blue being connected to the appearance of yellow indicates the importance of the polarity yellow - blue and as such light- darkness. This phenomenon is mentioned by Gage (1995) who indicates that colour-usage is not always understood by colour science. He mentions that the old French word ‘bloi’ both meant blue and yellow, and the term ‘sinople’ used in the Middle Ages, both meant red and green. Gage also describes that in non-European languages white has assimilated to black. The polarities of the usage of colour terms play an important role.
Bortoft (2010) speaks about ‘the organizing idea’ how we actually observe and as mentioned before, Helmholtz used the term ‘perzeption’. It is not purely the physical qualities that determine the impressions of personal images, but it is the organizing idea that determines what is seen. This organizing idea is dependent on time and space. Concerning the influence of time, Graves developed the model of Spiral Dynamics described by Beck and Cowan. The bio psychological Spiral Dynamics model connects time through history with specific types of drives, thinking methods, structures and processes (Beck and Cowan, 2004). Beck and Cowan developed the so called v-memes, (value attracting meta memes) that are units of cultural information (Fiandt et al, 2003). These v-memes can be conceived as psycho cultural DNA that influences our ways of thinking. These ideas are comparable with the ideas of Rupert Sheldrake concerning the morphogenetic fields: these fields contain genetic information for the development of form, behaviour and instinct (Bos, 2009). Time and culture influence the ‘idea’ that determines the inner world and forms the key factors of how humans experience colour. In its turn this ‘idea’ determines the mental representations that influence the way how people experience colour.

Conclusion

Ancient cultures did not discern colours by using specified colour names. In many cultures no specified colour names are found in the applied language. Ancient cultures perceived the intrinsic quality of colour relating to their connection between inner- and outer world and descriptions are mainly used to define the differences of darkness and lightness levels. In modern culture inner and outer world are separated. In addition, in modern culture colour is conceived as a separated cue. At present, mental representation determine the way how people experience colour.

6.5 Intermezzo: Intriguing blue, what is its secret?

The early ancestors of the hominids possessed dichromatic vision and saw some colour due to two types of cones with peak sensitivities in the yellow (middle wavelength) and the blue (short wave length) spectrum (Conway, 2009). The ability of seeing the colour blue is an intriguing phenomenon. To avoid the possibilities of oxidative damage due to chemical reactions induced by short wavelength illumination with the free radical cells, the eye had developed different protection methods to attenuate the short wave lengths (Lamb, 2013). The lens (Stockman et al, 1999; Margrain et al, 2004) attenuates the short wave lengths and near and on the fovea, an area of the retina is covered with macular pigment that also attenuates short wavelengths (Conway, 2009). It appears that human eye systems were developed to detect the colour blue in an appropriate way avoiding the risk of oxidative damage caused by the high energy of short wavelengths.

In addition, the percentage of the blue cones is low, 8%- 10% of all cones, compared to the percentages of the red and green cones (Stockman and Sharpe, 1999). In the fovea, the centre part in the eye with high acuity, the number of the blue cones amounts only 3% (Mollon, 1995) and in the foveola, the middle centre in the fovea with the highest acuity, there are no blue cones at all (Mollon, 1995; Stockman and Sharpe, 1999; Conway, 2009). So, with the part of our eye that enables us to see sharply, the blue cones do not contribute much. The pigment rhodopsin however enables the blue cone to discern the blue light appropriately: rhodopsin is very sensitive for blue light (Fortner and Meyer, 1997). Additionally, the short wave cones play a limited role in perceiving luminance (Stockman and Sharpe, 1999; Fortner and Meyer, 1997) and the short wave cones only relate, in a limited way, visual data to their spatial and temporal context to judge the totality (Stockman and Sharpe, 1999). As such, the functionality of the blue cones is remarkable as they play a minor role in observing totality and context. In addition, the short wave cones have genetically a different structure (Nathans and Hogness, 1986).

In the period of dichromaticy the yellows and the blues could be discerned. These yellows and blues are interesting colours. In contrast to Newton who stated that colours can be conceived as separated parts of the light, Goethe was convinced that colours appear in the dynamic process between the polarities light and darkness. This polarity of light and darkness is the central theme in his colour theory. Darkness is not conceived as a passive phenomenon of nonexistence of light, but as an influencing polarity of light. There must be both light and darkness as absolute preconditions for the existence of colour. Aristotle mentioned the phenomenon that colours are created by the 'blends of light and darkness' (Birren, 1969). In 1810, Goethe wrote: 'Yellow is a light which has been dampened by darkness; blue is a darkness weakened by light'. This basic colour effect can easily be observed during the day. When sunrays enter a room through cut glass edges and shine on the walls, one can discern the yellow and blue lines showing the edges of the glass. The same effect can be observed in a swimming pool with daylight with a white bottom and painted black lines. Looking down at the black lines, one sees at the white-black boundary blue lines and at the black-white boundary the colour yellow while physically at the bottom of the swimming pool no yellow or blue coloured lines exist. Looking from the opposite direction, both blue and yellow colours will change depending on the direction of looking at the dark lines.

Due to the fact that the blue cones genetically are differently structured and differently located in the retina than the red and the green cones, and that blue cones don't play any role to relate spatial and temporal context to judge the totality, it could be hypothesised that the blue cones only exist as a polarity to the yellow ones to balance the polarity of light and darkness. Etymologically, in ancient languages, the colour blue plays a minor role and blue is often used as a description of darkness. The focus of attention was the amount of light and even etymologically the original words for blue meant 'yellow' as yellow stood for light. Polarity is a basic phenomenon in the human sensory information system, for example one feels something as hard versus soft, warm versus cool, dynamic versus static. This is comparable with the on and off functionalities in the neuronal systems. The need for polarity may be the cause why people can see the colour blue. However, this is only a hypothesis.

6.6 Intrinsic colour quality

Is it the colour itself and as such its intrinsic colour quality that influences people?

People are unconsciously influenced by the intrinsic colour quality that we cannot influence (Goethe, 1810; Steiner, 1909). Physiological, affective and cognitive processes are closely intertwined and may be mental representations predominate how people react on colour. To what extent are people directly influenced by the intrinsic colour quality and what mental representations are constructed by the intrinsic colour quality? For instance, it can be questioned as to whether the activating effect of red or the calming effect of blue are intrinsic colour qualities themselves or purely learnt mental representations.

Natural themes: twelve polarities

To answer this question, a move to the direction of the colour world itself and how humans experience this world is in order. This colour world cannot be quantitatively measured. After collecting knowledge on colour from different perspectives, it appears that it is fundamental to conceive colour as a natural phenomenon, a view that is mentioned among others by Goethe (1810), Frieling and Auer (1961), Müller and Spillmann (1987) and Goldbeck-Löwe (2011). The intrinsic colour quality can be defined by carefully observing how colour expresses itself in nature, because the origins of the colour world begin with nature. By taking a closer look at nature, twelve natural phenomena with their polarities can be observed, realizing that this approach has a hypothetical character:

1. Colour appears or vanishes depending on light conditions. In the black of the night, colour disappears but colour also disappears when light is very intensive. People recognize this process as seen in under- and overexposed photographs. In living creatures a total lack of light is recognisable in the appearance of the colour white as can be seen in roots of plants or bulbs as the onion and the tulip, or in the skeletons which do not receive direct light. Appearance and disappearance concerns the polarity of to be or not to be.
2. Colour is a sign of life that can be recognised in the saturation of colours. No saturation of colour shows only black and white tones. For the life processes both light and warmth is necessary, however, not too little and not too much. Is there no light or warmth, but also is there an abundance of light or warmth, no life is possible. When there is no warmth at all, but only coldness, we recognize white in snow and ice. But also at the highest temperature, iron for instance will turn into a white coloured mass. The colour of death is black, as carbon existing out of dead materials is black. Only when life begins, colour reveals itself. As soon as springtime arrives, colour reveals itself very gently, more saturated in summer and burning in autumn, before fading away in wintertime. Living humans are connected with colour. When people do not feel well, one speaks of "off-colour" and when people die, colour disappears and the dead body grows pale. These phenomena show the polarity of growing and deceasing.

3. Colour is a dynamic phenomenon. Some colours in nature draw near, while others draw back. A field of yellow sunflowers or red roses seems closer and more defined than a field of violet lavender. The furthest row in a row of mountains appears more blue and atmospheric in the open landscape. This phenomenon is known as the colour perspective, a phenomenon that is strengthened by the functionality of the human eye (i.e. chromatic aberration 3). Colour perspective concerns a polarity between approaching and retreating.
4. The appearance of colours in plants is often accompanied by its complementary colours. A fresh green bud of a leaf often shows the complementary colour purple (Kadam, 1974; Goethe, 1981; Pavek et al, 1992; Jarret et al, 1993; Winthrop and Simon, 2000). In the spring, many yellow flowers appear, the daffodil, celandine and the crocus, but also violet flowers appear as the crocus and the violet. Another phenomenon is the coloured shadows, as we see the complementary colour of a light source. In addition we see the complementary colour in the so called afterimages, after looking at a certain colour for some time. Colour and its complementary colour are shown as polarities in the colour circle.
5. Colour in nature shows the status of the cradle to grave process and reveals the status of this process such as young, light green grass in the spring, green to dark green grass in the summer, dry, yellow grass in the autumn. We see green, then yellow, then red strawberries that turn brown when overripe. This polarity shows the conditions from fresh to decay.
6. Nature shows large amounts of striking and showy colour combinations and different harmonies. The most well-known colour natural phenomenon is the rainbow which like other atmospheric phenomena, shows colour in its natural brightness. Some colour combinations are more harmonious than others. This phenomenon is known as The Law of Müller, based on the natural brightness of colours. Aemilius Müller, professor at the Academy of Winterthur in Switzerland, discovered a universal colour preference based on the natural brightness of colours. The opposite phenomenon that colours do not correspond with their natural brightness is known as 'inversion'.The phenomenon that colour presents itself in a wide variety of colour combinations shows the polarity harmony and disharmony.
7. Colour is a phenomenon which appears in the interaction between light, darkness, material and the human eye. Goethe wrote: 'Yellow is a light which has been dampened by darkness; Blue is a darkness weakened by light' (Goethe, 1810; Zajonc, 1976; Ribe, 1985; Goldbeck-Löwe, 2011). Every colour has its own typical brightness: the highest level of brightness is shown in citron yellow, the lowest in blue violet (Gerritsen, 1972). This phenomenon concerns the polarity of light and darkness.
8. Colour can be experienced as warm or cool colours. The red and yellow colours are generally experienced as warm colours. The blue and bluish green colours are perceived as cool colours (Birren, 1950; Sivik, 1973; Jacobs and Suess, 1975; Bellizi et al, 1983; Mahnke, 1996; Stone and English, 1998; Tofle, 2004; Kaya and Epps, 2004). This concerns the polarity of warmth and coldness.
9. Colour shows order. Colour appears in daylight, in minerals and metals and living creatures in a natural order. Sulfur for instance is white when cold, but at 21 degrees it changes to the colour yellow, and at higher temperatures it turns to red (Frieling and Auer, 1961). Also the process of tempering steel shows white, yellow, gold-yellow, red, purple, violet, dark blue, blue, light blue, then grey. In the growing process of plants this sequence of colours is observed: in the dark earth, the seed and the roots are white, when receiving some light, the young plant turns yellow, then to yellow green. With more sunlight the plant colours change to green (Frieling and Auer, 1961; Frieling, 1968). This process, the intensification of colours (Steigerung), is first mentioned by Goethe and is found in his colour circle (Goethe, 1810; Goldbeck-Löwe, 2011) characterised by order and the appearance of intervals. Here the polarity of intensification is observed.

10. Colours appear with their own unique character. One colour is more elementary than another one, but all colours show their own typical hue. All together they create the so called colour space (Frieling and Auer, 1961; Hardin, 1988; Heller, 1990). Colour shows the polarity from distinction to non-identification by means of the hue.
11. Colours have symbolic meaning for different cultures in the world (Frieling, 1968; Gage, 1995; Mahnke, 1996) which in general seems to be comparable. Goethe (1810) tried to describe the sensual – moral aspects of colour, trying to find the objective inner quality. Later on other colour scientists used different colour systems such as the systems of Itten, Hering, Young, Munsell and Frieling to express the human colour experience basics (Birren, 1969) . All colour systems search for the intrinsic colour quality. Looking at applied systems, etymologically how colour words have developed, and philosophically some central issues can be discerned: yellow is the sign of light as blue is the sign of darkness. Green is the sign of the living world of plants as red is the sign of the living world of animals and people. Violet is a combination of red and blue, combining human life with darkness, causing mystic experience. Light green a combination of yellow as sign of light with green as sign of the world of the plants shows itself in the young leafs. All these signs show the deeper sense of colour. Colour shows the polarity from the deeper sense to showing no sense at all.
12. Colour immediately communicates with the adjacent colours. In nature colour is never experienced as a separated colour with separated colour qualities, but we experience colour relative to other colours. Colours interact and influence each other in their appearance (Chevreul, 1855). As such colour can never be experienced as an isolated phenomenon but only in context. This is recognisable in the polarity between separated identity and placement in context.

As people are part of nature, nature and a natural environment consequently has positive influence on people (Ulrich, 1981; Hartig et al, 1991; Ulrich et al, 1991; Kaplan, 1993, 1995, 2001; Frumkin, 2001; Van den Berg et al, 2003; Groenewegen et al, 2006; Van den Berg et al, 2007; Berman et al, 2008). It can be hypothesized that naturally applied colours with aforementioned the twelve characteristics, attribute to the most optimal conditions for people and in addition the optimal productive work environment. During a long period of millions of years, people and their ancestors are exposed to the twelve characteristics of colour in nature. There seems to be a general and universal trend on how colour influences the human psyche (Goethe, 1810; Adams and Osgood, 1973; Heller, 1990; Crozier, 1999; Ou et al, 2004). This universal trend shows stable connections between colour categories and meanings. In addition, trends can be observed in the development of applied colour words in language. Berlin and Kay (1969) formulated a hypothesis regarding the existence of semantic universals in colour lexicons and a constrained order in evolutionary development of basis colour vocabularies. Research has shown that applied colour names in languages follow an evolutionary pattern. The terms 'black' and 'white' are present in all languages. If a language shows three colour terms, the third one is 'red'. Languages with four colour terms always show either green or yellow and with five colour terms show both green and yellow. If six terms are used, the sixth term is blue and if seven terms the seventh term is brown. If more than seven colour terms are found, different orders of terms are observed for other colours such as pink, purple, orange and grey. In their search for causes Berlin and Kay supposed the existence of biological systems such as response patterns of non-opponent and opponent cells in the LGN providing information concerning hue, brightness and saturation (Kay et al, 1991). In addition, in epigenetic research learnt facts about stimuli belonging to the environment can be shown at least two generations later. Dias and Ressler (2013) recently showed that odour fear conditioning with mice can be inherited for two sequent generations at behavioural, neuroanatomical and epigenetic levels. This phenomenon covered by epigenetics, could possibly result in culturally learnt patterns concerning colour.

Preferences for colours show patterns that can be related to among other things culture, age, sex, education and human characteristics such as being emotional or being technical (Bakker et al, 2013c). Regarding culture, evidence exists that environmental conditions physiologically influence how people see colour. In 1973 Bornstein showed that people living in the regions concentrated near the equator had more yellow macular pigmentation than people living close to the poles. More macular pigmentation causes a decrease of the amount of short wavelengths reaching the retina. These people are less sensitive to blue and less able to distinguish blue from green (Hardin, 1988). It is possible that the effect of colour on people shows a certain order, due to the existing patterns in comparable semantic values of colours among different cultures, the application in languages and colour preferences. This order is originated in the colour itself and its intrinsic colour quality. The way colour influences the human psyche can be found in the twelve characteristics of colour. It seems to be that the intrinsic colour quality forms a large share of the human mental representations. The differences in the representations are due to local, cultural and temporal factors and individual differences such as personal characteristics and memories.

The existence of genetically based preferences" and/or "innate learning mechanisms is discussed in some colour research studies (Hurlbert and Ling, 2007). Hurlbert and Ling argue that the development of trichromacy caused a stronger colour preference for red in females rather than males as females were in accordance with the hunter-gather-theory supposed to gather ripe red coloured fruit. Indeed, for language and speech, evidence is found for the genetic influence by the gen FOXP2 (Fisher and Scharff, 2009), however language and speech are cognitive functions which is not purely the case for experiencing colours. Moreover, we cannot make simple linkages between researches on colour or on language or speech, as normal adults require more time to mention the name of a colour than to read the names of that colours presented in words (Mayfield Ligon, 1930. Moreover, Taylor et al (2012) showed evidence that the theory of Hurlbert and Ling is not consistent. Also colour associations can vary depending on culture (Madden et al, 2000). In addition, Block (2003) does not exclude the possibility of innate behavioural differences between the experience of different colours, although he asks questions about the existence of well-known associations. No genetic influence is found related to colour experience until now.

6.7 In search for a method to define the influence of the intrinsic colour quality.

6.7.1 A short view on colour research

Does colour research result in valid and reliable data?

To understand the exact influence of colour on people, valuable colour research is conducted and a large amount of interesting findings are available. However, the findings on colour frequently show conflicting results due to the complex environmental conditions, the complex test processes, human interactions, and the complexity of colour itself. In these studies two ways are generally followed to learn about the influences of colour: at the one hand subjects are asked about the influences and at the other hand effects on people's performances and physiological effects are measured. In the case of asking subjects about the influences of colour it is unclear whether the answers to questions (often mentioned in questionnaires) have anything to do with the intrinsic colour quality itself. Bakker et al, 2013(a) conducted research in a real-life setting during regular meetings and showed that the answers given do not concern factual information on the applied colour(s) but primarily address the personal, social and environmental contextual situation (see Chapter 7). Psychological phenomena such as social desirability, cognitive dissonance and a lack of exactness, muddle the truth on colour (Foddy, 1993; Vonk, 2003; Bakker et al, 2013b).

It appears that the second option to measure facts is more fruitful to tell something about the effects of colour. In colour research two topics are measured: different type of performances and physiological values. Measuring performances is complicated and difficult to define and to compare, not only due to the type of performances but also due to different contextual factors. Although the research shows trends with patterns based on larger number of subjects (Mikellides, 1990; Elliot et al, 2007; Küller et al, 2009), physiological measurements appear to be a more valid method for colour research due to factual and objective physiological data. The measurements in physiological colour research show quantitative data that at first glance seem to be comparable. A large amount of indicators is used such as different types of brainwaves (alpha to theta), galvanic skin conduction, blood pressure and heartbeat. A closer look on this research reveals weaknesses such as an unclear relationship between colour and physiological reaction, unclear and/or unknown physiological values, a weak explanation of physiological measurements, weaknesses in the measurement and an artificial, not natural application of light colours such as shining light beams with high frequency into the eye (Wilson, 1966; Ali, 1972; Jacobs and Hustmeyer, 1974; Noguchi and Sakaguchi, 1999; Kim, 2004; Yoto, 2007; Küller et al, 2009: Rajae-Joordens, 2011; Steer-Reeh, 2012; Kim et al, 2012; Yamashita et al, 2012). An extensive overview of the research applying physiological measurements is found in attachment A. It appears the quantitative data derived from physiological measurements does not provide clear information on the relationship of colour and physiological reaction. Some examples of physiological research on colour that does raise questions:

- Physiological measurements are used which not clearly indicate the relation between colour and colour effect. Kim (2004) indicates changes in beta and gamma waves and Küller et al (2009) in delta waves, as evidence of attention or arousal caused by colours, whereas beta waves primarily indicate intrinsic motivation related to motoric activity (Lal and Craig, 2001), gamma waves primarily are connected to very short stimuli (Hoogenboom, 2006) and delta waves primarily show activity in the auditory cortex (McGee et al, 1993; Lakatos et al, 2005). Further research and study is needed to develop a clear relationship between the effects of colour and a physiological reaction showing changes in brainwaves.
- Measurements are applied that (at this moment) cannot be clearly interpreted. Ali (1972) and Yoto (2007) used the AAC value. The AAC Value in general is an indicator of attention. However, what this AAC value exactly means in relation to the colour effects is not yet clear.
- Unknown measurements are used as the COH Value (coherence, i.e. correlation between respiration and heart rate; Rajae, 2011) while the general known RSA (Respiratory sinus arrhythmia) is not applied.
- Explanations concerning physiological reactions are unclear. Küller et al (2009) explains why subjects show a decrease of their heartbeat while seeing red as a reaction of such an excited state that this causes a paradoxical slowing heartbeat. However, physiologically a decrease of the heart beat always goes together with a decrease of arousal.
- Unclear measurements and weaknesses exist such as no or unclear categorisation of alpha waves, lacking data concerning the localization of electrodes, uncontrolled light and/or colour conditions, low numbers of subjects and combining methods as heartbeat, brainwaves and GSR with different reaction times.

It is questionable if completing questionnaires in psychological research or measuring physiological processes tell the truth about the effects of colours.

6.7.2 Twelve characteristics of colour and the twelve senses

Colour, context, test method and a diversity of measurements complicate the interpretation of findings. Perhaps, the twelve characteristics of colour which form the intrinsic colour quality in nature can function as a better guide for understanding a clearer relationship between colour and colour effects. According to Steiner (1909, 1910, 1911) people have twelve senses: four bodily senses (focusing on what), four senses which provide information about the environment (focusing on how) and four mental senses (focusing on why). Humans experience the environment with these twelve senses. Schneider (1987) translated what information is provided by which sense concerning the built environment. Each sense can be conceived as a lurch between two polarities. Depending on the features of the stimulus there is movement between the two polarities i.e. movement between warmth and coldness, form and motion and light and darkness. An overview of the twelve senses with their primary targets is shown in Table 1. It has to be mentioned that the concept of the twelve senses is an hypothetical approach to understand the sensory information system although evidence such as modern neurological research (Dijksterhuis, 2007) is growing on this concept.

Table 1: The twelve senses as mentioned by Steiner and Schneider and primary targets

table

physical senses	affective senses	cognitive senses
touch experience of bodily boundaries	**smell** observing purity	**proportion** recognising order
life experience of bodily constitution	**taste** experiencing modulation	**gestalt** recognising unities
movement experiencing targeted movement	**sight** connecting sight and insight	**symbol** recognising deeper values of unities
balance searching for balance	**temperature** recognising the difference between sympathy and not sympathy	**identity** recognising others learning about one's own identity

All twelve senses provide colour information as colour forms a part of the environment. Colour primarily is observed by the sense of sight as we see colour through the eyes. However, colour feeds the other senses which can be recognized through language and expressions such as warm colours (sense of temperature), soft colours (sense of touch) and sweet colours (sense of taste) (Soesman, 2005). Because people experience the outer world, colour inclusive, by means of the twelve senses, which all measure polarities, this could be a solution to understand the intrinsic colour quality in its totality. As a hypothesis, a model can be developed showing the connection between the twelve characteristics of the intrinsic colour quality such as these appear in nature and which are mentioned before (see paragraph 6.6) and the twelve senses with their polarity (see Table 2).

Table 2 : Relation between the twelve characteristics of the intrinsic colour quality as viewed in nature and the twelve senses with their character (This table is based on detailed information on the senses and asks for a short explanation: Senses are mainly sensitive for one specified stimulus and provide information about the status between two polarities. The sense of touch primarily provides sensory information about the existence of the outer world, providing additionally evidence of the own existence. The sense of life learns about someone's constitution. The sense of movement provides information about the situation between standstill and movement. The sense of balance helps to find balance. The sense of smell learns about the quality of the situation in the process and provides information about value what is healthy and good. The sense of taste is sensitive for modulation and harmony which can be found in nature. The sense of sight primarily focus on the differences between light and darkness. The sense of temperature indicates on warmth to coldness differences. The sense of proportion provides information on the level of order. The sense of gestalt focuses on unities which are recognisable due to learning processes. The sense of symbol provides background information about original meanings and symbols and explains about the sense. The sense of identity explains about the existence of other individuals and learns about one's own uniqueness. See for further explanation Bakker and De Boon, 2012).

table

Sense	Nature	Polarity
The four physical senses		
touch	colour appears or vanishes depending on light conditions	to be - not to be
life	colour appears with different saturation	growing - decreasing
movement	ccolour in nature is dynamical	form - motion
balance	colour is accompanied by its complementary colour	balance - unbalance
The four affective senses		
smell	colour reveals the state of the process	fresh - deceased
taste	colour appears in all kind of harmonies	natural - not natural
sight	colour appears between light and darkness	light - darkness
temperature	colour appears between warmth and coldness	warmth - coldness
The four cognitive senses		
proportion	colour apears in order and augmentation	chaos - order
gestalt	colour appears with a unique character	distinct - undistinct
symbol	colour appears in more or less expression	sense - no sense
identity	colour appears in totality	seperation - coherence

A connection is made between the mentioned colour characteristics and the human senses with their polarities. Humans experience the environment by means of their senses and each sense is sensitive for a specified polarity: for example the sense of sight is sensitive for the polarity light and dark. A mechanism to define colour experience in its totality could make use of this sensory information and their sensory polarities inclusive.

In paragraph 6.6 the twelve colour characteristics are shown accompanied by their colour polarities. It is generally accepted that colour shows itself by means of contrasts such as well-known and often used complementary contrast, warm-cool contrast and quality contrast. Colour contrasts are equivalent to polarities. Because senses all are sensitive for polarities, they are sensitive for contrasts. As such a match is possible between the twelve senses and colour contrasts. The sensory information system can be applied as mechanism to define the total colour quality (Table 3).

Table 3 : Relationship between the twelve characteristics of intrinsic colour quality as viewed in nature, the twelve senses and the twelve colour contrasts. (Explanation on contrast types: The sense of touch provides insight in existence/non-existence and mentions whether there is colour or no colour. Life reveals itself by showing colours by means of the level of saturation. When life vanishes, colours are growing pale and become unsaturated. The sense of life focus on the level of saturation. The sense of movement is linked to the motion contrast and the sense of balance shows itself by means of colours and their complementary colours finding balance in the opposite colours of the colour wheel. The sense of smell show the quality contrast and the polarity between pure and murky colours. The sense of taste is sensitive for harmony and as such for the harmony contrast. The sense of sight is sensitive for the light-darkness contrast as primary function of the eye. The sense of temperature reacts on the warm coldness contrast. The sense of proportion focus on the different tension between colours. The sense of gestalt is sensitive for unity and recognition and focuses on hue contrast. The sense of symbol provides information of the meaning and as such the sense itself, focusing on the contrast sense-no sense. The sense of identity shows the connection to adjacent colours that shows itself by means of the simultaneous contrast.

table

Sense	Nature	Colour contrast
The four physical senses		
touch	colour appears or vanishes depending on light conditions	colour - not colour contrast
life	colour appears with different saturation	saturation contrast
movement	ccolour in nature is dynamical	motion contrast
balance	colour is accompanied by its complementary colour	complementary contrast
The four affective senses		
smell	colour reveals the state of the process	quality contrast
taste	colour appears in all kind of harmonies	harmony contrast
sight	colour appears between light and darkness	light darkness contrast
temperature	colour appears between warmth and coldness	warm coldness contrast
The four cognitive senses		
proportion	colour apears in order and augmentation	Potential contrast
gestalt	colour appears with a unique character	hue contrast
symbol	colour appears in more or less expression	sense - no sense **contrast**
identity	colour appears in totality	simultaneous contrast

This mechanism with the twelve colour contrasts could provide a possibility to analyse and define in a more detailed way how colour influences people. This detailed way generates not only information about HSI-values (hue being information provided by the sense of gestalt, saturation being information provided by the sense of life and intensity being information provided by the sense of sight) but in addition takes the information of the other nine senses into account. By using all twelve senses people working in science such as researchers or in companies such as the paint industry are able to define colour in its totality and as such they are able to define colour experience in its totality. For architects, designers, employees in home decoration stores, shops for interior design or paint shops, this can be helpful for communication with customers such as residents and users of buildings such as offices and hospitals. People in general speak about sweet colours when they for instance want to decorate a nursery room or they speak about warm colours want they like to create a warmer atmosphere in their homes. It would be practical to support this communication supporting the way people in general speak about colours. Because the HSI-factors don't provide any information on qualities such as sweetness or warmth, a method would be practical that not only informs about the qualities, but in addition all sensory information. The twelve colour contrasts (Figure 6 and 7) provide this information and it is possible to create new colour cards and colour fans that can be applied in contacts between suppliers and users to select colours. This facilitates the communication and supports understanding what users and customers prefer.

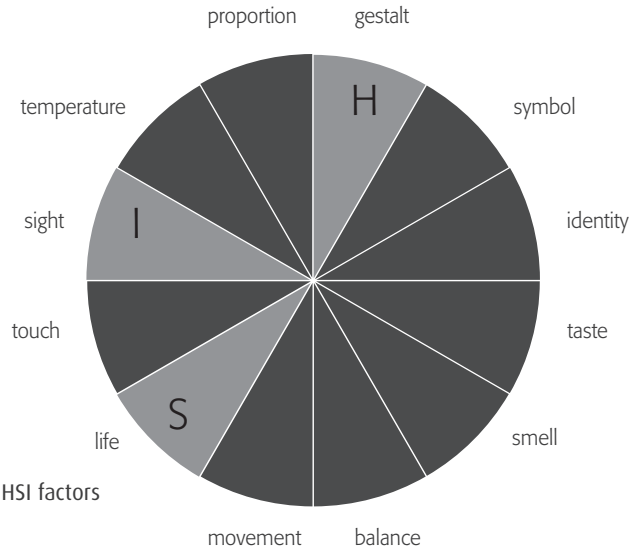


Figure 6: HSI factors only provide sensory information collected by the sense of gestalt, sense of life and the sense of sight.
There is missing data concerning the other nine senses

Senses providing information on HSI factors

Senses providing Colour sensory information not explained in the HSI factors

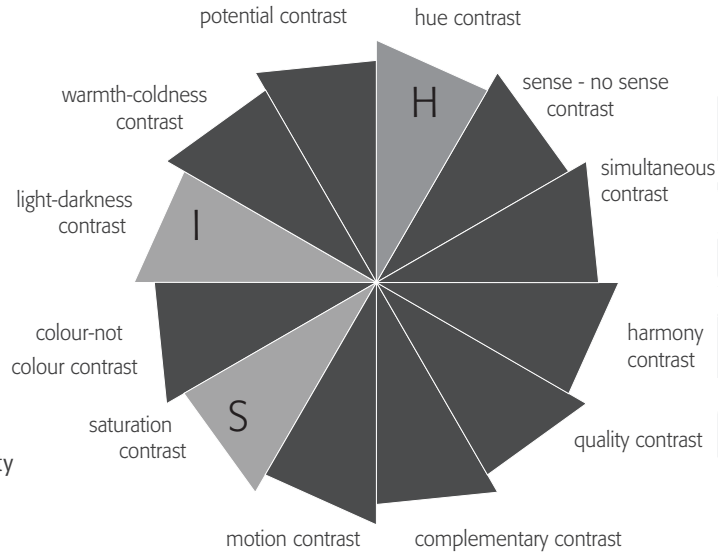


Figure 7: HSI factors only focus on the three colour contrasts and the other nine colour contrasts are missing

Applied HSI values

New values to reach totality

Research on colour shows many conflicting results. The method using all sensory information of the twelve senses, is a possible solution to understanding the influence of colour in its totality. It can be concluded that the present method to define the colour by means of the HSI-values should broadened to include the twelve indicators based on the twelve senses developed by Rudolf Steiner (see Figure 8 and 9). It is recommended to introduce a colour system focusing on all twelve colour contrasts. These colour contrasts are directly connected with the appearance of colours in nature (see Figure 8).

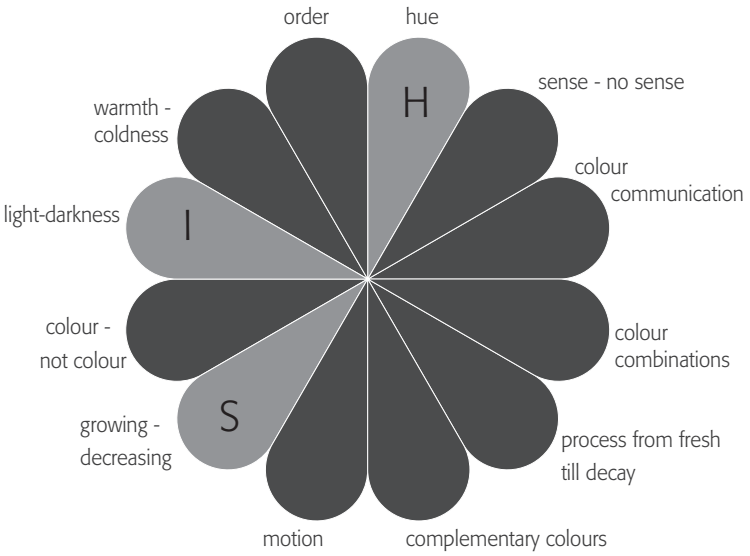


Figure 8: HSI factors related to natural phenomena (see chapter 4.5)

Nature phenomena related to HSI factors

Nature phenomena not explained in the HSI factors

6.8 Conclusion

The main question of this analysis on colour was whether any mechanism exists that accurately defines the human experience of colour and how physiological, affective and cognitive processes are influenced. Next, it is examined whether this analysis provides a practical guideline for applying colours in the physical environment that contribute to productivity.

