The effect of different classroom light settings on the behavior and emotions of children with Autism Spectrum Disorders

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The effect of different classroom light settings on the behavior and emotions of children with Autism Spectrum Disorders

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Preface

Exactly 6 years ago I started with the Introduction week to begin a hopefully exciting, new study and life in Eindhoven. Now looking back, these six years were exciting: three years of bachelor in Industrial Design and an internship, a year of pre-master and board of my futsal club, and two years of HTI master including a semester in Denmark. Now after six years of studying, I am proud to present my Master Thesis, which you just started reading.

There are several people without whom this thesis would not have been possible. I would like to thank my supervisors, Yvonne de Kort and Karin Smolders, who shared my enthusiasm about collecting data from the teachers and children, and gave me helpful tips and insights during the project to write this thesis.

I would like to thank all employees of the Talentencampus Venlo (TCV) who helped me with carrying out my experiments; especially Harm Claus, who offered me his nice office in the school to work during my weeks in Venlo and who brought me into contact with the teachers and experts. I would like to thank the teachers, who made time in their busy day schedule for the observation schemes and the association assignment with all the children. And of course I say thanks to all the children who were, maybe unconsciously, very interesting subjects of study. I hope I made a good explorative start of the investigation on the effects of the flexible light system on the children of the TCV. In general I hope I contributed to the understanding of the person-environment interaction and its impact on the behavior and development of primary school children.

Thanks to my fellow graduate students in the ‘Awesome Office’; our discussions about statistics and report writing were very helpful.
Lastly I want to thank my friends and family and especially my parents and Henrik, who supported me and frequently asked how my project was going.

Abstract

Previous research showed positive effects of different light settings on human functioning and school performance of children. Only few studies have been performed to investigate the effects of school light on children with Autism Spectrum Disorders (ASD), while more than 11,000 children in the Netherlands are diagnosed with ASD. Autistic children are often extra sensitive to stimuli in their direct environment and it is generally assumed that the functioning and school performance of autistic children can be improved by a well-designed classroom environment.

In this project, we explored the effect of four different classroom light settings (Setting A: 4100 K, 300 lx; Setting B: 7300 K, 500 lx; Setting C: 5100 K, 900 lx; Setting D: 3500 K, 300 lx) in a special education school on the behavior and emotions of children with and without ASD in two studies. An observation study investigated the influence of exposure to the four classroom light settings on the behavior of the children during two weeks, where the teachers observed the children when exposed to a different light setting every morning and afternoon. The second study investigated whether the children associated specific emotions and tasks with a certain light. Children were briefly exposed to the four light conditions (serially) in their classroom. During every light setting the children were asked, in a playful way, about their associations with the lighting in terms of pleasantness, headache and tiredness, and which tasks they associated with the specific light, by using a simple assignment developed for this purpose.

The results showed no clear effects of different classroom light settings on the classroom atmosphere, rated pleasantness and associated tasks of children in special education. We found significant effects of the light settings on associated headaches and pleasantness by the children. Headache was most associated with light settings with a high intensity and color temperature (setting B and setting C), tiredness was most associated with light settings with a low intensity and color temperature (setting A and D). Children with Autism Spectrum Disorders did not show clearly different behavior or emotions compared to the other children in special education.

This research made an explorative start in a relatively unknown field; more research is necessary to expand the limited knowledge about the effects of classroom lighting on the functioning of children with Autism Spectrum Disorders and children in special education in general.

Contents

1. Introduction

More than 11,000 children in the Netherlands have been diagnosed with Autism Spectrum Disorders (ASD; Trimbos-instituut, 2004). ASD is a disorder of neural development which causes people with ASD to perceive and understand the world around them differently. There is a lot known about the characteristics of autistic people, they are for instance often extra sensitive for stimuli in their direct environment. This knowledge about autism is used by various people and institutions to let people with ASD function at their best; for instance autistic children are often offered special education where the way of teaching and the environment is adjusted to their special needs. However, there have been conducted relatively few studies about the effects of ambient factors such as lighting in the classroom on the functioning of autistic children. This is remarkable since there are a lot of researchers that investigate the effect of ambient factors and lighting on the functioning of adults and schoolchildren in general.

Autistic children are soon distracted by environmental stimuli and can be hyper- or hyposensitive to light; hypersensitivity can cause avoidance of bright places and hyposensitive children can be attracted to light (Bogdashina, 2003). It is generally assumed that the functioning and learning of children with autism can be improved by a well-designed classroom environment, but researchers do not agree on how these classrooms should be designed (Henry, 2011; Long, 2010; Vogel, 2008). Therefore it is important that the influence of the classroom environment, and specifically classroom lighting, will be investigated; it can help the autistic children feel and learn better in their daily school life.

In this project, we will explore the influence of different light settings in the classroom on the behavior and emotions of autistic children. The research will take place at the Talentencampus Venlo, a primary school for all children, including those with a mental disorder, learning or social problems, and children with mental or physical disabilities. The studies will be carried out in nine special education classrooms where flexible classroom lighting has been installed, but is not used in a systemized way yet because the teachers are unsure of the effects.

The research is explorative in nature because the knowledge base on different light effects on children is limited, and the effects on autistic children are completely unknown. The research will consist of two studies. The first study explores the influence of exposure to four different pre-defined light settings on the behavior of autistic children in their classroom using observations. The second study investigates whether autistic children associate specific emotions and tasks with a certain light setting using a playful assignment.

With this Master project an explorative start will be made in the relatively unknown field of classroom lighting design for children with ASD. The research builds upon the current literature about effects of light on the functioning of adults, the knowledge about influences of light on school performance, and the knowledge about the potential role of light exposure on behavior and perception of children with ASD. The link I make between these three areas, to explore the effect of light on the behavior and emotions of autistic children in their classroom, is innovative. The following chapter will give an overview of the existing literature about influences of light on human functioning in general, effects of classroom lighting, characteristics of Autism Spectrum Disorders, and how children with ASD might be influenced by light and their classroom environment.

2. Theoretical framework

2.1 Effects of light on human functioning

Artificial lighting and daylight can have a substantial influence on the functioning of human beings. Many researchers already investigated various effects. Three light-effect mechanisms will now be discussed: the effects of light on visual performance, the effects of light on human functioning via psychological pathways and the effects of light via biological pathways.

2.1.1 Visual performance

Light allows us to see and engage in a visual task; sufficient light is needed for an optimal visual performance. A minimum amount of light required to, for example, read a book, can be defined, however, the visual performance depends on various factors that may influence each other.

Van Bommel and Van den Beld (2004) stated that the older the reader, the more light is needed, caused by the poorer condition of the lens. Next to that, more light would be preferred in a difficult task than in an easy task. According to Boyce and his colleagues (Boyce, Akashi, Hunter, & Bullough, 2003), font size is what influences task performance most and the illuminance to a much lesser extent. The positive influence of a smaller pupil size on visual performance is also discussed. A smaller pupil size causes less exposure of light in the eye and possible causes worse vision, but according to Berman et al. (1993), smaller pupil sizes cause better visual performance. This would be caused by the fact that a smaller pupil size will create a greater depth of field and reduce chromatic deviations.

Another possible influential factor on visual performance is luminance contrast. Berman, Fein, Jewett, and Ashford (1993) showed in an experiment that luminance contrasts are important for visual performance; a higher luminance contrast gives a better performance in the Landolt ring task (a task where the position of the gap in a ring has to be identified). However, their experiment also showed that the visual performance was always better in all different luminance contrasts with a green-blue light surround light source than a red-pink light source. This suggests that the color of the surround light can compensate for the luminance contrast in the effect on visual performance.
Rea and Ouelette (1991) showed in their Relative Visual Performance model that visual performance is relatively constant in a large range of the luminance levels and luminance contrasts, but soon decreases outside these ranges.
It can be concluded that visual performance is probably, outside this stable range, not only influenced by light intensity, but other factors such as font size and contrast of the displayed task, pupil size and age of the people do also play a role. The Dutch government set norms for contrasts and minimum light intensities in buildings like offices and schools, which ensures that in general people function in a well-lit environment for a good visual performance and that factors as font size, contrasts, pupil size, and age are of less influence.

2.1.2 Psychological pathways

Next to the fact that light can positively influence task performance via a good visual performance, light can have an effect on human functioning through how a person consciously or unconsciously thinks or feels about the light. Via a so called psychological pathway, light can for instance influence the well-being, performance or social behavior of persons.

A good example that shows the possible steps that occur from the experienced light setting via a psychological pathway to the well-being and task performance of humans is the linked mechanisms map of Veitch, Newsham, Boyce, and Jones (2008). They created the map after they performed two studies in an office environment (Figure 2.1). According to this map, the light setting influences appraisal (the perception of the light conditions), the visual capabilities of a person, and the person's preference, i.e., whether the light is experienced as pleasant or attractive. Preference has an effect on the mood of a person which in turn influences the well-being. Preference also directly influences task performance, and indirectly via motivation. Task performance is affected by visual capabilities (or: visual performance) too, which was already concluded in the previous section. The map also shows the influences of light on health, but this is questionable since the study of Veitch et al. (2008) did not measure the physical health of people, but asked about the subjective 'feelings of health'.

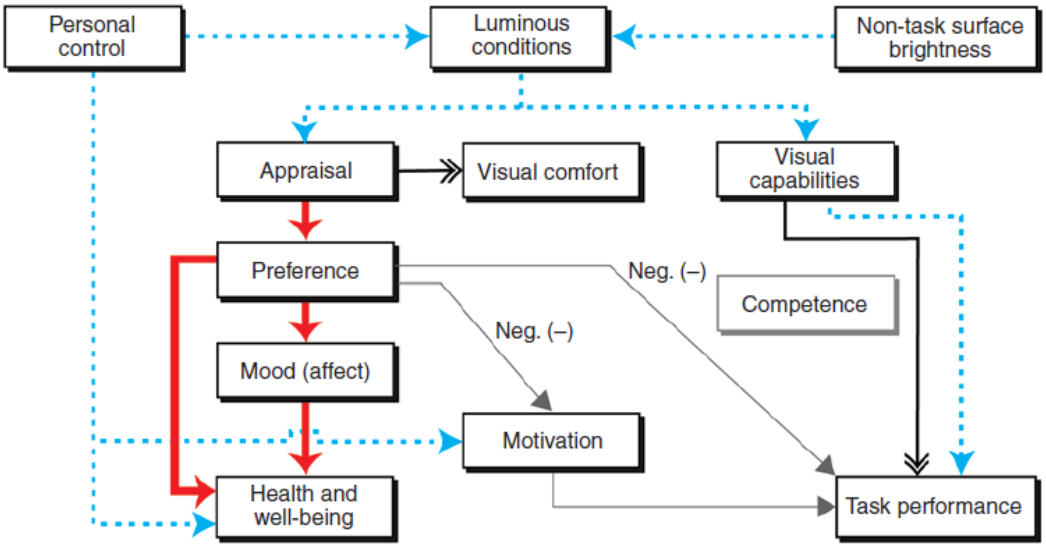

Figure 2.1 Mechanisms map of psychological pathway that is involved in the experience of light in an office environment. Reprinted from "Lighting appraisal, well-being and performance in open-plan offices: A linked mechanisms approach, by Veitch, J. A., Newsham, G. R., Boyce, P. R., & Jones, C. C. (2008). *Lighting Research and Technology*, 40, 133-151.