In an evolutionary perspective seeing colours is developed as an instrument to discern objects and not primarily to see colours. On both a conscious and unconscious level mental representations of colour permanently influence how people experience colour. Also time and culture influence the character of the mental representations which determine how people experience colours. As thinking in modern times is such an important activity, these mental representations are determining how people experience colour. Because people primarily focus on the activities they are doing, they experience the physical environment most often unconsciously. At this level, the intrinsic colour quality has an influence on people and their productivity. This intrinsic colour quality presents itself in nature by means of twelve themes. It appears that the way colour shows itself in nature creates the optimal circumstances for the productive environment.

Colour is a natural phenomenon that presents itself by means of twelve themes as they appear in nature, that are in accordance with twelve polarities and twelve colour contrasts. These colour contrasts are observed by the twelve senses (Figure 11). These twelve senses appear to be a mechanism to express colour experience in its totality. The current view to define colour by means of the three factors hue, saturation and intensity (HSI-system) is too limited as it only describes three colour contrasts. Using the sensory information mechanism including the twelve senses, can be a helpful mechanism that provides information how colour influences physiological, affective and cognitive processes.

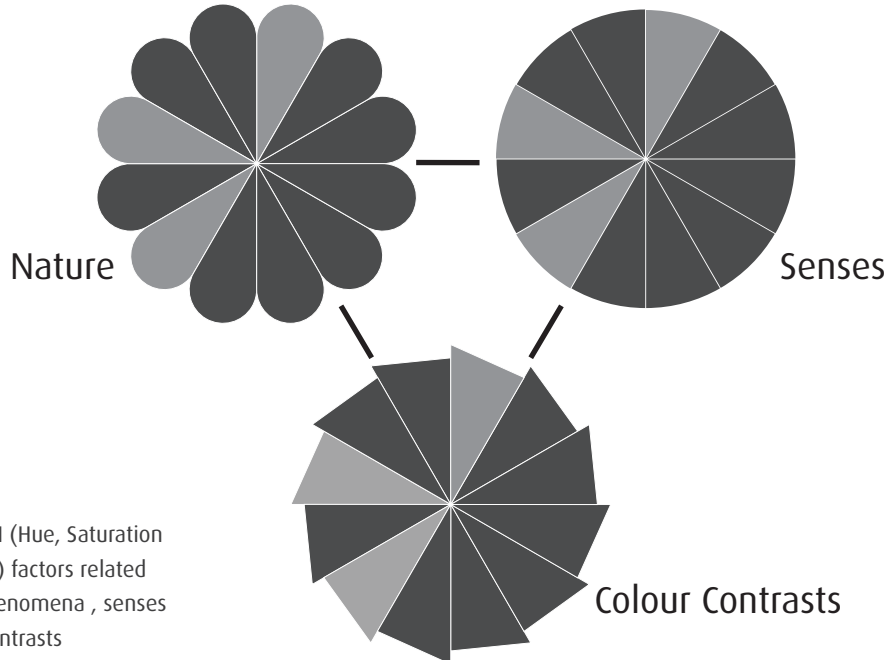


Figure 11: HSI (Hue, Saturation and Intensity) factors related to natural phenomena , senses and colour contrasts

Finally a small remark to show some modesty concerning the versatile and complex topic colour. It seems to be that the little man in our head telling us 'Hi there, that is magenta' or 'Hi there, that is the magenta of your grandma's hat' is an intriguing creature, and even a creature without any exactly located residence. (Ramachandran 2006).

6.9 Back to productivity

In order to understand the experience of colour from a broad perspective, this chapter mainly focused on the experience of colour in general and not particular on the effects of colour on productivity. Looking back at this analysis and the other chapters the next conclusions can be made about the relationship between colour and productivity:

1. No significant effects of colour could be found on perceived productivity, cohesion and wellbeing in the real life setting test of chapter 4. Most subjects mentioned that they did not have any preference concerning the red, the blue or the reference room and most subjects (65%) had the opinion that colour was not of importance for productivity. In the study on colour preferences (chapter 5) the colour 'white' is the most preferred colour: 41% of the participants chose white for the office and 30% chose white for the meeting room. Many participants stated that they had no colour preference: concerning the office 16% and concerning the meeting room 22% of the participants.
2. After selecting studies about the effects of colour on productivity with the selection criteria application of colour on walls in rooms without light manipulations and without other applications such as pictures, studies show the next results. Küller et al (2008) carried out three experiments focusing on a coloured versus grey condition and a red versus blue condition. No significant effects were found on clerical and creativity tasks. In addition, Ainsworth et al (1993) did not find any significant relationships of three colour conditions red, blue/green and white on typing performance. Analysing the effects of nine monochromatic colours in offices (1996) Kwallek found no significant differences between the effects of the colours. Only, in the white condition significantly more errors were made. In addition, in 1990 Kwallek et al found significant differences concerning a proofreading

task in a white, red and green coloured room: in the white condition significantly more errors were made than in the red condition. In her other studies (1997 and 2007) Kwallek found differences between high and low screeners but no significant differences between the effects of the colours red, blue/green and white. It is interesting that Küller et al (2008) found significant differences between subjects with a positive or negative mood.

3. In chapter 6 indications are found that physiological measurements do not give clear insights how colour influences can be related to the different measured values such as heart beat, pulse rate and brainwaves.

The studies show only in a limited way that environmental colours significantly influence productivity. Many people are not convinced of the importance of the applied environmental colours regarding the influence on productivity and more than half of the participants in the test on colour preferences choose for white or the option 'no colour preference' concerning their colour preferences for the office and the meeting room. However, in many circumstances people experience the physical environment unconsciously (Dijksterhuis, 2007). Since they are not or hardly aware of the effects they often do not express clear colour preferences and think that colours are not important. Since colour influences mood (Goethe, 1810; Rosenstein, 1985; Kwallek et al, 1988; Kwallek et al, 1997; Kuller, 1981; Küller et al, 2006, 2009), this effect may in turn influence productivity (Van der Voordt, 2010). In chapter 2 it is mentioned that four moods namely contemplation, awareness, collectiveness and social observation contribute to productivity. Due to the fact that colour significantly influences mood, it can be assumed that colour in addition influences productivity.

We live in a society in which we want to find quick solutions for everything without too much thinking or time for reflexion. The world of colour is different. There seems to be no one to one relationship between productivity and colour – this relationship is to the best of our knowledge never found- and there is no simple short term solution to know which colours should be applied in practice. For optimising knowledge productivity it might be worthwhile to explore if a harmonious environment with a balance between structure and variety, in which people feel psychologically safe and are nurtured in their identity leads to optimising productivity.

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Maybe because colour is too complex and too dynamic, the literature did not show unambiguous evidence how colour influences productivity. No 1:1 relationship came to the fore between colour and productivity regarding different types of work activities. However, colour is a component of the physical environment that highly contributes to the atmosphere of the environment and as such affects satisfaction and mood, both variables that are related to productivity. So, indirectly a relationship between productivity and colour seems plausible. One of the theories shows that the total environment is perceived by the twelve senses, which are connected to twelve colour contrasts.

6.10 References

http://www.jewishencyclopedia.com. dd. 30 july 2013

Adams, F.M., Osgood, Ch.E., (1973), A Cross-Cultural Study of the Affective Meanings of Colour, Journal of Cross-Cultural Psychology, Vol. 4(2), 135-156.

Albers, J. (2006), Interaction of Colour, Yale University, New Haven, Connecticut.

Ali, M.R. (1972), Pattern of EEG recovery under photic stimulation by light of different colours. Electroencephalography and Clinical Neurophysiology, 33, 332-335.

Attwell, D., Laughlin, S.B. (2001), An Energy Budget for Signaling in the Grey Matter of the Brain Journal of Cerebral Blood Flow and Metabolism, Vol 21, 1133–1145.

Bakker, I.C., De Boon, J, (2012), Zorg voor mens en omgeving, Het zintuig als maatstaf, Aedes-Actiz kenniscentrum Wonen - Zorg, Wilco Amersfoort.

Bakker, I.C., Van der Voordt, D.J.M., De Boon, J., Vink, P., (2013a), Red or blue meeting rooms: does it matter?: The impact of colour on perceived productivity, social cohesion and wellbeing, Facilities, Vol. 31(1/2).68 – 83.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J. (2013b), The use of questionnaires in colour research in real-life settings: in search of validity and methodological pitfalls, Theoretical Issues in Ergonomics Science, 1-13.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J., Bazley, C. (2013c). Colour preferences for different topics in connection to personal characteristics. Colour Research & Application. Online version.

Barnard, K., Cardei, V., Funt, B. (2002), A Comparison of Computational Colour Constancy Algorithms—Part I: Methodology and Experiments With Synthesized Data, IEEE Transactions on Image Processing, Vol 11(9), 972-983.

Beck, D.E., Cowan, Ch. C. (2004), Spiral Dynamics, Waarden, leiderschap en veranderingen in een dynamisch model. Altamira-Becht Haarlem.

Bellizi, J.A., Crowley, A.E. , Hasty, R.W. (1983), The effects of colour in store design, Journal of Retailing, Vol. 59(1), 21-45.

Bendin, E. (2008), Individuelle Stereotypen-Beobachtungen zur Präferenzfrage. III, Internazionales Dresdner Architektursymposium "Lehren, Gestalten, Lernen". Dresden.
Berlin, B., Kay, P.(1969), Basic Colour Terms, Berkeley and Los Angeles: University of California Press.

Berman, M. G., Jonides, J., Kaplan, S. (2008), The cognitive benefits of interacting with nature. Psychological science, 19(12), 1207-1212.

Berson, D.M., Dunn, F.A., Takao, M. (2002), Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock, Science Vol 295, 1070-1073.

Berson, D.M. (2003), Strange vision: ganglion cells as circadian photoreceptors, TRENDS in Neuroscience, Vol 26(6), 314-320.

Berson, D.M.(2013), personal email contact 11 November 2013.

Birren, F. (1950), Colour Psychology and Colour Therapy. McGraw-Hill Book Co.

Birren, F.(1982), Light colour & environment, Van Nostrand Reinhold Company, New York.

Birren, F.(1969), Principles of colour, Van Nostrand Reinhold Company, New York.

Block, N. (2003), Mental paint, In Reflections and Replies: Essays on the Philosophy of Tyler Burge edited by Martin Hahn and Bjorn Ramberg, MIT Press, 1-34.

Bohm, D. (1985), Heelheid en de impliciete orde, Lemniscaat Rotterdam.

Bornstein, M.H. (1973), Colour vision and Colour naming, in Hardin, C.L. (1988), Colour for Philosophers, Unweaving the Rainbow, Hackett Publishing Company, Indianapolis/Cambridge.

Bortoft, H. (2010), The Wholeness of Nature, Lindisfarne Press and Floris Books, Edingburgh.

Bos, A. (2009), Hoe de stof de geest kreeg, De evolutie van het ik, Uitgeverij Christofoor, Zeist.

Campbell, S.S. and Murphy, P.J. (1998) Extraocular circadian phototransduction in humans. Science 279, 396–399.

Cajochen, Ch, Münch, M., Kobialka, S., Kräuchi, K., Steiner, R., Oelhafen, P., Orgül, S., Wirz-Justice, A.(2005), High Sensitivity of Human Melatonin, Alertness,Thermoregulation, and Heart Rate to Short Wavelength Light, The Journal of Clinical Endocrinology & Metabolism, 90(3):1311–1316.

Camgöz, N., Yener, C., Guvenc, D. (2003), Effects of hue, saturation, and brightness: Part 2. Color Research and Application, 29, 20–28.

Castleman, K. R. (1998), Concepts in imaging and microscopy: color image processing for microscopy. Biological Bulletin, 100-107.

Chevreul, M.E. (1855), The Principles of Harmony and Contrast of Colours, and Their Applications to the Arts (2 ed.). London: Longman, Brown, Green, and Longmans. (English translation)

Conway, B.R.(2009), Colour Vision, Cones, and Colour-Coding in the Cortex. The Neuroscientist, Vol 15(3), 274-290.

Conway, B.(2013), personal email contact 21 august 2013.

Crozier, W.R. (1999),The meanings of colour: preferences among hues, Pigment & Resin Technology, Vol. 28 (1),6 – 14.

Damasio, A.R. (1994), Descartes' Error: Emotion, Reason, and the Human Brain, AVON BOOKS, Putnam Berkley Group, Inc., New York.

Danilova, M.V., Mollon, J.D. (2006), The comparison of spatially separated colours, Vision Res 46(6–7), 823–36 in Conway, B.R.(2009), Colour Vision, Cones, and Colour-Coding in the Cortex. The Neuroscientist, Vol 15(3), 274-290.

Das, P., Kemp, A.H., Liddell, B.J., Brown, K.J., Olivieri, G., Peduto, A., Gordon, E., Williams, L.M.(2005), Pathways for fear perception: Modulation of amygdala activity by thalamo-cortical systems, NeuroImage 26, 141 – 148.

Dias, B.G., Ressler, K.J.(2013), Parental olfactory experience influences behavior and neural structure in subsequent generations, Nature Neuroscience, doi:10.1038/nn.3594.

Dijksterhuis, A. (2007), Het slimme onderbewuste, denken met gevoel. Amsterdam: Uitgeverij Bert Bakker, 33, 53, 74–79, 95, 102.

Eastman, C.I. et al. (2000), Failure of extraocular light to facilitate circadian rhythm reentrainment in humans. Chronobiol. Int. 17, 807–826.

Elliot, A.J., Moller, A.C., Friedman, R., Maier, M.A. and Meinhardt, J. (2007), Color and psychological functioning: the effect of red on performance attainment , Journal of Experimental Psychology, Vol 136 (1), 154-68.

Emerson, R.W. (1836), website http://oregonstate.edu/instruct/phl302/texts/emerson/nature-emerson-a.html viewed at 19072013.

Frumkin, H. (2001). Beyond toxicity: human health and the natural environment. American journal of preventive medicine, 20(3), 234-240.

Fiandt, K., Forman, J., Erickson Megel, M., Pakieser, R.A., Burge,S. (2003), Integral Nursing: An Emerging Framework for Engaging the Evolution of the Profession, Nursing Outlook, Vol 51(3), 130- 137.

Finlayson, G.D. Trezzi, E.(2004), Shades of Gray and Colour Constancy, Colour and Imaging Conference, 12th Colour and Imaging Conference Final Program and Proceedings, 37-41(5).

Fisher, S.E., Scharff, C (2009), FOXP2 as a molecular window into speech and language, Trends in Genetics, Vol 25(4), 166-177.

Foddy, W. (1993), Constructing Questions for Interviews and Questionnaires: Theory and Practice in Social Research, 2–6. William; Cambridge University Press.

Fortner, B., Meyer, Th.E. (1997), Number y Colours, A guide To Using Colour To Understand Technical Data, Springer-Verlag New York, Inc.

Foster, R.G.(2005), Neurobiology: Bright blue times, Nature 433, 698-699.

Foster, R. G., Provencio, I., Hudson, D., Fiske, S., De Grip, W., Menaker, M. (1991), Circadian photoreception in the retinally degenerate mouse (rd/rd). Journal of Comparative Physiology A, 169(1), 39-50.

Frieling, H.(1968), Das Gesetz der Farbe, Musterschmidt-Verlag, Göttingen, Zürich, Berlin, Frankfurt.

Frieling, H., Auer, X. (1961), Mensch-Farbe-Raum, Angewandte Farbenpsychologie, Verlag Georg D.W. Callwey Münschen, dritte verbesserte und engänzte Auflage.

Gage, J.(1995), Colour and Culture,in Lamb, T., Bourriau, J. (1995), Colour, Art and Science, Cambridge University Press, Cambridge.

Garcia-Rill, E.(2002), Chapter 4, Mechanisms of Sleep and Wakefulness, in Lee-Chiong, T.L., Sateia, M.J., Carskadan, M.A. (2002), Sleep Medicine, published by Hanley & Belfus Inc Philadelhia, 31-39.

Gegenfurtner, K.R., Kiper, D.C. (2003), Colour Vision, Annu.Rev. Neurosci, 28, 181-206.

Gerritsen, F. (1972), Het fenomeen kleur, de nieuwe kleurenleer gebaseerd op wetmatigheden van kleurperceptie, Cantecleer bv, de bilt.

Goldbeck-Löwe, H. (2011), Der Farbenstreit Goethe-Newton, in Wolfschmidt, G.(Hg.),(2011), Farben in Kulturgeschichte und Naturwissenschaft, Beiträge zur Geschichte der Naturwissenschaften, Hamburg.

Goleman, D. (1996), Emotionele intelligentie; Uitgeverij Contact, Amsterdam/Antwerpen.

Goodale, M.A., Milner, A.D.(1992), Separate visual pathways for perception and action, T.I.N.S., Vol 15(1), 20-25.

Gregory, R.L. (1998), Eye and Brain, Oxford University Press, Oxford.

Groenewegen, P. P., Van den Berg, A. E., De Vries, S., Verheij, R. A. (2006), Vitamin G: effects of green space on health, well-being, and social safety. BMC public health, 6(1), 149.

Grossberg, S. (1994), 3-D vision and figure–ground separation by visual cortex. Percept Psychophys 55:48–120 in Pollen, D.A. (1999), On the Neural Correlates of Visual Perception, Cerebral Cortex, Vol 9(1), 4-19.

Grossberg, S., Mingolla,E., Ross, W.D. (1997), Visual brain and visual perception: how does the cortex do perceptual grouping? Trends in Neurosciences, Vol 20(30), 106-111.

Hankins, M.W., Lucas, R.J.(2002), The Primary Visual Pathway in Humans Is Regulated According to Long-Term Light Exposure through the Action of a Nonclassical Photopigment, Current Biology, Vol 12(3), 191-198.

Hardin, C.L., (1988), Colour for Philosophers, Unweaving the Rainbow, Hackett Publishing Company, Indianapolis/ Cambridge.

Hartig, T., Mang, M., Evans, G. W. (1991), Restorative effects of natural environment experiences. Environment and behavior, 23(1), 3-26.

Heller, E. (1990), Kleur, Symboliek, Psychologie, Toepassing (1990), Inleiding en Hoofdstuk 5, Het Spectum, Utrecht, 13-2- and 83-103.

Hoogenboom, N., Schoffelen, J. M., Oostenveld, R., Parkes, L. M., Fries, P. (2006), Localizing human visual gamma-band activity in frequency, time and space. Neuroimage, 29(3), 764-773.

Hubel, D. H.(1990), Visuele informatie, Schakelingen in onze hersenen. Valkenburg Offset BV, Ect, original title: Eye, Brain and Vision, The Scientific American Library, United States.

Hurlbert, A, Wolf K.(2004), Colour contrast: a contributory mechanism to colour constancy. Progress in Brain Research 144:147–60 in Conway, B.R.(2009), Colour Vision, Cones, and Colour-Coding in the Cortex. The Neuroscientist, Vol 15(3), 274-290.

Hurlbert, A.C., Ling, Y. (2007), Biological components of sex differences in colour preference, Current Biology, Vol 17 (16), 623-625.

Itten, J. (1961), Kunst der Farbe, Seemanverlag Leipzig, 23.

Jarret, R.L., Vuylsteke, D.R, Gawel, N.J., Pimentel, R.B., Dunbar, L.J.(1993), Detecting genetic diversity in diploid bananas using PCR and primers from a highly repetitive DNA sequence, Euphytica, Vol 68(1-2), 69-76.

Jacobs, K.W. Hustmeyer, F.E. (1974), Effects of four psychological primary colours on GSR, Heartrate and respiration rate, Perceptual and Motor Skills, 38, 763-766.

Jacobs, K. W. and Suess, J. F. (1975), Effects of Four Psychological Colours on Anxiety States. Perceptual and Motor Skills, Vol. 41, 201-210.

Kadam, B.S. (1974), Patterns of Anthocyanin Inheritance in Rice V. Purple Plant, Indian Journal of Genetics and Plant Breeding, Vol 34 (1), 100-117.

Kandel, E.R., Schwartz, J.H., Jessell, Th.M. (2000), Principles of Neural Science, Fourth Edition, McGraw-Hill Companies, United States.

Kaplan, R. (1993), The role of nature in the context of the workplace. Landscape and urban planning, 26(1), 193-201.

Kaplan, S. (1995), The restorative benefits of nature: Toward an integrative framework. Journal of environmental psychology, 15(3), 169-182.

Kaplan, R. (2001), The nature of the view from home psychological benefits. Environment and Behavior, 33(4), 507-542.

Kay, P., Berlin, B., Merrifield, W,(1991), Bio cultural Implications of Systems of Colour Naming, Journal of Linguistic Anthropology, Vol 1(1), 12-25.

Kaya, N., Epps, H.H. (2004), Relationship between colour and emotion, a study of college students, College Student Journal, 396-405.

Kim, J.Y. (2004), Interior Colour Design Using Psychophysiological Responses Towards User Oriented Smart Environments, Thesis Yonsei University, South Korea.

Kim, T.H., Song, J.K., Jeong, G.W, (2012), Neural Responses to the Human colour Preference for Assessment of eco-friendliness: A functional Magnetic Resonance Imaging Study, Int. J. Environ. Res., 6(4):953-960.

Küller, R., Mikellides, B, Janssens, J.(2009), Colour, Arousal, and Performance, A Comparison of Three Experiments, COLOUR Research and application, Vol 34 (2), 141-152.

Küller, R.,Ballal, S., Laikea, T., Mikellides, B., Tonellod, G. (2006), The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments, Ergonomics, Vol 49(14), 1496-1507.

Kwallek, N., Lewis, C.M., Robiens, A.S. (1988), Effects of Office Interior Colour on Worker' Mood and Productivity, Perceptual and Motor Skills, Vol.66 (1) 123-128.

Lakatos, P., Shah, A. S., Knuth, K. H., Ulbert, I., Karmos, G., Schroeder, C. E. (2005). An oscillatory hierarchy controlling neuronal excitability and stimulus processing in the auditory cortex. Journal of neurophysiology, 94(3), 1904-1911.
Lal, S. K., and Craig, A. (2001), A critical review of the psychophysiology of driver fatigue. Biological psychology, 55(3), 173-194.

Lamb, T., Bourriau, J. (1995), Colour, Art and Science, Cambridge university Press, Cambridge.

Lamb, T.D., Collin, S.P., Pugh, E.N.(2007), Evolution of the vertebrate eye: opsins, photoreceptors, retina and eye cup. Nature Reviews, NeuroScience, Vol 8, 960-975.

Lamb, T.D. (2013), personal email contact 20 July 2013.

Land, E. H.,McCann, J. (1971), Lightness and retinex theory. JOSA, 61(1), 1-11.

Lindblom, N., Heiskala, H., Hätönen, T., Mustanoja, S., Alfthan, H., Alila-Johansson, A., Laakso, M. L. (2000), No evidence for extraocular light induced phase shifting of human melatonin, cortisol and thyrotropin rhythms. Neuroreport, 11(4), 713-717.

Loose, J. (2010), personal email contact 4 nov. 2010.

MacLaury, R.E. (2005), So-Called Brightness in Colour Ethnography: Potentials for LCD Technology in Fieldwork and Categorization Research, Cross-Cultural Research, 39, 205-227.

Madden, T. J., Hewett, K., Roth, M. S. (2000), Managing images in different cultures: A cross-national study of color meanings and preferences. Journal of international marketing, 8(4), 90-107.

Mahnke, F. (1996), Colour, Environment, and Human Response. New York: Van Nostrand Reinhold.

Margrain, T.H., Boulton, M., Marshall. J., Sliney, D.H. (2004), Do blue light filters confer protection against age-related macular degeneration?, Progress in Retinal and Eye Research, Vol 23 (5), 523-31.

Mayfield Ligon, E. (1930), A genetic study of colour naming and word reading, The American Journal of Psychology, Vol 44 (1), 103-122.

McGee, T., Kraus, N., Killion, M., Rosenberg, R., King, C. (1993), Improving the reliability of the auditory middle latency response by monitoring EEG delta activity. Ear and hearing, 14(2), 76-84.

Mikellides, B. (1990), Color and Physiological Arousal. Journal of Architectural & Planning Research, 7(1), 13 - 20.

Milner, A.D., Goodale, M.A. (1995), The visual brain in action, Oxford Psychology Series, Second Edition, Oxford University Press, USA.

Milner, P.M. (1974), A model for visual shape recognition, Psychol Rev 81:521–535 in Pollen, D.A. (1999), On the Neural Correlates of Visual Perception, Cerebral Cortex, Vol 9(1), 4-19.

Mishkin, M., Ungerleider, L.G., Macko, K.A.(1983), Object vision and spatial vision: tow cortical pathways, T.I.N.S. 6, 414-417.

Mollon, J.(1995), Seeing Colour in Lamb, T., Bourriau, J. (1995), Colour, Art & Science, Darwin College Lectures, Cambridge University Press, 127-150.

Morris, J.S., Frith, C.D., Perretti, D.I., Rowland, D., Young, A.W., Calder, A.J., Dolan, R.J.(1996), A differential neural response in the human amygdala to fearful and happy facial expressions, Nature 383, 812 – 815.

Müller, A., Spillmann, W. (1987), Color order and aesthetics : the oeuvre of Dr. Aemilius Müller : the Bertha and Karl Leubsdorf Art Gallery, Hunter College.

Nathans, J., Thomas, D., Hogness, D.S.(1986), Molecular Genetics of Human Colour Vision: The Genes Encoding Blue, Green, and Red Pigments, Science, Vol 232, 193-202.

Nathans, J.(1999), The Evolution and Physiology of Human Review Colour Vision: Insights from Molecular Genetic Studies of Visual Pigments, Neuron, Vol 24, 299-312.

Niven J.E., Laughlin S.B. (2008), Energy limitation as a selective pressure on the evolution of sensory systems. J Exp Biol.,211:1792–1804.

Noguchi, H., Sakaguchi, T.(1999), Effect of Illuminance and Colour Temperature on Lowering of Physiological Activity, Applied Human Science, Journal of Physiological Anthropology, 18 (4), 117-123.

Ou, L.C., Luo, M.R., Woodcock, A., Wright, A., (2004), A study of colour emotion and colour preference. Part I: Colour emotions for single colours, Colour Research & Application, Vol 29 (3), 232–240.

Pavek, J.J., Corsini, D.L., Love, S.L., Hane, D.C., Holm, D.G., Iritani, W.M., James, S.R., Martin, M.W., Mosley, A.R., Ojala, J.C., Stanger, C.E., Thornton, R.E. (1992), Ranger Russet: a long Russet Potato Variety for Processing and fresh Market with Improved Quality, Disease Resistance, and Yield, American Potato Journal, Vol 69 (8), 483-488.

Pollen, D.A. (1999), On the Neural Correlates of Visual Perception, Cerebral Cortex, Vol 9(1), 4-19.

Rajae-Joordens, R.J.E. (2011), The effect of coloured light on Valence and Arousal, Investigating Responses Through Subjective Evaluations and Psycho-Physiological Measurements, Chapter 5, in J. Westerink et al. (eds.), Sensing Emotions, Philips Research Book Series 12, Springer Science+Business Media B.V.

Ramachandran, V.(2006), Het bewustzijn, Een korte inleiding, (original title: The Emerging Mind), Bagas & partners, Nijmegen.

Ribe, N.M. (1985), Goethe's critique of Newton: A reconsideration, Studies in History and Philosophy of Science Part A, Vol 16 (4), 315-335.

Rosenstein, L.D.(1985), Effect of colour of the environment on Task Performance and Mood of males and females with high or low scores on the scholastic aptitude test, Perceptual and Motor Skills, Vol 60(2) 550-550.

Saper, C.B., Scammell, Th.E, Lu,J. (2005), Hypothalamic regulation of sleep and circadian rhythms, Nature, 437, 1257-1263.

Sarter, M., Bruno, J.P., Berntson, G.G.(2006), Reticular Activating System, Encyclopedia of Cognitive Science (1999-2013), John Wiley and Sons, Inc.

Scheuerle, H.J. (1984), Die Gesamt-Sinnes-Organisation. Überwindung der Subjekt-Objekt-Spaltung in der Sinneslehre, 2. neubearb. A. Thieme, Stuttgart.

Schneider, G.E. (1969), Two visual systems, Brain mechanisms for localization and discrimination are dissociated by tectal and cortical lesions, Science 163 (3870), 895-902.

Schneider, W. (1987), Sinn und Un-Sinn, Umweltt Sinnlich Erlebbar Gestalten in Architektur und Design. Wiesbaden und Berlin: Bauverlag GMBH, 43, 106.

Sennett, R. (1992), The Conscience of the Eye, Design and Social Life of Cities, W.W. Norton & Company, New York, London.

Sivik, L. (1973), General and Applied Research on Colour Perception, Proceedings of the Lund Conference, Dowden, Hutchinson & Ross, Stroudsburg, PA, 181–197.

Soesman, A (2005), De twaalf zintuigen, leraren van de mensheid, Uitgeverij Vrij Geesteleven, Zeist.

Steer-reeh, A., (2012), Wirkung von farbigem Licht auf die Herzfrequenzvariabilität und den Puls-Atem-Quotienten gesunder Probanden (Inaugural dissertation Eberhard Karls Universität zu Tübingen).

Steiner, R. (1909, 1910, 1911), Anthroposophie – Psychosophie – Pneumatosophie, Berlijn, 1909-1910,1911, GA 115.

Steiner, R. (1914), Buildings will speak, Dornach june 17, 1914 in Howard, M.(1998), Art as Spiritual Activity, Rudolf Steiner's Contribution to the Visual Arts, Anthroposophic Press, United States of America.

Stockman, A., Sharpe, L. T., Fach, C.(1999), The spectral sensitivity of the human short-wavelength sensitive cones derived from thresholds and colour matches, Vision Research 39, 2901–2927.

Stockman, A., Sharpe, L. T. (1999), Cone spectral sensitivities and color matching. Color vision: From genes to perception, 53-88.

Stockman, A., Brainard, D.H. (2010), Colour Vision mechanism, in the OSA Handbook of Optics (3rd edition, M. Bass, ed), McGraw-Hill, New York, 11.1-11.104.

Stone, N. J., English, A. J. (1998), Task type, posters, and workspace colour on mood, satisfaction, and performance. Journal of Environmental Psychology,18(2), 175-185.

Taylor, Ch., Clifford, A., Franklin, A. (2012), Colour Preferences Are Not Universal, Journal of Experimental Psychology: General, Advance online publication. doi:10.1037/a0030273, 1-13.

Tedford, W. H., Bergquist, S.L., Flynn, W.E. (1977), The Size-Color Illusion, Journal of General Psychology, Vol. 97, no.1, 1977, pp. 145-149. in Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Tofle, R.B., Schwartz, B., Yoon, S. and Max-Royale, A. (2004), Colour in Healthcare Environments:
A Critical Review of the Research Literature, The Coalition for Health Environments Research (CHER), Bonita, CA.

Ulrich, R. S. (1981), Natural versus urban scenes some psychophysiological effects. Environment and behavior, 13(5), 523-556.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., Zelson, M. (1991), Stress recovery during exposure to natural and urban environments .Journal of environmental psychology, 11(3), 201-230.

Valdez, P., Mehrabian, A. (1994), Effects of color on emotions. Journal of Experimental Psychology: General, 123, 394–409.

Van Beek, H. C. A. (1983), LightÐinduced colour changes in dyes and materials. Color Research & Application, 8(3), 176-181.

Van den Berg, A. E., Koole, S. L., Van der Wulp, N. Y. (2003), Environmental preference and restoration:(How) are they related?, Journal of environmental psychology, 23(2), 135-146.

Van den Berg, A. E., Hartig, T., Staats, H. (2007), Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. Journal of social issues, 63(1), 79-96.

Van der Sijs, N. (samensteller) (2010), Etymologiebank, on http://etymologiebank.nl/

Van de Weijer, J. , Gevers, Th., Gijsenij, A. (2007), Edge-Based Colour Constancy, IEEE Transactions on Image Processing, Vol 16 (9), 2207-2214.

Von Goethe, J.W. (1810), Zur Farbenlehre, Tübingen : J.G. Cotta'schen Buchhandlung

Von Goethe, J.W.(1981), De metamorfose van de planten, Inleiding en toelichtingen van Rudolf Steiner, Uitgeverij Christofoor, Rotterdam.

Vonk, R.(2003), Cognitieve Sociale Psychologie, 2e druk, Uitgeverij LEMMA BV, Utrecht.

Walusinki, O.(2006), Yawning: Unsuspected avenue for a better understanding of arousal and interoception, Medical Hypotheses, Vol 67 (1), 6-14.

Wilson, G.D.(1966), Arousal properties of red versus green, Perceptual and Motor Skills, 23, 947-949.

Winthrop, B.P., Simon, J.E. (2000), Shoot regeneration of young leaf explants from basil (Ocimum basilicum L.), In Vitro Cellular & Developmental Biology - Plant, Vol 36(4), 250-254.

Wong-Riley, M.T.T. (2010), Energy metabolism of the visual system, Eye and Brain 2, 99-116.

Wright, K.P. Jr and Czeisler, C.A. (2002) Absence of circadian phase resetting in response to bright light behind the knees. Science 297, 571

Yamashita, M., Yamada, I., Yasuda, M. (2012), Psychophysiological effects of tones of coloured lights in a dark environment, NES2012 Proceedings, Saltsjöbaden, Sweden, August 19-22.

Yoto, A., Shimomura, Y., Iwanaga, K., Katsuura, T.(2007), Effects of Object colour Stimuli on Human Brain Activities in Perception and Attention Referred to EEG Alpha Band Response, Journal of Physiological Anthropology, 26(3), 373-379.

Zajonc, A.G. (1976), Goethe's theory of colour and scientific intuition, American Journal of Physics,Vol 44(4), 327-333.

Zajonc, A. (1993), Het licht zien, Het verbonden bestaan van licht en bewustzijn, Uitgeverij Vrij Geestesleven, Zeist.

Zeylmans van Emmichoven, F.W. (1923), De werking van de kleuren op het gevoel; Dissertation, Utrecht.

Zeki, S., Marini, L. (1998), Three cortical stages of colour processing in the human brain, Brain, 121, 1669-1685.

research	research question	(neuro)physiological findings	research conclusions
Küller,R., Mikellides, B, Janssens, J.(2009), color, Arousal, and Performance, A Comparison of Three Experiments; TEST 1.2002; Kaplan& Kaplan, 1989)	Has a colourful or grey room physiological impact?	Less alphawaves and lower heart beat in colourful room	Colourful room causes arousal
Küller,R., Mikellides, B, Janssens, J.(2009), color, Arousal, and Performance, A Comparison of Three Experiments; TEST 2.	Does a red or a blue room causes physiological differences?	Significant differences in deltawaves in blue characterizing a sleepy and drowsy state. Alpha waves showed only tendencies and no significant effects. In red room lower heart rate.	The colour red puts the brain into a more excited state, to such an extent as to cause a paradoxical slowing of the heart rate. Red interiors are more arousing than blue ones.
Jacobs, K.W. Hustmeyer, F.E. (1974), Effects of four psychological primary colors on GSR, Heartrate and respirationrate.	Do red, green, blue and yellow coloured slides effect GSR, heart rate and repiration rate?	Significant higher GSR values, but no significant changes concerning heart rate and respiration rate while looking at red.	Red is a more arousing colour than yellow, green and blue.
Wilson, G.D.(1966), Arousal properties of red versus green.	Do the colours red and green cause different levels of arousal?	Red causes a higher level of GSR.	Red is a more arousing colour than green
Yoto, A., Shimomura, Y., Iwanaga, K.,Katsuura, T.(2007), Effects of Object color Stimuli on Human Brain Activities in Perception and Attention Referred to EEG Alpha Band Response.	Does red, green and blue paper stimuli effect physiological indicators?	The power of the alpha band and the thetaband, and the total power of the theta-beta bandwidth as measured by EEG while looking at red are higher than while looking at blue. No effects bloodpressure.	Blue elicits more arousal based on AAC values. Activating effect of red paper on the central cortical region with regard to perception and attention was considerably more distinguishable than the biological activating effect of bluish light.
Kim, Y. (2004), Interior color Design Using Psychophysiological Responses Towards User Oriented Smart Environments (Dissertation).	Target is developing an online architectural virtual reality model to link colour to moods	Different effects are found of colours red, green, yellow, blue, black and white on alpha relative power, slow alpha, fast alpha, slow beta, fast beta, theta, gamma and VEP.	These effects are translated into moods and used in the model.
Noguchi, H., Sakaguchi, T.(1999),Effect of Illuminance and color Temperature on Lowering of Physiological Activity.	Analysing effects of illuminance and colour temperature on physiological activity	Effects are shown on AAC (lower AAC values at lower colour temperature-conditions) and no effects on heart variability	Low colour temperature light creates lowering of central nervous system activity.
Steer-Reeh, A.(2012), Wirkung von farbigem Licht auf die Herzfrequenzvariabilität und den Puls-Atem-Quotienten gesunder Probanden (Inaugural dissertation).	Analysing effects of coloured light on heartvariability and respiration rate	Seeing red seems to cause arousing effects relative to heart beat and respiration rate, however HF (High Frequency Heart variability) shows a possible opposite effect. Blue has a positive influence on heart variability.	Colour causes physiological effects.
Yamashita, M., Yamada, and Yasuda, M. I, (2012), Psychophysiological effects of tones of coloured lights in a dark environment (Proceedings).	What are the effects of six tones of red, green and blue effects on alpha waves?	The alpha 2 waves (9-11 Hz) increase is correlated to an increase of lightness. This increase is independent of the colour (R,G,B). The alpha2 proprotion is highest for green and lowest for red.	More lightness (the vivid, bright, light and pale) tones causes positive effects on alpha 2 waves. Green causes more alpha 2 waves than red. Alpha 2 is conceived as the most optimal condition because this wave indicates relaxation and concentration.
Ali, MR. (1972), Patterns of EEG recovery under photic stimulation by light of different colours.	Do different coloured lights show differences in recovery in the EEG?	Larger recovery period in red light exposure.	Red light causes larger cortical arousal.
Rajae-Joordens, R.J.E. (2011), Investigating Responses Through Subjective Evaluations and Psycho-Physiological Measurements.	What are the effects of coloured lights (R,G,B) on valence and arousal?	No significant effects on skin conductance and blue light causes significant higher heart rate in dimmed conditions versus bright conditions.	A discrepancy exists between questionnaires and psycho-physiological measurements.
Kim, T.H., Song, J.K., Jeong, G.W, (2012), Neural Responses to the Human color Preference for Assessment of eco-friendliness: A functional Magnetic Resonance Imaging Study.	Are there any linkages between neural mechanisms and subjective colour preferences?	Stimulation with favourite colours shows activated areas as the pons, supramarginal gyrus, paracentral lobule, midbrain and globus pallidus. Stimulation with unfavourite colours shows activated areas the body of the caudate nucleus, parahippocampal gyrus, anterior cingulate gyrus, splenium of the corpus callosum, hippocampus, orbitofrontal gyrus, amygdala, thalamus and angular gyrus.	Linkages exist between emotional response and neural mechanisms

comment	research question						
	A	B	C	D	E	F	G
Changes in alphawaves show evidence for arousal. The lowered heartbeat however shows the opposite pattern that in general indicates a decrease of arousal.	x	x			x	x	
A lower heartbeat means in general a decrease of arousal. Deltawaves show primarily information concerning the auditory cortex.	x					x	
Two indicators for arousal don't show significant effects.	x		x	x	x		dm
This research shows weaknessess in the statistical approach. The applied intervals are unnatural in colour vision. Interpretation of conductance level and GSR unclear and makes comparison difficult.	x		x	x	x		dm
The AAC value only indicates attention. No occipital effects are striking as alpha waves in this region are most prominent. Comparison with research Ueda (2004) is unvalid as he used beta waves that primarily indicate motoric motivation.	x	x	x	x	x	x	x
No consistent patterns are shown in the results. Types of brainwaves can not be attribited to moods. VEP is only usable for short time stimuli.	x		x			x	
AAC is not yet a clear indicator	x	x	x				no
Due to the limited time periods of 10 minutes of colour experience, priming - and as such learnt opinions (cognitions) - may be a cause of the measured effects. In addition, blue has a positive effect on SDNN (method to measure heartvariability). This method currently concerns a longer duration of measuring.	x		x	x	x		dm
Exposure of light is very short which can be the cause that only differences are found in alphawaves and not in heart rate. The increase of alpha 2 waves may be caused by psychological effects due to learnt associations (cognitions). The alpha waves are not occipital measured, the location where these waves mostly are shown. The differences between significant alpha 2 waves and no significances at the other alphawaves are striking.	x		x				x
No differences are made between different types of alpha waves. As alpha waves show personal values, an experiment is necessary 'within subject'. AAR is not yet a well understood measurement and can not be conceived as evidence.	x	x	x				
Much attention is paid to the COH value; this value however is rather unknown. More practical is the RSA. Data are too limited to make sound conclusions.	x	x	light				dm
Presenting colours by flickering stimuli is not in accordance with environmental experience in reality. Different area's are mentioned that possibly can be related to emotions rather than positive or negative preferences.	x		x				dm

A
artificial

B
limited number subjects

C
concerns light stimuli

D
no clear light conditions

E
no clear colour conditions

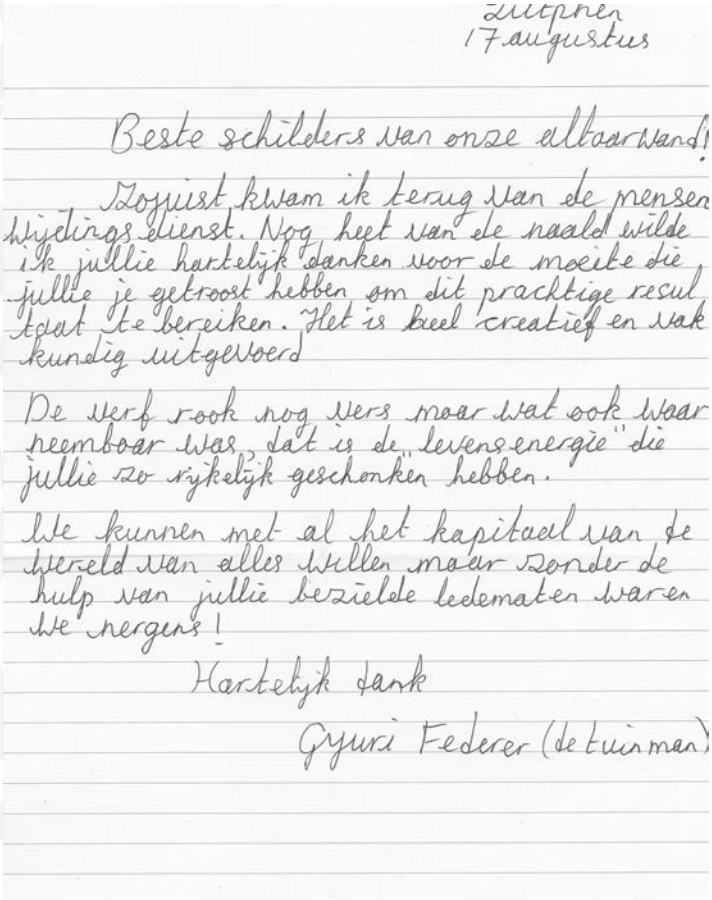
F
no clear reflection data

G
appropriate specification alpha waves

dm = doesn't matter

Attachement A: Researches on colour effects using physiological data

After painting the church in Zutphen, Jan de Boon received this letter from the gardener.
What a great gift for a painter, if he can see how people can get ensouled by the colours he has made.



Zutphen
17 augustus

Beste schilders van onze altaarwand!

Zojuist kwam ik terug van de mensen wijdings dienst. Nog heet van de naald wilde ik jullie hartelijk danken voor de moeite die jullie je getroost hebben om dit prachtige resultaat te bereiken. Het is heel creatief en vakkundig uitgevoerd

De verf rook nog vers maar wat ook waarneembaar was, dat is de "levensenergie" die jullie zo rijkelijk geschonken hebben.

We kunnen met al het kapitaal van de wereld van alles willen maar zonder de hulp van jullie bezielde ledematen waren we nergens!

Hartelijk dank

Gyuri Federer (de tuinman)

Zutphen, August 17,

Dear painters of our altar wall,

I just came back from the Consecration of Man. Still hot off the press, I wanted to thank you for the efforts you have devoted to achieve this wonderful result. It is very creatively and expertly executed.

The paint smelled fresh but what also was observable, is the '' life energy '' that you so generously have donated.

We may want everything with all the capital of the world, but without the help of your spirited limbs we were nowhere,

Thank you,
Gyuri Federer (the gardener)

A small talk with the pig can bring innovative insights for the knowledge worker (Roos Vonk).

In many scientific researches people are asked about their opinions using questionnaires. However, the human spirit is sparkling and elusive and the answers in questionnaires are the results of inscrutable human thinking processes. Many pitfalls are hidden on the scientific path searching for the truth.

Chapter Seven

The use of questionnaires in colour research in real life settings

Bakker I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J. (2013), The use of questionnaires in colour research in real-life settings: in search of validity and methodological pitfalls. Theoretical Issues in Ergonomics Science, (ahead-of-print), 1-15. DOI: 10.1080/1463922X.2013.815287.

After studying the demand side in Chapter 2 and the supply side in the Chapters 3 - 6, it was obvious that in many studies the methods are not always applied in an unambiguous way. Therefore, this chapter focuses on possible risks of using questionnaires in colour tests like the one that was described in Chapter 4. Additional data were gathered to understand why differences between questionnaire outcomes and impressions of the researcher were found. In preparation of the colour test, discussions have taken place with experts of the OTB TU Delft institute for research of the built environment and experts of TNO on how to measure effects of colour during a meeting in a real-life setting. Applying questionnaires seemed to be the best method, because camera's or physiological measurements would make the situation of the real-life setting too artificial and the recorded measurements are difficult to interpret. Questionnaires that were used in former colour researches were analysed, but it was concluded that no standardised questions were applied. However, to measure productivity during meetings, OTB TU Delft used a standard method. Using this questionnaire as a basis and in consultation with experts, the colour questionnaires used in the real life test have been developed. Because the seven point Likert scale is often used in colour researches this method is used here as well. Another discussion topic was whether the researcher had to be present during the meetings. The advantage of knowing what happens during the meetings to be able to interpret the answers in the questionnaires overruled the disadvantage of possible influences of the observer. To reduce this possible effect, the observer was present during the meeting. Due to her presence, the researcher was able to observe the meeting process closely and to interpret the answers of the questionnaires more clearly. By means of standardised forms, facts were written down such as posture, communication lines, location at the table, number of questions and remarks of the subjects. In a standardised logbook the specific cases were registered.

abstract

This research discusses the validity of applying questionnaires in colour research in real life settings. In the literature conclusions concerning colour influences on human performance and wellbeing are often conflicting. This can be caused by the artificial setting of the test process. Applying questionnaires could also be a cause. To avoid the disadvantages of an artificial setting, a colour research process was organised in a real life setting. In order to get a better understanding of the validity and possible pitfalls in using questionnaires, the responses to the questionnaires were analysed and compared with findings from observations of respondents' behaviour and additional interviews with the respondents. Discrepancies were found indicating weaknesses of applying questionnaires in colour research. The findings suggest that questionnaires alone are not a fully appropriate tool to establish the colour influences.

Keywords: *questionnaires, observations, methodology, validity, social psychology, colour influences*

7.1 Introduction

7.1.1 Conflicting results in colour research

Much colour research analysing the influences of colour on human beings is being conducted in an artificial setting by employing students performing artificial tasks, using different test materials and measuring different effects by using questionnaires (Elliot et al, 2007; Elliot and Niesta, 2008; Bellizzi et al, 1983; Maier et al, 2008; Stone, 2001). The results are often conflicting (Elliot et al, 2007; Tofle, 2004). There are several possible reasons for these conflicting results. Firstly, laboratory situations are a reduction of the complex physical and social contexts of real life situations (Vonk, 2003). The use of laboratory facilities (such as in Elliot et al, 2007; Moller and Maier, 2009; Roberts et al, 2010; Bellizzi et al, 1983), is often criticised (Tofle, 2004), because the effects of colour are highly dependent on its context (Crowley, 1993; Elliot et al, 2007, Maier et al, 2008; Conway, 2009; Beach et al, 1988). The effects of colours are for instance dependent on physical context variables such as daylight, space dimensions and textures, and on social context variables i.e. social interactions are different in a natural environment compared with a laboratory situation. Secondly, most colour research is conducted with subjects who are students (such as in Elliot et al, 2007; Elliot and Niesta, 2008; Zentall et al, 2000; Read et al, 1999; Roberts et al, 2010; Maier et al, 2008; Mehta and Zhu, 2009, Wilson, 1966, Claessen, 1995; Moller and Maier, 2009). Colour testing with students results in selection bias (Sears, 1986) as students are not representative for the overall population. The intrinsic motivation of students often differs from subjects in a real life situation. For example employees are motivated by social and organisational dependencies, whereas students are more interested in having fun (Bellizzi et al, 1983) or in getting course credits (Mehta and Zhu, 2009; Elliot et al, 2007). Thirdly, it is difficult to compare artificial tasks with real life task performances, where social interdependencies and organisational responsibilities are involved.

Fourthly, in the laboratory settings different coloured test materials are used such as virtual colouring with screens (Mehta and Zhu, 2009; Kaya and Epps, 2004; Dijkstra, 2009); clothing (Roberts et al, 2010), slides (Bellizzi et al, 1983), colour photographs (Sivik, 1973), colour samples like pegs (Claessen, 1995) and colour pictures (Wilson, 1966). Materials and devices with different characteristics may influence colour research results. An example are the studies of Kwallek et al (1996) who delivered evidence for the colours red and green as being preferred colours for walls in a physical test environment. Schloss et al (2012) used screens and found evidence for light colours such as white as preferred colours for walls. Next to these four causes of the conflicting results, using questionnaires could also be a cause. Often questionnaires are used for testing the colour influences on diverse cognitive, emotional and affective aspects (Bellizzi et al, 1983; Coad and Coad, 2008; Yoto et al, 2007; Lichtenfeld et al, 2009; Stone, 2001). Focusing on different topics such as anxiety and pleasure (Verhoeven et al, 2008), stress, attractiveness and professional quality (Dijkstra, 2009), and mood, arousal, vigilance and eagerness (Elliot et al, 2007), makes comparison of research findings difficult.

Furthermore, the validity of questionnaires might be questioned. Answers are mixtures of individual opinions influenced by psychological phenomena and contexts (Vonk, 2003; Ekman, 2008). The question is whether the responses to questionnaires are sufficiently valid in order to be able to draw sound conclusions concerning the influence of colour. In 2004, Hancock and Szalma wondered how empirical evidence can be verified. Next to quantitative methods, in addition qualitative methods have limitations, due to among other things attitudes of the subjects. Research concerning the application of questionnaires as an appropriate means to analyse the truth indicates that questionnaire findings may have limited validity, e.g. due to a lack of interest of respondents, the fact that respondents not always tell the truth and the unwillingness of respondents to admit certain attitudes or behaviour (Foddy, 1993). In summary, the main drawbacks of current studies on the influence of colour is, that most studies are conducted in an artificial setting using questionnaires as a main method to measure effects.

7.1.2 Testing the validity of completing questionnaires in a real life setting

From a methodological point of view, an interesting question is whether the influence of colour as a complex phenomenon and as an integral part of the environment, influencing all human senses, can be analysed in an artificial environment with questionnaires. Because people experience colour in real life, the optimal approach to test the influence of colour is testing in a real life setting. However, in real life situations there are other factors that may influence the process of completing questionnaires and the results. Hignett (2001) shows in her human interaction model the complexity of among other things cognitive, emotional, social and physiological influences. Differences in outcomes may be caused by context factors related to the test environments, the test situations and the test processes on the one hand and human characteristics on the other hand. A human characteristic could be a certain level of sensitivity (e.g. Mehrabian and Russell, 1974) or being affected by psychological phenomena such as unconsciousness of the environment. These three types of impact factors can be identified as contextual factors, personal characteristics and psychological phenomena.

7.1.3 Contextual factors

Mental processes can only be understood within the context of the interaction between human beings and their situation (Damasio, 2006). The way of experiencing the test environment depends on the physical environments subjects are accustomed to. When people work for instance in a white coloured work environment, every new colour will be conceived as irregular and approached rather critically.
Also the organisational and social context with their organisational and social norms, might affect the process of completing questionnaires. Rafaeli and Vilnai-Yavetz (2004) show the multiplicity of relationships between among other things social, psychological and organisational aspects. Tasks, responsibilities and attitudes influence the way employees observe and perceive the physical environment (Küller, 1973). For instance, when an employee with serious responsibilities is involved in a meeting process, his attention is primarily directed to the meeting's topics and not to environmental aspects (Appleyard, 1973). Another serious contextual factor is the test process. Involvement in a specific test process is a special event, which probably might activate attention and enlarges personal status and feelings of importance. As a consequence the test process itself can affect the attitude of the subject and the existing social context.

7.1.4 Personal characteristics

Personal characteristics determine the way subjects experience the physical environmental and the social and organisational context and how they express these experiences in completing questionnaires. In real-life settings differences in environmental sensitivities may result in different experiences of the environment (Mehrabian and Russell, 1974).

7.1.5 Psychological phenomena

Psychological phenomena influence the process of completing questionnaires. People are for instance unconscious of their physical environment (Dijksterhuis, 2007; Schneider, 1987), don't tell everything in questionnaires (Vonk, 2003) and are unconscious of their own cognitions about the environment (Vonk, 2003). In human behaviour 'cognitive dissonance' may play a role: people don't like to have cognitions that are conflicting with each other and try to bring their cognitions into harmony (Festinger, 1957). The phenomenon of social desirability bias might have an impact as well. Some respondents' answers to questions may be related to their perception of the social desirability of their answers (Bryman, 2012).
The factors and phenomena described earlier are clearly mentioned in the environmental and psychological literature. However in the literature on the influence of colour, no reflections were found that these factors and phenomena influence the process of completing questionnaires and as such might influence the results and conclusions. The question can be asked if reported results based on completed

questionnaires can be conceived as clear and true facts which directly can be connected to the research topic: the impact of colour.

Considering the critical remarks on using questionnaires, in the present study the influence of differently coloured meeting rooms was tested in an existing office and not in a laboratory, with governmental employees and not with students, conducting usual tasks – regular team meetings - and no artificial tasks, and with real coloured walls in a real life setting instead of artificial materials in a laboratory setting. In order to test the validity of questionnaires to collect opinions about perceived productivity, social cohesion and wellbeing, the meeting process and the process of applying questionnaires was observed and monitored and analysed so that the aforementioned phenomena could be discerned. The present paper discusses whether the findings from questionnaires were consistent with observed behaviour, in order to answer the question: are questionnaires an appropriate measurement to collect data that can be used to draw clear conclusions concerning the influences of colour in a real-life situation? Due to the complexity of the surrounding environment and more specifically the phenomenon colour, the complexity of the human psyche and psychological processes related to the transformation processes of affect into cognitive verbalisation of perceptions, the hypothesis was that questionnaires alone don't give a valid understanding of the influences of colour.

7.2 Method

7.2.1 Test setting

The influence of colour was tested in a real working situation, with two coloured meeting rooms (a red and a blue one) and a standard reference room in a government building in Rijswijk, the Netherlands. Seven regular meeting teams with totally 52 members were observed, each during seven formal routine meeting sessions (in total 49 test sessions). Standard questionnaires were systematically composed based on both former colour research and research on productivity. The government employees completed the questionnaires with statements on a seven point scale (ranging from strongly disagreeing to strongly agreeing) concerning the meeting productivity, social cohesion and wellbeing, appraisal of room aspects (including colour) and preferred rooms. The results of this test are published in a separate paper (Bakker et al. 2013) and not presented here because this paper focuses on the validity of using questionnaires in a real life setting.

7.2.2 Test process: data collection

For collecting data, four questionnaires were used. One questionnaire was administered directly before the meeting (questionnaire Q1), one directly after the meeting (Q2), both in the meeting room. A third questionnaire was disseminated two to three days after the meeting by e-mail (Q3). Two to three weeks after the last meeting session, a fourth endquestionnaire was sent out by e-mail (Q4), asking for personal opinions related to the three meeting rooms (the two coloured test rooms and the standard reference room), such as room preferences and the relative importance of interior elements (among other things colour, inner climate and comfortable chairs). The first three questionnaires Q1, Q2, Q3 were completed by the participants seven times (once per meeting session). The end-questionnaire Q4 was completed only once.

7.2.3 Test process: completing questionnaires

To get a clear insight into the subjects' considerations while completing questionnaires on the impact of colour during the test process, data were systematically analysed on possible bias according to the next table (see Table 1).

Table 1: contextual, personal and psychological factors and phenomena which may appear during colour research using questionnaires

table

factors and phenomena	types	examples
contextual	physical organisational social test related	being accustomed to the physical environment norms and culture social desirability personal interest
personal	personal characteristics	sensitive to the environment
psychological	cognitive dissonance	reducing differences between two cognitions such as avoiding discrepancies between made remarks and new opinions
	unconsciousness of the environment unconsciousness of the own cognitions	not knowing the colour of the wall not realising the relation between cognitions and stimuli, such as positive feelings of space not realising what's the cause
	don't tell everything	not telling about personal dissatisfaction

Because of the particular interest in methodological validity and possible pitfalls, the full research process was watched closely to be able to establish the validity of the answers mentioned in the questionnaires. Therefore during the 49 test sessions the researcher was present. In a research process document the researcher listed subjects' positions at the table and their behaviour such as communication patterns, duration and number of questions subjects asked during the meeting, time for giving information, laughing and posture. Comments and remarks of subjects and incidents before, during and after the meetings were recorded in a logbook. Directly after the meeting these data was compared with the data in the questionnaires Q1, Q2 and Q3. Discrepancies between the observed behaviour and statements of the participants during the meeting session and their responses to these questionnaires were captured in the logbook. In four cases showing discrepancies between the observed behaviour and their answers in the questionnaire that were difficult to explain, subjects were personally interviewed regarding the background of their responses. These interviews were conducted one or two days after the meeting session at their private office. Subjects were told that the research was focused on the influence of colours, but that also the processes such as forming opinions constituted a serious part of it. In summary, three types of documents were used during the test process: questionnaires, a research process document per meeting session and a logbook. As such, the possibility was created to discern any discrepancies between responses to the questionnaires Q1, Q2 and Q3, observations of actual behaviour and findings from additional interviews, which might be caused by the psychological factors and phenomena mentioned in Table 1.

7.3 Results

The research findings pointed to ambivalence about the impact of colour that was intended to measure. After analysing the questionnaires Q1, Q2 and Q3, research process documents and logbooks, thirteen discrepancies were recorded between subject's responses to the questionnaires and observed behaviour (see cases below) and/or the interview results, showing ambiguous relationships. Various cases represent discrepancies that refer to more than one person or to a whole team.

Case 1: Light-dark contrast with the previous environment

A meeting team had to wait a while in the sunny corridor before the meeting started. The team members entering the red test room had a discussion about the darkness of the room. They were unanimously

convinced of the darkness of the red coloured room. However, the discussion did not have any influence on the mentioned scores in the questionnaires Q1, Q2 and Q3, neither on the rating of the room, the wall colour or the light. The fact that only this time the darkness of red room was discussed was caused by contextual factors: a short period in the sunny corridor caused an enlarged experience of darkness in the room. A possible explanation for not observing any effect in the responses to the questionnaires is that subjects are not aware of the connection between cognition (it is dark) and stimulus (the darkness) and that they pay no further attention to the environment because they were primarily focused on the meeting.

Case 2: Discrepancies in appraisal of the furniture
Many subjects spontaneously made positive remarks about the round shape of the table in the coloured rooms. According to them this shape stimulated human movement and created a pretty space. However, the scores on importance for this item in the end questionnaire Q4 were remarkably low. A possible explanation for the enthusiasm about the shape and the low rating in the questionnaire Q4 is that subjects are not actively focused on elements of the physical environment and do not remember relations between cognitions and stimuli.

Case 3: Dissatisfaction with the meeting topic
Directly after one of the meetings subject A told that he was not satisfied about the approach of the meeting topic. Nevertheless in questionnaire Q2 and Q3, the scores regarding satisfaction about the meeting, the meeting process, results and productivity, were all positive. When asked about his answers, he admitted he gave high scores although he was not satisfied. Because he could not change the situation in the complex government organisation, he opted for the scores he thought as being generally accepted in connection with his function, job responsibility and organisation culture. He chose the scores he thought other people expected him to make that did not necessarily correspond with his personal opinion. The effect is related to several factors and phenomena: impact of the organisational culture and generally accepted norms, social desirability and the phenomenon that people don't tell everything.

Case 4: Irritation about unclear decisions during the meeting
Subject B several times asked the chairman to make more clear decisions, however no decision was made. Surprisingly subject B completed both questionnaires Q2 and Q3, with positive scores regarding the meeting results, meeting process and productivity. In an interview later on, subject B told that he was not satisfied but he could not change either the person or the situation. Low scores would not change this situation, so he decided to choose what he called "normal' scores. These scores were not a valid representation of his personal opinion but were influenced by organisational culture, generally accepted norms, social desirability and the phenomenon that people don't tell everything.

Case 5: Dissatisfaction with the team process and the results
After a meeting subject C told that he was not satisfied about the team process, the meeting and the results and more specific the input of his colleagues. Nevertheless the scores in questionnaires Q2 and Q3, were positive. In an interview with him later on, he told that his opinion did not matter at all and that he could not change the quality of the organisational process. He filled out high scores corresponding to his perceived job context and job responsibility. His responses can also be conceived as a result of organisational culture, generally accepted norms, social desirability and as such did not show his personal opinions.

Case 6: Interruptions
During a meeting subject D could not accomplish his own presentation because one of the team members took over. An analysis of the answers of subject D did not show any differences with his scores

in other meetings on the items 'I felt respected by the others' and 'They listened to me well'. No clear correlation exists between the incident during this particular meeting and the scores filled out in the questionnaires Q2 and Q3. Possible explanations are that he was used to being treated this way in the organisation and the person who interrupted him or personal characteristics such as being a shy.

Case 7: Getting compliments from colleagues

In one meeting a substitute chairman (subject E) was asked to chair the meeting, because the regular chairman could not be present. At the end of the meeting one of the members told him that he was so happy because now he had felt someone was really listening to him and this had never happened before. The other team members agreed. However, the substitute chairman, who is a regular team member, filled out neutral scores in questionnaire Q2 and Q3, on the item ''I felt respected by the others'. In comparison to his scores in the questionnaires Q2 and Q3, regarding all other meetings, no difference was found although this time he got many compliments. Probably subject E, being the chairman only once, mainly paid attention to the process as being his responsibility. Another cause could be a personal characteristic (for instance being modest) or that subject E is unconscious of his own cognitions.

Case 8: Negative opinions versus positive scores

After a meeting in the blue room, subject F told that he was fond of the colour blue but he did not like the light. In contrast with this opinion, both scores in questionnaire Q2 and Q3, regarding light intensity and light colour were positive and did not differ from the scores in the other rooms. In an interview afterwards, subject F told he was satisfied about the meeting so he also mentioned satisfaction concerning the environment, although on a conscious level he was not content with this environment. His score is primarily based on his focus on the meeting and has nothing to do with the environmental conditions.

Case 9: Lack of interest: copying of responses

It turned out that some subjects did not complete all questionnaires Q1, Q2 and Q3 quite seriously. For instance, subject G copied his scores in questionnaire Q1 into questionnaire Q2. He got critical comments from his team members and his data was not used in the analysis. This example is related to his attitude to the research: subject G is not seriously committed to the research, or there is no personal interest.

Case 10: Responding (too) quickly

Subject H completed the questionnaires Q1, Q2 and Q3 rather quickly and after a check by the researcher it appeared that during the complete test process subject H used almost the same scores. It is questionable whether these answers really reflect his opinion or are more or less standardised because he was not seriously committed to the research, or there is no personal interest.

Case 11: Apologies for not having any colour preference

Subject I told the researcher that he was very sorry that he had no colour preference and that he mostly liked the reference room. The reason for apologising could be that he felt affection for the researcher and/or assumed that the researcher expected him to have a colour preference or that he thought the researcher tried to find evidence for colour preferences. In the additional interview subject I told that he was convinced that the researcher had a colour preference and expected him to have one as well. This seems to refer to the so-called interviewer effect, trying to please the interviewer, in this test the researcher. In many types of researches, the interviewer effect seems to have influenced the findings (Davis et al, 2010; Dykema et al, 2012; Johnson and Parson, 1994; Huddy et al, 1997).

Case 12: Mentioning colour perception

While completing the questionnaires Q1, Q2 and Q3 during the meetings, at least 30% of the subjects looked up and around. May be these subjects recorded their individual colour perceptions and not their

actual experiences and actual feelings. People may be not sensitive for their environment, unconscious of the environment or unconscious of their own cognitions.