Besides well-being and task performance, other researchers showed that a psychological pathway can be involved in the influence of light on the social behavior of people. Baron, Rea, and Daniels (1992) found in a study where subjects had to rate an imaginary employee, that ratings were more positive in a low illuminance atmosphere (150 lx) than in a high illuminance atmosphere (1500 lx), suggesting that people show more social behavior if they are in a low intensity light setting. However, a limitation was that this result was not found in all their four color temperature settings (3000 K, 3600 K, 5000 K; results not found in 4200 K). In addition Baron et al. (1992) concluded that in a warm white light setting (3000 K), participants had a stronger preference for resolving conflicts through collaboration and less preference for resolving conflicts through avoidance, than in the cool-white light setting (4200 K). A psychological mechanism was possibly involved here; the lower color temperature and lower illuminance caused a positive affect and this influenced the social behavior positively. A third study confirmed the influence of warm white light (3000 K) on social behavior through positive affect. Exposure to a warm light setting as well as receiving a gift increased people's willingness to do voluntary work. However, concluding that a positive affect is caused by the warm light setting because the light gives the same result (willingness for voluntary work) as when someone receives a gift (and gets a positive affect) seems a too narrow reasoning.

2.1.3 Biological pathways

Next to visual performance and psychological pathways where people see and experience light, light can also have an influence on human functioning via biological pathways; pathways where the human eye does not consciously sees or form an image of the light.

Some years ago, researchers found that light can have influence on human physiology (biological processes in the human body) while people are not consciously seeing the light or even when they are blind (Zaidi et al., 2007). Through the discovery of a third class of photoreceptors (intrinsically photosensitive retinal ganglion cells; ipRGCs) in the human eye (Berson, Dunn, & Takao, 2002), which are not directly responsible for human vision, knowledge increased about how light can affect human physiology and behavior via the non-image forming pathway, the biological pathway.

Light can have two kinds of effects on human physiology and behavior via the biological pathway: phase shifting (circadian) and acute (non-circadian) effects. Phase shifting effects are temporal changes in the circadian rhythm, while acute effects are immediate changes in people's behavior and physiology. By explaining the functioning of the newly discovered photoreceptors (ipRGCs) and the circadian rhythm, these two effects will be discussed.

The ipRGCs in the human eye sends information to the brain area where the biological clock is located (the suprachiasmatic nuclei, SCN) and to brain areas that involve human's alertness, mood and regulation of sleep and wakefulness (Hattar, Liao, Takao, Berson, & Yau, 2002; Lucas, 2013). The biological clock regulates humans' circadian rhythm to secure an accurate behavior and physiology during the day. So this circadian pattern is the systematic variation in behavior and physiology with time of the day and causes the timing and amplitude of physiological and psychological processes; it regulates for instance hormone patterns, heart rate, feelings of sleepiness, and body temperature. (Van Bommel & Van den Beld, 2004; Cajochen, Wyatt, Czeisler, & Dijk, 2002). The hormone melatonin influences the sleep-wake pattern; when it is dark, melatonin induces sleep, and when the eye is exposed to light, the level of melatonin is lower. During night time when the melatonin level is high, exposure to light causes suppression of melatonin. (Van Bommel & Van den Beld, 2004).
The circadian rhythm changes according to the 24 hour day-night pattern. The light-dark cycle is the most important environmental cue for the inner clock of humans. If the circadian rhythm does not align with this 24 hour light-dark pattern, physiological and psychological processes may run out of phase.
If people are exposed to a light-dark pattern that is different than their internal clock, the circadian rhythm can be disrupted and phase shifting effects can take place. This insight that light can influence the internal clock is relevant for people that live in a different environmental rhythm than their internal

clock, for instance people with a jet leg or sleep disorders or people that work during the night. Being in light or darkness at the right time can help them synchronize their internal clock again.
Next to that, the circadian rhythm might affect the alertness of people. Cajochen (2007) discussed in a review of various studies the involvement of the circadian rhythm in the effects of light on alertness; he concluded that illuminance levels, duration, timing and wavelength of the exposed light are relevant light characteristics for its effect on alertness of humans.

The spectral sensitivity of the ipRGC is different from that of the rods and cones; it is more sensitive to the blue part of the visual spectrum (Provencio, Rodriguez, Jiang, Pär Hayes, Moreira, & Rollag, 2000). However, it should be noted that the division between the contribution of classical rods and cones for image forming and the ipRGC's involvement for non-image forming is not that clear cut (Lucas, 2013). Exposure to blue light can effectively influence circadian regulation. Therefore various researchers recently have tried to investigate for instance if sleep disorders can be solved by exposing people to blue light for a certain amount of time (Holzman, 2010).

Besides these relatively long-term effects of light on human physiology and behavior, light can also have immediate effects via the biological pathway.
Most research on acute light effects on human functioning was performed at night time. This is done since the circadian drive for sleep, as well as the homeostatic need for sleep due to time awake, is maximal during the night. The melatonin levels are highest at night and light then has the largest effect on melatonin suppression. Therefore the effects of light can be easiest found during night time.
Several studies investigated the influence of light on human physiology and behavior. Rüger, Gordijn, Beersma, de Vries, and Daan (2006) compared light effects during day and night and found that bright light (5000 lx) increased heart rate and core body temperature at night, but that these physiological measures did not increase during daytime. Badia, Myers, Boecker, and Culpepper (1991) found effects of bright light (5000 lx) compared to dim light (50 lx) on body temperature (increased in bright light), sleepiness (greater in dim light) and behavioral task performance (better in bright light), but these effects were again not found in daytime.
Only a few studies are performed during day time. In the day-night comparison study of Rüger et al., differences between day and night were found on psychological measurements such as subjective sleepiness and fatigue. However, the study did not represent a common real life situation because people were exposed to only 10 lx before and after the study and were sleep deprived.
Smolders, de Kort en Cluitmans (2012) studied effects during daytime where participants were not sleep or light deprived. The study showed that the higher illuminance setting (200 lx vs. 1000 lx, 4000 K) had a positive effect on subjective alertness and vitality, sustained attention in tasks, and increased physiological arousal during daytime, when melatonin levels were low.
These daytime studies show that light can also have an effect on human physiology and behavior via the biological pathway without suppression of melatonin.
Considering again the spectral sensitivity of the ipRGC, researchers started investigating acute effects of blue light on the physiology and behavior of people; children might be more alert and perform better when increasing the blue portion of the artificial light in classrooms (which will be discussed in the next section).

Concluding the main effects of light on human functioning; enough light is important in visual performance. However, other factors like luminance contrast, the font size, and age of the subject can also influence the visual performance. Next to the fact that light can positively influence task performance via a good visual performance, other effects of light on human functioning possibly occur via psychological or biological pathways. Light can influence someone's experience of the environment and mood or affect and that in turn might influence the well-being, performance or social behavior. Effects via biological pathways are separated in circadian and non-circadian effects. In circadian effects light causes a phase shifting in the circadian rhythm, which can affect for instance people's behavior. In non-circadian effects the physiology and psychological processes of the human are immediately influences and this can affect for example the alertness and vitality of people. Different pathways and effects were now separately discussed, while in real a complex interplay of more pathways can be involved in effects of light on human functioning.

2.2 Classroom light effects

The previous section showed that light can have positive effects on human functioning such as vision, mood, communication, circadian rhythm and alertness. Since these functions are essential in daily school life, the effects of light on children's behavior and learning cannot be dismissed.
This section will discuss the influence of light on the visual performance of children, and will elaborate on the several studies that tested the effect of light on the behavior and learning of children in normal education. Different kinds of studies will be discussed: studies that involve daylight, artificial light and a flexible light system.

2.2.1 Visual performance

The ability to see and engage in a visual task through good lighting in the classroom is important for the functioning and behavior of children. Berman and his colleagues found that children have a better visual acuity under a higher color temperature (5500 K) than under a lower color temperature (3600 K) when doing the same task under the same task luminance (85cd/m²; Berman, Navvab, Martin, Sheedy, & Tithof, 2006). The pupil size of the children was measured in both color temperature settings and the pupil size appeared to be significantly smaller in the higher color temperature setting than in the lower color temperature setting. According to earlier research (Berman et al., 1993) with adults, a smaller pupil size improves visual acuity. Berman et al. (2006) concludes in his study with children that since a higher color temperature gives a smaller pupil size and a better visual acuity, it is proven that a high color temperature gives a better visual acuity in children. However, Berman et al. (2006) show in a second experiment that there is no significant difference in visual acuity between the low and high color temperature setting if the tasks luminance of both settings is low (42.5 cd/m²).
Overall, only a few studies investigated the effect of light on visual performance especially in children and the literature is quite inconclusive.
Besides the visual performance, the behavior and performance of children can be influenced by light. The influence of daylight and artificial light on the behavior and performance of children in the classroom will be discussed in the following sections.

2.2.2 Daylight

It is generally thought that daylight contribution to a building is good for a person's health, however, what is so special about daylight and which aspect of the daylight contribution (for instance the light level or the view to the outside) causes the positive effects on humans is often not clear. Küller & Lindsten (1992) did a study where they observed children in two classrooms without natural daylight contribution (one classroom with artificial light, the other with artificial daylight, with a light intensity of 200-300 lx), and compared them with children in two classrooms with daylight (one classroom also had artificial light and one classroom also had artificial daylight, the illuminance level varied over the year between 300 and 6950 lx). The classroom lacking both natural daylight and artificial daylight disrupted the cortisol pattern of children. Children with higher than average levels of morning cortisol had the smallest annual body growth and children with low to average levels of morning cortisol could better concentrate. With these results Küller and Lindsten (1992) concluded that classrooms without windows should be avoided. The most likely underlying mechanism investigated in this study was the biological pathway; the daylight influenced the regulation of the hormones of the children which had an effect on their body growth and concentration. Yet, we should be aware of the many possible confounds that go along with the effects of daylight contribution. The classrooms without daylight contribution had no windows, and thus no view to outside. Perhaps they had fewer possibilities for fresh air, less natural cues about weather and time of the day, etc. The negative effects of no daylight contribution on children in their classroom can be caused by a lot more factors than only the fact of 'no daylight'. Therefore, from the study of Küller and Lindsten (1992) it cannot be concluded that daylight contribution alone is enough for a better body growth and concentration of children.

Another study investigating daylight showed that school buildings with bigger windows and skylights, have a positive effect on students' performance (Heschong et al., 2002). In this study Heshong et al. (2002) compared children's performance in classrooms with different window designs in three school districts in the USA with in total 18,000 students. The daylight contribution and façade window design had a positive significant effect on reading and math scores in all the three districts, and some types of skylights also had a positive significant effect on the student performance in two of the three districts. Various possible mechanisms can cause these effects. Firstly, more light caused by bigger windows can improve vision (Van Bommel & Van den Beld, 2004). Secondly, the light setting can positively influence the mood of teachers and students which in turn improve the performance of the children (Veitch et al., 2008). And thirdly, more light in a classroom can have a positive influence on the performance via the biological pathway; mental alertness of the children might be improved due to the circadian responses to daylight (Cajochen, 2007). Again it should be noted that the positive effect on children's performance found in the study can also be caused by other factors that co-occur with daylight contribution, such as a view to outside, the warmth of the sun, etc.