Case 13: Impact of the chairman

For the first time entering the test room (in this case the red room), one chairman called out loudly 'What an awful colour'. Consequently, he gave the red wall a low score and the blue wall a high score. Maybe his scores were influenced by cognitive dissonance reduction: it is possible that during the meeting the chairman realised that the colour red was not as bad as he at first thought. However because he was aware of the fact that the other team members had heard his remarks, he may have felt forced to mention that red was awful. Although this possibility exists, it cannot be proven with any certainty. Furthermore the remark of the chairman may have influenced the opinions of the other team members as well and as such made employees being inclined to give the same 'socially desirable' answers.

These cases can be related to the contextual, personal and psychological factors and phenomena that were discussed in the introduction (see table 2).

Table 2: contextual, personal and psychological factors and phenomena which may have influenced the responses to the questionnaires

table

factors and phenomena	types	observed factors and phenomena	cases												
			1	2	3	4	5	6	7	8	9	10	11	12	13
contextual	physical	being accustomed to the physical environment													
	organisational	norms and culture													
		attention to performances													
	social	social desirability													
	test related	attitude													
		affection to the interviewer													
		personal interest													
personal	personal characteristics	psychological factors													
		sensitive to the environment													
psychological	cognitive dissonance	reducing differences between two cognitions such as avoiding discrepancies between made remarks and new opinions													
	unconsciousness of the environment	not knowing the colour of the wall													
	unconsciousness of the own cognitions	not realising the relation between cognitions and stimuli, such as positive feelings of space not realising what's the cause													
	don't tell everything	not telling about personal dissatisfaction													

influencing factors and phenomena described in the cases
factors influencing all cases

Per case the specific contextual, personal and psychological factors and phenomena are marked (black) that may be a cause why answers in the questionnaire Q1, Q2 and Q3 are not in accordance with subjects' behaviour and/or interview results. Three aspects - marked grey - play a role in all cases. Firstly, the physical environment the subjects are accustomed to determines how people judge their new environment (Vonk, 2003). Next, two test related issues always play a role: the attitude of the subject (whether the subject is serious, interested or involved) and personal interest (do subjects attach any importance to the research).

7.3.1 Time of responding

The correlation between the overall appraisal of the meeting room and the appraisal of the interior elements directly after the meeting was highest for wall colour and lowest for temperature and air quality (see table III below). Directly involved in the research process and knowing the research topic, the subjects related their appraisal above all to wall colour, and least at the aspects of the inner climate such as temperature and air quality.

Table 3: Inter Item Correlation Matrix. Appraisal of the meeting room and wall colour showed highest correlations.

table

Interior elements	Correlation between appraisal of the meeting room and appraisal of interior elements directly after the meeting
Top desk table	0,551
Wall colour	0,789
Light Intensity	0,569
Temperature	0,385
Air quality	0,402
Light colour	0,720

However, asking subjects after all test meeting sessions to rank the relative importance of twelve different interior aspects (Q4), subjects assigned a low score to wall colour (Table 4) and highest scores to temperature and air quality. Male subjects ranked wall colours at the tenth position and female subjects at the eighth. These data are comparable with the work environment factors analysed by Dul et al(2007). Valuing the room is based on valuing elements or parts of it. High correlations with the test aspects colour of the light and colour of the wall indicate that the appraisal of the room is influenced by these test aspects and that subjects attach importance to these aspects. However, the same subjects attached opposite importance at the room after all sessions. Apparently the moment of completing the questionnaires affects the opinion about the importance of the interior elements.

Table 4: Relative positions subjects assigned to interior elements

table

order	men	women	total
1st	air quality	air quality	air quality
2nd	temperature	temperature	temperature
3rd	chairs	daylight	daylight
4th	light intensity	light intensity	light intensity/ chairs
5th	daylight	light colour/ chairs	light intensity/ chairs
6th	acoustics	light colour/ chairs	acoustics
7th	light colour	acoustics	light colour
8th	shape table	wall colour	shape table
9th	colour table top	shape table	wall colour
10th	wall colour	plants	colour table top
11th	plants	art	plants
12th	art	colour table top	art

7.4 Discussion

Analysing the research process carefully, evidence is found for confirmation of the hypothesis that questionnaires alone do not give a valid understanding of the influences of colour. Causes are probably due to the complexity of the surrounding environment, the complex phenomenon colour itself and the complexity of psychological processes regarding the transformation process of affect into cognitive verbalisation of perceptions. Remarkably, most subjects did not show any colour preference at all . When at the end of the test process all subjects were asked to mention their colour preferences in the end questionnaire Q4, 63% of the male subjects and 61% of the female subjects admitted they had no favourite wall colour.

7.4.1 Time of responding: influence of the test process

At the moments that the subjects were present in the test environment and more directly involved in the research process, the responses to the questionnaires showed a high correlation between the appraisal of the room and the appraisal of the wall colour and a low correlation with the appraisal of the inner climate. On the contrary, two to three weeks after all test meeting sessions, when subjects had more distance to the research process, wall colour did not play an important role in valuing the room (Table 4) and temperature and air quality got highest scores (Q4). Apparently, the test setting influences the results. When participants completed the questionnaires Q1, Q2 and Q3 they were in the test room with the researcher being present as well, that both accentuated the colour issue of the research. The end questionnaire Q4 was completed in their own room at a distance from the test rooms and without the presence of the researcher. In this situation colour being the research topic was less accentuated or partly forgotten. Moreover, in the existing building some problems existed on the inner climate. When completing Q1, Q2 and Q3 specific attention was paid to the research topic and not to the regular inner climate problems, while at the time of completing Q4, the regular office situation with the inner climate problems got more attention.

7.4.2 Impact of a close contact between the researcher and subjects

In order to be able to understand the answers in the questionnaires Q1, Q2 and Q3 and to interpret the thinking processes of the subjects translating their opinions into the questionnaires, the researcher had to be present during all meeting sessions. Due to the continuous presence of the researcher, a kind of relationship developed between the researcher and the subjects. For instance, some test persons apologised for not having any preference for a specific colour or for preferring the neutral 'reference' room (see case 11). It seems that these subjects assumed that the researcher was expecting them to have a colour preference or that the researcher had a colour preference herself. Indeed, when the researcher asked subjects if they thought that the researcher expected that colour had any effect, all subjects answered positively. Probably these ideas have influenced the opinion of the subjects and the responses to the questionnaires. It is possible that more subjects mentioned a preferred colour than they otherwise would have done. This phenomenon is known as the interviewer effect (Choi and Comstock, 1975). These considerations have to be taken into account in colour research. The colour research process itself is complex and process aspects such as time and role of the interviewer, both possibly influence the results.

7.5 Conclusions and recommendations

It can be concluded that the responses to questionnaires are not always a clear representation of subjects' opinions. Using these answers in colour research, it is not in all cases possible to draw valid conclusions on the colour influences. The responses to the questionnaires Q1, Q2 and Q3 can be considered as a contamination of feelings, cognitive thinking and psychological considerations by the subjects.

All mentioned factors and phenomena have influenced the answers subjects completed in the questionnaires. It can be concluded that responses to questionnaires used in colour research in real- life settings are a result of complex considerations, which makes it difficult to draw clear, reliable and valid conclusions about the influences of colour. The present research in a real-life situation showed evidence about the risks of wrong interpretations of data from questionnaires. Questionnaires alone are no valid instruments to give a clear insight into the influences of colours applied in the physical environment in real-life situations.

A general recommendation concerning both colour research and other research using questionnaires is to include other sampling techniques. For instance making use of beeping from a pager to define the moments that participants are asked questions with relatively quick responses reduces the effects of influences of context factors (Csikszentmihalyi, 1999). Some specific recommendations can be given to conduct colour research in real-life situations that more clearly indicate influences of colours. The context has to be kept simple. It is important to locate the test rooms in the inner space of the building in order to avoid the impact of changeability of daylight.

Real-life settings within an organisational context can bring a range of emotional, social and organisational aspects that may influence the answers to questionnaires. Hignett and Wilson (2004) emphasise in their model showing the interactions between multiple dimensions, the importance of social influences. As such, questions that could be related to the complex social context should be avoided while questions concerning personal aspects are more preferable. Due to the often white (Kwallek and Lewis, 1990) and colourless environments in offices, a period of at least three months is necessary to get accustomed to the test colours. The chance that subjects will guess the research topic will be smaller and subjects will experience the surrounding colours in a more natural way and less as a special test event. The influence of the presence of the researcher – to be able to observe what is going on – could be avoided by using cameras. However, this also could influence respondents' behaviour. Physiological measurements, which easily can be applied without any bodily irritations or barriers, like measurement of Galvanic Skin Response, could be added for reasons of triangulation. If these kinds of measurements and responses to questionnaires result in similar findings, reliability and validity of the conclusions will be improved. When using questionnaires, it is recommended to interview subjects directly after completing the questionnaires to get a better understanding about motives. Taking all these recommendations into account, the validity of the findings i.e. the possibility of finding the real influences of colour will be increased.

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It is concluded that applying questionnaires in colour research in real life settings during meetings, is not the optimal method to measure the influences of colour on perceived productivity, social cohesion and wellbeing. Many psychological constructs influence the answers in the questionnaires. This extra study did result in insights in pitfalls of doing this type of research and is useful for other researchers. In order to measure how the environment is being experienced, often the method of Mehrabian and Russell (1974) is used, with the dimensions pleasure, arousal and less frequently dominance. The question arises if this method gives clear insights into how the physical environment influences people. In Chapter 8 it will be explored how pleasure, arousal and dominance have to be interpreted to assess the physical environment in a clear way.

7.6 References

Appleyard, D. (1973), Professional priorities for environmental psychology. in Architectural psychology. Proceedings of the Lund Conference. Dowden, Hutchinson & Ross, Inc. Stroudsburg, Pennsylvania, 85-111.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J. (2013), Red or Blue meeting rooms: does it matter? The impact of colour on perceived productivity, social cohesion and well-being. Facilities, Volume 31 no 1-2, 68-83.

Beach, L., Wise, B. K., Wise, J. A. (1988), The Human Factors of Colour in Environmental Design: a critical review. Moffe Field, CA.: National Aeronautics and Space Administration, Ames Research, in Tofle, R. B., Schwartz, B., Yoon, S., Max-Royale, A. (2004). Colour in Healthcare Environments: A Critical Review of the Research Literature, United States of America, The Coalition for Health Environments Research (CHER).

Bellizzi, J.A., Crowley, A.E., Hasty, R.W. (1983), The effects of colour in store design. Journal of Retailing, 59, 1, 21-54.

Bryman, A. (2012), Social research methods. Oxford: Oxford University Press, 4th edition, 228.

Choi, I.C., Comstock, G.W. (1975), Interviewer effect on responses to a questionnaire related to mood, American Journal of Epidemiology, 101, 1, 84-92.

Claessen, J.P. (1995), Shaped by colour, a study on the effect of colour on the perceived shape of objects. Thesis, Technical University Delft.

Coad, C., Coad, N. (2008), Children and young people's preference of thematic design and colour for their hospital environment. Journal of Child Health Care, 12,1, 33-48.

Conway, B. R. (2009), Colour Vision, Cones and Colour Coding in the cortex. The neuroscientist, 15, 3, 274-290.

Crowley, A.E.(1993),The two dimensional impact of colour on shopping, Marketing letters , 4(1), 59-69.

Csikszentmihalyi, M.(1999), De weg naar Flow, Amsterdam: Uitgeverij Boom, 25.

Damasio, A. (2006). De vergissing van Descartes, 6e druk Wereldbibliotheek, Amsterdam. 90-95. Original title: Descartes' Error-Emotion, Reason and the Human Brain.

Davis, R.E., Couper, M.P., Janz, N.K., Caldwell, C.H., Resnicow, K.(2010), Interviewer effects in public health surveys, Health Education Research, 25 (1), 14-26.

Dul, J., Ceylan, C., Hendriks, H. (2007), A practical instrument to measure the creativity potential of the work environment; Proceedings of the 10th European conference on Creativity and Innovation, Copenhagen, Denmark.

Dijksterhuis, A.(2007), Het slimme onderbewuste, denken met gevoel. Amsterdam: Uitgeverij Bert Bakker, 33, 53. 74-79, 95,102.

Dijkstra, K. (2009), Understanding healing environments. University of Twente Publications, Twente. 60, 80, 86, 92.

Dykema, J., Diloreto, K., Price, J.L., White, E., Schaeffer, N.C. (2012), ACASI Gender-of-Interviewer Voice Effects on Reports to Questions about Sensitive Behaviours Among Young Adults, Public Opinion Quarterly, 76(2), 311-325.

Ekman, P., (2008), Gegrepen door emoties, Wat gezichten zeggen, Uitgeverij Nieuwezijds, Amsterdam, 28-31. Original title: Emotions Revealed, Recognising Faces And Feelings To Improve Communication And Emotional Life.

Elliot A.J., Moller, A.C., Friedman, R., Maier, M.A., Meinhardt, J. (2007), Colour and Psychological Functioning: The Effect of Red on Performance Attainment. Journal of experimental psychology, 136, 1, 154–168.

Elliot, A.J., Niesta, D. (2008), Romantic Red: Red enhances Men's attraction to Woman. Journal of Personality and Psychology, Vol 95, no 5, 1150-1164.

Festinger, L. (1957), A theorie of cognitive dissonance. Evanston, IL: Row, Peterson.

Foddy, W. (1993), Constructing questions for interviews and questionnaires: theory and practice in social research. William; Cambridge University Press, 2-6.

Hancock, P.A., Szalma, J.L. (2004), On the relevance of qualitative methods for ergonomics, Theoretical Issues in Ergonomics Science, 5:6, 499-506.

Hignett, S. (2001), Using Qualitative Methodology in Ergonomics: theoretical background and practical examples. Ph.D. thesis, University of Nottingham.

Hignett, S., Wilson, J.R. (2004), The role for qualitative methodology in ergonomics: a case study to explore theoretical issues, Theoretical Issues in Ergonomics Science, 5:6, 473-493.

Huddy L., ,Billig J., Bacciodieta J., Hoeffer L., Moynihan P. J., Pugliani P.(1997), The effect of interviewer gender on the survey response, Political Behaviour,19, 197-220.

Johnson, T. P., Parsons, J. A. (1994), Interviewer effects on self-reported substance use among homeless persons, Addictive Behaviours, 19,83-93.

Kaya N, Epps H. (2004), Relationship between colour and emotion: A study of college students. College Student Journal, 38 (3), 396–405.

Küller, R. (1973), Beyond semantic measurement. in Architectural psychology. Proceedings of the Lund Conference. Dowden, Hutchinson & Ross, Inc. Stroudsburg, Pennsylvania, 181-197.

Kwallek, N., Lewis, C.M. (1990), Effects of environmental colour on males and females: A red or white or green office. Applied Ergonomics, 21.4, 275- 278.

Kwallek, N., Lewis, C. M., Lin-Hsiao, J. W., and Woodson, H. (1996), Effects of nine monochromatic office interior colours on clerical tasks and worker mood. Colour Research and Application; Vol 21.6: 448–458.

Lichtenfeld, S., Maier, M.A., Elliot, A.J., Pekrun, R. (2009). The semantic Red effect: Processing the word Red undermines intellectual performance. Journal of Experimental Social Psychology 25, 1273-1276.

Maier, M.A., Elliot, A.J, Lichtenfeld S.(2008), Mediation of Negative Effect of Red on Intellectual Performance. Personality and Social psychology Bulletin 2008, 34, 1530-1540.

Mehrabian, A., Russell, J. A. (1974), An approach to environmental psychology. Cambridge, MA: M.I.T. Press, 30.

Mehta R., Zhu, R.J. (2009), Blue or Red? Exploring the Effect of Colour on Cognitive Task Performances. Science Express, 323, 5918, 1226-1229.

Moller, A.C., A.J., Maier, M.A. (2009), Basic Hue Meaning associations. Emotion, 9, 6, 898-902.

Rafaeli, A., Vilnai-Yavetz, I. (2004), Instrumentality, aesthetics and symbolism of physical artifacts as triggers of emotion, Theoretical Issues in Ergonomics Science, 5:1, 91-112.

Read, M.A., Sugaware, A.I., Brandt, J.A.(1999), Impact on space and colour in the physical environment on preschool children's cooperative behaviour. Environment and behaviour, 31. 3.

Roberts, S.G., Owen R.C., Havlicek, J. (2010), Distinguishing between perceiver and wearer effects in clothing colour attributions. Evolutionary Psychology, 8, 3, 350-364.

Schneider, W. (1987). Sinn und Un-Sinn, Umweltt sinnlich erlebbar gestalten in Architektur und Design, Wiesbaden und Berlin: Bauverlag GMBH, 43, 106.

Sears, D.O. (1986), College sophomores in the laboratory: Influences of a narrow data base on social psychlogy's view of human nature. Journal of Personality and Social psychology, 51, 515-530, in Vonk, R. (2003). Cognitieve sociale psychologie. Uitgeverij Lemma BV, Utrecht, 15-19, 33- 40, 72, 255.

Sivik, L. (1973). General and applied research on colour perception. Proceedings of the Lund Conference. Dowden, Hutchinson & Ross, Inc. Stroudsburg, Pennsylvania, 181-197.

Schloss, K.B., Strauss, E.D., Palmer, S.E. (2012), Object Colour Preferences, Colour Research & Application, as early view online published at 18 July 2012.

Stone, N.J. (2001), Designing effective study environments. Journal of Environmental Psychology, 21, 179-190.

Tofle, R. B., Schwartz, B., Yoon, S., Max-Royale, A. (2004), Colour in Healthcare Environments: A Critical Review of the Research Literature, United States of America, The Coalition for Health Environments Research (CHER).

Verhoeven, J.M.W., Rompay, Th., Pruyn, A.T.H. (2008), Interior colour in healthcare environment. paper ter gelegenheid van congres 2009 van de 3TU federatie.

Vonk, R. (2003), Cognitieve sociale psychologie. Uitgeverij Lemma BV, Utrecht, 15-19, 33- 40, 72, 171-172, 255.

Wilson, G. D. (1966), Arousal properties of red versus green. Perceptual and Motor Skills, 23, 947-949 in Tofle, R. B., Schwartz, B., Yoon, S., Max-Royale, A. (2004). Colour in Healthcare Environments: A Critical Review of the Research Literature, United States of America, The Coalition for Health Environments Research (CHER).

Yoto, A., Katsuura, T., Iwanaga, K., Shimomura, Y. (2007), Effects of object colour stimuli on Human Brain activities in Perception and Attention referred to EEG Alpha Band Response. Journal of Physiological Anthropology, 26, 373-379.

Zentall, S.S., Grskovik, J.A., Javorky, J., Hall, A.M.(2000), Effects of Noninformational Colour on the Reading Test Performance of Students with and without Attentional Deficits. Diagnostique, 25, 2, 129- 146.

Innovative architectural pine tile style.

A walk through nature provides inspiration and health for every knowledge worker (Theo van der Voordt).

To be able to interpret findings in researches, it is recommendable to have a closer look at the applied methods. In environmental psychology often the method of Mehrabian and Russell is used. It is the question whether this method provides optimal results and how it is applied.

Chapter Eight

Pleasure, arousal, dominance: Mehrabian and Russell revisited

Bakker I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J. (2014), Pleasure, Arousal, Dominance: Mehrabian and Russell revisited. Current Psychology,33(3), 405-421.

In many environmental psychology research the method of Mehrabian and Russell (1974) is applied using the dimensions pleasure arousal and dominance. However, the studies show conflicting results. These conflicting results may be caused by the applied methods. For this reason an in-depth analysis of the method of Mehrabian and Russell has been conducted to understand the original ideas and backgrounds.

abstract

This paper presents a discursive review of the dimensions pleasure, arousal and dominance that Mehrabian and Russell developed in 1974 to assess environmental perception, experience, and psychological responses. Since then numerous researchers applied these dimensions to assess the experience of the physical environment and its perceived qualities. Although the dimensions appeared to be useful, there is a long-lasting debate going on among environmental psychologists about the interpretation of pleasure, arousal and dominance and its underlying mechanisms. Due to the lack of clarity researchers use different adjectives to describe environmental experiences, which makes any comparison between research findings difficult.

This paper shows that the three dimensions can be linked to the current ABC Model of Attitudes: pleasure, arousal and dominance can be respectively related to affective, cognitive and conative responses , i.e. Affect, Cognition and Behaviour (ABC). In addition, connecting the three dimensions to the triad feeling, thinking and acting, can also help to improve our understanding, interpretation and measurement of pleasure, arousal and dominance. Based on this review, it is proposed to re-introduce the three dimensions and to replace the nowadays often used two dimensional model with pleasure and arousal by a three dimensional model, including dominance as a third dimension, to represent the complete range of human responses.

Keywords: *pleasure, arousal, dominance, ABC psychology, tripartite view of feeling, thinking, acting, experience*

8.1 Introduction

An often applied approach to assess and describe environmental experiences is the environmental psychology method of Mehrabian and Russell (1974). They use three emotional dimensions - pleasure, arousal and dominance - to describe human perceptions of physical environments. In the last four decades, pleasure, arousal and to a lesser extent dominance have been used and are still used by numerous researchers in the field of environmental psychology (Bellizi et al, 1983; Bradley et al, 1992; Baker et al, 1992; Donovan et al, 1994; Dubé et al, 1995; Berleant, 1997; Floyd, 1997; Eastman, 1997; Kaplan et al, 1998; Wirtz et al, 2000; Mattila and Wirtz, 2001; Chebat and Michon, 2003; Stamps, 2003; Bigné et al, 2005; Laroche et al, 2005; Ryu and Jang, 2007; Arifin and Cheung, 2007; Kuppens, 2008;

Van Hagen et al, 2009; Morrisson et al, 2011; Hyun et al, 2011). Pleasure and arousal are also applied in other disciplines such as the neurological and neuropsychological sciences (Bradley et al, 1992; Bonnet et al, 1995; Costa et al, 2010; Walter et al, 2011), marketing research (Menon and Kahn, 2002; Laroche et al, 2005; Wu et al, 2008; Lin,2010; Ha and Lennon, 2010; Penz and Hogg, 2011), computer systems (Colomo-Palacios et al, 2011) and psychological research (Reisenzein, 1994; Bradley et al, 2008).
In the field of environmental psychology, pleasure, arousal and dominance are conceived as three basic dimensions of emotional responses that indicate peoples' state of feeling (Mehrabian and Russell, 1974; Russell, 1980; Russell and Pratt, 1980; Zajonc, 1980; Russell et al, 1981; Bell et al, 2001; Gifford, 2001). However, since 1974 discussions are going on among (environmental) psychologists such as Russell (1980), Russell and Prat (1980), Russell et al (1981), Russell and Lanius (1984), Russell et al (1989), Russell and Carroll (1999), Russell and James (2003) and Zajonc and Markus(1984) about the exact interpretation of the dimensions in connection to cognition and affect and the role of dominance. Based on a critical review of the literature including findings from recent studies conducted in England and Venezuela Yani-de-Soriano and Foxall (2006) show that dominance is as legitimate an environmental descriptor as pleasure and arousal. In much research less attention is paid to dominance or even not at all (Russell, 1980; Russell et al, 1981; Chebat and Michon, 2003; Mattila and Wirtz, 2006; Kuppens, 2008). In these studies models are used (see Figure 1) with two axes: horizontally the degree of pleasure and vertically the degree of arousal.

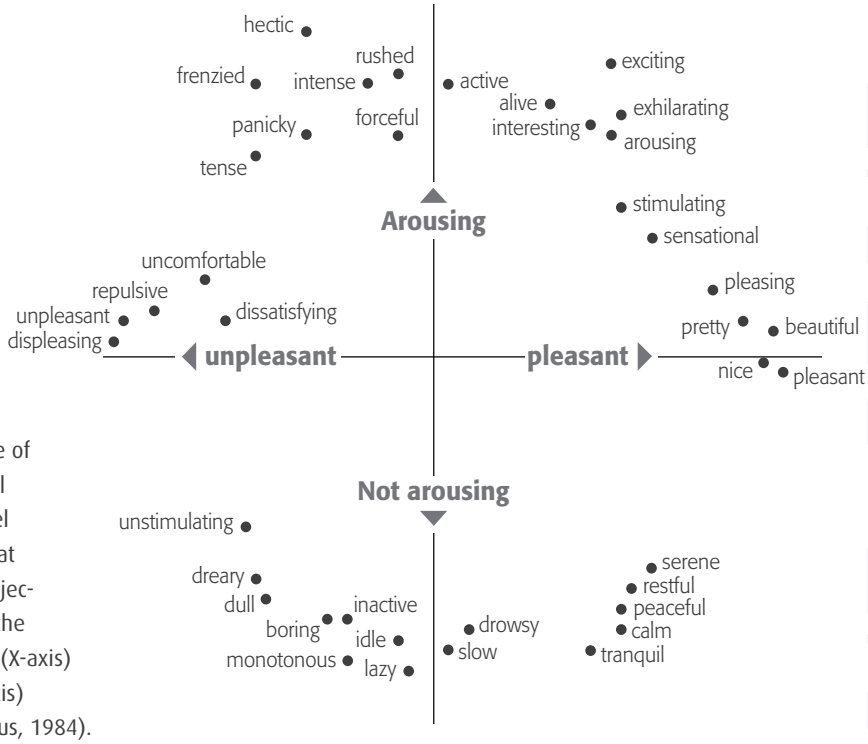


Figure 1: Example of an environmental psychology model with two axes that shows various adjectives to indicate the level of pleasure (X-axis) and arousal (Y-axis) (Russell and Lanius, 1984).

8.2 Pleasure, Arousal and Dominance revisited

In the literature a huge variety of different adjectives is used to operationalise pleasure, arousal and dominance. This makes research findings about the experience and perception of the physical environment difficult to compare. In order to gain a better understanding of the three dimensions, this

paper analyses various adjectives related to pleasure, arousal and dominance that were applied by Mehrabian and Russell and other authors. Furthermore this paper explores the underlying mechanism in connection to the ABC Model of Attitudes i.e. a tripartite view with the three indicators affect, behaviour and cognition. As such it tries to answer the following questions:

1. What were the original operationalization's of pleasure, arousal and dominance defined by Mehrabian and Russell in 1974?
2. How are pleasure, arousal and dominance being applied by other researchers?
3. What are the main causes for different applications?
4. Which underlying mechanisms and psychological phenomena can be found to improve our understanding of pleasure, arousal and dominance?

8.3 Interpretations by Mehrabian and Russell (1974)

Mehrabian and Russell introduced pleasure, arousal and dominance as three independent emotional dimensions to describe people's state of feeling. They conceived pleasure as a continuum ranging from extreme pain or unhappiness to extreme happiness and used adjectives such as happy – unhappy, pleased-annoyed, and satisfied-unsatisfied to define a person's level of pleasure. Arousal was conceived as a mental activity describing the state of feeling along a single dimension ranging from sleep to frantic excitement and linked to adjectives such as stimulated-relaxed, excited- calm and wide awake-sleepy to define arousal. Dominance was related to feelings of control and the extent to which an individual feels restricted in his behaviour. To define the degree of dominance Mehrabian and Russell used a continuum ranging from dominance to submissiveness with adjectives such as controlling, influential and autonomous. Mehrabian (1996) mentioned the noun 'relaxation' as indicator for all three dimensions pleasure, arousal and dominance.

8.4 Comparison with the factors mentioned by Osgood et al.

Mehrabian and Russell (1974) compared the three dimensions pleasure, arousal and dominance with the three factors evaluation, activity and potency used by Osgood et al (1957) and Osgood (1963)(Table 1). The first scientists who used these three factors were Solomon (1954) in analysing sonar signals and Tucker(1955) in his experiments judging paintings. Whereas both triads show some similarities, some dissimilarities come to the fore as well.

Table 1: Relationships between the three dimensions used by Mehrabian and Russell and the three factors used by Osgood

table

Three dimensions mentioned by Mehrabian and Russell (1974)	Three factors mentioned by Osgood et al. (1957)
Pleasure	Evaluation
Arousal	Activity
Dominance	Potency

8.4.1 Pleasure <-> Evaluation

Mehrabian and Russell described pleasure purely in terms of positive or negative feelings. The evaluation factor applied by Osgood et al. (1957) is quite ambiguous. It is based on factor-analysis and linked to a broad spectrum of adjectives such as good-bad, optimistic-pessimistic, positive-negative, complete-incomplete and timely-untimely . Twenty years after their first joint paper on this issue, Mehrabian (1996)

operationalised pleasure in a rather different way and used connotations such as excitement, relaxation, love, and tranquillity versus cruelty, humiliation, disinterest and boredom. Table 2 shows different interpretations of pleasure according to Mehrabian and Russell. The number of different interpretations in the literature of the term 'pleasure' is smaller rather than the terms 'arousal' and 'dominance'.

Table 2: Interpretations of pleasure by Mehrabian and Russell

table

Pleasure	
affective (emotional) responses	Mehrabian and Russell, 1974
affective (emotional) responses	Russell and Mehrabian, 1977
pleasantness-unpleasentness is analogous to the semantic differential dimension of evaluation	Russell and Mehrabian, 1977
pleasure is a continuum ranging from extreme pain or unhappiness at the one hand to extreme happiness or exstasy at the other end.	Russell and Mehrabian, 1977
positive versus negative affective states (e.g. excitement, relaxation, love, and tranquility versus cruelty, humiliation, disinterest, and boredom)	Mehrabian, 1996

8.4.2 Arousal <-> Activity

Although Mehrabian and Russell (1974) conceived arousal as a feeling state, they applied primarily adjectives that concern mental activity. In 1977 they described arousal as ranging from sleep and intermediate states of drowsiness and alertness to frenzied excitement. However, in 1996 Mehrabian defined arousal as a combination of mental alertness and physical activity. He operationalised arousal by using adjectives ranging from sleep, inactivity, boredom and relaxation at the lower end to wakefulness, bodily tension, strenuous exercise and concentration at the high end. Osgood, Suci and Tannenbaum (1957) defined activity as attention and used adjectives such as fast-slow, active-passive, excitable-calm, hot-cold. In his vision activity has also 'some relation to physical sharpness or abruptness as well' (see also Osgood, 1963). As such, Osgood used the activity factor for different types of activity, varying from physiological activity and mental activity to physical activity. Other authors used the activity factor in their research as well, with different interpretations (e.g. Lindsley, 1951; Duffy, 1957; Berlyne, 1966, 1970; Thayer, 1967; Bellizi et al, 1983; Mano, 1992; Bigné et al, 2005; Ryu and Jang, 2007). Lindsley (1951) and Duffy (1957) conceived activity as a physiological activity. Berlyne (1966, 1970) linked activity to attentiveness and connected activity to the arousal potential, known as the Wundt curve of 1874. This arousal potential concerns all types of stimulus properties that tend to raise alertness. Thayer (1967) used adjectives such as wide awake, aroused, aflame, impassioned, alert, and roused. Mano (1992) also related arousal to capacity. Table 3 shows different interpretations of pleasure by different researchers.

Table 3: Interpretations of arousal by different researchers

table

Arousal	
Wundt curve (1874) showing the arousal potential related to novelty and complexity (in Berlyne, 1970)	Wundt (1874)
arousal connected to attentiveness; relation between arousal and exploratory activities evoked by novel, complex and ambiguous stimuli. Annimal's arousal level concerns wide-awake, attentive, excited,	Berlyne, 1966
arousal described in terms such as: wide awake, aroused, aflame, impassioned, alert, roused.	Thayer, 1967 in Russell, 1979

arousal related to novelty and complexity as hedonic value based on the Wundt curve	Berlyne, 1970
activity factor	Mehrabian and Russell, 1974
initially proposed to account for the intensity, but not the quality or direction, of a behaviour	Mehrabian and Russell, 1974
feeling state varying along a single dimension ranging from sleep to frantic excitement such as stimulated, relaxed, excited and sleepy	Mehrabian and Russell, 1974
the arousal dimension is analogous to the semantic differential dimension of activity	Russell and Mehrabian, 1977
responsiveness	Russell and Mehrabian, 1977
Arousal ranges from sleep through intermediate states of drowsiness and then alertness to frenzied excitement at the opposite extreme.	Russell and Mehrabian, 1977
relation with attentional capacity	Mano, 1992
level of mental alertness and physical activity. (e.g. sleep, inactivity, boredom, and relaxation at the lower end versus wakefulness, bodily tension, strenuous exercise, and concentration at the higher end).	Mehrabian, 1996
activity or activation	Russell and Carroll, 1999
arousal items: active, alert, attentive, excited.	Russell and Carroll, 1999

8.4.3 Dominance <-> Potency

Mehrabian and Russell (1974) connected dominance to feelings of control and behaviour restrictions caused by physical or social barriers. The adjectives they used to indicate a person's level of dominance - controlling, influential, autonomous - are different from the adjectives used by Osgood (1957) who described the potency factor by adjectives such as hard-soft, heavy-light, masculine-feminine, severe-lenient, strong-weak, tenacious-yielding. Thayer (1967) used potency in the same way as Osgood did. In 1996 Mehrabian interpreted dominance also in line with Osgood but he used different adjectives such as anger, relaxation, power and boldness versus anxiety, infatuation, fear and loneliness. Table 4 shows different interpretations of dominance according to different researchers.