Although a really big sample was used for the study of Küller and Lindsten (1992), conclusions about the effect of window design on school performance should be made carefully. Compared to the more controlled study of Küller and Lindsten (1992), Heschong et al. (2002) only used already existing school data about the performance of the children and the window design of the classrooms; the reading and math tests could be done differently in every classroom.

Besides daylight, studies are done on the effect of artificial light on students in their classroom, which will be discussed in next section.

2.2.3 Artificial light

Some studies investigated the effect of intensity and color temperature of light on the learning and behavior of children in their classroom. The following two sections describe two individual studies and three studies that used the same relatively new flexible lighting system. However, giving legible conclusions by comparing the different studies is difficult because the light conditions, settings and way of measurement are really diverse.

A study in 1986 suggested that students' mood improved and the classroom noise was reduced with a warm light and when the walls the students were facing were painted yellow and the blackboards blue, compared to when the walls were in their normal, grey color (Wohlfarth, 1986). Additionally off-task behavior of children in their classroom was reduced when fluorescent lighting was eliminated. It was also found that ultraviolet light caused lower absences due to illness. The positive effect of light on the health of the children through lower absences can be both explained by psychological and biological pathways via the mood and respectively the hormone regulation. However, since the color of the walls was also changed while investigating the effects of the light setting, it is difficult to conclude effects of only light setting from this study.

Another researcher (Hathaway, 1992) found positive effects of fluorescent classroom lights with ultraviolet supplements on the school attendance, school performance such as reading and mathematics, and body growth of children, compared to children exposed to the three other light settings (full spectrum fluorescent lamp without UV, cool white fluorescent lamps, and high pressure sodium vapor lamps). However methodological limitations weaken the value of the study; the light intensity in the classrooms was fluctuating since daylight exposure was not controlled and the color temperature of the lights was unknown.

In addition artificial light in classrooms can also have negative effects: the flicker and glare produced by the fluorescent lighting and interactive boards can cause discomfort, headaches, and impair visual and cognitive performance (Winterbottom & Wilkins, 2009).

2.2.4 Flexible light system

As described in section 2.1, research investigating the effects of light on adults showed positive effects on different variables such as task performance, communication and well-being. It is generally thought that these effects also apply for school children (although until now there is only little evidence for this), and therefore a special flexible light system, intended to support children in their behavior and learning during different school activities, was designed. In this context, flexible means that the light can be changed to pre-defined light settings that differ in intensity and color temperature.
Three studies investigating potential effects of this flexible light system showed that the lights have an effect on reading speed (Barkmann, Wessolowski, & Shulte-Markwort, 2011) and oral reading fluency of children (Mott, Robinson, Walden, Burnette, & Rutherford, 2012;). Positive effects were also found on the performance in the d2 Test of Attention (Barkmann et al, 2011; Sleegers, Moolenaar, Galetzka, Pruyn, Sarroukh, & van der Zande, 2013). Yet, no effects were found on children's achievement motivation and classroom atmosphere (Barkmann et al., 2011; Mott et al., 2012).

The three flexible light system studies used different designs; in the study of Barkmann et al. (2011) teachers of the experimental group could choose themselves for nine months which (of the seven) light settings they wanted to use during their lessons. During the reading and concentration tests with the children that were done at the start of the experiment, children in both the experimental and control group were exposed to a 'standard' light setting of 4000 K and 300 lx. The reading and concentration tests were done again after nine months, now in a cold, bright setting (5800 K, 1060 lx). Compared to the control group, the flexible lighting group showed a significant improvement in reading speed and fewer errors of omission in the d2 Test of Attention. Yet the question is whether this improvement in the flexible lighting group was caused by the use of the flexible light system for nine months which improved the children's general learning development, or that the children were already used to the cold, bright, setting and therefore could perform better at the end-test.

Mott et al. (2012) had the same methodological problem. They exposed the pupils for half a year to a 'standard' light setting (3500 K, 500 lx; control group) or a cold, bright light setting (6500 K, 1000 lx; experimental group). However, the reading tests were done in both groups in the 'standard' setting, which could be an advantage of the control group. In contrast to the study of Barkmann et al. (2011), no effects were found of light setting on the d2 Test of Attention.

In the study of Sleegers et al. (2013), the children in the experimental setting were on the day of the concentration end-test (d2 Test of Attention) exposed to a predefined pattern of the four light settings (the test itself was in a cold, bright, setting, 6500 K, 1000 lx). During the rest of the two months the teachers could choose the light setting themselves. In the control group children were exposed for the whole experimental period to a light of 4000 K and 600 lx and so the concentration test was also done in that setting. In this experimental design the light setting during the test was now more representing the light condition that the children were exposed to during the length of the whole experiment, however now the tests of both groups could be influenced by the different light settings at the moment of testing. No significant positive effect on the performance in the d2 Test of Attention was found in this study. However, in another experiment Sleegers et al. (2013) did find a positive effect on the d2 Test of Attention. In this study was controlled for daylight contribution, by exposing children at different days to different light settings (6500 K, 1000 lx vs. 3500 K, 100 lx) in an experimental classroom without windows. These differences in results suggest that daylight contribution can be an influential factor in the classroom light effects and should be taken into account when discussing results of the different studies.

Although the just described studies all used the same flexible light system, they used different durations of light exposure, different methods of measuring, controlled for different factors, etc. This makes it difficult to compare the studies and more studies should be done in the future to get more insights into the effects of this specific flexible light system.

Different pathways were possibly involved in the effects of the flexible light system on the children. Barkmann et al. (2011) attributed their positive results under a cold, bright light setting (5800 K, 1060 lx) to the short term influence of natural and artificial daylight on concentration and to the neuronal and hormonal effects of lighting on vision (the biological pathway). But in the other studies the authors are unclear about which pathways are possibly involved in the effect of the dynamic lighting on the performance of the children. Possibly the psychological pathway is involved too; it has been found that light can influence the mood, motivation and task performance of adults (Veitch et al., 2008); this might be also applicable for children. However, the results of the study of Barkman et al.

(2011) would not confirm this because the light that gave positive results on the d2 Test of Attention, was often perceived as unpleasant.

In conclusion, we described some studies that show effects from different classroom lights on the behavior and well-being of children. A warm color temperature might positively influence the mood of children, reduces noise, and improves communication (Wohlfart, 1986). A cold color temperature might positively affect the visual acuity, concentration, reading speed and oral reading fluency (Barkmann et al., 2011; Berman et al, 2006; Mott et al., 2012). Ultra violet light possibly positively influences the school attendance, school performance and body growth (Hathaway, 1992). Additionally daylight maybe influences body growth and causes improved concentration, reading and mathematics scores Heschong, 2002; Küller & Lindsten, 1992). This is a long list of interesting effects, however these effects should be considered with the utmost care since the design of studies are really different; for instance the light settings, time and duration of exposure to the light, classroom design, measurements of terms as 'concentration' and 'performance', the control setting, sample size, etc. were all different in these studies.

2.3 Autism Spectrum Disorders

A user group that is not involved at all in the classroom studies, are children with Autism Spectrum Disorders (ASD). It is thought that the influences of light on children with ASD can deviate from normally developing children because of their different sensory responsiveness and other specific characteristics of ASD. In this section common characteristics of ASD will be described and in the next section the possible different influences of light on children with autism will be discussed and how this affects the classroom design.

Autism Spectrum Disorders is the name for a group of disorders (Autism Research Institute, 2013). Therefore the following described characteristics are a collection of various symptoms and do not especially count for all people with autism. Additionally, the research on the causes and symptoms of ASD is still in progress and not everything is already well understood. In this report the term 'ASD' or 'autism' will be used as a general term for all the disorders that belong to ASD.

According to the Diagnostic and Statistical Manual for Mental Disorders (DSM-IV-TR), autism is 'A neural development disorder, characterized by qualitative impairments in social interaction and communication skills, along with a restricted repetitive and stereotyped pattern of behavior, interests and activities' Autism is often discovered during early childhood. It can be recognized when children are lagging behind in communication, social skills and/ or cognition (Autism Research Institute, 2013).

The causes of autism are often not clear; it is assumed that a genetic factor plays an important role, but environmental factors such as a virus or toxin can also be a cause (National Autism Association, 2013). Brain scans show that autistic people have dysfunctions in the neural structure of the brain and abnormal biochemistry of the brain (Autism Research Institute, 2013). Next to that, the amygdala and hippocampus are underdeveloped, which are responsible for processing emotions, aggression, sensory input, and learning (Autism Research Institute, 2013). Research on causes of autism is still in progress.

Commonly described in the research on the characteristics of autism, are the differences in sensory processing and -responding of autistic people compared to the general population (Bogdashina, 2003; Kern et al., 2007). A main characteristic of people with autism is that one or more senses are impaired; it differs from person to person which senses are not functioning well and these senses can be hypersensitive or hyposensitive (Bogdashina, 2003). Problems with auditory processing are often the case. Someone can be over sensitive to certain sounds or frequencies such as a ticking clock in the classroom, but they can also ignore sounds around them. For instance it can seem like they never listen to the teacher (Autism Research Institute, 2013). Uncommon visual responding such as avoidance of eye contact is also reported. Quite some autistic people do not like to be touched, while others are almost insensitive to tactile impulses or pain (Tomchek & Dunn, 2007; Temple Grandin, 2010).

Another commonly observed characteristic of people with ASD is their inability of understanding that other people have their own unique view of the world, which is also called 'theory of mind'. Theory of mind refers to our ability to understand other people's mental states such as desires, imagination, and emotions (Baron-Cohen, 2001). Autistic people have difficulties in understanding the perspective of other people which can cause problems with for instance playing with other children at school.

Besides that, people with ASD can have difficulties with understanding and coping with new situations. If something changes in their environment or time schedule, they can get confused or upset (Autism Research Institute, 2013). A well-structured day can be helpful; for instance strict time schedules for daily activities such as going to school and eating, and having a fixed place in the classroom.

Often autistic people have special skills; they may be really good in one thing, such as playing a music instrument or doing math calculations. They can be so enthusiastic and concentrated on the skill, that it is difficult to stop and go further with the daily school routine (Autism Research Institute, 2013).

Another problem for people with ASD in understanding the world around them is 'stimulus overselectivity'. This means that the attention span of a person is narrow or focused (Autism Research Institute, 2013; Bogdashina, 2003). One can only focus on one, often irrelevant, part of an object. Because attention is the first step in processing information, it can be difficult for a person with autism to learn something about objects or people around him. (Autism Research Institute, 2013). Children with ASD can have problems with learning at school because they have difficulties with filtering out unimportant sensory information and prioritizing the more salient information which is needed to do a task well (Reynolds, Bendixen, Lawrence, & Lane, 2011).

From the just described characteristics it can be stated that people with autism have to cope with a variety of difficulties in their daily life. Unfortunately until now researchers did not find a cure that works for all forms of autism. However, some people notice clear benefits of specific medicines, diets or sensory intervention techniques (Autism Research Institute, 2013). Besides from trying to cure the disorder, adjusting the environment to the special needs of people with autism can be a first step in making their lives more comfortable. The classroom is an environment where children stay every day and it is an important place where children develop their social and cognitive skills; therefore classroom design for children with autism should be taken well into consideration.

2.4 Autism, light and the classroom environment

When considering the characteristics of ASD, one can expect that autistic children react differently on their classroom environment and -lighting, than normally developing children.

When building school buildings for autistic children, architects have clear ideas about how to design for autism; however these ideas are often contradicting. According to Christopher Henry, researcher on autism design and owner of Autism Design Consultants, some designers argue that a classroom should have limited outside views to prevent distracting views and next to that it should have low ceilings, small classrooms and soft colors (Henry, 2011). However, Henry (2011) states that other people think large, light spaces with a lot of outside views and high ceilings are the best classrooms for autistic children because it is shown that daylight enhances school performance and health in normally developed children (e.g., Heschong et al., 2002; Küller & Lindsten, 1992). Henry makes it clear, though, that research is lacking to prove his design ideas.
Emily Long, a master student who did research on classroom lighting design for children with ASD by simulating sunlight in classroom models, collecting questionnaires and interviewing school psychologists and teachers, has another opinion than Henry (2011). She is in favor of a combination of the classroom design characteristics: high ceilings but small windows and soft colors (Long, 2010). However, the empirical data which Long (2010) based her conclusions on is not really extensive; questionnaires are only filled out by three special education teachers and it is not clear how many interviews she did with teachers and psychologists.

Actually the design challenge already starts with different general views on how to help school children with ASD in the best way. The question is whether you want to limit the sensory distractions so that they can function at their best, or whether you want to prepare the children for the ‘real’ world by letting them experience a normal setting and teach them how to handle the sensory overload. For instance the Kuwait Autism Center did not take into account the special needs of its occupants at all when designing the daylight penetration in the classrooms (Al-Mohaisen & Khattab, n.d.). Whether they purposely or not purposely forgot the needs of the building its occupants is not clear. They tested their design multiple times, but they only considered daylight contributions and not the effect on autistic children.
Another question is whether, as for instance Vogel (2008) also mentions, it is even possible to build an ideal classroom for all the autistic children in one class with so diverse characteristics and habits. Current schools have different views and use different designs for daylight and artificial light. What will be the best design is not clear, because well designed studies with good measurements and sample size do not exist (Henry, 2011). Different insights for classroom light design for children with autism will be discussed now, although clear evidence if often absent.

As stated before, autistic children have difficulties with filtering out unimportant sensory information. They cannot always distinguish the difference between what is socially important during class instruction and something audible or visible that is distracting them. Therefore the general focus of light design is that it should not be distracting (Long, 2010; Reynolds et al., 2011).

Children with ASD can have an impaired visual sense which can cause that they are hypersensitive or hyposensitive to light. When a child is hypersensitive to light, he or she dislikes bright lights and is frightened by sharp flashes of light. When a child is hyposensitive it is attracted to light and can be fascinated by reflections or bright colors (Bogdashina, 2003). However, Tomcheck & Dunn (2007) did not find a significant result in difference in light sensitivity in their study when they compared the behavior of normally developed children with children with autism. No significant higher scores were found on ‘Is bothered by bright lights after others have adapted to the light’ and ‘Covers eyes or squints to protect eyes from light’. Yet Long (2010) concluded from her three surveys with school teachers that bright light caused anxiety, frustration and aggressiveness among children with autism. Bright spots or glare caused distraction of the children. To limit bright light, dimmable lights in the classroom are preferred. On top of that the reflectance of the ceiling, wall and floor could be made lower to restrict the bright light.

Next to the brightness, the flicker and humming sound of fluorescent lighting is often reported by people with autism as annoying (Colman, Frankel, Ritvo, & Freeman, 1976; Long, 2010). The flicker of the light can cause fatigue of the eyes, headaches or can even trigger epileptic symptoms (Rea, 2000). On top of that children with autism might not be able to filter out unimportant stimuli like the flickering, which can cause information overload and stress (Bogdahina, 2003). Fluorescent lights and fixtures have been improved to reduce the flicker and noise. A possible solution is a fluorescent light with electronic ballasts; it does not need an induction coil and therefore reduces the audible hum (Rea, 2000). Additionally, electronic ballasts operate at a frequency of 20-60 kilohertz which reduces the visible flicker and gives a low lamp flicker index compared to magnetic and hybrid ballasts (National Lighting Product Information Program, 2000). Although normally developing children would not experience any flicker or sound with this improved technique, children with ASD might still see the flicker and hear the hum. Long (2010) therefore strongly recommends to not use fluorescent lamps in a classroom for children with ASD. However, she did not test whether different fluorescent lamps are experienced differently by children with autism.

It was discussed earlier in this report that high color temperature of classroom light might positively affect the visual acuity, concentration, reading speed and oral reading fluency of normally developing children. However, Long (2010) argues that light for autistic children should have a lower color temperature because a cool light would be experienced as more bright and would cause for instance distracting contrasts on objects; warmer light would create a better, calmer atmosphere for children with ASD to work in. Yet it is not clear what Long (2010) bases her recommendations on. Unfortunately no more research is done on the influence of color temperature on the functioning of children with autism; this leaves a gap for investigation.

Besides that classroom light for children with autism should be not too bright, not flicker and not give an audible hum, another important factor to take into account is that children in one classroom might possibly have different individual light preferences. Therefore Long (2010), Vogel (2008) and Winterbottom and Wilkins (2009) agree that classroom lighting for autistic children should be flexible and controllable by children and the teachers.

As ideal light in a classroom for autistic children, Long (2010) proposes an incandescent dimmable light with a color temperature of 3000-3500 K. A dimmable incandescent light avoids the flicker or audible hum that distracts autistic children and can be dimmed if the light is perceived to be too bright. Yet it should be mentioned that every school should make its own trade-off between the costs and energy efficiency of a lamp. Next to that Long (2010) is the only researcher that suggests such precise light settings for autistic children and more research should be performed to confirm these suggestions.

As stated in the previous section, coping with new situations is difficult for children with autism; they have a high need for structure and need clear cues to tell them when to change from for instance doing a math task to a writing assignment. Sometimes teachers need to give several cues (telling to stop, showing instructions on the board, showing the time schedule) before a child switches to the new task. According to an expert in the field of school children with ASD, providing a certain lighting condition for every task could be an additional cue to help the children switch between tasks (A. van Gastel, personal communication, April 24th, 2013).

We have seen in earlier studies with adults that light can influence someone's mood which in turn influences the well-being or task performance. In addition visual performance has an influence on the task performance of adults and children.
Communication and interpreting emotions can be difficult for children with autism. The question is whether they do not know how to *show* their emotions or whether they do not *feel* emotions. It would be interesting to know if autistic children have certain feelings or associations with light which cause their behavior while exposed to that light (the psychological pathway). Next to that possible limitations in the sensory perception and especially in the vision of autistic children (visual performance) can cause different light experiences and reactions than in normally developing children.

To summarize the theoretical framework: elaborate research is done in the light effects on the functioning of people via the visual, psychological, and biological pathway. Some effects are also found of classroom lighting on the performance of children such as reading speed and communication, but via which pathway these effects occur is less clear. Because of the characteristics of children with ASD, light might have different effects on them than on normally developing children and the question is whether the results of lighting experiments in regular schools also hold for autistic children. Schools for autistic children use special design guidelines for the classroom environment, but these guidelines are inconsistent and well-designed studies to test the effect of the light designs on the behavior and emotions children with ASD do not exist. This project makes a first step in investigating the influence of different classroom lighting on autistic children. Therefore my research question is:

What is the effect of different classroom light settings on the behavior and emotions of children with Autism Spectrum Disorders?

Since there is little known about the influence of artificial classroom lighting on children with ASD, the research will be of an exploratory nature. The focus of this first investigation will be on the effects of different classroom light settings on the behavior and emotions of children with ASD.

To answer the research question, the aim is to measure the behavior and emotions of children with autism while exposed to various artificial classroom light settings. To this end we perform two studies; in the first study children's behavior will be observed. The second study will investigate the emotions and tasks (school activities) children associate with the light. Doing the studies in this order, the behavior of the children cannot be influenced by their emotions which they reveal in the emotion study. Because of the time constraints of a Master graduation project, we decided to investigate acute (non-circadian) effects.

In the behavior observation study children will be observed in their classroom for two weeks by their teachers, while exposed to one of the four light settings each morning and each afternoon. In this way effects of different light settings in the classroom on group behavior and general atmosphere can be investigated. Because the children are exposed to the light settings for several hours during different times of the week, we will investigate the effect of the light independent of the situation, task or time.

In association assignment study children are individually asked about their feelings and task associations with the different light settings. As discussed earlier in this thesis, light can have an effect on the well-being and task performance via the mood of people (psychological pathway; see section 2.1.2). Therefore it is interesting to investigate the emotions of the children in the different light settings; their emotions (or mood) might influence their well-being or task performance in class.
This study will give teachers, designers and researchers insights into the effects of light on children with ASD and it can maybe help them in the usage of the flexible light system. The results of the study can suggest which light setting is in general most preferred by the children. Moreover results can indicate which light setting is most suitable or preferred by children in which classroom activity; this can be used to for instance bringing more structure or calmness during class by exposing children to a specific light setting during a specific activity. Results can also suggest which light setting might be not appropriate for children with ASD if they are for instance associated with tiredness or headaches.

While the first study is on a group level, the second study investigates light effects on the individual level. The next two chapters will describe the method, analysis, results and discussion of the two studies.

3. Study 1 – Behavior observations by teachers

3.1 Method

3.1.1 Design

In the first study, teachers observed their pupils in their classrooms for a period of two weeks while they were exposed to different light settings; so the study followed a within-groups design with repeated exposure to each of the settings.
Because the observer needs to be experienced with the behavior of the children to indicate whether the behavior and atmosphere is different from the normal behavior of the children, the observation was done by teachers, and not by external observers. Teachers used an observation scheme which they filled out at the end of each morning and at the end of each afternoon.
Children were exposed to a certain light setting for a time period of one morning or one afternoon. The goal is to get a general view of the effect of the lights on the children independent of the time or situation and therefore the children were observed on multiple days, on different times of the day and during various situations and types of tasks.

3.1.2 Setting

The experiments were carried out at the Talentencampus Venlo, in the south eastern part of the Netherlands. The Talentencampus is a primary school for all children, including those with a mental disorder, learning or social problems, and children with mental or physical disabilities. The studies were carried out in nine Special Education classrooms where a flexible light system had been installed. All classrooms differ in size and placement of the windows. The windows of all classrooms are oriented to the west, except from classroom 1 and 2, whose windows are oriented north. Pictures of the classrooms can be found in Appendix A. Each classroom is used by the same group of children throughout the year.

3.1.3 Participants

The children of the nine groups were all diagnosed to be in special education and could have mental disorders, learning or social problems, or mental or physical disabilities. Children were between 6-14 years old and placed in different groups according to their age and diagnosis. Groups had 9 to 14 children each, of which 74% were male. An overview of the group properties can be found in Table 3.1. As can be seen in the table, the children with ASD are spread out over various classes. It was decided to include all special education groups and all their children in the sample; for groups with some children with ASD it would be difficult for the observer to exclude the non-ASD children when observing the overall atmosphere in the classroom. The groups for special education with no ASD children were also included in the study to have a bigger sample and to be able to later investigate differential effects, depending on the percentage of children with ASD.