Table 4: Interpretations of dominance by different researchers

table

Dominance	
Dominance described as dominant, controlling, influential,important, autonomous; submissiveness described as: submissive, controlled, influenced, awed, guided (in Russell, 1979)	Thayer, 1967
connected to behaviour such as controlling, influential, autonomous	Mehrabian and Russell, 1974
potency	Russell and Mehrabian, 1977
"ranges from feelings of total lack of control or influence on events and surroundings to the opposite extreme of feeling influential and in control.	Russell and Mehrabian, 1977
a third factor is not only dominance, but a number of dimensions such as locus of causation, importance of the emotion, and locus of control. These dimensions are interpretable as cognitive rather than affective (in Russell and Pratt, 1980)	Russell 1978
perceptual cognitive dimension	Russell, Pratt, 1980
perceptual cognitive dimension	Russell, Ward, Pratt, 1981
a feeling of control and influence over one's surroundings and others versus feeling controlled or influenced by situations and others (e.g., anger, relaxation, power, and boldness versus anxiety, infatuation, fear, and loneliness).	Mehrabian, 1996

8.5 Reflections on possible causes of different applications and interpretations

The different applications and interpretations might be due to different ideas about how people perceive and assess their environment and how this is expressed in their individual internal representations. A third issue that points out to differences between the three dimensions of Mehrabian and Russell and the three factors of Osgood et al. can be found in different levels of explained variance.

8.5.1 Affect and cognition

Russell and Pratt (1980), Russell et al (1981, 1989), Russell and Lanius (1984), Russell and Carooll (1999), Russell and James (2003) and Zajonc and Markus (1984) conceived pleasure and arousal as indicators of affect, and considered dominance to be a more cognitive indicator (Russell and Pratt, 1980; Russell et al, 1981). In environmental psychology research affect is a central theme (Russell and Pratt, 1980; Baker et al, 1992; Ang and Leong, 1997; Chebat and Michon, 2003; Ryu and Jang, 2007). According to Ulrich (1983), "Affect is central to conscious experience and behaviour in any environment, whether natural or built, crowded or unpopulated. Because virtually no meaningful thoughts, actions, or environmental encounters occur without affect". In addition, the cognitive component is of considerable value in experiencing the physical environment as well, because a building has a function and a meaning with a cognitive recognition (Ittelson, 1973; Russell and Pratt, 1980; Russell, 1980; Russell et al, 1981). Mehrabian (1996) used the term 'disinterest' as a noun to explain pleasure. This term concerns primarily a mental effect that is related to cognition. In 1974 Mehrabian and Russell described arousal as a mental activity in terms of 'a dimension ranging from sleep to frantic excitement'. Due to their references to Berlyne (1966, 1970) and Thayer (1967) and the adjectives Mehrabian and Russell used, such as stimulated, excited and wide awake, it can be concluded that arousal refers to a cognitive and not to an affective factor. This is in contrast to their original description of arousal as a state of feeling, but in accordance to the mental terms Mehrabian and Russell used in 1977, namely responsiveness and alertness. Mehrabian and Carroll (1999) linked 'activity' to adjectives such as alert, attentive and excited which are all focused on mental activity and as such refer to a cognitive response. Arousal explained by nouns such as attentiveness, awakeness and alertness has also to be conceived as a mental processor and a cognitive factor that may contribute to physiological activity. Whereas Mehrabian and Russell (1974) interpreted arousal as an affective factor, it shows to be a cognitive one that can be connected with thinking and thoughts. Regarding dominance, it can be questioned whether dominance has to be conceived as affective or cognitive, and how to measure this dimension (Russell and Pratt, 1980; Russell et al, 1981). In the literature dominance is consequently related to freedom or limitations regarding someone's behaviour. This means that dominance is neither affective, nor cognitive, but conative.

8.5.2 Stimulus or response

The dimensions pleasure, arousal and dominance used by Mehrabian and Russell describe the state of feeling of the observer and as such concern a response, whereas the factors evaluation, activity and potency used by Osgood concern a judgment of the appearance of the (physical) environment and as such represent a stimulus. For instance the evaluation factor of Osgood represents a rather evaluative and contemplative dimension and values the positive and negative characteristics of the stimulus. This means that evaluation and pleasure can be considered as different terms with different interpretations. Mehrabian and Russell (1974) linked arousal to mental activity ranging from sleepy to excited, while Osgood described activity with stimulus characteristics such as fast-slow and warm-cold, and physical aspects such as sharpness or abruptness. Mehrabian and Russell (1974) used the dimension dominance to express the degree of restriction of behaviour i.e. to responses, whereas Osgood did not directly link his potency factor to behaviour but interpreted potency as a factor to describe aspects of general nature like hard-soft and heavy-light. As a consequence, dominance and potency are not comparable as well. Later on, Russell et al (1981) considered dominance also as more related to the stimulus.

8.5.3 Different levels of explained variance

A third indication of incomparability between Mehrabian and Russell and Osgood et al. can be found in the different proportions of variance. According to Russell et al (1981), both pleasure and arousal account for a large proportion of variance, whereas dominance showed a small percentage of explained variance (Russell, 1980; Russell and Pratt, 1980; Russell et al, 1981). This might be due to the fact that dominance was not clearly interpreted and defined by an unclear mix of adjectives. Due to the low contribution to explained variance, many researchers do not pay attention to the influence of the dominance dimension. However, Osgood mentioned 'evaluation accounting for approximately double the amount of variance than potency or activity, these two in turn being approximately double the weight of any subsequent factors'. Apparently, potency did not have a low proportion of explained variance, whereas dominance did. It thus can be concluded that potency and dominance are different dimensions. Overall it can be concluded that serious differences exist between the triple pleasure, arousal and dominance and the triple evaluation, activity and potency.

8.6 In search of underlying mechanisms of pleasure and arousal

In order to be able to understand the relationship between environmental characteristics (stimuli) and the way people experience these characteristics (responses) and to clarify what actually happens in the mental processes between stimuli and response, this section discusses possible underlying mechanisms of pleasure and arousal. Figure 2 shows a diagram that is often used to valuing the physical environment by the dimensions pleasure and arousal (Russell, 1979, 1980; Mano, 1992; Barrett and Russell, 1998; Knez and Hygge, 2002) Our assumption is that the centre (the grey square) represents the conditions which people experience as harmonious. The outside area shows the area of disharmony, whereas the area in between shows the transition zone. A very low degree of pleasantness will cause feelings of disharmony; whereas too much pleasantness may also cause feelings of disharmony as people get lazy and bored without any challenges (Soesman, 2005). A very low degree of arousal makes people feel drowsy and a very high degree of arousal makes them highly agitated (Kandel et al, 2000).

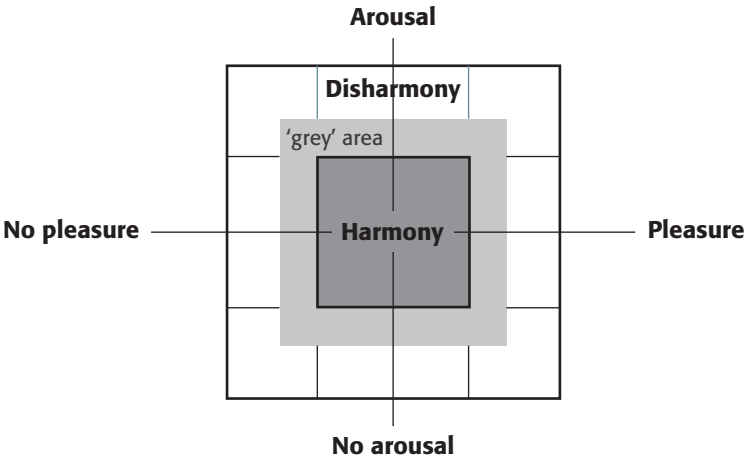


Figure 2: Pleasure and arousal as indicators for harmony and disharmony in the physical environment (Bakker and de Boon, 2012)

An underlying mechanism to explain pleasure and arousal might be the degree of order and variation. Regarding the environment, anthropologists make a distinction between the 'planet' which is shaped by natural forces and the 'world' which is built by human effort (Csikszentmihalyi and Rochberg-Halton,

1981). Both in the planet and the world an identical phenomenon can be observed: living creatures and man-made things can be recognized although all creatures and things are unique. Every oak for instance is unique and a particular building always differs from any other building. They both belong to a particular concept or archetype with a particular order (Goethe, 1810; Bortoft, 1996). Due to these concepts recognition is possible. We recognize any oak as an oak and we recognize any building as a building. Within these concepts, variations occur, both in planet and in world, which results in different appearances of the concepts caused by specific conditions and contexts. For the planet for instance, every oak shows a unique appearance while all features of this particular oak can be attributed to the oak concept. Also in the world due to the existence of concepts, recognition is possible as for instance the concepts of the old Egypt or the Islam, while the appearances of a particular Egyptian pharaoh image or a specific Islamite mosque all are unique. It can be concluded that the physical environment comes up with two characteristics: order based on concepts and variations as a result of unique conditions and contexts. The way we experience the environment depends on the degree of order and variation (Van Wegen, 1970; Steffen, 1980).

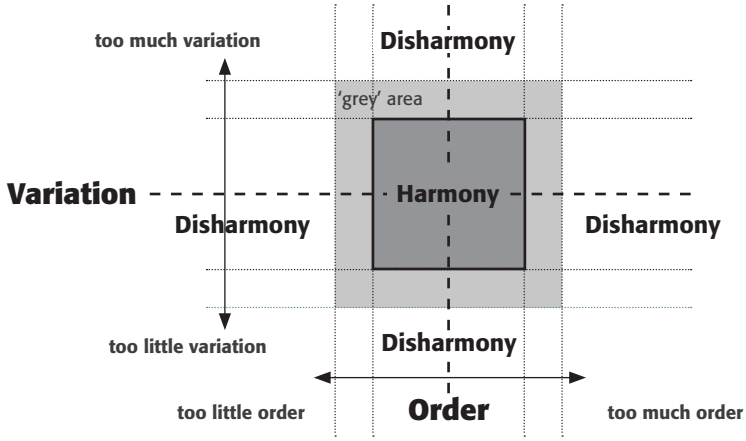


Figure 3: The degree of order and variation as indicators for harmony and disharmony in the physical environment (Bakker and De Boon, 2012)

Figure 3 shows the degree of order (horizontal axis) and variation (vertical axis) in connection to the experience of harmony and disharmony. An environment with a well-balanced level of order and variation (the grey square in Figure 3) will be experienced as an harmonious environment (Van Eyck, 1962). The outside area shows the area of disharmony: a too low degree of order means chaos, whereas too much order means rigidity (Schneider, 1987). A low degree of variation evokes dullness and a high degree means overstimulation. The area in between shows the transition zone. Although the axes in Figure 2 and 3 are different, both grey squares represent a positive response. Our assumption is that judgments of individuals regarding degrees of dominance and arousal can be linked to the degree of order and variation of the physical environment. If this assumption is true, the level of order and variation can explain why people get pleased and how the feeling state of the observer is influenced by environmental features.

Another psychological phenomenon that influences pleasure and arousal are our expectations (Steffen, 1972; Wilson et al, 1989; Vonk, 2003). Expectations can also be related to order and variation. During a lifetime people get accustomed to concepts and people build up recognitions which form people's expectations. Psychological evidence shows that affect induces when people recognize things even when they are not aware of their recognitions (Zajonc, 2001). Deviations of expectations lead to arousal (Vonk,

2003). A positively experienced deviation leads to pleasure and a negatively experienced deviation leads to displeasure (Vonk, 2003). It is hypothesized that expectations are connected with learnt habits and mental representations (Vonk, 2003) and behaviour and as such are connected to the dimension dominance.

8.7 Connections with general theories in psychology

In 1960 Rosenberg and Hovland developed the so-called ABC-psychology that adds behaviour as a third dimension, in addition to affect and cognition. This tripartite view includes behaviour as a conative dimension (Allport, 1940; Wolff and Baumgarten in Hilgard, 1980; Arriaga and Agnew, 2001; Gerdes and Stromwall, 2008). Since then, many authors pay attention to the interrelated role of affect, cognition and behaviour (Ostrom, 1969; Breckler, 1984; Knopf, 1987; Fiedler and Forgas, 1988; Polivy, 1998; Gabriel and Gardner, 1999; Thompson and Fine, 1999; Farley and Stasson, 2003; Stangor, 2013). The ABC psychology demonstrates a strong affinity with the three functions of the soul that were already mentioned by Plato: feeling, thinking and acting The distinction between feeling, thinking and acting is used since a long time until nowadays as a common view on psychological experience, e.g. by Wolff (17th century); Baumgarten (18th century), Bain (1864), Allport (1940), Smith (1947), Harding et al. (1954), Katz and Stotland (1959), Rosenberg et al, (1960), Ostrom (1969), Brodwin (1976), Ajzen (1988), Hilgard (1980), Breckler (1984), Kay (1993), Arriaga et Agnew (2001), Jorgensen and Stedman (2001), Van de Grindt (2004), Sno (2008), and Gerdes and Stromwall (2008). According to this view, people show three types of responses while interacting with stimuli: affect, behaviour and cognition (ABC factors). These experiences lead to feelings, thoughts and/or acting (Ostrom, 1969; Brodwin, 1976; Schneider, 1987; Ajzen, 1988; Kay, 1993; Arriaga and Agnew, 2001; Van de Grindt, 2004; Covey, 2005; Smidts, 2002; Csikszentmihalyi, 1999). Asking people about their experiences results in expressions such as verbal statements of affect, perceptual responses and verbal statements of belief (cognition) and reports of behavioural intentions and commitment (Ostrom, 1969; Jorgensen and Stedman, 2001).

The ABC trilogy shows similarities with the three response dimensions of Mehrabian and Russell. Pleasure corresponds with affect. Arousal appeared to express cognition. When dominance is interpreted as Mehrabian and Russell originally did, dominance refers to the degree in which people experience their environment as being restrictive versus supporting to the way they want to act, their drives and their behaviour. As such, dominance represents a conative dimension, a term that Mehrabian and Russell did not use. Table 5 shows the relationships between the original three dimensions of Mehrabian and Russell (1974), the three factors of Osgood et al. (1957), the ABC psychology and the three functions of the souls according to Plato.

Table 5: Connections between the three dimensions of Mehrabian and Russell, the three factors of Osgood, the tripartite ABC-psychology and the triad mentioned by Plato

table

Three dimensions mentioned by Mehrabian and Russell to describe human responses	Three factors mentioned by Osgood to describe stimuli	ABC-psychology	Plato
Pleasure Arousal Dominance	Evaluation Activity Potency	Affect Cognition Behaviour (Conation)	Feeling Thinking Acting

8.8 Conclusion

This paper demonstrated that the original ideas of Mehrabian and Russell (1974) about pleasure, arousal and dominance can be connected to the ABC psychology and the distinction between feeling, thinking and acting that is used since ages and are still useful to describe environmental experiences. Both tripartite views bring us back to the first models in environmental psychology that included the dominance

dimension as well, but now based on a better understanding of all three dimensions. For this reason it is suggested to replace the often used two dimensional model with pleasure on the horizontal axe and arousal on the vertical axe (Figure 1) by a three dimensional model with dominance on the third axe (Figure 4).

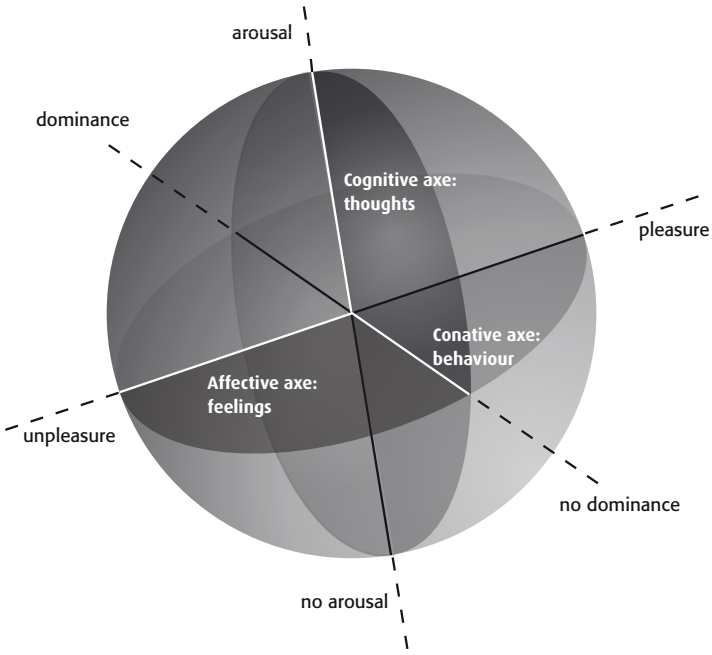


Figure 4: Three dimensional model of pleasure, arousal and dominance as tripartite view of experience (Bakker and De Boon, 2012)

Although different interpretations of pleasure, arousal and dominance can be found in literature, the original meanings developed by Mehrabian and Russell in 1974 are still valid. In future research pleasure and arousal have to be conceived as respectively affective and cognitive concepts and dominance as a conative aspect. Regarding dominance, many researches showed the importance of feelings of control related to behaviour (Seligman, 1975; Frijda, 1988; Gaillard, 2003) and health (Johnson and Hall, 1988; Furda et al, 1994; Warr, 1994; Gaillard, 2003; de Lange et al, 2003, 2004). These aspects were also mentioned by Karasek and related to workload and stress in his model together with Theorell in 1990 (in Gaillard, 2003). In research concerning topics such as picture processing (Bradley and Lang, 1994) or defining the effects in advertising (Morris et al, 2002) the dimension dominance plays an important role as well. It is recommendable that also in environmental psychology dominance is conceived as an influential factor which deserves serious attention and that this dimension will be rehabilitated. Additional research is needed to validate the proposed three-dimensional model. In current research a new list of adjectives is being tested on its applicability to measure the perceptual qualities of a meeting room (Bakker et al., forthcoming). The first findings confirmed the relevance of the triple pleasure, arousal and dominance.

In the in-depth analysis of the original meaning of pleasure, arousal and dominance and the interpretations made during latter research, different interpretations of the dimensions came to the fore, and as a consequence studies are hard to compare. Valuing the results of environmental research it is important to take in account how factors are interpreted and which definitions are used. It appears that clear definitions of the dimensions and selecting the appropriate adjectives are difficult. A sound argumentation is needed to select appropriate adjectives within a certain context of research, which is now often rudimentary done. This is essential because the adjectives provide the basic information to assess the physical environment. In the next chapter a framework will be presented that are based om the twelve senses.

8.9 References

Allport, G.W. (1940), The Psychologist's Frame of Reference. Psychological Bulletin 37, 1-28 in Hilgard, E.R. (1980), The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioural Sciences, 16 (2), 107–117.

Ajzen, I. (1989), Attitude, structure and behaviour, in Pratkanis, A.R., Breckler, S.J., Greenwald, A.G. (1989), Attitude Structure and Function. Lawrence Erlbaum Associates, IncPublishers New Yersey.

Ang, S.H., Leong, S.M. (1997), The mediating influence of pleasure and arousal on layout and signage effects, comparing more and less customized retail services. Journal of Retailing and Consumer Services, 4(1), 13-24.

Arifin, S., Cheung, P.Y.K. (2007), A Computation Method for Video Segmentation Utilizing the Pleasure-Arousal-Dominance Emotional Information. Proceedings of the 15th international conference on Multimedia, 68-77.

Arriaga, X.B., Agnew, Ch.R. (2001), Being Committed: Affective, Cognitive, and Conative Components of Relationship Commitment. Pers Soc Psychol Bull, 27, 1190-1203.

Bain, A. (1864), The senses and the intellect. 2e edition; London, Logman, Green, Longman, Roberts and Green.

Baker, J., Levy, M., Grewal, D. (1992), An Experimental Approach to Making Retail Store Environmental Decisions. Journal of Retailing, 68(4), 445-460.

Bakker, I.C., De Boon, J.C. (2012), Zorg voor mens en omgeving, Het zintuig als maatstaf, KCWZ, Utrecht, 84-89.

Bakker I.C., Van der Voordt, T., Vink, P., De Boon, J. (forthcoming), A framework to select adjectives for a uniform assessment of the physical environment. Work in progress.

Barrett, L.F., Russell, J.A.(1998), Independence and Bipolarity in the Structure of Current Affect, Journal of Personality and Social Psychology, 74 (4),967-984.

Baumgarten, A.G. in Hilgard, E.R.(1980), The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioural Sciences, 16 (2), 107–117.

Bell, P. A., Greene, T. C., Fisher, J. D., Baum, A. (2001). Environmental psychology (5th ed.). Fort Worth, TX: Harcourt College Publishers.

Bellizi, J.A., Crowley, A.E., Hasty, R.W. (1983), The Effects of Colour in Store Design. Journal of Retailing, 59 (1), 21-45.

Berkowitz, L. (1987), Advances in experimental social psychology, Vol 20, Academic Press Inc, London.203-251.

Berleant, A. (1997), Living in the landscape: Towards an aesthetics of environment. Lawrence, KS: University Press of Kansas.

Berlyne, D.E. (1966), Conflict and arousal. Scientific American, Inc, 82-87.

Berlyne, D.E. (1970), Novelty, complexity, and hedonic value. Perception & Psychophysics, 8 (5A), 279-286.

Bigné, J.E., Andreu, L., Gnoth, J. (2005), The theme park experience: An analysis of pleasure, arousal and satisfaction. Tourism Management 26, 833–844.

Bonnet, M., Bradley, M.M., Lang, P.J., Requin, J. (1995), Modulation of spinal reflexes: arousal, pleasure, action. Psychophysiology, 32(4), 367–372.

Bortoft, H. (2010), The Wholeness of Nature, Goethe's ay off Science, Floris Books, fourth printing, Edingburgh, 50-64.

Bradley, M.M., Greenwald, M.K., Petry, M.C., Lang, P.J. (1992), Remembering pictures: Pleasure and arousal in memory. Journal of Experimental Psychology, 18(2), 379-390.

Bradley, M. M., Lang, P. J. (1994). Measuring emotion: the self-assessment manikin and the semantic differential. Journal of behaviour therapy and experimental psychiatry, 25(1), 49-59.

Bradley, M.M., Miccoli, L., Esgrig, M.A., Lang, P.J. (2008), The pupil as a measure of emotional arousal and autonomic activation. Psychophysiology, 45(4), 602–607.

Breckler, S. J. (1984), Empirical validation of affect, behaviour, and cognition as distinct components of attitude. Journal of Personality and Social Psychology, 47(6), 1191-1205.

Brodwin, M.G. (1976), Two Hundred Years of the Psychology of Attitude-2000 Years of Contributions, From Plato to Allport. Paper presented at the 56th Annual Convention of the Western Psychological Association. Los Angeles, California, April 8-11, 1976.

Canter, D. (1969), An intergroup comparison of connotative dimensions in architecture. Environment and Behaviour, 1 (1), 37-48.

Chebat, J.C., Michon, R. (2003), Impact of ambient odors on mall shoppers' emotions, cognition, and spending: A test of competitive causal theories. Journal of Business Research 56, 529-539.

Colomo-Palacios, Casado-Lumbreras, Ch., R., Soto-Acosta, García-Crespo, A. (2011), Using the Affect Grid to Measure Emotions in Software Requirements Engineering. Journal of Universal Computer Science, 17(9), 1281-1298.

Costa, V.D., Lang, P.J., Sabatinelli, D., Versace, F., Bradley, M.M. (2010), Emotional Imagery: Assessing Pleasure and Arousal in the Brain's Reward Circuitry. Human Brain Mapping 31, 1446–1457.

Covey, S.R.(2005), De 8e eigenschap van effectiviteit naar inspiratie, Uitgeverij Business Contact Amsterdam/Antwerpen.

Craik, K. H. (1971). The assessment of places. In P. McReynolds (ed.), Advances in Psychological Assessment, 2, 40-62. Palo Alto, Calif.: Science and Behaviour Books.

Csikszentmihalyi, M. (1999), De weg naar Flow. Boom Amsterdam, 38-41.

Csikszentmihalyi, M., Rochberg/Halton, E. (1981), The meaning of things, Domestic symbols and the self, Cambridge University Press, page 15.

de Lange, A.H., Taris, T.W., Kompier, M.A.J., Houman, I. L.D.,Bongers, P.M.(2003), The very best of the Millennium': Longitudinal research and the Demand-Control-(Support) Model. Journal of Occupational Health Psychology, 8, 282- 305.

de Lange, A. H., Taris, T. W., Kompier, M. A., Houtman, I. L., Bongers, P. M. (2004). The relationships between work characteristics and mental health: Examining normal, reversed and reciprocal relationships in a 4-wave study. Work & Stress, 18(2), 149-166.

Donovan, R.J., Rossiter, J.R., Marcoolyn, G., Nesdale, A. (1994). Store atmosphere and purchasing behaviour, Journal of Retailing, 70(3), 283–294.

Dubé, L., Chebat, J.C., Morin, S. (1995), The effects of background music on consumers' desire to affiliate in buyer-seller interactions, Psychology & Marketing, 12(4), 305–319.

Duffy, E. (1957), The psychological significance of the concept of arousal or activation. Psychological Review, 64, 265-275 in Russell, J.A., Weiss, A., Mendelsohn, G.A. (1989), Affect Grid: A Single-Item Scale of Pleasure and Arousal. Journal of Personality and Social Psychology, 57(3), 493-502.

Eastman, S, T.(1997), Uses of television viewing and consumer life styles: A multivariate analysis. Journal of Broadcasting, 23(4), 491-500.

Farley, S.D., Stasson, M.F. (2003), Relative Influences of Affect and Cognition on Behaviour: Are Feelings or Beliefs More Related to Blood Donation Intentions? Experimental Psychology, Vol. 50(1): 55- 62.

Fiedler, K. (1988), Emotional mood, cognitive style, and behaviour regulation, in Fiedler, K. ,Forgas, J., (Eds.), (1988), Affect, cognition and social behaviour: New evidence and integrative attempts. Toronto, Canada: Hogrefe.

Fiedler, K. ,Forgas, J., (Eds.), (1988), Affect, cognition and social behaviour: New evidence and integrative attempts. Toronto, Canada: Hogrefe.

Floyd, M.F. (1997), Pleasure, arousal, and dominance: Exploring affective determinants of recreation satisfaction, Leisure Sciences, Leisure Sciences: An Interdisciplinary Journal, 19(2), 83-96.

Frijda, N.H. (1988), De emoties. Amsterdam, Bert Bakker.

Furda, J., Jonge, J. de, Blanc, P. le, Meijman, T., Scheurs, P., Scheenen, J.(1994), Het demand-control-support model in relatie tot gezondheidsklachten en herstelklachten. Gedrag en Organisatie, 7, 225-237.

Gabriel, S., Gardner, WL. (1999), Are there "his" and "hers" types of interdependence? The implications of gender differences in collective versus relational interdependence for affect, behaviour, and cognition.Journal of Personality and Social Psychology, Vol 77(3), 642-655.

Gaillard, A.W.K. (2003), Stress, productiviteit en gezondheid, second edition, Uitgeverij Nieuwezijds, Amsterdam.

Gerdes, K.E., Stromwall L.K. (2008), Conation: a missing link in the strengths perspective. Soc Work, 53(3):233-42.

Gifford, R. (2001), Environmental psychology, principles and practice. Allyn and Bacon, third edition, Boston.

Goethe, J.W. (1981), De metamorfose van de planten, Inleiding en toelichtingen van Rudolf Steiner, Uitgeverij Christofoor, Rotterdam, 7,8, 13.

Ha, Y., Lennon, S.J. (2010), Online Visual Merchandising (VMD) Cues and Consumer Pleasure and Arousal: Purchasing versus Browsing Situation. Psychology & Marketing, 27(2), 141–165.

Harding, J., Kutner, B., Proshansky, H.,Chein, I. (1969), Prejudice and ethnic relations. In Ostrom, T. M. (1969). The relationship between the affective, behavioural, and cognitive components of attitude. Journal of Experimental Social Psychology, 5(1), 12-30.

Hilgard, E.R.(1980), The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioural Sciences, 16 (2), 107–117.

Hyun, S.S., Wansoo, K., Myong J.J. (2011), The impact of advertising on patrons' emotional responses, perceived value, and behavioural intentions in the chain restaurant industry: The moderating role of advertising-induced arousal. International Journal of Hospitality Management, 30(3), 689–700.

Isen, A.M. (1987), Positive affect, Cognitive processes, and social behaviour in Berkowitz, L. (1987), Advances in experimental social psychology, Vol 20, Academic Press Inc, London.203-251.

Ittelson, W.H. (1973), Environment and Cognition, Seminar Press, Oxford, England.

Johnson, J.V., Hall, E.M. (1988), Job strain, workplace social support, and cardiovascular disease: a cross sectional study of a random sample of the Swedish working population. American Journal of Public Health, 78, 1336-1342.

Jorgensen, B.S., Stedman, R.C.(2001), Sense of Place an Attitude: Lakeshore owners attitudes toward their properties. Journal of Environmental Psychology, 21(3), 233-248.

Kandel, E.R,. Schwartz, J.H., Jessell, Th.M. (2000), Principles of Neural Science, The MacGraw-Hill Companies, Fourth Edition, United State of America, 414, 982-986.

Kaplan, R., Kaplan, S., Ryan, R.L. (1998), With people in mind: Design and management of everyday nature. Washington, DC: Island Press.

Katz, D., Stotland, E. (1959). A preliminary statement to a theory of attitude structure and change. In Ostrom, T. M. (1969). The relationship between the affective, behavioural, and cognitive components of attitude. Journal of Experimental Social Psychology, 5,(1) 12-30.

Kay, R.H.(1993), An Exploration of Theoretical and Practical Foundations for Assessing Attitudes Toward Computers: The Computer Attitude Measure (CAM). Computers in Human Behaviour, 9 (4), 371-386.

Knopf, R. (1987), Human behaviour, cognition, and affect in the natural environment in Stokols, D., Altman, I.(1987), Handbook of environmental psychology., New York: Wiley.

Kuppens, P. (2008), Individual differences in the relationship between pleasure and arousal. Journal of Research in Personality, 42(4), 1053–1059.

Laroche, M., Teng, L., Michon, R., Chebat, J.C.(2005), Incorporating service quality into consumer mallshopping decision making: a comparison between English and French Canadian consumers. Journal of Services Marketing, 19(3), 157–163.

Lin, I.Y. (2010), The interactive effect of Gestalt situations and arousal seeking tendency on customers' emotional responses: matching colour and music to specific servicescapes. Journal of Services Marketing, 24 (4),294 – 304.

Lindsley, D. B. (1951), Emotion, in Russell, J.A., Weiss, A., Mendelsohn, G.A. (1989), Affect Grid: A Single-Item Scale of Pleasure and Arousal. Journal of Personality and Social Psychology, 57, no 3, 493-502.

Mattila, A.S., Wirtz, J. (2001), Congruence of scent and music as a driver of in-store evaluations and behaviour. Journal of Retailing, 77 (2), 273–289.

Mattila, A.S., Wirtz, J. (2006), Arousal expectations and service evaluations. International Journal of Service Industry Management, 17 (3), 229-244.

Mehrabian, A. (1996), Pleasure-Arousal-Dominance: A General Framework for Describing and Measuring Individual Differences in Temperament. Current Psychology, 14(4), 261- 292.

Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America, 216-217.

Menon, S., Kahn, B. (2002), Cross-category effects of induced arousal and pleasure on the Internetshopping experience. Journal of Retailing, 78 (1), 31–40.

Morris, J. D., Woo, C., Geason, J. A., Kim, J. (2002). The power of affect: Predicting intention. Journal of Advertising Research, 42(3), 7-18.

Morrison, M., Gan, S., Dubelaar, Ch., Oppewal, H. (2011), In-store music and aroma influences on shopper behaviour and satisfaction. Journal of Business Research 64 (6), 558–564.

Osgood, Ch., Suci, G.J., Tannenbaum, P.H. (1957), The measurement of meaning, University of Illinois Press, Urbana, Chigago and London, 36, 38, 62, 63, 149, 185, 186, 325.

Osgood, Ch. E. (1963), Part four, Psychological approaches, Semantic Differential Technique in the Comparative Study of Cultures. American Anthropologist, 66 (3), 171-200.

Ostrom, T. M. (1969). The relationship between the affective, behavioural, and cognitive components of attitude. Journal of Experimental Social Psychology, 5 (1), 12-30.

Penz, E., Hogg, M.K.(2011), The role of mixed emotions in consumer behaviour Investigating ambivalence in consumers' experiences of approach-avoidance conflicts in online and offline settings. European Journal of Marketing, 45 (1/2), 104-132.

Polivy , P. (1998), The Effects of Behavioural Inhibition: Integrating Internal Cues, Cognition, Behaviour, and Affect, Psychological Inquiry: An International Journal for the Advancement of Psychological Theory, Vol 9(3), 181-204.

Reisenzein, R. (1994), Pleasure-Arousal Theory and the Intensity of Emotions. Journal of Personality and Social Psychology, 67 (3), 525-539.

Rosenberg, M.J, Hovland, C.I., McGuire, W.J., Abelson, .P., Brehm, J.W.(1960), Attitude organisation and change: an analysis of consistency among attitude components, New Haven. Connecticut: Yale University.
Russell, J.A. (1980), A Circumplex Model of Affect. Journal of Personality and Social Psychology, 39 (6), 1161-1178.

Russell, J.A., Carroll, J.M. (1999), On the Bipolarity of Positive and Negative Affect. Psychological Bulletin, 125 (1), 3-30.

Russell, J.A., James, A.(2003), Core Affect and the psychological construction of emotion. Psychological Review, 110 (1), 145-172.

Russell, J.A., Lanius, U.F. (1984), Adaptation level and the affective appraisal of environments. Journal of Environmental Psychology, 4(2) 119–135.

Russell, J.A., Mehrabian, A. (1977), Evidence for a Three-Factor Theory of Emotions, Journal of Research in Personality, 11, 273-294.

Russell, J.A., Pratt, G.(1980), A description of the affective quality attributed to environments Journal of Personality and Social Psychology, 38(2), 311-322.

Russell, J.A., Ward, L.M. Pratt, G.(1981), Affective Quality Attributed to Environments
A Factor Analytic Study. Environment and Behaviour, 13 (3), 259-288.

Russell, J.A., Weiss, A., Mendelsohn, G.A. (1989), Affect Grid: A Single-Item Scale of Pleasure and Arousal. Journal of Personality and Social Psychology, 57 (3), 493-502.

Ryu, K., Jang, S.(2007), The effect of environmental perceptions on behavioural intentions through emotions: the case of upscale restaurants. Journal of Hospitality & Tourism Research, 31(1), 65-72.

Schneider, W. (1987), Sinn und Un-Sinn, Umweltt sinnlich erlebbar gestalten in Architektur und Design, Wiesbaden und Berlin: Bauverlag GMBH, 43, 106.

Seligman, M. (1975), Helplessness. On depression, development and death. San Francisco. Freeman.

Sno H.N. (2008), The psychiatric assessment and mental status examination from an EBM perspective. Tijdschrift Psychiatrie, 50(6), 353-8.

Smidts, A. (2002), Kijken in het brein, Over de mogelijkheden van euromarketing, Erasmus Research Institute of Management, Rotterdam.

Smith, M. B. (1947). The personal setting of public opinions: A study of attitudes toward Russia. Public Opinion Quarterly, 11, 507-523 in Kay, R.H.(1993), An Exploration of Theoretical and Practical Foundations for Assessing Attitudes Toward Computers: The Computer Attitude Measure (CAM). Computers in Human Behaviour; 9 (4), 371-386.

Soesman, A. (2005), De Twaalf zintuigen, 4e druk, Vrij Geestesleven, Zeist

Solomon, L.N. (1954), A factorial study of the meaning of complex auditory stimuli, Unplublished doctoral dissertation, University of Illinois in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America, 216-217.

Stangor, Ch.(2013), Affect, behaviour, and cognition, Principles of Social Psychology, Flat World Knowledge, Inc.

Stamps, A.E. (2003), Advances in visual diversity and entropy. Environment and Planning B: Planning and Design, 30, 449-463.

Steffen, C. (1972). Perceptieonderzoek en stedebouw. Delft, Technische Hogeschool Delft,rapport C.A. 72.05.01.

Steffen, C. (1980) Psychologische aspecten van complexiteit. Delft, Technische Hogeschool Delft,rapport C.A.80.10.01.

Stokols, D., Altman, I.(1987), Handbook of environmental psychology , New York: Wiley.

Thayer, R.E.(1967), Measurement of activation through self-report, Psychological Reports 20, 663- 678 inMehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America, 216-217.

Thompson, L., Fine, G.A.(1999), Socially Shared Cognition, Affect, and Behaviour: A Review and Integration, Pers Soc Psychol Rev , Vol 3(4), 278-302

Tucker, W.T. (1955), Experiments in aesthetic communications. Unpublished doctoral dissertation, University of Illinois in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America, 216-217.

Ulrich, S. R., (1983), Aesthetic and Affective Response to Natural Environment, Behaviour and the natural environment, Human Behaviour and Environment, Vol 6, 85-125

Van Eyck, A. (1962). De verkapte opdrachtgever en het grote woord 'neen'. Forum 16, 79-122 in Steffen, C. (1980) Psychologische aspecten van complexiteit. Delft, Technische Hogeschool Delft, rapport C.A.80.10.01.

Van de Grind, W. A. (2004). Natuurlijke Intelligentie, over denken, intelligentie en bewustzijn van mensen en andere dieren. Uitgeverij Nieuwezijds, Amsterdam.

Van Hagen, M., Galetzka, M, Pruyn, A., Peters J. (2009), Effects of Colour and Light on Customer Experience and Time Perception at a virtual Railway Station, Proceedings Experiencing Light 2009; International Conference on the Effects of Light on Wellbeing; 137-145.

Van Wegen, H.B.R. (1970), De invloed van variatie op aandacht en waardering voor eenvoudige vormstrukturen. Delft, Technische Hogeschool Delft,rapport C.A. 70.01.03

Vonk, R. (2003). Cognitieve sociale psychologie. Uitgeverij Lemma BV, Utrecht, 375-380.

Walter, S., Kessler, H., Gruss, S., Jerg-Bretzke, L., Scheck, A., Ströbel, J., Hoffmann, H., Traue, C. (2011). The influence of neuroticism and psychological symptoms on the assessment of images in three-dimensional emotion space. Psychosoc Med Published online 2011 June 6.

Warr, P.(1994), A conceptual framework for the study of work and mental health. Work and Stress, 8, 84-97.

Wilson, T.D., Lisle, D. J., Kraft, D., Wetzel, Ch. G. (1989), Preferences as expectation-driven inferences: Effects of affective expectations on affective experience. Journal of Personality and Social Psychology, 56(4), 519-530.

Wirtz, J., Mattila, A.S.,Tan, R.L.P.(2000), The Moderating Role of Target-Arousal on the Impact of Affect on Satisfaction—An Examination in the Context of Service Experiences. Journal of Retailing, 76(3), 347–365.

Wolff, Ch. in Hilgard, E.R.(1980), The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioural Sciences, 16(2), 107–117.

Wu, Ch.S., Cheng, F,F, Yen, D.C.(2008), The atmospheric factors of online storefront environment design: An empirical experiment in Taiwan. Information and Management, 45 (7), 493-498.

Yani-de-Soriano M.M., Foxall G.R. (2006), The emotional power of place: the fall and rise of dominance in retail research, J of Retailing and Consumer Services 13(6):403-416.

Zajonc, R.B. (1980), Feeling and Thinking, Preferences Need No Inferences. American Psychologist, 35 (2), 151-175

Zajonc, R.B. and Markus, H. (1984), Affect and cognition: the hard interface, in Izard, C.E.,
Kagan, J., Zajonc, R.B. Emotions, Cognition, and Behaviour, Cambridge University Press, 17, 73-102.

Zajonc, R.B. (2001), Mere exposure: A Gateway to the subliminal. Current Directions in Psychological Science, 10(60), 224-228.

Floating thinking cubes.

For the knowledge worker a helicopter view is necessary to approach topics from different perspectives. A camel can be helpful (Tony Gaillard).

To define environmental experience people are asked to describe their opinions by means of adjectives. It is the question whether these adjectives are clear, objective and concern the totality of environmental experience.

Chapter Nine

Toward a new framework for a uniform assessment of people's experience of the physical environment

Referring to the problems mentioned in chapter 8 and 9 there was a need to develop a framework with well-argued adjectives, which describe people's experience of the built environment accurately. Because our senses provide information about environmental features, the sensory system will be used to develop this framework. In the beginning of the 20th century Steiner mentioned twelve senses. His vision is used to assess the functionalities of all senses. This information is the base for the development of a framework with appropriate adjectives to assess the physical environment.

abstract

The physical environment influences our wellbeing, mood and performance. In order to be able to design and manage a physical environment that fits with the needs of the users, one has to understand the interaction between the stimulus (i.e. the built environment) and the response of the observer. Frequently bipolar adjectives are used to assess environmental experiences. Due to the huge variety in applied adjectives, findings are not well comparable and therefore multi interpretable. Besides, most adjectives refer to the global experience of the observer and do not make clear which particular physical characteristic causes which response. This paper proposes a new framework with adjectives that express environmental features in connection to a list of environmental elements that can be observed.

Because our senses provide information about environmental features, the sensory system has been used to develop the framework for the selection of appropriate adjectives. The framework is based on the trichotomy of twelve senses as defined by Rudolf Steiner (1909) that corresponds to the tripartite view of Mehrabian and Russell (1974) with the three dimensions pleasure, arousal and dominance, and the triad of affect, behaviour and cognition from the ABC model of attitude. The framework has been tested for clarity and applicability in a pilot study with designers and user groups. The results are promising and confirm the usability as a tool to measure and discuss user experiences of the physical environment both for laymen and designers.

9.1 Introduction

To define peoples' experiences of the physical environment many studies have been carried out using bipolar adjectives (Ross, 1938; Osgood et al, 1957; Osgood, 1963; Venturi, 1966; Mehrabian and Russell, 1974; Hershberger and Cass, 1974; Oostendorp and Berlyne, 1978; Russell, 1980; Russell and Pratt, 1980; Russell et al, 1981; Russell and Lanius 1984; Kunishima and Yanase, 1985; Baker et al, 1992; Bradley et al, 1992; Bellizi et al, 1993; Donovan et al, 1994; Dubé et al, 1995; Mehrabian, 1996; Eastman, 1997, Taft, 1997; Floyd, 1997; Wirtz et al, 2000; Nagumo, 2000; Mattila and Wirtz, 2001; Knez, 2002; Chebat and Michon, 2003; Ou, 2004; Bigné et al, 2005; Laroche et al, 2005; Ryu, 2007; Manav, 2007; Wu et al, 2008; Chen and Chen, 2008; Van Hagen et al, 2009; Chen and Chen, 2010). Participants are asked to mark their experience on a scale with two opposite adjectives. These adjectives show a huge variety from happy-unhappy, dreary-gay, dingy-sparkling (Mehrabian and Russell, 1974) and disappointed-delighted, bored-entertained (Ryu and Jang, 2007) till dull-enthusiastic and nervous-calm (Knez, 2002).

Applying adjectives appears to be a practical instrument to define the experience of the physical environment (Venturi, 1966; Hershberger and Cass, 1974; Hershberger, 1975) and is still widely used in environmental psychology research. However, some problems come to the fore as well.

9.1.1 Poor comparability of research findings

The lack of a standardised and widely agreed system of uniform adjectives and the huge variety of different terms makes the comparison between findings difficult. Moreover, similar adjectives are used in different bipolar pairs that makes a uniform interpretation complicated. For instance, Mehrabian and Russell (1974) used the bipolarity 'bored-relaxed', whereas Knez (2002) used 'bored-lively', Ryu and Jang (2007) 'bored-entertained', and Russell and Pratt (1980) 'boring-interesting'. These different opposites of 'bored/boring' have different meanings. As the opposite of 'calm', Knez (2002) used 'nervous', Russell and Carroll (1999) 'upset', Russell and Pratt (1980) 'rushed' and Mehrabian and Russell (1974) 'excited'. These counterparts of 'calm' have different meanings as well. Gardner (1987) already mentioned the risk of ambivalence when making use of adjectives and the justification of bipolarity of the applied adjectives is seriously discussed (Cacioppo et al, 1997; Russell and Carroll, 1999).

9.1.2 Stimulus or response

Using words such as happy (Mehrabian and Russell (1974), depressed (Russell, 1980), nervous (Knez, 2002) or bored (Ryu and Jang, 2007) reflect the state of the observer but do not tell much about the environmental conditions that evoke these experiences. It is the observer who is happy, depressed, nervous or bored, and not the environmental stimulus although there could be an intrinsic quality which causes these effects. As such, these adjectives reveal primary information about internal personal interpretations and feelings and provide to a much lesser extent information about the objective qualities of the physical environment (Van Wegen, 1970, Steffen, 1972). The transformation process of experiencing the environment into valuing the environment is a complicated process (Hershberger, 1975). This process is influenced by both feelings and cognitive processes (Gifford et al, 2000) and is extra complicated by verbalisation processes (Zajonc, 1980). As a result, responses using traditional bipolar adjectives are a mix of external influences and internal feelings and beliefs. To be able to improve the physical environment, it is necessary to know in which way the features of the physical environment itself are valued, without influences of internal individual feelings and learned representations (Vonk, 2003). Therefore, using adjectives that primarily describe the features of the environment itself seems to be a better approach.

9.1.3 Senses

The current method of applying adjectives that directly refer to the environment in terms of a positive or negative appraisal, appears less useful to describe the experience value as it is difficult to find out what exactly in the environment elicits these experiences. If the observer experiences for instance arousal, it is not clear by which environmental cue this arousal is caused. Because the physical environment is experienced by means of the senses (Geldard, 1953; Gibson, 1966; Schneider, 1987; Ernst and Bülthoff, 2004), it seems appropriate to use the sensory information system to understand the mechanism between environmental cues (stimuli) and the observer's experience (response). Earlier environmental studies already mentioned sensory information as an indicator of experiences, inter alia referring to the effect of synesthesia i.e. connecting experiences from different senses such as "hearing" or "smelling" colours (Hazzard, 1930; von Hornbostel, 1931; Zietz, 1931; Karwoski and Odbert, 1938; Odbert et al, 1942: Karwoski et al, 1942; Uhlich, 1957; Holt-Hansen; 1968; Luria, 1969; Rosenberg et al, 1969; Loveless et al, 1970). Osgood (1963), the founder of the semantic differential method, assumed that his three dimensions of the semantic space - evaluation, activity and potency - correspond with how the sensory

nervous system classifies environmental information. However, in his analysis he could not find any clear connections between dimension and type of sensory information. Other authors paid attention to particular senses such as taste and smell (Rozin, 1982; Korsmeyer, 2002; Shepherd, 2004; Shepherd, 2012), touch (Robles-De-La-Torre, 2006; Maheshwari and Saraf, 2008), a cluster of sound, sight, smell and touch (Sonneveld, 2007; Soars, 2009) or the five senses that were mentioned by Aristotle: touch, taste, smell, sight, hearing (Lindström, 2005). It can be concluded that many scientific researchers are convinced of a relationship between sensory information and environmental experience (Geldard, 1953; Osgood, 1963, Gibson, 1966; Ayres et al, 1980; Pennebaker and Brittingham, 1982; Schneider, 1987; Hillis et al, 2002; Ernst and Bülthoff, 2004; Soesman, 2005). However, in the environmental psychology connections between senses and environmental features have not been found.

9.2 Towards a new framework to assess of the perceptual qualities of the built environment

In order to explore if it is possible to define and understand environmental experiences in a more clear way, two research activities have been conducted:

1. The development of a framework with adjectives that clearly defines the perceptual qualities of the physical environment (section § 9.2).
2. A pilot to test if this framework can be used in Post-Occupancy Evaluations (section § 9.3).

9.2.1 The twelve senses of Rudolf Steiner

The system of Rudolf Steiner (1909) that classifies twelve senses into three groups of affective, physical and cognitive senses could be an appropriate system that can be used to develop a practical framework (Kirn, 1989). Rudolf Steiner (1909) linked the physical senses to information about the physical human body, behaviour and acting, the affective senses to the human soul and feeling, and the cognitive senses to the provision of information about cognition that is related to thinking (Schneider, 1987; Soesman, 2005; Nordlund, 2006) (see Table 1).

This triad corresponds well with the tripartite view of attitude, known as the ABC-psychology, (ABC = Affect, Behaviour and Cognition, see for instance Allport, 1940; Rosenberg and Hovland, 1960; Hilgard, 1980; Arriaga and Agnew, 2001; Gerdes and Stromwall, 2008; Garg, 2012). Additional research supports this trichotomy (Ostrom, 1969; Breckler, 1984; Knopf, 1987; Fiedler, 1988; Polivy, 1998; Gabriel and Gardner, 1999; Thompson and Fine, 1999; Farley and Stasson, 2003; Stangor, 2013). There is also a clear parallel with the three functions of the soul as mentioned by Plato: feeling, acting and thinking (Van Schilfgaarde, 1938). Finally the triads seem to be comparable with the tripartite view on people's experience of the built environment using the three dimensions pleasure, arousal and as proposed by Mehrabian and Russell (1974).

Table 1: Parallels between the three groups of senses according to Steiner (1909), the three functions of soul according to Plato, the ABC-model of attitude, the three dimensions of Osgood (1963) and the three dimensions of Mehrabian and Russell (1974).

table

the groups of senses according to Rudolf Steiner	affective senses	cognitive senses	physical senses
Three functions of soul according to Plato	feeling	thinking	acting
relation to the ABC model of Attitude	affect	cognition	behaviour
Dimensions of Osgood(1963)	evaluation	activity	potency
Dimensions of Mehrabian and Russell (1974)	pleasure	arousal	dominance

9.2.2 Sensory information as a source of information about the physical environment

Table 2 shows the twelve senses that were mentioned by Rudolf Steiner, clustered into three groups. The affective senses give information about the affective quality of environmental aspects and are related to feelings. For instance the sense of taste provides information about the quality of composition. With the physical senses, people experience internal drivers how to act and how to behave. Physical senses concern the physical body and provide sensory information about physical features. For instance the sense of touch gives insight into the position, condition and boundaries of the physical human body (Steiner, 1909; Schneider, 1987; Soesman, 2005) and provides information about the textures of materials and the physical borders. Cognitive senses such as the sense of symbols provide people with information about meanings and are related to thinking. The group of cognitive senses is rather difficult to transform into environmental information, due to its focus on thinking. In his extensive research Schneider (1987) has shown how the four cognitive senses can be interpreted as an environmental sensory information system. Research of among others Dozi (1984), Scheuerle (1984), Schneider (1987), Berman (1998) and Pascha (2004) support his view on how the cognitive senses contribute to environmental experience. The classification of Rudolf Steiner shows which sense is responsible for which information and is therefore used as leading conceptual framework for the selection of adjectives.

Table 2: Twelve senses that provide environmental information according to Steiner (1909) and Schneider(1987)

table

affective senses	cognitive senses	physical senses
smell observing purity	**proportion** recognising order	**touch** experiencing the bodily boundaries
taste experiencing modulation	**gestalt** recognising unities	**life** experiencing the bodily constitution
sight connecting sight and insight	**symbol** recognising deeper values of unities	**movement** experiencing targeted movement
temperature recognising the difference between sympathy and not sympathy	**identity** recognising others learning about one's own identity	**balance** searching for balance

9.2.3 Connection between the three groups of senses and three parts of the physical environment

To define a framework with appropriate adjectives that can be used to assess human experiences of environmental features, it is necessary to know which senses primarily interact with which parts of the built environment. As was shown before, the physical senses primarily provide information about the physical borders. Physical borders existing out of materials such as walls that create space, and physical connections such as stairs and corridors, enable us to act and to behave how we want. The affective senses provide feelings about the environment (Schneider, 1987) and as such primarily focus on the indoor climate (e.g. a 'friendly' climate) and atmosphere (e.g. a 'cosy' or 'warm' atmosphere or a 'tastefully' decorated home). The cognitive senses provide information about expression. We recognise a building as a church or a school. We recognise things in buildings such as the cross and the pulpit in a church or school desks and the black board in a school. This recognition is based on learnt meanings and is related to cognition.

Baker et al. (1992) made a distinction between design factors, ambient factors and social factors that shows similarities with the classification of Steiner and Schneider. Design factors are comparable with the physical qualities (e.g. materials). Ambient factors are comparable with the inner climate and atmosphere. Social factors are comparable with cultural qualities related to meaning and expression.

The relationships between groups of senses and environmental parts can be used to select appropriate adjectives and to classify them in three groups and twelve subgroups (see Table 3). Hard and soft are for instance adjectives that are related to the physical senses (sense of touch) and as such to the material part of the environment. Warm and cold are adjectives that are related to the affective senses (the sense of temperature) and as such to the atmosphere and the indoor climate. General and authentic are adjectives that are related to the cognitive senses and as such related to meaning or identity. By using the classification of 12 senses into three groups in connection to three related parts of the environment, adjectives can be chosen in a systematic way, to acquire a balanced representation of the environment. Using the lists of Schneider (1987), a shortlist of adjectives is being proposed (left part of Table 3). The adjectives are presented as a semantic differential and systematically categorised according to the three groups of senses (middle column) and the three parts of the physical environment (right column). The terms are arranged in such a way that adjectives that primarily describe the materials are combined with the physical senses, the adjectives that primarily describe the inner climate and atmosphere are combined with the affective senses, and the adjectives that primarily describe the meaning and expression are combined with the cognitive senses. As such a framework has been developed that can be used to describe environmental features and sensory information in order to assess and discuss the perceptual qualities of the built environment

Table 3: The new framework with all adjectives related to three groups of in total twelve senses and three parts of the physical environment

Semantic Differential									Senses	Global list for observing elements objectively	
	3	2	1	0	1	2	3			**Materialisation**	
smooth								rough	Sense of touch	substructure	
hard								soft		decking	
straight								curved/bent		wall finish	
blunt								pointed		ceiling finish	
crude								refined		window/door frame	
closed								open		stairs	
passive								active	Sense of live	fencing	
deathlike								lively		finishing	
weak								strong			
artificial								natural			
motionless								dynamic	Sense of movement		
rigid								flexible			
aimlessly								directed			
massive								fragile	Sense of balance		
skew								straight			
labile								stable			
chaotic								balanced			
	3	2	1	0	1	2	3			**Atmosphere and inner climate**	
airless								fresh	Sense of smell	Artificial light	light quantity
dirty								clean			light colour
not cozy								cozy	Sense of taste	Daylight	
not varied								nuanced		Sound	in the space
unstylish								stylish			out of space
messy								neatly		Acoustics	sound facilities
colorless								colorful	Sense of sight	Heating	facilities
dark								light		Ventilation	facilities
full of contrast								no contrast		Electrical Engineering	switchgear
unsaturated								saturated		Facilities	blinds
cold								warm	Sense of temperature		lighting elements
repulsive								sympathetic			furnishing
											plants
											art
											colors
	3	2	1	0	1	2	3			**Expression**	
discordant								harmonic	Sense of proportion	Proportion and shape	size
noisy								silent			height
simple								complex			length
monotonous								varied			width
not proportionated								proportionated			form
divided								cohesive	Sense of gestalt		expression
trivial								significant			form consistancy
functionless								functional			symmetry
meaningless								meaningful	Sense of symbols		window/door opening
of former times								modern		Sight/View	on space outside
fashion sensitive								timeless			on space outside green
modest								luxurious			on space outside urban
indefinable								recognisable	Sense of identity		
general								authentic			
strange								familiar			
no character								with character			
standardized								playful			

9.3 Empirical test of the proposed framework

In order to test the framework on its applicability in practice and to test the list of adjectives on completeness and usefulness, an empirical study has been conducted. In six sessions with different groups of 6-8 people in total 45 respondents were asked to express their experience of a meeting room. The test process included a step-by-step procedure that fits with the way people experience their environment. Findings from environmental psychological research (Dijksterhuis, 2007; Vonk, 2003) show that people do not observe their physical environment carefully, and do not consciously realise which elements are present in the observed environment. However, though not being fully aware of the existing environmental elements, people entering a room immediately have a general feeling and perceive the space for instance as cosy or unpleasant. In order to be able to understand the experienced perceptual qualities of the meeting room all respondents were asked about their feelings and then asked to observe the present environmental features carefully to be able to define cause-effect relationships between stimuli and responses. The test process included five steps:

1 First all respondents were welcomed in a test room, and got an explanation of the trichotomy of twelve senses, its meanings and interactions.
2 Then the respondents were asked to enter the nearby meeting room and individually to write down their first impression in maximal three keywords.
3 After a short instruction in the test room, the respondents were asked to go back to the meeting room and to complete the list of adjectives of the semantic differential individually (left part of Table 3, presented on a separate form), in order to record people's individual perceptions of the physical environment.
4 Again after a short instruction the respondents were asked to observe the meeting room individually by using a standard checklist of physical elements (right part of Table 3, presented on a separate form), to become aware of all elements of this environment;
5 Finally the respondents were asked to connect the list of adjectives with the observed elements, individually (both columns of Table 3), as input for a plenary discussion in search of a better understanding of which individual perceptions were evoked by which elements of the physical environment, and how to improve the test environment.

Two researchers observed and guided the process. Weather conditions such as daylight and temperature were quite similar in all 6 sessions.

9.3.1 Composition of the sample

The respondents included end users such as employees of care organisations (nurses, group leaders and therapists) and non-users such as consultants, architects and a researcher, see table 4.

Table 4: Characteristics of the study sample

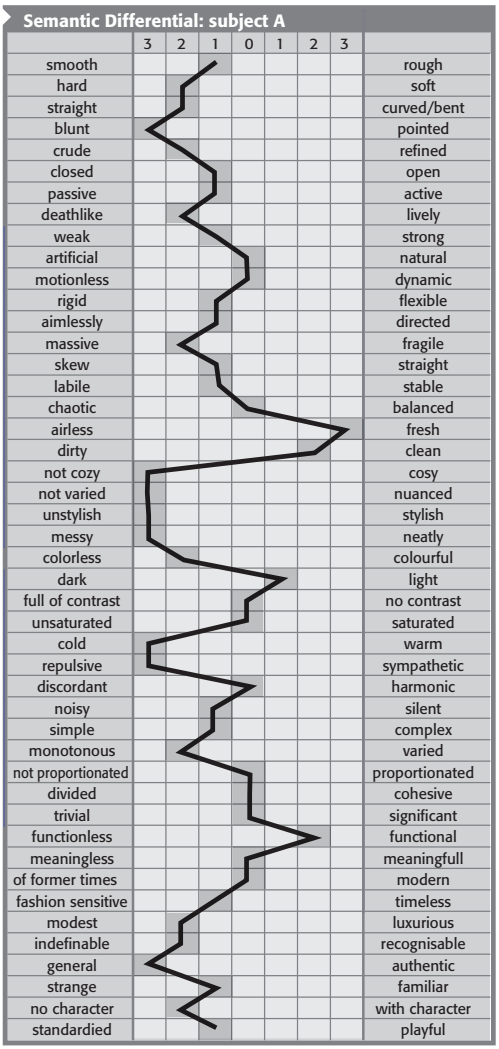
table

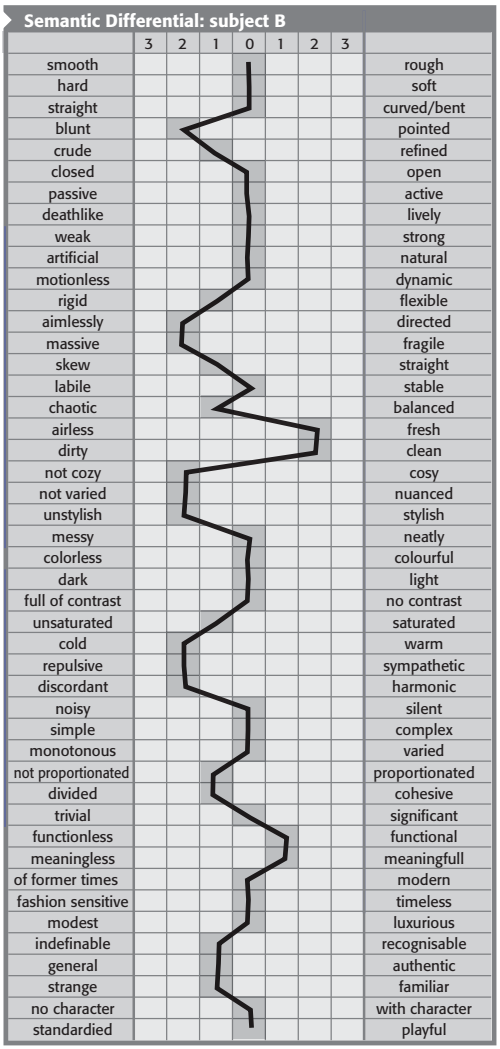
	number	percentage
users/non-users		
users	18	40
not users	27	60
total	45	100
gender		
male	11	24
female	34	76
total	**45**	**100**
age range		
21 t/m 25	3	7
26 t/m 30	3	7
31 t/m 35	2	4
36 t/m 40	7	16
41 t/m 45	9	20
46 t/m 50	5	11
51 t/m 55	9	20
56 t/m 60	4	9
61 t/m 65	2	4
> 65	1	2
total	**45**	**100**
education		
university level	14	31
higher vocational level	28	62
lower vocational level	3	7
	45	**100**

9.3.2 Main findings

Figure 1 presents two examples of the semantic differential completed by two subjects. The lines show the connections between the chosen numbers in the scale. By means of this line it is easier for the participants to see differences between each other's opinions.

Figure 1: example of the scores on the list of adjectives





Subjects were quite well able to express their experience of the meeting room by using the adjectives in step 2, but missed words such as loving. Words as saturated-unsaturated and labile-stable showed to be difficult to interpret. However, on a seven points Likert-scale subjects valued the list of adjectives as rather complete with a score of 5,84. 95% of the subjects agreed with the assumed relationships between adjectives and specified senses, for example 'rough' is connected to the sense of touch and 'warm' is connected to the sense of temperature.

In step 3 the subjects observed the environment more carefully by using form 2 i.e. the list of environmental features. 93% of the subjects admitted to have seen more elements than during step 1 and 2 without using a list of elements. Elements that were most frequently mentioned as not being observed (in step 1 and 2) were the heater, lighting and art.

In step 4 the participants tried to understand the relationship with their first impressions (step 1) and possible causes in connection to environmental cues. The mean score on a seven points Likert scale asking for the degree people got a better understanding of their feelings by observing carefully was 5,9. In the final step 4 the discussions among the participants contributed to a better understanding of the experience of the environment and interpretations of the adjectives. Also the impact of personal backgrounds of opinions became more clear. The mean score on a seven point Likert scale asking for the degree participants conceived the method as applicable to discuss opportunities for improvement was 6.0. Most subjects (82%) were positive about the effects of an increased awareness of the senses on the way they observed the test environment. 98% thought that an increased awareness of the senses generated more conscious information.

9.3.3 Impact of personal characteristics

Being a user or a non-user showed to affect how subjects value the method. Although in general all subjects are positive about the method, users are more positive than non-users. All users (100%) observed more physical features after completing form 2, while 89% of the non-users observed more elements than the users. The average score on the 7-point scale asking for "Experiencing the environment in a more consciousness way and as such a better understanding of one's feelings" was 6,2 for the users and 5.7 for the non-users.

With a mean score of 6,2 on "applicability of the method", female respondents were more positive than male subjects (mean score 5,4). Also the level of education evoked slightly different responses: participants with university level had a mean score of 6,1 on a seven-points scale concerning the applicability of the instrument, whereas respondents at higher vocational level had a mean score of 5,9. 100% of the subjects younger than 35 years experienced more conscious information of their environment being more conscious about their senses, while this percentage for the subjects with the age of over 56 years was 80%.

9.4 The framework related to knowledge productivity

The presented framework to select appropriate adjectives is a method to assess and value the physical environment as a whole. In connection to this thesis, it is an interesting question whether this framework can help to understand which characteristics of the existing environment in particular contribute to productivity. In Chapter 2 four key factors are described: structure, variety, psychological safety and identity. Although all senses cooperate together and peoples' responses cannot 1:1 be linked to a particular sense, some accents can be mentioned referring to the three groups of the senses. Structure in a building is mainly experienced by means of the physical senses. The physical aspects are for instance boundaries and possibilities for movement. However, all subsequent choices for other aspects like furnishing and decoration contribute to the experience of structure. The second group of senses, the affective senses, mostly appeal to the feelings of psychological safety. The affective senses highly contribute to the experience of the atmosphere. The group of the cognitive senses mostly appeal to the fourth key factor, namely identity. These senses provide information about for instance meaning and uniqueness that both contribute to feelings of identity. The foundations to obtain variety are laid in the physical aspects of the building, just like structure. However, variety is strongly supported by both the affective and the cognitive group of senses. As such there is a certain connection between different groups of senses and the four key factors. The frame work that is presented can be helpful to be able to focus on those elements that relatively high contribute to productivity.