Table 3.1 Overview of participants of the behavior observation study

Group	Number of children	Average age	Percentage of the children with ASD
1	13	7	0% ASD (all mentally or physically disabled)
2	12	10	0% ASD (all mentally or physically disabled)
3	13	10	0% ASD (all mentally or physically disabled)
4	14	12	7% ASD
5	9	12	44% ASD
6	11	9	55% ASD
7	12	12	58% ASD
8	12	8	67% ASD
9	12	9	91% ASD
Total students	Total students: 108	Average age: 9,8	Percentage ASD of all children: 36%

3.1.4 Manipulation

In this study four different light settings were used. Setting A was a standard white light as is often used in office environments (4132 K, 316 lx). Setting B was a cold, quite bright light with a blue tone (7300 K, 489 lx). Setting C was a really bright, white light (5130 K, 891 lx). And setting D was a warm, low illuminance light with a yellow tone (3460 K, 287 lx).
Measurements across five classrooms at the Talentencampus were done to determine the light intensity and the color temperature of the four light settings. The measurements were performed on a morning in April with overcast weather and done at table height (approximately 0.6m high) in the middle of the classroom. An overview of the average measured light settings can be found in Table 3.2.

The study lasted 8 days, on 3 of which the children had the afternoon of. The study thus consisted of 13 sessions where on each session the groups were exposed to one of light settings. Since there are four light settings, a group is exposed to every light setting three or four times. The light setting scheme per group can be found in Appendix B.

The lighting that was used in the classrooms was a special flexible light system called SchoolVision, developed by Philips. The flexible light system consists of luminaires, a light sensor and a control panel. From the outside, the lights look like normal fluorescent lights. The light consist of three TL5 fluorescent tubes, two tubes of 17000 K and one tube of 2700 K, which together form the different intensities and color temperatures of the four light settings. On top of that the lights have an electronic ballast which reduces the audible hum (Rea, 2000).
To control the lights a control panel with five buttons is placed on the wall in the classroom; there is a button for each light setting and an off-button. The light sensor keeps the light intensity during the day at a constant level; if there is more daylight contribution, the lights will be less intense. For more light specifications and its elements, see Appendix C.

Table 3.2 The average measured color temperature and light intensity of the four light settings of the flexible light system at Talentencampus Venlo.

Light setting	Color temperature (K)	Illuminance (lx)	Appearance
Setting A	4100	300	Standard white light as often used in workplaces
Setting B	7300	500	A cold light with a blue tone
Setting C	5100	900	A bright white light
Setting D	3500	300	A warm light with a yellow tone

3.1.5 Measurements

The aim in this study was to measure the general atmosphere in the group by observing the group behavior during different light exposures. To register the group behavior, teachers used an observation scheme. The observation scheme consisted of two parts, the first six questions were about the general atmosphere in the groups and the last questions were about exceptional behavior of individual children. To not burden the teachers too much in their already busy job, filling out the observation scheme was designed to take at most three minutes. The teachers of the nine groups observed the children. The teachers that filled out the observation schemes were all female and see the children they were observing at least one day per week in their classroom.

3.1.5.1 Atmosphere

By observing different elements of group behavior, the goal was to get insights into the general atmosphere of the group.
Because no existing observing scheme was exactly suitable for this type of observation, six items that describe group behavior were chosen from a combination of the Pervasive Development Disorder Behavior Inventory (PDDBI; Cohen & Sudhalter, 2005) and the advice of the autism expert of the Talentencampus (A. van Gastel, personal communication, April 24th, 2013). Teachers had to indicate the group behavior according to the following six items: restlessness, being social, concentration, listening to the teacher, calmness and ambience. Answers were given on a 5-point scale ranging from (1) children show specific behavior less than an average day to (5) children show specific behavior more than an average day. Every group is different; therefore the questions in the observation scheme asked teachers to report the behavior of the children 'compared to an average day'.
The whole observation scheme can be found in Appendix D.

After data collection it was investigated whether the six atmosphere questions were correlated. A Principal Axis Factor Analysis showed that all items loaded on one factor. The factor structure was determined based on Eigenvalues and a Scree plot and the factor had a reliability of Cronbach's α =.81. Consequently, item 'restlessness' was recoded (so that in all items a high score was positive behavior), and the six items were combined to one overall scale, 'General atmosphere'. A general atmosphere of (1) means that there was a bad atmosphere in the classroom, while the score (5) means a really good atmosphere.

3.1.5.2 Exceptional behavior

Since the general atmosphere in the classroom can be influenced by one or more children with extreme behavior, after the six atmosphere questions, teachers were asked to indicate how many children showed uncommon externalized and internalized behavior and what this behavior exactly was. After data collection the variables externalized behavior and internalized behavior were transformed into one variable 'Exceptional behavior', which indicated whether there was any externalized and/or internalized behavior in the classroom or not.

3.1.5.3 Remarks and external factors

Teachers also wrote down if children gave any positive or negative remarks about the light. Lastly, teachers were asked to record uncommon factors that could have influenced the class atmosphere such as the weather, unexpected visits or a change of the program, etc. Teachers also had space to give other remarks.

3.1.6 Procedure

Four weeks before the study started parents and teachers received an e-mail to inform them about the research that would be carried out at their school. An information evening was offered to the parents, but no parents had a need for it. Besides that, teachers were informed during a general teachers' meeting to make sure that they were aware of the study and to give them the opportunity to ask questions. Teachers were told about the background and the goal of the research, but no information was given that could give them possible expectations about the effects of light on the behavior of the children.

Three days before the start of the first study the teachers were reminded about the most important aspects: teachers were asked to fill out two observation schemes a day, they should not change the light themselves and they were not allowed to talk with the children about the light.

When the researcher was in the classroom for the first time, the light settings on the light panel were made invisible with tape.

On a typical day, before class started, the researcher set the different light settings in the nine classrooms and gave the morning and afternoon observation schemes to the teacher or if she was not present yet, put it on the desk of the teacher. The teacher observed the children during the morning and at the end of the morning the teacher filled out the morning observation scheme. During the lunch break when the children were playing outside (the lunch break time differed in some groups by half an hour), the researcher picked up the morning observation scheme and changed the light to another setting. During the afternoon the teachers again observed the children and at the end of the afternoon filled out the afternoon observation scheme. After school time the researcher came to pick up the afternoon observation schemes (see Figure 3.1 for a visual representation of the procedure).

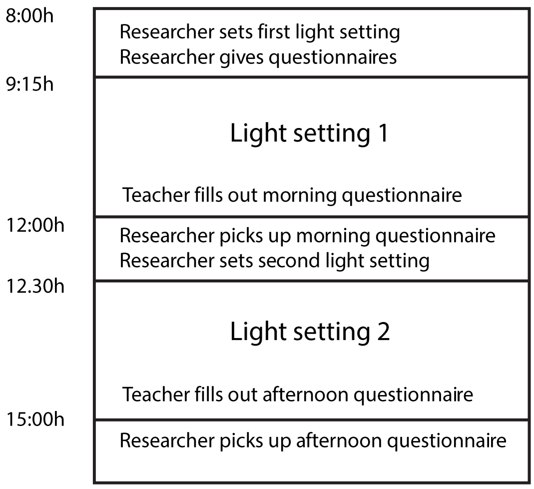

Figure 3.1 A typical experimental day in one classroom

3.1.7 Statistical analysis

117 observation schemes were collected (9 groups times 13 parts of the day). After reading all comments the teachers wrote on the observation schemes (for instance the children were not in their classroom because of swimming lessons), some observation schemes were excluded from the data, which finally resulted in 96 valid sessions (setting A: 26; setting B: 23; setting C: 25; setting D: 22). The analysis was split up in two parts; the analysis of the General atmosphere and the analysis of the Exceptional behavior. A Linear Mixed Model (LMM) for the General atmosphere analysis followed a within-groups design and the fact that each group had multiple observations per setting. The dependent variable was General atmosphere, independent fixed factors were Part of day and Light setting, and Group was added as an independent random intercept to let the LMM take into account that cases within a group were not independent.

The differences between groups were not tested but trends and differences in means were observed. After that it was investigated with a LMM whether the part of the day when the observation scheme was filled out had an influence on the atmosphere, i.e. whether the atmosphere was significantly different in the morning compared to the afternoon.

In the analysis of Exceptional behavior, an independent-samples T-test was first performed to test whether Exceptional behavior was related to the observed atmosphere in the classroom. So, the average General atmosphere of all observation schemes where any exceptional behavior was mentioned was compared to the average General atmosphere of all observations schemes where no exceptional behavior was mentioned.

After that a Chi-Square test was performed to analyze whether there was an effect of Light setting on the Exceptional behavior.

The General atmosphere and Exceptional behavior was analyzed for all children, however in this research we are especially interested in the effect of the light settings on children with ASD. We should be careful with analyzing the results of the autistic children because the measurements are on group level and cannot just be translated to individual children with autism. However, results of groups with a high percentage of children with autism can be compared with groups with no children with autism to get an impression about the possible influence of children with autism on the group behavior and atmosphere while exposed to different light settings.

3.2 Results of the whole population

In this section the results of the different light settings on the behavior and general atmosphere in the groups will be given.

3.2.1 General atmosphere

A Linear Mixed Model (LMM) analysis was performed to investigate the effect of Light setting and Part of day on the general atmosphere in the group. The analysis showed that General atmosphere was not significantly different across the light settings, $F(3,85)=.13$, $p>.10$. This means that the average atmosphere in the groups did not significantly vary between the different light settings. The mean atmosphere per light setting can be viewed in Table 3.3. From this table it can be observed that all values of the mean atmosphere are quite close to 3, indicating that the atmosphere in all four light settings were slightly lower compared with an 'average day' (since the value 3 meant in the observation schema that the behavior was as on an average day).

Table 3.3 Mean General atmosphere per light setting

Light setting	Mean General atmosphere	Std. deviation
Setting A	2.77	.08
Setting B	2.73	.09
Setting C	2.79	.08
Setting D	2.79	.09

Differences in mean atmosphere between groups can be viewed in Table 3.4. The table shows that the mean atmosphere was, during the two weeks of exposure to different lights, in all groups slightly below normal, except from group 7, which had an average atmosphere similar to a normal day. Figure 3.2 shows that groups have different patterns of atmosphere across the light settings. It suggests that group 3, 8 and 9 look like each other because setting A and D give the best atmosphere, while group 6 showed the opposite because there the best atmosphere was noticed when children were exposed to setting B and C. Group 7 had an average score of 3 in the setting A, C and D, suggesting that these light settings had no influence on the atmosphere in comparison to a regular day. Setting A was never scored highest and setting B never the lowest. As can be seen in Figure 3.2, the error bars are relatively large and interpretations should be done carefully. Group 7 has relatively small error bars; this is because the observed atmosphere was really consistent in every light setting.