9.5 Conclusion and discussion

Due to the positive responses on the explanation of the framework and the high scores on the evaluation form, it can be concluded that the proposed method is promising and can be used as a practical instrument to assess the experience of the physical environment and to make transparent connections between individual perceptions and objective environmental features. The scores on all seven- point Likert scales are high (means range from 5,8 till 6) and a high percentage of the answers to the evaluative questions were positive (ranging from 82% till 98%). However, the frame work needs further testing on both its applicability validity and internal consistency, in different environments, with more respondents. A factor analysis is needed to examine whether the factor loadings reflect the tripartite view of Steiner and whether the adjectives within the same sense have a high load on the same factor and not on other factors.

This paper showed clear similarities between different concepts and views on people's experience of the built environment. Fifty years ago Osgood (1963) developed the differential method to measure responses to environmental stimuli by means of adjectives. Although Osgood was convinced that sensory information would be the basis to understand environmental experience, he could not find any clear system. More than fifty years earlier, Rudolf Steiner (1909) presented his sensory information system theory. Although this system is often judged as non-scientific, this system showed to correspond to the tripartite view on attitude (ABC psychology) and the frequently applied method of Mehrabian and Russell that links various adjectives to three dimensions: pleasure, arousal and dominance. These insights appeared to be a useful basis for the proposed framework with clear adjectives to define the perceptual qualities of the physical environment. The distinction between affective, physical and cognitive indicators showed to be applicable to defining environmental experience as these indicators are often used to describe perceptions, attitudes, experiences and responses (Ostrom, 1969; Smith and Swinyar, 1982; Breckler, 1984; Tappan, 1990; Arriaga and Agnew, 2001; Back and Parks, 2003; Pike and Ryan, 2004; Da Silva and Alwi, 2006; Yuksel et al, 2010). The new framework connects experiences caused by the environment to particular environmental elements and as such enables to focus discussions, to improve transparency, and to facilitate decision-making regarding how to improve the physical environment. When used as a standard system it will be possible to compare the research findings from different researches in different environments.

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The sensory information provided by the twelve senses showed to be useful to assess the physical environment. At first sight this seemed to be a new way to look at the physical environment. However the old theory of Plato concerning feeling, acting and thinking, the three dimensions of Mehrabian and Russell pleasure, arousal and dominance, and the insights of the ABC psychology with the three factors affect, behaviour and conation all show likewise insights. The pilot test of the framework with well-argued adjectives showed that this framework provides concrete directions how to judge the key factors structure, variety, psychological safety and identify that are fundamental for knowledge productivity. In future research this framework should be tested and optimised further.

9.6 References

Allport, G.W. (1940), The Psychologist's Frame of Reference. Psychological Bulletin 37, 1-28 in Hilgard, E.R. (1980), The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioral Sciences, 16 (2), 107–117.

Ayres, J., Ginger Grass, O. T. S., Schools, C. P. (1980), Sensory Integration, Los Angeles.

Arriaga, X.B., Agnew, Ch.R. (2001), Being Committed: Affective, Cognitive, and Conative Components of Relationship Commitment. Pers Soc Psychol Bull, 27, 1190-1203.

Back, K.J. , Parks, S.C. (2003), A Brand Loyalty Model Involving Cognitive, Affective, and Conative Brand Loyalty and Customer Satisfaction, Journal of Hospitality & Tourism Research, Vol. 27(4), 419-435

Baker, J., Levy, M., Grewal, D. (1992), An Experimental Approach to Making Retail Store Environmental Decisions. Journal of Retailing, Vol 68(4), 445-460.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J.(2014), Pleasure, Arousal, Dominance: Mehrabian and Russell revisited, Current Psychology, Vol. 33 (3), 405-421.

Bellizi, J.A., Crowley, A.E., Hasty, R.W. (1983), The Effects of Color in Store Design. Journal of Retailing, Vol 59 (1), 21-45.

Berman, M.(1998), Coming to Our Senses: Body and Spirit in the Hidden History of the West, Seattle Writers' Guild; America.

Bigné, J.E., Andreu, L., Gnoth, J. (2005), The theme park experience: An analysis of pleasure, arousal and satisfaction. Tourism Management Vol 26, 833-844.

Bradley, M.M., Greenwald, M.K., Petry, M.C.,Lang, P.J. (1992), Remembering pictures: Pleasure and arousal in memory. Journal of Experimental Psychology, Vol 18(2), 379-390.

Breckler, S. J. (1984), Empirical validation of affect, behavior, and cognition as distinct components of attitude. Journal of Personality and Social Psychology, 47(6), 1191-1205.

Cacioppo, J.T., Gardner, W.L., Berntson, G.G. (1997), Beyond Bipolar Conceptualizations and Measures: The Case of Attitudes and Evaluative Space. Personality and Social Psychology Review, Vol 1(1), 3-25.

Chebat, J.C., Michon, R. (2003), Impact of ambient odors on mall shoppers' emotions, cognition, and spending: A test of competitive causal theories. Journal of Business Research Vol 56, 529-539.

Chen, Y., Chen, Z.(2008), Analysis and evaluation of color perception. International Journal of Clothing Science and Technology, Vol. 20(3),184-191.

Chen, Ch.F., Chen, F.S. (2010), Experience quality, perceived value, satisfaction and behavioral intentions for heritage tourists, Tourism Management, Vol 31, 29-35.

Da Silva, R.V., Alwi, S.F.S. (2006), Cognitive, affective attributes and conative, behavioural responses in retail corporate branding, Journal of Product & Brand Management, Vol 15(5), 293–305.

Dijksterhuis, A. (2007), Het slimme onbewuste, denken met gevoel, Uitgeverij Bert Bakker, Amsterdam.

Donovan, R.J., Rossiter, J.R., Marcoolyn, G., Nesdale, A. (1994),Store atmosphere and purchasing behavior, Journal of Retailing,Vol 70(3), 283–294.

Dozi, G. (1984), Die Kraft der Granzen. München: Trikont-Verlag.

Dubé, L., Chebat, J.C., Morin, S. (1995), The effects of background music on consumers' desire to affiliate in buyer-seller interactions, Psychology & Marketing, Vol 12(4), 305–319.

Eastman, S, T.(1997), Uses of television viewing and consumer life styles: A multivariate analysis. Journal of Broadcasting, Vol 23 (4), 491-500.

Ernst, M.O., Bülthoff, H.H. (2004), Merging the senses into a robust percept, TRENDS in Cognitive Sciences Vol.8(4), 162-169.

Farley, S.D., Stasson, M.F. (2003), Relative Influences of Affect and Cognition on Behavior: Are Feelings or Beliefs More Related to Blood Donation Intentions? Experimental Psychology , Vol. 50(1): 55- 62.

Fiedler, K. (1988), Emotional mood, cognitive style, and behavior regulation in Fiedler, K. ,Forgas, J., (Eds.), (1988), Affect, cognition and social behavior: New evidence and integrative attempts, Toronto, Canada, Hogrefe.

Floyd, M.F. (1997), Pleasure, arousal, and dominance: Exploring affective determinants of recreation satisfaction, Leisure Sciences: An Interdisciplinary Journal, Vol 19(2), 83-96.

Gabriel, S., Gardner, WL. (1999), Are there “his” and “hers” types of interdependence? The implications of gender differences in collective versus relational interdependence for affect, behavior, and cognition. Journal of Personality and Social Psychology, Vol 77(3), 642-655.

Gerdes, K.E., Stromwall L.K. (2008), Conation: a missing link in the strengths perspective. Soc Work, 53(3):233-42.

Gardner, P. L. (1987), Measuring ambivalence to science. Journal of Research in Science Teaching Vol 24(3), 241–247.

Garg, M.(2012), Attitudinal correlates of academic performance of teacher trainees in distance and face-to-face mode, International Journal of Social Sciences and Education, Vol 2(1), 535-554.

Geldard, F.A. (1953), The human senses, Oxford, England: Wiley.

Gibson, J.J.(1966), The senses considered as perceptual systems. Oxford, England: Houghton Mifflin.

Gifford, R., Hine, D. W., Muller-Clemm, W., D’Arcy, J. R., & Shaw, K. T. (2000), Decoding Modern Architecture A Lens Model Approach for Understanding the Aesthetic Differences of Architects and Laypersons. Environment and Behavior,32(2), 163-187.

Hazzard, F.W. (1930), A descriptive account for odors. Journal of Experimental Psychology 13, 297-331 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Hershberger, R. G. (1975), The representation and evaluation of environments. Responding to Social Change, Environmental Design Research Association, 6, 109-116.

Hershberger, R. G., Cass, R. C. (1974), Predicting user responses to buildings. Man-environment interactions: Evaluations and applications, 117-134.

Hilgard, E.R.(1980), The trilogy of mind: Cognition, affection, and conation. Journal of the History of the Behavioral Sciences, 16 (2), 107–117.

Hillis, J. M., Ernst, M. O., Banks, M. S., Landy, M. S. (2002), Combining sensory information: mandatory fusion within, but not between, senses. Science, 298(5598), 1627-1630.

Holt-Hansen, K.(1968), Taste and pitch. Perceptual and Motor Skills, 27, 59-68 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Karwoski, T.F.F.W., Odbert, H.S. (1938), Color Music, Psychol. Monogr. 50 (2) (whole no. 222), 21 in Osgood, Ch., Suci, G.J., Tannenbaum, P.H. (1957), The measurement of meaning, University of Illinois Press, Urbana, Chigago and London, 36, 38, 62, 63, 149, 185, 186, 325.

Karwoski, T.F.F.W., Odbert, H.S., C.E. Osgood (1942), Studies in synesthetic thinking: II. The roles of form in visual responses to music. J.gen.Psychol. 26, in Osgood, Ch., Suci, G.J., Tannenbaum, P.H. (1957), The measurement of meaning, University of Illinois Press, Urbana, Chigago and London, 36, 38, 62, 63, 149, 185, 186, 325.

Kirn, M. (1989), Hegels Phaenomenologie des Geistes und die Sinneslehre Rudolf Steiners : zur Neubegruendung der Wissenschaft aus dem Wesen des Menschen, Urachhaus, Stuttgart.

Korsmeyer, C. (2002), Making Sense of Taste: Food and Philosophy. Cornell University Press.

Knez, I., Hygge, S.(2002), Irrelevant Speech and Indoor Lighting: Effects on Cognitive Performance and Self-Reported Affect. Appl. Cognit. Psychol. 16, 709–718.

Knopf, R. (1987), Human behavior, cognition, and affect in the natural environment in Stokols, D., Altman, I.(1987), Handbook of environmental psychology, New York: Wiley.

Kunishima, M. , Yanase, T. (1985),Visual effects of wall colours in living rooms. Ergonomics, Vol. 28 (6), 869-882.

Laroche, M., Teng, L., Michon, R., Chebat, J.C.(2005), Incorporating service quality into consumer mallshopping decision making: a comparison between English and French Canadian consumers. Journal of Services Marketing, 19/3, 157–163.

Lee, J.H., Qian, W.(2004), Color Your Feeling, Design Support System for Color Coordination. Recent Advances in Design and Decision Support, Kluwer Academic Publishers.

Lindström, M.(2005), Brand Sense: How to Build Powerful Brands Through Touch, Taste, Smell, Sight and Sound, Kogan Page Publishers.

Loveless, N.E., Brebner, J., Hamilton, P. (1970), Bisensory presentation of information. Psychological Bulletin, 73, 161-199 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Luria, A.R. (1969), The mind of a mnemonist. New York: Avon Books.

Manav B. (2007),Color-emotion associations and color preferences: A case study for residences. Color Res Appl, 32, 144–150.

Maheshwari, V., Saraf, R., (2008), Tactile Devices To Sense Touch on a Par with a Human Finger. Angewandte Chemie International Edition, Vol 47 (41), 7808–7826.

Mattila, A.S., Wirtz, J. (2001), Congruence of scent and music as a driver of in-store evaluations and behaviour. Journal of Retailing, 77, 273–289.

Mehrabian, A. (1996), Pleasure-Arousal-Dominance: A General Framework for Describing and Measuring Individual Differences in Temperament. Current Psychology, (14),4 ,261- 292.

Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Nagumo, H., (2000), Color Image Chart, Long See International Book Co Ltd., Taipei in Lee, J.H., Qian, W.(2004), Color Your Feeling, Design Support System for Color Coordination. Recent Advances in Design and Decision Support, Kluwer Academic Publishers.

Nordlund , C.Y.(2006), Art experiences in Waldorf education: graduates' meaning making reflections. Dissertation. Faculty of the Graduate School, University of Missouri–Columbia.

Odbert, H.S., Karwoski, T.F.F.W., Eckerson, B. (1942), Studies in synesthetic thinking: I. Musical and verbal associations of color and mood. J.Gen. Psychol., 26, 153-73 in Osgood, Ch., Suci, G.J., Tannenbaum, P.H. (1957), The measurement of meaning, University of Illinois Press, rbana, Chigago and London, 36, 38, 62, 63, 149, 185, 186, 325.

Oostendorp, A., Berlyne, D.E. (1978), Dimensions in the perception of architecture, III. Multidimensional preference scaling, Scand. J. Psychol. 19, 145-150.

Osgood, Ch., Suci, G.J., Tannenbaum, P.H. (1957), The measurement of meaning, University of Illinois Press, Urbana, Chicago and London, 36, 38, 62, 63, 149, 185, 186, 325.

Osgood, Ch. E. (1963), Part four, Psychological approaches, Semantic Differential Technique in the Comparative Study of Cultures. American Anthropologist, Vol 66, Issue 3, 171-200.

Ostrom, T. M. (1969), The relationship between the affective, behavioral, and cognitive components of attitude. Journal of Experimental Social Psychology, 5 (1), 12-30.

Ou, L.C., Luo MR.(2004), A study of colour emotion and colour preference. Part I. Colour emotions for single colours. Color Res Appl, 29,232–240.

Pascha, K.S.(2004), „Gefrorene Musik", Das Verhältnis von Architektur und Musik in der ästhetischen Theorie. Dissertation. Fakultät VII – Architektur der Technischen Universität Berlin.

Pennebaker, J. W., Brittingham, G. L. (1982), Environmental and sensory cues affecting the perception of physical symptoms, Advances in environmental psychology, 4, 115-136.

Pike, S., Ryan, Ch. (2004), Destination Positioning Analysis through a Comparison of Cognitive, Affective, and Conative Perceptions, Journal of Travel Research, Vol. 42(4), 333-342.

Polivy , P. (1998), The Effects of Behavioral Inhibition: Integrating Internal Cues, Cognition, Behavior, and Affect, Psychological Inquiry, Vol 9(3), 181-204.

Robles-De-La-Torre, G.(2006), The Importance of the Sense of Touch in Virtual and Real Environments. Int. Soc. for Haptics, MDM Coyoacan, Vol 13 (3), 24-30.

Rosenberg, M.J, Hovland, C.I., McGuire, W.J., Abelson, .P., Brehm, J.W.(1960), Attitude organization and change: an analysis of consistency among attitude components, New Haven. Connecticut: Yale University.

Rosenberg, B.G., Langer, J., Stewart, J. (1969), Nonverbal learning. American Journal of Psychology 82, 181-190 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Ross, R.T. (1938), A statistic for circular scales. Journal of Educational Psychology, Vol 29, 384-389, in Russell, J.A. (1980), A Circumplex Model of Affect. Journal of Personality and Social Psychology, Vol 39, no 6, 1161-1178.

Rozin, P.(1982), "Taste-smell confusions" and the duality of the olfactory sense. Perception & Psychophysics, 31 (4), 397-401.

Russell, J.A. (1980), A Circumplex Model of Affect. Journal of Personality and Social Psychology, Vol 39(6), 1161-1178.

Russell, J.A., Carroll, J.M. (1999), On the Bipolarity of Positive and Negative Affect. Psychological Bulletin, Vol 125 (1), 3-30.

Russell, J.A., Lanius, U.F. (1984), Adaptation level and the affective appraisal of environments. Journal of Environmental Psychology, Vol, Issue 2, 119–135.

Russell, J.A., Pratt, G.(1980), A description of the affective quality attributed to environments. Journal of Personality and Social Psychology, Vol 38(2), 311-322.

Russell, J.A., Pratt, G., Ward, L.M.(1981), Affective Quality Attributed to Environments, A Factor Analytic Study. Environment and Behavior, Vol. 13 no. 3 259-288.

Ryu, K., Jang, S.(2007), The effect of environmental perceptions on behavioural intentions through emotions: the case of upscale restaurants. Journal of Hospitality & Tourism Research, Vol 31(1), 65-72.

Scheuerle, H.-J. (1984), Die Gesamtsinnesorganisation – Überwindung der Subjekt- Objekt- Spaltung in der Sinneslehre. Stuttgart/New York: George Thieme Verlag.

Schneider, W. (1987), Sinn und Un-Sinn, Umweltt sinnlich erlebbar gestalten in Architektur und Design, Wiesbaden und Berlin: Bauverlag GMBH, 43, 106.

Shepherd, G.M. (2004), The Human Sense of Smell: Are We Better Than We Think? PLoS Biol 2(5).

Shepherd, G.M. (2012), Neurogastronomy: How the Brain Creates Flavor and why it Matters. Columbia University Press.

Smith, R.E, Swinyar, W.R. (1982), Information Response Models: An Integrated Approach, The Journal of Marketing, Vol 46, 81-93.

Soars, B. (2009), Driving sales through shoppers' sense of sound, sight, smell and touch. International Journal of Retail & Distribution Management, Vol. 37 (3), 286-298.

Soesman, A. (2005), De Twaalf zintuigen, 4e druk, Vrij Geestesleven, Zeist.

Sonneveld, M.H. (2007), Aesthetics of tactual experience, About the body language of objects, Dissertation University of Technology, Delft.

Stangor, Ch.(2013), Affect, behavior, and cognition, Principles of Social Psychology, Flat World Knowledge, Inc.

Steffen, C. (1972),Perceptieonderzoek en stedebouw. Delft, T.H. rapport C.A. 72.05.01.

Steiner, R. (1909), Zur Sineslehre, 8 Vortrage , Thermen aus dem Gesamtwerk 3, 'Antroposophie. Die Sinne des Menschen'. Voordracht dd. 23 oktober 1909, Herausgegeben von Christoph Lindenberg (1981) Verlag Freies Feistesleben, Stuttgart, 48-67.

Taft, Ch.(1997), Color Meaning and Context: Comparisons of Semantic Ratings of Colors on Samples and Objects. COLOR research and application, Vol 22 (1), 40-50.

Tappan, M.B. (1990), Hermeneutics and moral development: Interpreting narrative representations of moral experience, Developmental Review, Vol 10(3), 239-265.

Thompson, L., Fine, G.A.(1999), Socially Shared Cognition, Affect, and Behavior: A Review and Integration, Pers Soc Psychol Rev , Vol 3(4), 278-302.

Uhlich, E. (1957), Synästhesie und Geschlecht (Synesthesia in the two sexes). Zetschrift für Experimentelle und Angewandte Psychologie, 4, 31-57 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Van Hagen, M., Galetzka, M, Pruyn, A., Peters J. (2009), Effects of Colour and Light on Customer Experience and Time Perception at a virtual Railway Station, Proceedings Experiencing Light 2009; International Conference on the Effects of Light on Wellbeing; 137-145.

Van Schilfgaarde, P. (1938), De Zielkunde van Aristoteles, uitgegeven met de Amsterdamsche Universiteits- vereeniging.

Van Wegen, H.B.R. (1970), De invloed van variatie op aandacht en waardering voor eenvoudige vormstrukturen. Delft, T.H.-rapport in Steffen, C. (1972). Perceptieonderzoek en stedebouw. Delft, T.H. rapport C.A. 72.05.01.

Venturi, R. (1966), Complexity and contradiction in architecture, New York, The Museum of Modern Art, in Hershberger, R. G. (1975). The representation and evaluation of environments.Responding to Social Change, Environmental Design Research Association, 6, 109-116.

Von Hornbostel, E.M.(1931), Über Geruchshelligkeit'', Pflüger's Archiv für die gesamte Physiologie des Menschen und der Tiere 227, 517-538 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

Vonk, R. (2003), Cognitieve sociale psychologie. Uitgeverij Lemma BV, Utrecht, 375-380.

Wirtz, J., Mattila, A.S.,Tan, R.L.P.(2000), The Moderating Role of Target-Arousal on the Impact of Affect on Satisfaction—An Examination in the Context of Service Experiences. Journal of Retailing, Vol. 76(3), 347–365.

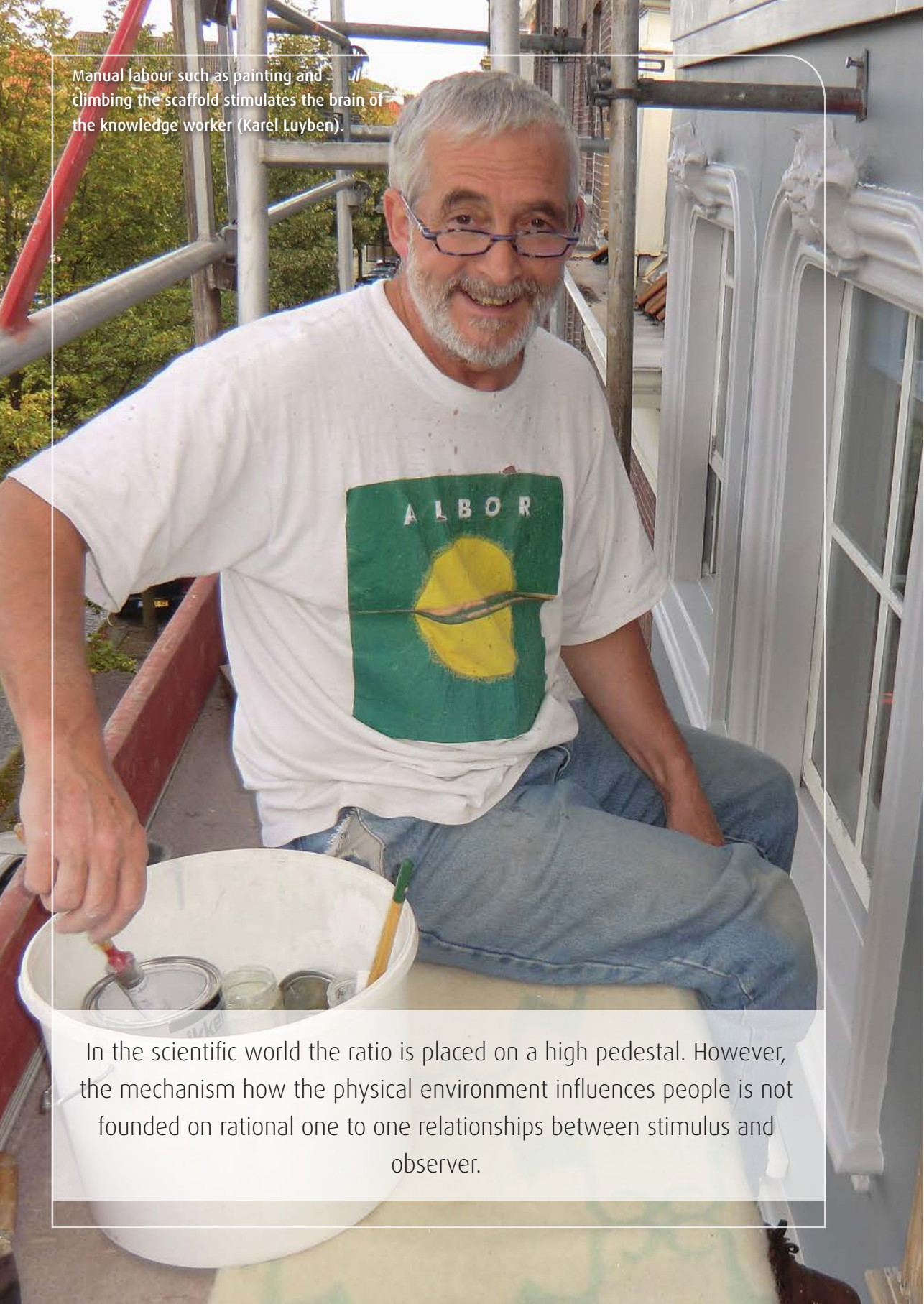
Wu, Ch.S., Cheng, F,F, Yen, D.C.(2008), The atmospheric factors of online storefront environment design: An empirical experiment in Taiwan. Information and Management 45, 493-498.

Yuksel, A., Yuksel, F., Bilim, Y (2010), Destination attachment: Effects on customer satisfaction and cognitive, affective and conative loyalty, Tourism Management, Vol 31(2), 274–284.

Zajonc, R.B. (1980), Feeling and Thinking, Preferences Need No Inferences. American Psychologist, Vol. 35 (2), 151-175

Zietz, K. (1931), Gegenseitige Beinflussung von Farb und Tonerlebnisses. Zeitschrift für Psychologie , 121, 311-314 in Mehrabian, A., Russell, J.A. (1974), An Approach to Environmental Psychology, The Massachusetts Institute of Technology, United States of America.

A flowered Mathieu Weggeman sending tunes to the rosy future.



Manual labour such as painting and climbing the scaffold stimulates the brain of the knowledge worker (Karel Luyben).

In the scientific world the ratio is placed on a high pedestal. However, the mechanism how the physical environment influences people is not founded on rational one to one relationships between stimulus and observer.

Chapter Ten
Reflection, conclusions and recommendations

10.1 Introduction

This PhD thesis concerns the relationship between the physical environment and productivity. As is argued in chapter 1 it is necessary to know how the physical environment affects productivity to create a physical environment that supports the productivity of knowledge workers in an optimal way. At least three elements play a role: the physical environment, people influenced by this environment, and the outcome: productivity. To understand the knowledge worker and his needs, new empirical research has been conducted in combination with a review of literature in search of scientific evidence, old and modern psychological views and ancient eastern insights.

Studying the whole physical environment is too complex. Therefore two components of the physical environment have been selected to assess the characteristics in depth: plants and colour. A critical review was carried out on the relationship between plants and productivity and an analysis of the relationship between colour and productivity was performed. This analysis consists of three steps. First, a test on the effects of colour on productivity in a real work environment was conducted. Second, realising that opinions of people about colour have a major influence on colour experience, colour preferences were analysed by setting up a comprehensive database concerning various types of colour preferences and human characteristics to be able to analyse significant relations. Third, due to the difficulties in getting clear insight into the way how colour influences people and their productivity an in-depth analysis of the experience of colour was carried out.

During the first phase of the study there were concerns about the reliability and validity of various research methods. Therefore, a study on possible pitfalls in using questionnaires was conducted on the data gathered in this PhD. Furthermore, a critical assessment has been carried out of the widely applied methods to measure people's experience of the built environment that were developed by Mehrabian and Russell in the seventies of the last century. Next a method was developed to define environmental experience in a more clear way, using appropriate adjectives. For this purpose a combination of formal scientific knowledge from different knowledge disciplines and the insights of Steiner and Goethe were used. Connecting knowledge from different disciplines has led to knowledge that can be applied to create a productive environment. This final chapter presents the main findings, some guidelines how to use these findings in practice and recommendations for future research.

10.2 Findings

Plants and nature

1 **Plants have a universal and positive influence on knowledge productivity.**
Although research on the relationship between plants and productivity shows different findings and results are not comparable due to different research methods, research settings and context factors, a universal positive influence of plants on productivity came to the fore.

2 **Worldwide people experience nature as harmonious because nature shows both structure and variety.**
All creatures in nature show structure i.e. characteristics that are helpful for recognition and in addition variety that contributes to uniqueness.

Colour

3 **Colour can be conceived as a natural phenomenon, which manifests itself depending on its context.**
No one to one relation exists between colour and its influence on people. Being a natural phenomenon colour is dynamic and its influence depends on the context.

4 **Humans perceive colour by means of their twelve senses which are fed by twelve specified colour contrasts.**
Colour manifests itself to people based on twelve colour contrasts. These twelve colour contrasts correspond to twelve colour characteristics by which colour manifests itself in nature. The senses are sensitive for these contrasts and all sensory information contributes to environmental experience.

5 **No significant relations were found between colour and productivity. However, colour affects significantly people's mood.**
People's moods affect their performance. It is assumed that colour significantly influences productivity with mood as a mediating variable.

Experience of the built environment

6 **People experience the environment as a whole. The various components of the physical environment, which together constitute the totality, influence each other.**
The physical environment consists of different components such as the spatial layout, colours and materials, indoor climate, facilities and art, that influence each other. The influence of a component depends on the appearance of that component, the appearances of adjacent other components, personal characteristics of the observer such as his mental representations, and contextual factors. People experience the totality.

7 **People experience the environment mainly unconsciously.**
People primarily focus on the activities they are doing and are in standard circumstances mainly unconscious of the physical environment.

8 **Internal representations have a major influence on how people experience the environment.**
People are thinking creatures. Their cognitive capacities have an overwhelming influence on the way they experience the physical environment. For this reason, people are inclined to create an environment they are accustomed to. This can lead to "conservative" and suboptimal solutions.

9 **People experience their environment as optimal if that environment is harmonious and offers sufficient structure and variety.**
It is useful to state that people are part of nature and during human evolution they are influenced by nature and its characteristics. A large amount of evidence is available about the positive impact of nature on people. Basic characteristics of nature are the balance between structure and variety that are fundamental for harmony. It is hypothesised that people will flourish in an environment that shows structure and variety that are in balance. This hypothesis is supported by the polar operation of the senses such as warmth versus coldness or light versus darkness. In addition, senses provide relative information (related to the context) and give signals when stimuli are divergent from the way people are accustomed to.

10 **People experience their environment with twelve senses.**
Aristotle mentioned in the ancient times five senses. Steiner developed in 1909 the sensory mechanism with twelve senses. These senses are divided into four physical senses, four affective senses and four cognitive senses. These twelve senses work closely together.

Research methods

11 **Research on the effects of plants on productivity needs improvement.**
In research into the impact of plants, next to methodological issues such as an unambiguous test process and controlling contextual factors, the characteristics of the plant itself like structure, leaf shape and colour need more attention. Standardisation of research methods regarding the test characteristics and clarity about the characteristics of the plants is needed to be able to compare research findings and to build an evidence based body of knowledge on the impact of plants on people in general and productivity in particular.

12 **The effect of colour on knowledge productivity during meetings in a real work environment cannot be measured by only using questionnaires.**
In real work situations employees focus primarily on the activities they are doing and mainly unconsciously experience the physical environment. Asking participants about topics such as the physical environment and colour using questionnaires, does not provide clear data about how they really experience the physical environment. The empirical test of the influence of a red or blue meeting room showed that responses completed in questionnaires were influenced by factors such as social desirability, cognitive dissonance and unconsciousness of the environment. Due to careful observations discrepancies were found between the answers completed in the questionnaires, observed behaviour and comments made during the meeting. In additional interviews causes were found for this discrepancies, reasons were analysed and factors were defined that muddle the process of completing questionnaires.

13 **Overall current research methods to assess the influences of the physical environment on people and knowledge productivity need improvement.**
Research findings are not comparable due to the use of different and often unclear conceptual frameworks, different contexts, different research methods, different research settings, and the huge variety of adjectives that are used to measure people's experiences. The widely used dimensions arousal and pleasure – that were developed by Mehrabian and Russell in 1974 - are interpreted differently. The dominance dimension is usually erroneously omitted. For this reason a new conceptual framework has been developed in order to be able to measure stimulus-response interactions in a more valid and standardised way.

14 **The sensory information system with the twelve senses can be used as a mechanism to define environmental experience in its totality.**
Because people experience the physical environment with the senses, the sensory information system directly informs them about the characteristics of the physical environment. Using this information system, a selection has been made of appropriate adjectives with a minimal observer influence that can be applied in a semantic differential method to define environmental experience in a clear way. The selected adjectives that provide maximal objective information can be connected with particular components of the physical environment. This makes it possible to design and manage the physical environment.

15 **The commonly used definition of colour by the HSI- coding that is based on only three colour contrasts, requires the extension to twelve colour contrasts to be able to understand colour in its totality.**
Because colour in its totality can be defined by means of twelve colour contrasts, the HSI-coding of Hue, Saturation and Intensity is too limited. This HSI-coding is based on only three colour contrasts. Important colour information that is currently used such as warm and cold colours, or sweet and bitter colours cannot be defined by means of HSI-coding.