Table 3.4 Mean atmosphere per group

Group	Mean	Std. deviation
1	2.33	.13
2	2.90	.13
3	2.87	.13
4	2.75	.12
5	2.83	.13
6	2.81	.12
7	3.04	.16
8	2.74	.14
9	2.66	.12

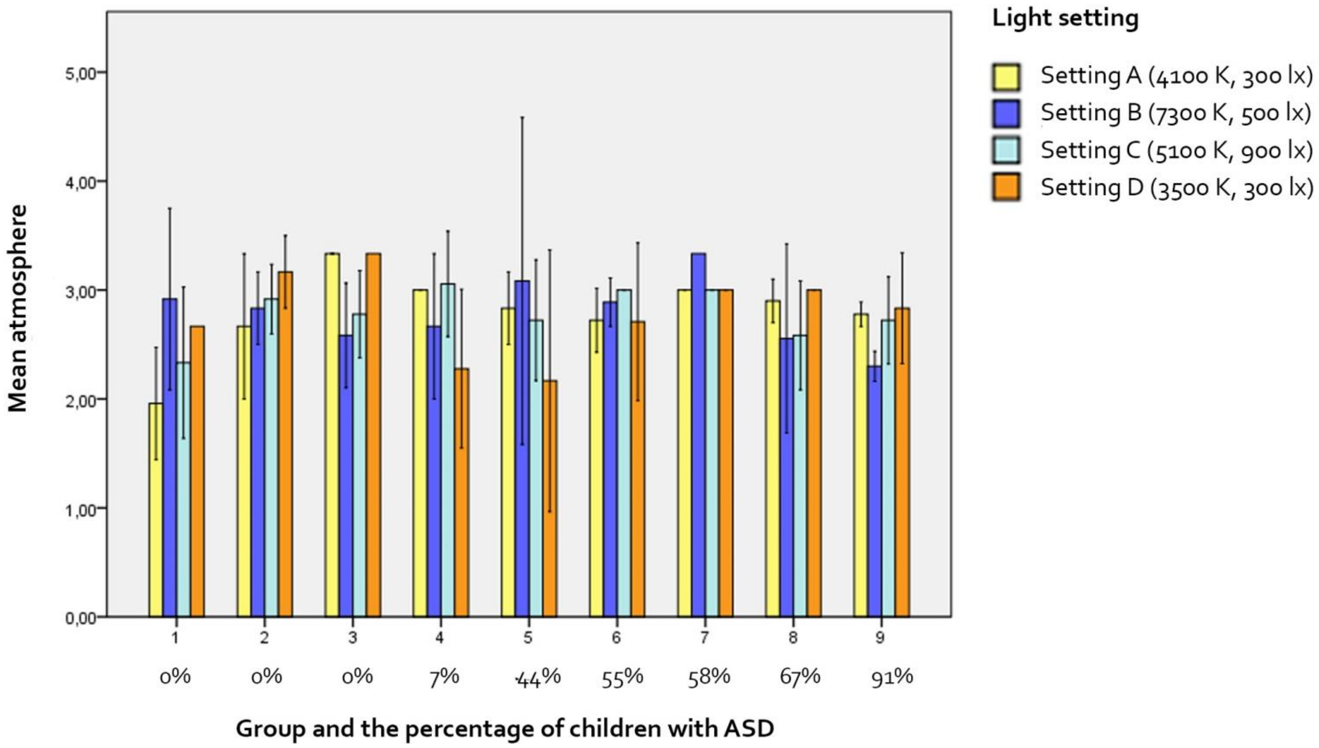

Figure 3.2 The mean observed atmosphere in every light setting across groups. Per group the percentage of children with ASD is given. No error bars in group 1, setting D; group 3, setting D; and group 7, setting B because that data only consisted of one case.

When analyzing the effect of the part of the day on the atmosphere in the classroom, a LMM showed that the observed atmosphere was not different across Part of day, $F(1,84)=.23$, $p>.10$. This means that whether it was morning or afternoon did not significantly influence the general atmosphere.

3.2.2 Exceptional behavior

Next to the general atmosphere in the classroom, teachers indicated in the observation scheme the occurrence of exceptional behavior of the children (such as being aggressive or really quiet).
First it was tested whether Exceptional behavior was related to the observed atmosphere in a classroom. An independent-samples T-test showed that when no exceptional behavior was mentioned in the observation scheme, the General atmosphere was higher (M = 2.85, SE=0.05) than when there was exceptional behavior (M=2.47, SE=-.11). This difference was significant t(90) = 3.77, $p<.05$. Note that although we added exceptional behavior as independent variable and atmosphere as dependent variable in this analysis, both directions of the relation between Atmosphere and Exceptional behavior might be possible. A better atmosphere in the classroom can cause less children to show exceptional behavior, but less exceptional behavior in the classroom can also cause a better atmosphere.

From Table 3.5 it can be seen that from all the exceptional behavior that was reported, the most exceptional behavior was shown in light setting B (34.8%). Next to setting B, during exposure of the setting A, quite some exceptional behavior was reported (30.4%), which occurred at a higher frequency than in setting C (17.4%) and setting D (17.4%). However, a Chi-Square test showed no significant effect of Light setting on Exceptional behavior, $\chi^2(3) = 9.29$, $p>.05$.

Table 3.5 Numbers of observed exceptional behavior by teachers of 96 observations

Light setting	**Observed Exceptional behavior**		
	No	Yes	Total
Setting A	19	7 (30.4%)	26
Setting B	15	8 (34.8%)	23
Setting C	21	4 (17.4%)	25
Setting D	18	4 (17.4%)	22
	73	23	96

3.2.3 Remarks and external factors

Next to the exceptional behaviors, teachers also wrote down if children or teachers themselves had any positive or negative remarks about the light. In total teachers reported 11 remarks about the light; most negative remarks were given during exposure of the setting B (Table 3.6). Teachers did not report any positive comments of children about the light.

Table 3.6 Reported negative remarks about the light settings out of 96 observation schemes

Light setting	Number of remarks	The remark
Setting A	1	- Child: 'I don't like the light'
Setting B	4, 1, 1	- 4 children during one lesson angry because of the light - Child: 'Maybe you should put the light on focus setting when making a test' - Headache
Setting C	1, 1	- Child: 'I get tired of this light' - Teacher experiences this as too bright
Setting D	1, 1	- Child: 'This doesn't give enough light' - (what kind of remark not written down)
Total	11	

At the end of the observation scheme teachers were asked if there were any uncommon external factors that could have influenced the class atmosphere. From the 96 observation schemes, 45 times uncommon factors were noted (see Table 3.7). A lot of factors had to do with a change in schedule, like another start of the week and another planning because of the teacher's birthday. Next to that environment factors were often mentioned like the change of weather or another teacher. In addition, factors were mentioned which could made the teachers or children more nervous like taking tests and having visitors.

Table 3.7. Number of mentioned uncommon factors that can influence the classroom atmosphere, out of 96 observation schemes

External factors	Occurrences
Quarrel in the lunch break	1
Monday free, week starts with Tuesday	5
Teachers busy, less time for children	2
Children absent	4
Birthday of teacher	3
Children have to do tests	6
Children angry	1
Change in planning	4
Busy schedule	2
Weather change	4
Visitors (education inspector)	2
Children do a performance/ play	2
Other teacher than usual	4
Total	45

3.3 Comparing results between groups with and without children with autism

3.3.1 Atmosphere

Table 3.1 and Figure 3.2 show the percentage of children with autism in the different groups; groups 1, 2 and 3 do not have children with autism and group 9 has a really high percentage of children with autism. Differences in atmosphere between groups across the light settings can be observed. However, no clear trends can be found when taking into account the percentage of autistic per group. Groups without children with autism do not show a clear atmosphere pattern across the light settings; neither do the groups with a higher percentage of autistic children.

3.3.2 Exceptional Behavior

To compare the exceptional behavior between groups with a high percentage autistic children and groups without any children with ASD, Figure 3.3 can be observed. This graph confirms the results from section 3.2.2; most exceptional behavior was reported in setting A and B.
It can be seen that in group 5 and 9, all the times these groups were exposed to setting B, exceptional behavior was observed (100%). Furthermore it can be observed that the teachers of group 6 and 7 never reported any exceptional behavior. No trend can be observed in the groups without autistic children and no trend either can be found in the groups with children with ASD.

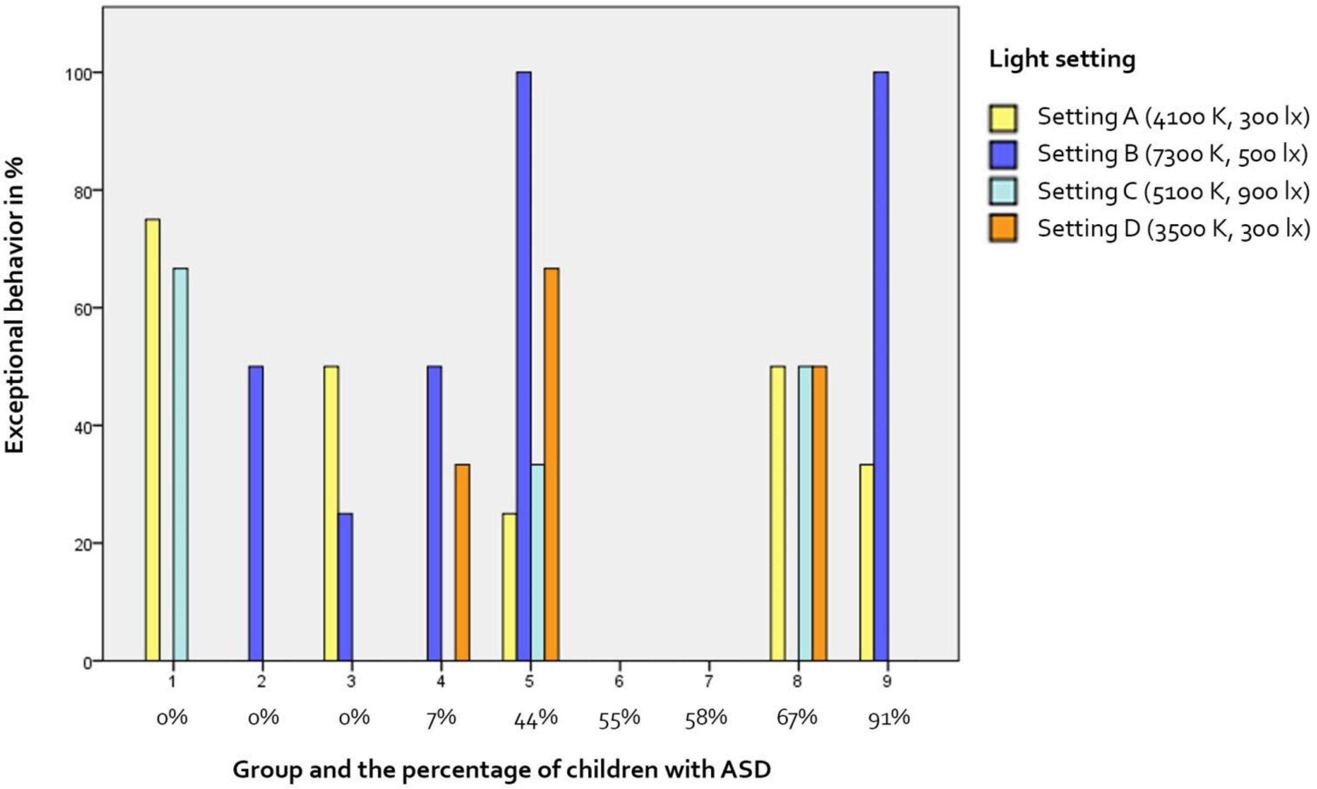

Figure 3.3 Observed exceptional behavior per group per light setting, as a % of the times the group was exposed to that light setting

3.4 Discussion

The aim of the observation study was to investigate the effect of different light settings on the observed atmosphere in the classroom. In this section, the main results of this study and the method will be discussed.