Productivity

16 **A harmonious environment has a positive effect on knowledge productivity**

In general people experience feelings of wellbeing in a harmonious environment that shows like nature a balance between structure and variety. In the short term, a disharmonious environment could have a positive effect because it causes arousal and wakefulness due to the deviation of expectations. However, in the long term, it causes distraction that negatively influences productivity. It is hypothesised that a harmonious environment with a balance between structure and variety contributes to (knowledge) productivity.

17 **Four environmental characteristics determine the productive work environment: structure, variety, psychological safety and identity**.

These four key factors are fundamental to optimise productivity and ask special attention during designing and creating a productive environment.

18 **The productive environment needs to support four types of work mood: contemplation, awareness, collectiveness and social observation.**

The knowledge worker has four types of work moods that need to be supported by the physical environment. Depending on his work mood – and taking into account organisational schedules and appointments with other knowledge workers- the knowledge worker should be able to choose a place that supports the activities he wants to do.

10.3 Conclusions: answering the research questions

What is the influence of colours and plants in the physical environment on knowledge productivity? Both the supply side, i.e. the physical environment, and the demand side, in this case the knowledge worker, are too complex to find simple cause-effect relationships. The physical environment shows an infinite number of variations in appearances and the way in which people experience the environment is highly heterogeneous as well. As a consequence no clear 1:1 relationships can be found between colour and productivity. However, plant research shows an overall positive effect on productivity, and it appears that the positive influence of nature is universal. Furthermore, by focusing on the deeper needs of the knowledge worker, it turned out to be possible to define some characteristics of the environment that are essential, i.e. structure and variety, psychological safety, and identity. These four characteristics are essential to create a work environment where knowledge workers can be productive. The activities of the knowledge worker can be connected to four basic work attitudes or work moods: contemplation, awareness, collectiveness and social observation. By connecting the four basic building characteristics to the four basic work attitudes it is possible to explore which environmental solutions fit best, depending on the context. People need an harmonious environment with a balance between structure and variety. The harmony within the environment is achieved through a balance between structure and variety, as nature shows. The application of colours can contribute to this harmony. Colour directly influences the mood that on its turn affects productivity.

Which research methods do lead to valid and reliable results?

The colour test that is conducted in a real work environment, showed that the often used method to use questionnaires is not in itself a valid and reliable method to be able to draw clear conclusions about the influence of colour on productivity under the chosen test circumstances. Next, an analysis of tests conducted in an artificial setting such as lab experiments showed that many methodological weaknesses exist. As a consequence it can be questioned whether research results are in accordance with the real world. A review of research in which physiological measurements are applied, showed weaknesses as well. In search for a

clear mechanism to define environmental experience this PhD research re-assessed the still widely applied method of Mehrabian and Russell (1974) using the dimensions pleasure, arousal and dominance and the semantic differential developed by Osgood et al (1957). It appeared that in environmental psychology research these dimensions are differently and also often wrongly interpreted and the dimension dominance is often not mentioned at all. Next, the applied adjectives to describe the environmental experience are a mix of personal feelings of the observer and information about the environment. Due to these incorrect adjectives research shows unclear results and research findings are not comparable. In search for a mechanism to understand the interaction between the observer and the physical environment in a more clear way, the sensory information system appeared to be an appropriate mechanism.

People experience the totality of the environment with all their senses. Because the senses are the only instrument with which people experience the environment, it makes sense to use sensory information to define environmental experience. In 1909, Rudolf Steiner appointed twelve senses, which are connected to body, soul and mind, and as such are connected to acting, feeling and thinking, the concept of Plato, and the ABC-model of attitude on Affect, Behaviour and Cognition. By completing the method of the semantic differential of Osgood with adjectives that correspond to the twelve senses, the totality of the experience of the environment can be defined.

The nowadays often used HSI-coding Hue, Saturation and Intensity to define colour showed to be too limited because it is linked to only three colour contrasts which are mainly detected by only three of the twelve senses. With the twelve senses people observe twelve colour contrasts by means of which colour presents itself in its totality in nature. A mechanism is proposed using knowledge of the twelve senses to appoint the colour experience of the environment in its totality.

10.4 Limitations of the research

Both the physical environment (stimulus) and the observer (response) are complex, dynamic and heterogeneous. To understand the mechanism of experiencing the physical environment simplification is needed. At the same time, simplification represents a major limitation as it is questionable whether the results correspond with reality. Because people experience the totality of the environment and components directly influence each other, it is difficult to isolate a particular stimulus. Colour for instance cannot be separated as it is an integrated cue that immediately communicates with its environment.
In addition, because human thinking plays a prominent role in human experiences and perceptions, cognition highly affects the test results because it is not the pure stimulus that affects people but the mental representation of this stimulus. It is difficult to learn from subjects about their environmental experience because subjects do not always tell the truth, responses are biased by their mental representations, people are often not conscious of the environment and subjects may complete questionnaires in a social desirable way or by reducing cognitive dissonance.
A limitation of the test on colour in the real work environment was that the subjects were accustomed to a white coloured governmental environment and the applied colours in the test rooms created an artificial setting. This could have influenced the results. Also, the meetings had so much content and very present chairmen that perhaps the colour effect could not be measured due to the overruling effects of these aspects. A limitation of the database of research into colour preferences was that subjects completed the questionnaire in different circumstances (at school, at home, in the work environment) and in different ways (completing the questionnaire crossing with a pencil or at the computer). In this research the focus was on the Netherlands with its own culture and its habits and it is obvious that the Dutch context has influenced the test results. Also, no longitudinal research on colours has been conducted and the influence of colours for instance or preferences for colours could possibly change over time. It can be concluded

that both the physical environment (stimulus) and the observers (giving responses) have a complicated character, which makes it difficult to define clear cause-effect relationships.

10.5 Recommendations for future research

In future research, the totality of the environment needs more attention. Topics should be examined in their broader context. This requires cooperation with professionals from various disciplines such as neurology, (neuro) physiology, psychology and philosophy. It is important that the stimulus i.e. the physical environment is objectively analysed. The phenomenological method of Goethe that learns to focus objectively on stimuli offers valuable suggestions for this purpose. As we experience the environment with our senses, for future research it is very interesting to focus carefully on sensory information by means of the twelve senses. Every sense provides the information for which that sense is sensitive. (Neuro) physiological research could be combined with environmental research to measure sensory information by methods such as the semantic differential or concepts such as pleasure, arousal and dominance. This could deepen our understanding of these concepts and causes of effects.

Concerning colour, this PhD research found that productivity can be linked to four work moods. For future research it is interesting to focus on delimited parts of productivity, i.e. the four mentioned moods. It is assumed that colour influences these delimited parts and as such it is possible that evidence can be found on the relationship between colour and work moods.

It is recommended to further explore the possibilities that art can offer. For instance, using the light and colour art of Turrell (see chapter 4) it might be possible to measure people's experience of colour with a reduction of context complexity and a reduction of the intertwining of sensory influences. Next to art it could be interesting to conduct colour research with subjects with specified types of visual defects in order to assess the influence of colour on physiological processes and to reduce the influence of mental representations. With a reduction of the influence of mental representations the influences of colour itself can be shown.

10.6 Practical implications

Some practical recommendations can be given which can be useful for architects, designers, consultants, or other people who are in search of how to create a productive environment. Concerning the key factor structure, creating sightlines inside the building is important for providing the possibility to see other knowledge workers and to support interactions and collaboration and to make clear where someone is. Creating outside view provides contacts with nature as daylight, flying birds or swaying trees showing dynamics and movement that support wakefulness and also provides feelings where to be. Because walking can be inspiring as it stimulates creative thinking and interactions with others, a building needs a certain level of inefficiency; corridors and staircases ask for design that stimulates movement. Variety can be created by different spaces, from open spaces till places to withdraw, with different atmospheres, from cosy till industrial, different materials, artificial or natural. Psychological safety asks for environments in which people feel free and/or sheltered due to pleasant environmental proportions or enclosure. The atmosphere should not be too strictly organised so that people feel to have the ability to choose their own way doing their work. Identity asks for physical solutions to express the organisational culture or history, the character of products or the type of industry. The groups identity, asks for example for products or rewards of the group, or additionally things such as a punch bag or a football table game. In addition, people like to show something of their own identity by small things as own coffee mugs or pictures. Personal things invite to small talk that often is the beginning of enthusiastic talk about work and as such personal things can be a stimulus for productivity.

Individual differences.

Traditional office concept.

Samenvatting

Hoofdstuk 1: Introductie
Deze dissertatie gaat over de relatie tussen de fysieke omgeving en kennisproductiviteit. Om een optimale werkomgeving te creëren is het belangrijk goed te begrijpen wat de kenniswerker nodig heeft en welke kenmerken van de fysieke omgeving daarvoor van belang zijn. Twee componenten van de fysieke omgeving zijn onderzocht: planten en kleur. De effecten van planten op productiviteit zijn aan de hand van een literatuuronderzoek bestudeerd. Het effect van kleur is onderzocht aan de hand van een uitgebreid literatuuronderzoek en een test waarbij de effecten van een rode en een blauwe vergaderruimte zijn onderzocht. Daarnaast zijn verschillende soorten kleurvoorkeuren verzameld. De keuze voor planten is voortgekomen uit een persoonlijke interesse voor planten en kleur en omdat het relatief eenvoudig is om planten en kleur in werkelijke test omgevingen toe te voegen en weer te verwijderen. Naast het onderzoeken van de vraagzijde ofwel de behoeften van de kenniswerker en de aanbodzijde, namelijk het effect van planten en kleur op productiviteit, is ook gekeken naar de verschillende onderzoeksmethodes die worden benut in de omgevingspsychologie om de mechanismen te leren begrijpen achter de interacties tussen mensen, hun productiviteit en de omgeving die hen omringt. Gebaseerd op de ontstane inzichten is een nieuw raamwerk ontwikkeld waarmee mensen hun ervaring met de omgeving gestructureerd vast kunnen te leggen.

Hoofdstuk 2 bespreekt de relatie tussen productiviteit van de kenniswerker, zijn netwerken en kennis in relatie tot de fysieke omgeving. Uitgegaan wordt van de hypothese dat de kenniswerker alleen gelukkig en productief kan zijn als hij zijn behoeften invulling kan geven. De psychologen Ryan en Deci (2000, 2001) noemen drie basale psychologische behoeften: verder kunnen ontwikkelen van competenties, relaties hebben met anderen en autonoom zijn. Pink (2010) voegt daar twee andere behoeften aan toe: invulling kunnen geven aan persoonlijke doelen en het streven naar meesterschap. In kenniswerk kan onderscheid worden gemaakt in vier werkinstellingen die niet alleen overeen komen met de moderne Westerse psychologie maar ook met de wijsheid van het oude Oosten: sociale observatie, collectiviteit, contemplatie en bewustzijn. Op basis van een nadere analyse is geconcludeerd dat met name vier gebouwkenmerken bijdragen aan optimalisatie van kennisproductiviteit: structuur, variatie, psychologische veiligheid en identiteit. Deze vier gebouwkenmerken kunnen afhankelijk van de aard van de vier werkhoudingen en de context een concrete invulling krijgen.

Hoofdstuk 3 bevat een review gebaseerd op literatuuronderzoek over de effecten van planten op productiviteit. Naast onder andere effecten op de luchtkwaliteit en relatieve luchtvochtigheid, hebben planten in het algemeen een positief effect op productiviteit. De reacties van mensen kunnen fysiek/fysiologisch van aard zijn, affectief of cognitief. Gelet op de grote variatie van toegepaste onderzoeksmethodes en testsituaties zijn de onderzoeksresultaten niet vergelijkbaar. Om deze reden is een overzicht gemaakt van testkenmerken en plantkenmerken die gebruikt kunnen worden bij toekomstig onderzoek. In deze dissertatie ligt de focus op de totaliteit van de omgeving. Na de review op een onderdeel van de omgeving dat eenvoudig geïsoleerd kan worden, zal gekeken worden naar een component die geïntegreerd is in zijn omgeving en alleen benaderd kan worden in zijn totaliteit.

Hoofdstuk 4 beschrijft de test waarbij tijdens vergaderingen in een reële werkomgeving het effect van verschillend gekleurde vergaderruimten (een rode, een blauwe en een referentie ruimte) is beoordeeld aan de hand gerapporteerde meningen over productiviteit. Geen significante effecten zijn vastgesteld op

basis van de antwoorden die vermeld werden in vragenlijsten. Verondersteld wordt dat de deelnemers dermate in beslag waren genomen door de vergaderingen dat zij de kleuren in de ruimten niet bewust hebben ervaren. Een relatief groot deel van de deelnemers antwoordde dat volgens hen kleur in de ruimte geen effect had op productiviteit(65%), samenwerking (65%) of welzijn (33%).

Hoofdstuk 5 biedt een overzicht van de kleurvoorkeuren die zijn verzameld aan de hand van een vragenlijst ingevuld door 1077 mensen uit Nederland. Geslacht, leeftijd en opleiding en een aantal persoonlijke eigenschappen zoals de mate waarin mensen zich technisch of emotioneel vinden hebben significante invloed. De lievelingskleur is over de totale groep blauw, hoewel blauw vooral de voorkeurskleur is van mannen. De algemene voorkeur voor kleding is zwart, maar vrouwen hebben een grotere voorkeur voor zwart dan mannen. De kleurvoorkeur voor het interieur is wit. Ook om rustig te kunnen zijn en zich te kunnen concentreren kiezen de meeste mensen voor wit. Een rode ruimte draagt volgens de meeste mensen bij om energiek te zijn, terwijl de meeste mensen geen kleurvoorkeur hebben om creatief te kunnen zijn. Het is opvallend dat zoveel mensen voor het interieur de kleur wit kiezen (30 tot 40%) en ook zoveel mensen geen voorkeur hebben (16 tot 22%). Op basis van deze analyse van kleurvoorkeuren blijkt dat mensen zich niet zoveel bezig houden met toepassing van kleuren in hun omgeving.

Hoofdstuk 6 betreft een diepte analyse van kleurervaring om fysiek/fysiologisch, affectief en cognitief te verduidelijken hoe mensen kleur ervaren. Deze analyse is gebaseerd op theoretische kennis die in de literatuur is te vinden. Wetenschappers, filosofen, kunstenaars en architecten zijn sceptisch wat betreft het kunnen begrijpen van kleur vanuit een puur rationale en wetenschappelijke benadering. Theoretisch kunnen twaalf kleurkenmerken worden onderscheiden waarmee kleur zich in de natuur manifesteert. Deze kenmerken kunnen gekoppeld worden aan de twaalf zintuigen zoals die benoemd zijn door Rudolf Steiner en bovendien aan twaalf kleurcontrasten. Zowel in de praktijk als in de wetenschap wordt kleur gedefinieerd aan de hand van de HSI waarden (tint, verzadiging en intensiteit), een codering die is beperkt tot slechts drie kleurcontrasten. Om kleurervaring echter in zijn totaliteit te benaderen, zal rekening moeten worden gehouden met alle twaalf de kleurcontrasten.

Hoofdstuk 7 beschrijft de valkuilen die bestaan bij het uitvoeren van kleuronderzoek waarbij gebruik wordt gemaakt van vragenlijsten. Aan de hand van zorgvuldige observaties tijdens de vergaderingen tijdens de uitvoering van de test die beschreven is in hoofdstuk 4, bleek dat de antwoorden die vermeld stonden in de vragenlijsten niet altijd eenduidig te relateren waren aan de vraag en bovendien niet altijd exact de mening van de respondent weergaven. Een aantal respondenten is separaat geïnterviewd na de test. Het bleek dat contextuele, persoonlijke en psychologische factoren de antwoorden beïnvloed hadden, waaronder persoonlijke belangen, sociale wenselijkheid en reductie van cognitieve dissonantie

Hoofdstuk 8 reflecteert op de vaak toegepaste methode om de ervaring van de fysieke omgeving vast te stellen met de dimensies ‘arousal, pleasure en dominance’, zoals deze is ontwikkeld door Mehrabian en Russell (1974). De resultaten van vele studies over de interactie tussen mens en omgeving zijn moeilijk te vergelijken omdat de dimensies verschillend worden geïnterpreteerd en omdat er een groot aantal verschillende bijvoeglijke naamwoorden wordt gebruikt. In dit onderzoek is een poging gedaan te analyseren wat de drie dimensies exact betekenen, mede in relatie tot het ABC model van attitudes (met de factoren Affect (affect), Behaviour (gedrag) en Cognition (cognitie)) en de drie functies van de ziel, (voelen, handelen en denken) zoals benoemd door Plato. Geconcludeerd kan worden dat de oorspronkelijke betekenissen zoals Mehrabian en Russell deze oorspronkelijk bedoeld hebben, passend zijn om de ervaring van de omgeving te beschrijven op voorwaarde dat de dimensies beschreven zijn met de juiste bijvoeglijke naamwoorden. De dimensie ’dominance’ verdient rehabilitatie.

Gebaseerd op de onjuistheden die in omgevingsonderzoeken zijn gevonden wat betreft de toepassing van de dimensies 'pleasure, arousal en dominance', toont **hoofdstuk 9** een nieuw raamwerk met bipolaire bijvoeglijke naamwoorden om de ervaring van de omgeving in zijn totaliteit te beschrijven. Dit raamwerk is gebaseerd op de twaalf zintuigen zoals benoemd door Rudolf Steiner. Door sensorische informatie afkomstig van de twaalf zintuigen te linken aan specifieke delen van de fysieke omgeving, is het mogelijk om de ervaring van de fysieke omgeving eenduidig en meer objectief weer te geven. Het raamwerk is getest met huisvestingsdeskundigen, gebruikers afkomstig uit de zorgsector en architecten. Het bleek een bruikbaar instrument te zijn om de kwaliteiten van de omgeving te benoemen, te begrijpen waarom mensen verschillend reageren op hun omgeving en hoe gezamenlijk een oplossing kan worden gevonden voor een situatie die verbetering behoeft. Nader onderzoek is nodig met andere groepen mensen in andere testomgevingen om het raamwerk te valideren.

Hoofdstuk 10 vormt het slot van de dissertatie en biedt een overzicht van de belangrijkste conclusies en aanbevelingen, reflecteert op de beperkingen van het onderzoeken en benoemt de noodzakelijke toekomstige stappen. Dit onderzoek ontrafelde het complexe concept 'productiviteit' in vier werkinstellingen (sociale observatie, collectiviteit, contemplatie en bewustzijn). Het noemt vier belangrijke onderdelen van de fysieke omgeving die een belangrijke invloed hebben op productiviteit (structuur, variatie, psychologische veiligheid en identiteit). Het literatuuronderzoek met betrekking tot het effect van planten op productiviteit geeft aan dat planten in het algemeen een positief effect hebben. Het kleuronderzoek toont geen eenduidig effect aan van kleur op productiviteit mede gelet op de complexiteit van beide begrippen. Kleur heeft echter een significant effect op stemming. Omdat productiviteit kan worden beschouwd als een fenomeen dat uit vier werkhoudingen bestaat, kan in toekomstig onderzoek gerichter worden gekeken naar deze begrippen. Het ontwikkelde raamwerk kan behulpzaam zijn om de totaliteit van de omgeving eenduidig te kunnen benoemen.

Epilogue and acknowledgement

When I look back at the PhD process, this makes me a happy person. Confidence, the space and the time I got were precious gifts. At first my husband Olaf gave me every opportunity and he accepted thick layers of dust and chaos in our home while I sat for hours at the computer. My supervisor Peter Vink and co-supervisor Theo van der Voordt also gave me confidence, space and time which are important conditions to develop insights. Along with the dog Door I spend a lot of time daydreaming at the pastures and I am convinced that musing is one of the main activities to achieve maximal knowledge productivity. What would it be great if musing will be a generally accepted activity within organisations. I am grateful for the tremendous help of Peter and Theo. Peter with his huge amount of humour and ideas and always seeing somewhere opportunities and Theo with a matchless perseverance, care, and open for ideas of a spiritual nature. Without Peter and Theo I had many times thrown in the towel. I am also glad that I was able to meet many enthusiastic people during my research, Robbert Dijkgraaff to Rinnooy Kan, Mathieu Weggeman, to Joseph Kessels. These people gave energy and brought new ideas and insights. I have also followed consistently recommendations of others to read specific books. Tony Gaillard for instance told me to read the books of Csikszentmihalyi , which were an enormous source of inspiration. Thanks to all these advices I ended up on paths that I otherwise never would have found.
The collaboration with the painter Jan de Boon brought a huge deepening of knowledge. I'm afraid I would have continued the already paved paths of the ratio without him and then to collide against an enormous wall with an incredible amount of unruly data. Jan opened the doors from affect to collective consciousness, from the meaning of the senses to feelings, from Rudolf Steiner to Goethe. In this way, nature became an increasingly powerful force in the research and colour received the colour that it deserved.
My biggest struggle was the grandeur and beauty of our environment. Everything I touched turned to be a mirror palace with unexpected reflections with new doors that again were entrances to new mirror palaces. This caused a sense of reverence and respect, and at the same time a fear of not being able to approach things in a sufficient careful way. After the first year, I had the feeling to understand a little bit of something, but after a few years I was actually quite sure to understand nothing of everything. It is a quest how we can approach the incredibly complex reality. Environmental psychologists and other scientists are forced to make separations and simplify this complex world in order not to get lost in an overload of data. Quantum physicists like Einstein, Bohm and Bortoft and the scientist in organisational development, Senge highlight the connectedness and the importance of coherence. In essence, it is wrong to cut reality into pieces as stand-alone things, because the secrets of reality are hidden in the relationship, just like light colours appear in process and are not isolated elements.
The approach towards science is primarily by means of the ratio as ratio is concerned as managing actual and objective facts which are conceived as 'true'. It is the question whether this approach is not too limited. It is noteworthy that ' ratio' is based on the Latin 'reri' that means ' think or consider', a purely human mental matter, which cannot be conceived as handling purely objective facts. Also the word 'fact' is based on the Latin 'facere' that means 'what people make '. Ratio and fact are thus both based on human mental ideas, which may be skilled and knowledgeable, but neither are actually nor objective. The etymological meaning of 'emotion' shows the interesting link to the Latin term 'emovere' that means 'actuate' and the Latin 'movere' that means 'move'. So emotion has to do with movement and is closely connected to the dynamics of reality. The experience of the brain expert Jill Bolte Taylor, who at the age of 37 years had a stroke shows clearly the important role of the emotional brain. When

her rational brain (the left hemisphere) completely failed, the right hemisphere, i.e. the emotional brain showed how beautiful everything is connected to wholeness. In scientific research emotion, feelings and intuition ask for an equivalent foundation and a respectful connection with the ratio.
Despite the growing awareness of ignorance, thanks to my research I started to see more. I now have a trained eye for seeing after-images, and I notice for example staying in the bathroom how often shampoo manufacturers apply complementary colours on their shampoo bottles to make them stand out. In the swimming pool, I see the phenomenon that Goethe discovered how the light turns bright blue and deep yellow hues along the black lines painted on the bottom of the pool. Beautiful colours that do not physically exist, but our eyes show these surprises. Thanks to the research one feels more guided by the phenomena that occur in nature, whether it happens in the bathroom or in the swimming pool or elsewhere. So one sees more and feels more, partly due to an in-depth study of the operation of the senses. It would be wonderful if we would more intensely use the advantages of nature in the design of the built environment.
What I hope is that science gradually - and there are many signs- will allow the less measurable phenomena as feelings, intuition and spirituality in a more respectful way and will try to build a fruitful bridge between the two insights of our two hemispheres. If something is not measurable, it does not mean it is not there. Next to the inspiring environment with all its secrets, I am wandered about the human spirit. I am convinced that Newton would even have invented his famous law of gravitation if he had lived in a meter box. The human mind is so sparkling that nothing can hinder, if only there is Sense. That sense is the driving force of all human beings. The physical environment supports this sense, encourages, challenges, shakes awake and calms. For this reason the physical environment deserves a sincere, careful and dedicated attention.

Iris Bakker

Curriculum Vitae

Iris Bakker was born in 1961 in Utrecht. In 1979 she graduated from 'Het Nieuwe Lyceum, gymnasium' Bilthoven and studied Architecture and Restoration at Delft, University of Technology. She graduated in 1985 and worked for eight years as maintenance manager at the Real Estate Division of the Ministry of Defence in The Hague. At an office for architectural and interior design, she worked for eight years as an engineering consultant supporting housing projects, for offices, industry, education and labs and developed among other things programs of requirements. In 2007 she started her own business Levenswerken. She was for several years member of the editorial board of Facility Management Netherlands (FMN) and wrote for many years columns about the sense and nonsense at the workplace.

Scientific Publications

Bakker, I.C., Van der Voordt, D.J.M. (2010), The influence of plants on productivity: a critical assessment of research findings and test methods. Facilities, 28(9/10), 416-439.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P. De Boon., J. (2013), Red or Blue Meeting Rooms: Does it Matter? The Impact of Colour on Perceived Productivity, Social Cohesion and Well-Being. Facilities 31 (1–2): 68–83.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J. (2013), The use of questionnaires in colour research in real-life settings: in search of validity and methodological pitfalls, Theoretical Issues in Ergonomics Science, 1-13.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J., Bazley, C. (2013), Colour preferences for different topics in connection to personal characteristics. Colour Research & Application, Article first published online: 30 October 2013, DOI: 10.1002/col.21845.

Bakker, I.C., Van der Voordt, D.J.M., Vink, P., De Boon, J. (2014), Pleasure, Arousal, Dominance: Mehrabian and Russell revisited. Current Psychology, Vol 33 (3), 405-421.

Publications in Professional Journals (all articles written in Dutch)

In Facility Management Magazine (FMM):

Het Programma van Eisen bij een bouwproject, [Program of Requirement for buildings in construction], May, 2001, 49-52.
Kantoorconcept, en kwestie van de dartschijf of een nadere overpeinzing, [Concept Offices], November, 2001, 20 - 27, co-author Herweijer, M.

Menselijk huisvesten: hoezo strategie, [Housing with humanity, a strategy?], September, 2002, 28-32.
De Homo Sapiens Energeticus, [The Homo Sapiens Energeticus], February, 2006, 26-31.

Zorgsector wordt kleurrijk, [Care sector will be colourful], Vol 161, June, 2008, 36-39, co-author Faasen L.
Standaard werkplek als leidraad voor flexibiliteit, [The standardised governmental working place], Vol 162, August, 2008, 8-11, co-author Van der Voordt, D.J.M.

De werkomgeving voor de productieve kenniswerker, [The work environment for the productive knowledge worker], Vol 167, February, 2009, 19-23.

Leren van de natuur, Biomimicry ofwel Homo Humiliation, [To learn from nature, Biomimicry], Vol 168, March, 2009, 29-31.
Een integraal huisvestingsmodel, Oosterse en westerse wijsheden naast elkaar, [Integrated Housing Model, eastern and western views], Vol 176, December, 2009, 38-41.

Niet managen, maar faciliteren, [Do not manage, facilitate], an interview with prof. Kessels, Vol 192, August, 2011, 55-59, co-author Van der Voordt, D.J.M.

Universitair vastgoed als sturingsmiddel in onderwijs en onderzoek, [University Real Estate as tool for education and research], an interview with rector Karel Luyben, May 2013, 38-41, co-author Van der Voordt, D.J.M.

In Business

Kantoorinrichting, meer dan een spel met meters, [Furnishing of offices, more than meters], 2001, co-authors Herweijer, M., Wielart, S., Heldens, M.

In Facility Management Informatie (FMI):

Huisvestingsmanagement, Integratie van alle facetten, [Management of housing], August 1999, 4-6, co-author Van der Maas, T.

Mensgericht huisvesten, Strategisch gericht huisvesten voorwaarde voor maximalisatie productiviteit, [Human housing to optimise productivity], April, 2006, 10-13.

De levenskunstenaar: Hans Becker, [The artist of life, an interview with Hans Becker about housing for care], April 2006, 42-43.

De innovatieve stiltewerkplek, [The innovative silent work place], September, 2006, 12-15.

De therapeutische route door het Gezondheidspark Hengelo, [The therapeutic route through the park of health in Hengelo], February, 2007, 12-15.

Altrecht: vastgoed als levensader voor de zorg, [Altrecht: Real Estate, the centre for care], February, 2007, 12-15.

De huisvestingshomeopaat, [The homeopath for housing], November 2007, 20-23.

Productiviteit en kennisontwikkeling, Een gesprek met hoogleraar Mathieu Weggeman, [Productivity and knowledge development, an interview with prof. Weggeman], Nov 2007, 44-45.

Villa Flora, het groenste kantoor van Nederland, [Villa Flora, the greenest office of the Netherlands], January, 2008, 12-15.

Planten en de invloed op productiviteit, het effect van planten op het functioneren van de mens, [Plants and the influence on productivity], January, 2008, 16-19.

Het wezen van kleur, [The phenomenon colour], February,2008, 36-39.

De visie van helend genezen en facility management, [The view of healing and facility management], May, 2008, 48-49.

Healing Environment, [Healing environment], sept 2008, 24-28.

Green Office 2015, [Green Office 2015], Dec 2008, 38-41.

De levende werkomgeving, [The living work environment], December, 2008, 46-51.

Vergadertest: Wat is het effect van kleur?, [Meeting test: what is the influence of colour?] Vol 2, 2009, 50-51.

Cradle-tocragdle: van extase naar energie, [Cradle to cradle], an interview with prof. Luscuere, Vol 4, 2009, 16-19.

Zonder samenwerking geen duurzaamheid, [Without cooperation, no sustainability], Vol 4, 2009, 22-24.

Gezond werken en de waan van de dag, [Healthy work and the hurry of the day], an interview with prof Tony Gaillard, Vol 5, 2009, 24-27.

Oost West, huis best, [East West, House Best], Vol 10, 2009, 30-33.
Het FNJW-PVE, Het Programma van Eisen om Fluitend Naar Je Wek te gaan, [The happy program of requirements], Vol 11, 34- 37.

De regenboog en de blije bergbeklimmer, [The rainbow and the happy mountaineer], Vol 1, 2010, 6-9.

De verwonderlijkheden van het oog, [The miracles of the eye], Vol 2, 2010, 6-9.

Huisvesting als middel tot social-economische vitaliteit, [Housing as method to find social economic vitality], an interview with Rinnooy Kan, Vol 5, 2010, 32-35, co-author Van der Voordt, D.J.M.

Een plek die ons stimuleert zo vrij mogelijk te denken, [A place that stimulates to think free], an interview with prof. Dijkgraaf, Vol 1, 2012, 32-37, co-author Van der Voordt, D.J.M.

In Facility Management Executive

Performance en Productiviteit in het kennistijdperk: welke fysieke omgeving past hierbij?, [Performance and Productivity in the knowledge era: which physical environment fits?], November, 2008, 8-13.

Publications in Books:

Kazernebouw, in '300 jaar bouwen voor de landsverdediging', [The history of barracks construction, in, 300 years building for Defence of the Netherlands], 1988, editors: Van den Beemt, F.H., Boekema, D., Thijssens, Ministry of Defence, original title '300 jaar bouwen voor de landsverdediging, Ministerie van Defensie, Dienst Gebouwen, Werken en Terreinen, 179-189.

Productiviteit in het kennistijdperk, in Succesvolle Kantoorhuisvesting, [Productivity in the knowledge era, in Housing of Offices with Success], 2008, editors: Van Scheijndel, P.A.M., Horsten, F., Sdu uitgevers, original title 'Succesvolle Kantoorhuisvesting', 47-56.

Huisvesting krijgt menselijk perspectief, [Housing gets a human perspective], in Kooyman, W. (ed), 2008, Facility Management Magazine, Book of the year 2008, Nieuwegein, Arko Uitgeverij 2-6.

De breinwerker, [The brainworker], in The brainworker, 2010, editor, Bakker I.C., FMN Naarden, original title, De Breinwerker, 37-57.

Zorg voor mens en omgeving, het Zintuig als maatstaf, [Care for human and environment, the sense as measure], (co-author Jan de Boon), 2012, editors Ooijevaar, O. en Van der Voordt, D.J.M., Aedes-Actiz, Kenniscentrum Wonen en Zorg, original title 'Zorg voor mens en Omgeving, het zintuig als maatstaf'.

Website: www.levenswerken.eu

Iris and Saar

In the first Email of Theo van der Voordt in June 2007, he warned me for the vulnerability and difficulty to prove theories of eastern wisdom, philosophies of Plato and insights of Steiner. He was right, but nevertheless these can be vital fundaments for modern western visions on the productive physical environment.

How can we create an environment for the productive knowledge worker? To answer this question, it is not only necessary to understand the knowledge worker. It is also necessary to know how to approach the totality of the work environment. This is difficult because both the knowledge worker is a versatile person, but also the environment shows a rich variety of characteristics. To understand the complexity of the physical environment a study is conducted on two aspects: plants and colour. Four features of the physical environment mainly support the productive environment. It turns out that the totality of the physical environment is approachable on the basis of a model-based ordering of sensory information.