3.4.1 Atmosphere and exceptional behavior

The statistical analysis showed no significant effect of the light settings on the observed behavior and atmosphere, suggesting that the children did not show different behavior in one of the light settings compared to the others. Also no significant effect was found of the light setting on the observed exceptional behavior. Because we measured in this study on group level and not on the individual children level, results were compared between groups with high and low percentages of children with autism. The pattern between light settings of atmosphere and exceptional behavior was different between groups. Neither in the groups without children with ASD, nor in the groups with a higher percentage of children with ASD a trend of atmosphere and exceptional behavior across the light settings could be found. Interpretations of the results within groups should be done carefully since differences were small, relatively few observations per group per light setting were done and the data per group showed large variances within the light settings.

Our results on the observed atmosphere concur with the finding from the study of Barkmann et al. (2012) investigating the effects of light settings on the atmosphere in the classroom. In this study no change of classroom atmosphere (rated by children and teachers using a pre- and post-intervention questionnaire) was detected after using the special flexible light system for nine months. However, the study of Barkmann et al. (2012) investigated the effect on normally developing children, while we studied special education children. Furthermore the exposure of the light settings was different in the study of Barkman et al. (2012); the children were exposed for nine months to light settings that were chosen by the teachers, instead of our study were children were exposed for two weeks to pre-defined light settings.

3.4.2 Method evaluation

Since the behavior observation study was a field study, it was difficult to control for all possible external factors. From the 96 observation schemes the teachers filled out, 45 environmental factors as the weather, visitors, and change of schedule were reported that could influence the behavior of the children. The reported environmental factors might have an influence on the behavior and atmosphere in the classroom.

The high number of reported external factors that possibly influence the behavior of the children might say something about the characteristics of the children in the special education: their behavior is easily influenced by environmental factors. As already stated in the theoretical framework (section 2.3) children with ASD can be hypersensitive for environmental factors because of their impaired sensory processes (Autism Research Institute, 2013; Bogdashina, 2003). On top of that autistic children have difficulties with filtering unimportant environmental cues and concentrating on the relevant information (Reynolds et al., 2011), therefore it makes sense that teachers indicate several causes of the children’s behavior in the environmental factors.

A possible cause of the non-significant result of light setting on atmosphere could be the way of measuring the group atmosphere. However, this is unlikely since Cronbach's α showed a good reliability of the observation scheme and the errors across groups and light settings suggest that it was an appropriate scale with enough variance. Furthermore, the questions were formulated in such a way that it was possible to control for the different standard atmosphere in a group, by asking how the behavior was 'compared to an ordinary day'. Also the statistical analysis took into account the possible differences between groups by including Group as a random intercept.

Apart from these limitations, this behavior observation study in a short time gave much useful data about the behavior of children in their classroom across different light settings by using an observation scheme designed for this purpose. The design of our study gave more precise insights into classroom atmosphere compared to for instance the study of Barkman et al. (2012; with one pre- and post-intervention questionnaire), since teachers in our study observed their children multiple times on different times of the day, and during different school activities across light settings.
The observation scheme was an effective and suitable measure and required only a few minutes per day from teachers. All teachers filled out all observations schemes, which showed the ease of filling out the observation scheme as well as the involvement of the teachers in the research.

In conclusion, no effects were found of light setting on the atmosphere and exceptional behavior in the group. The average atmosphere in all groups was comparable with the normal atmosphere. Drawing conclusions per group should be done carefully because the number of observations per light setting per group was low and variances big. Moreover, methodological limitations can affect the results; a lot of external influential factors were reported and differences between light settings may have been more subtle due to daylight contribution in the classrooms. Though, this study used an effective observation scale that was specially designed for this purpose, which resulted in useful insights into group behavior across different light settings.

This study showed that the children did not behave differently in the four light settings and might implicate that the children do not have a preference for a specific light setting. To further investigate the preferences of children, we performed a second study. This study gives hopefully more insights into preferences and feelings of the children. The measured emotions of the children in this association assignment study might explain the behavior of the children in the observation study.

4. Study 2 - Individual emotion- and task- association assignment with children

4.1 Method

4.1.1 Design

The aim of the second study was to directly ask the children their experiences and associations with the four different light settings. The study followed a within-groups appraisal survey design with exposure to each of the settings. The assignment was done individually by all children in one group at the same time, while the researcher changed the light settings about every three minutes. During every light setting the children had to indicate which emotions and tasks (classroom activities) they associated with the light, by using a special playful assignment was designed for this purpose.

4.1.2 Setting and participants

For this second study the same groups, teachers and children were used as in the first study. In consultation with the teachers, two groups (group 1 and 2) were excluded from the study since these children would in all probability not be able to do the task in a meaningful way. In some other groups, some children were also not cognitively able to do the task in a meaningful way, but still participated to not be socially excluded from the other children in the group. After the task was finished, teachers indicated on the results of the children if they thought the results would not be meaningful. Not all children of each group were present during the assignment, so the number of children per group and percentage of ASD sometimes differs from that in the first study. In Table 4.1 can be seen that in total 68 children participated in the assignment. 11 of them were indicated by the teachers as not to be able to do the assignment in a meaningful way and removed from the sample. This resulted in 57 children; 34 of them were diagnosed with ASD and 23 were not.

Table 4.1 Overview of participants of the association assignment study

Group	Total number of children	Number of children that were not able to do the assignment in a meaningful way	Number of children with ASD	Number of children not having ASD
3	13	7	1	5
4	9	4	0	5
5	7	0	5	2
6	8	0	5	3
7	7	0	5	2
8	11	0	7	4
9	13	0	11	2
Total:	68	11	34	23
	68 - 11 = 57 children in the final sample		34 + 23 = 57	

4.1.3 Manipulation

The same flexible light system with the four different light settings (setting A-D) of the behavior observation study was used in this second study (see section 3.1.4). While the children in the first study were exposed to one light setting during the morning (start of the school day until lunch) or afternoon (after lunch to the end of the school day), in the second study children were exposed to every light setting for about 3 minutes directly after each other. When finishing the assignment, the light was switched back to the preferred setting of the teacher.

4.1.4 The emotion- and task-association assignment

In this study we wanted to measure which emotions and task every child associate with the four different light settings. Asking children good questions can be difficult and some children can have difficulties with understanding, interpreting or answering a question (Read & MacFarlane, 2006). Moreover, in this study setting interviewing children individually after each other would take a lot more time than asking their opinions on paper in a group session. Since a standard questionnaire scale with words and numbers can be difficult to interpret by children (Airey, Plowman, Connolly, and Luckin, 2002; Read & MacFarlane, 2006), a scale with smiley faces was preferred above a standard scale. Since smileys and pictograms are often used in all the special education groups at the Talentencampus to make emotions and activities clear to the children, it was decided to use smileys and pictograms for the survey.

To measure the emotion of the children, the Smileyometer scale was used. This is a measurement of pleasantness or fun that is used in various research with children before (Read and MacFarlane, 2006; Van der Sluis, van Dijk, & Perloy, 2012). However, some researchers argue that the Smileyometer is not suitable for young children because they tend to easily give extreme (positive) scores (Van der Sluis, 2012). Furthermore children with autism can have difficulties with interpreting emotions from faces and the question is if they would understand smileys. (Begeer, Rieffe, Meerum Terwocht, & Stockmann, 2006). Yet, according to an autism expert of the Talentencampus (A. van Gastel, personal communication, April 24th, 2013) and various teachers, the Smileyometer would be suitable as scale in our study; the children learned what the different smileys of the Smileyometer mean and how to interpret them and they use different kinds of smileys already in class. Except from ‘headache’ and ‘tiredness’, it was decided to use no additional smileys that represent emotions as fear and sadness; this would make the number of different emotions too large for the children. On top of that, according to the autism expert these smileys could provoke negative emotions or behavior of the children.

To ask children which tasks they associate with the light settings, a set of activities was picked were they could choose from. Requirements for the activities we choose were that the activities are done at least once a week in all the groups and that they include as many as possible different school scenarios, such as: working together versus working alone, concentration tasks versus relaxing tasks, creative tasks versus concrete tasks, and talking versus being silent.

In order to ask the children in a fun and easy way about their emotion- and task- associations during the different light settings in the classroom, a special playful sticker assignment was designed for this purpose. The assignment was done individually by all children in one group at the same time, while the researcher changed the light settings about every three minutes. During every light setting the children had to indicate, by using different emotion- and task- stickers, which emotions and tasks they associated with the light.

For the assignment every child got a booklet with five pages. On the first page the child wrote his or her name and then there was one page for every light setting where the child could put the stickers. The pages were indicated with the numbers 1 to 4 and did not indicate the specific light setting belonging to that page (although the researcher knew the order of the light settings). Every page had a blue square with the title ‘feeling’ and a green square with the title ‘task’ (Figure 4.1). Two sets of stickers belong to every page; one set with emotions stickers with a blue border (Figure 4.2), and one set with task stickers with a green border (Figure 4.3). The stickers have pictograms that were taken from the pictogram data-base of the school. The lay-out and pictograms of the assignment were discussed with different teachers.

The Smileyometer scale consisted of five smiley stickers containing ‘annoying’, ‘somewhat annoying’, ‘normal’, ‘somewhat pleasant’, and ‘pleasant. ‘Tiredness’ and ‘headache’ were also expressed through smiley stickers. The task stickers consisted of ‘reading’, ‘listening’, ‘mathematics’, ‘work in silence’, ‘playing together’, ‘arts and crafts’, and ‘eating’ pictogram stickers. All stickers also had a written description, giving an extra explanation of the emotion or task for the children that could read.

Figure 4.1 Result of a child (without ASD) of group 5 in setting C and result of a child (with ASD) of group 5 in setting B.

Figure 4.2 Emotion stickers consisted of ‘annoying’, ‘somewhat annoying’, ‘normal’, ‘somewhat pleasant’, ‘pleasant’, and ‘tiredness’ and ‘headache’.

Figure 4.3 Task stickers consisted of ‘reading’, ‘listening’, ‘mathematics’, ‘work in silence’, ‘playing together’, ‘arts and crafts’, and ‘eating’.

4.1.5 Procedure

In consultation with the teachers a time and date was arranged for every group to do the assignment. An explanation of the assignment was sent to the teachers in advance so that the teachers could prepare themselves and to make sure that teachers across different groups give the same instructions (for the exact instructions see Appendix E). The teachers were asked to explain the assignment to the children instead of the researcher so that the children got instructions in the way they are used to and understand the assignment well.

The researcher came into the classroom and was introduced by the teacher. The teacher explained to the children that the light would be changed four times and that during every light setting the children had to indicate by using the stickers which emotion and which tasks fitted the best to the light setting. An important note to the children was that the assignment was about their own opinion and therefore their answer would be always right and they should make their task on their own. Children were allowed to use more than one emotion- or task-sticker for every light setting and they were allowed to write extra notes down to explain their choice or to indicate an emotion or task that was not present on the stickers.

The researcher gave every child in the group a booklet and stickers and subsequently set the first light (when the researcher entered the classroom the light was switched off). The teacher asked ‘What feeling fits the best with this light?’ and ‘What task fits the best with this light?’. The teacher and researcher walked around in the classroom to help the children when needed. When all children finished the assignment for the first light setting, the researcher set the next light setting. The procedure of selecting stickers was repeated for the second, third and fourth light setting. The order of the light settings was counter-balanced across the different groups (see for the exact lighting scheme Appendix F). At the end the assignment booklets were collected and the children were asked if they had anything to say about the light which they were not able to make clear using the stickers. When no one had anything left to say, the researcher left the classroom.

At the end of the assignment the teacher was asked to indicate on every booklet whether the child was diagnosed with ASD and was able to make the task in a meaningful way. Before the data left the Talentencampus, the names of the children were removed from the front page of the booklet.

4.1.6 Statistical analysis

First the results were coded in SPSS, data was tested for normality, and then analyses were performed on the Pleasantness (Smileyometer stickers), Headache, Tiredness, and task association. Thereafter the analysis was performed again, but now for children with ASD and children without ASD separately.

4.1.6.1 Pleasantness

The children used stickers of the Smileyometer scale to express their associated emotions with the different light settings. The five stickers with the scale from annoying to pleasant, were coded as a five point scale; 1 meant that the children selected the 'annoying' smiley, 2 meant that the children selected the 'somewhat annoying' smiley, 3 meant the 'normal' smiley, 4 the 'somewhat pleasant' smiley and 5 the 'pleasant' smiley. When two adjacent Smileyometer stickers were used in one light setting, an average was taken. When two contradicting Smileyometer stickers were selected in one light setting, that case was deleted from the sample.

When starting the analysis the data appeared to be not normally distributed. The non-normal distribution of the data could be caused by the few cases when the children chose two smileys stickers and an average was computed (see Figure 4.4). To overcome this problem scores were rounded, but the data was still not normally distributed, $D(183) = 0.87$, $p < .05$.

Another cause of the non-normal distribution could be the extreme positive and negative scores, many children (23.7%) chose 'pleasant', the most positive smiley (see Figure 4.4). The non-normal distribution can be caused by the idea that young children (below 9 years old) tend to give always extreme scores (Van der Sluis et al., 2012). But after removing the group with children younger than 9 years old from the data, the distribution was still significantly non- normal, $D(152) = 0.87$, $p < .05$, so the younger children were left in the data. Because the data did not meet the assumption of normality, for the analysis testing the relation between the light settings and the pleasantness, a non-parametric test was used. A related samples analysis (Friedman Anova) was performed, which is used when the same participants have been participated in two or more conditions and the parametric assumptions are not met.

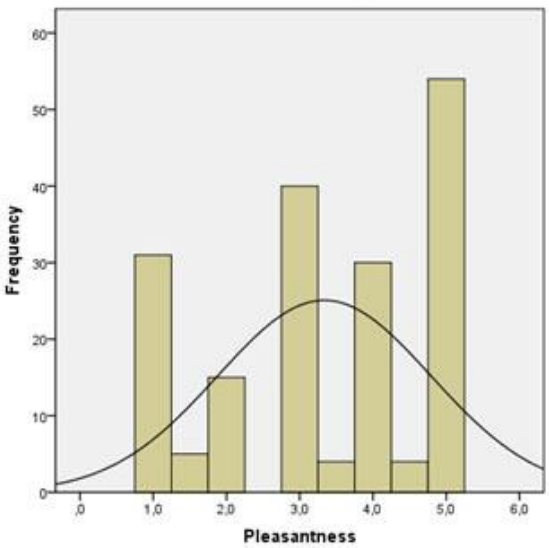

Figure 4.4 The distribution of Pleasantness (Smileyometer scale).

4.1.6.2 Headache and tiredness

For analyzing the relation between the light settings and the associated headache and tiredness of the children (by sticking the 'headache' or 'tiredness' sticker), Chi-Square tests were performed.

4.1.6.3 Task association

Next to the Smileyometer scale and the headache and tiredness stickers, the association of tasks with the different light settings was an important part of the assignment. One all-including analysis was difficult to perform because children could indicate more tasks per light setting. Therefore Chi-Square tests were performed to test the relation between the light settings and each task separately.
Underlying dimensions in the preference of tasks in certain light settings were explored with a Multidimensional Scaling. The goal of a Multidimensional Scaling is to transform judgments of preference (in our study the number of different associated tasks per light setting) into distances represented in a multidimensional space. The resulting map shows the relative positioning of all objects (Van Deun & Delbeke, 2000). Thus, a Multidimensional Scaling is not a statistical test but a way of presenting data.
The task association data was restructured in a way that the tasks and the four light settings were all separate variables, all with an own column. One row represented the results of one child in one light setting. A PROXSCAL (Proximity Scaling, the most suitable way of Multidimensional Scaling in this context) was performed in SPSS with the light settings and tasks all as variables in one analysis. Distances between the tasks and light settings were created by SPSS using 'Binary pattern difference' since this gave the best Stress value. This is an indication of how well the distances in the solution approximate the original distances.

4.1.6.4 Differences between children with and without ASD

In the individual emotion- and task- association assignment the teacher wrote down on the assignment if a child had autism, and therefore it was known which results come from children with autism and which results come from children without autism. Analyses that were done with the whole sample were performed again but with two different groups of data; the data of children with ASD and the data of children without ASD. The results of all analyses of both groups were compared with each other.
Before the pleasantness (Smileyometer stickers) of the groups was analyzed, they were checked for normality. Both groups of children with autism and without autism were not normally distributed; ASD, $D(117) = .87$, $p<.05$, and non-ASD, $D(70)=.84$, $p<.05$, and therefore a non-parametric related samples analysis (Friedman Anova) was performed to analyze the effect of light setting on the pleasantness.

4.2 Results of the whole population

In this section, we report on the results of the association assignment study, which investigated the children's associated emotions and tasks while exposed to the different light settings. The results are discussed in three parts; the effect of light setting on the Smileyometer (Pleasantness), the effect of light setting on reported headache and tiredness, and the relation between the light settings and the associated tasks.

4.2.1 Pleasantness

The number of ratings in the Pleasantness scale per light setting can be viewed in Table 4.2. Setting B, C and D were most rated with 'pleasant' (5), setting A was most rated with 'normal' (3). As can be seen in the column 'missing', quite some children did not rate a light setting; the probable cause of this will be discussed later.

Since the data did not meet the assumption of normality, a non-parametric test was used. A related samples analysis (Friedman Anova) was performed to explore the relation between light settings and pleasantness, and showed that the rated pleasantness was not significantly different between the four light settings, $\chi^2_F(3) = 1.71$, $p = .64$. This suggests that children did not rate a specific light setting significantly more pleasant than another light setting. Table 4.3 shows the mean per light setting; since the data is not normally distributed the median is also given.

Table 4.2 Number of ratings in the pleasantness scale per light setting

	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	Missing	Total
Setting A (4100 K, 300 lx)	5	0	4	0	18	0	8	0	9	13	57
Setting B (7300 K, 500 lx)	9	1	3	0	9	0	4	1	13	17	57
Setting C (5100 K, 900 lx)	8	2	4	0	10	3	4	2	17	7	57
Setting D (3500 K, 300 lx)	9	2	4	0	3	1	14	1	15	8	57
Total	31	5	15	0	40	4	30	4	54	45	

Table 4.3 Mean pleasantness per light setting. All light settings had a minimum pleasantness of 1 and a maximum of 5

	Mean pleasantness	Std. deviation	Median
Setting A (4100 K, 300 lx)	3.34	1.16	3.0
Setting B (7300 K, 500 lx)	3.10	1.57	3.0
Setting C (5100 K, 900 lx)	3.50	1.38	3.5
Setting D (3500 K, 300 lx)	3.42	1.33	4.0

4.2.2 Headache

In total, the children used the headache sticker in 20.2% (46 out of 228) of all cases. Results of a Chi-Square test revealed a significant effect of Light setting on Headache, $\chi^2(3) = 8.39$, $p < .05$, indicating that the associated headache was significant different between the four light settings. 39.1% of the total associated headaches was during exposure to the setting C (see Table 4.4).

Table 4.4 Number of associated headaches of 57 children with the four different light settings

Light setting	Associated headache		
	No	Yes	Total
Setting A (4100 K, 300 lx)	50	7 (15.2%)	57
Setting B (7300 K, 500 lx)	44	13 (28.3%)	57
Setting C (5100 K, 900 lx)	39	18 (39.1%)	57
Setting D (3500 K, 300 lx)	49	8 (17.4%)	57
Total	182	46 (100%)	228

4.2.3 Tiredness

Analyzing the associated tiredness with the light settings showed that the effect of the light settings on Tiredness was significant, $\chi^2(3) = 9.03$, $p<.05$, meaning that the associated tiredness of children was dependent on the light setting. Of the 228 cases, 43 times (18.6%) a tiredness sticker was used. In Table 4.5 can be seen that 37.2% of all reported tiredness was during exposure of setting D. Also a large percentage (32.6% of all reported tiredness) was reported during setting A.

Table 4.5 Number of associated tiredness of 57 children with the four different light settings

Light setting	**Associated tiredness**		
	No	Yes	Total
Setting A (4100 K, 300 lx)	43	14 (32.6%)	57
Setting B (7300 K, 500 lx)	52	5 (11.6%)	57
Setting C (5100 K, 900 lx)	49	8 (18.6%)	57
Setting D (3500 K, 300 lx)	41	16 (37.2%)	57
Total	185	43	228

4.2.4 Task association

When testing the relation between the light settings and each task separately, Chi-Square analyses showed a significant effect of light setting on each task ($p<.05$), except for ArtsCrafts ($p=.30$). This means that the frequency of using a specific task sticker was significantly different across the light settings, except from the arts and crafts activity. This can be confirmed when viewing Table 4.6; the frequency of associating a task, is in all tasks the highest in setting A, while in arts and crafts the frequencies are across the light settings quite the same. This suggests that children associated arts and crafts not with a specific light setting. Figure 4.5 shows the percentage of associated tasks per task for the four light settings. It can be noted that in general more children like to do a task in setting A than in the other settings. Arts and crafts is most frequently associated in setting B, while in the three other settings children mentioned eating most often, though the differences are quite small.

Table 4.6 Number associated tasks per light setting

	Reading		**Listening**		**Maths**		**WorkSilent**		**PlayTogether**		**ArtsCrafts**		**Eating**	
Setting A (4100 K, 300 lx)	23	*34%*	24	*44%*	18	*35%*	23	*37%*	23	*32%*	18	*29%*	26	*33%*
Setting B (7300 K, 500 lx)	14	*21%*	9	*16%*	8	*16%*	10	*16%*	13	*18%*	16	*26%*	12	*15%*
Setting C (5100 K, 900 lx)	12	*18%*	10	*18%*	15	*29%*	10	*16%*	20	*27%*	13	*21%*	22	*28%*
Setting D (3500 K, 300 lx)	19	*28%*	12	*22%*	10	*20%*	19	*31%*	17	*23%*	15	*24%*	20	*25%*
Total	68	*100%*	55	*100%*	51	*100%*	62	*100%*	73	*100%*	62	*100%*	80	*100%*

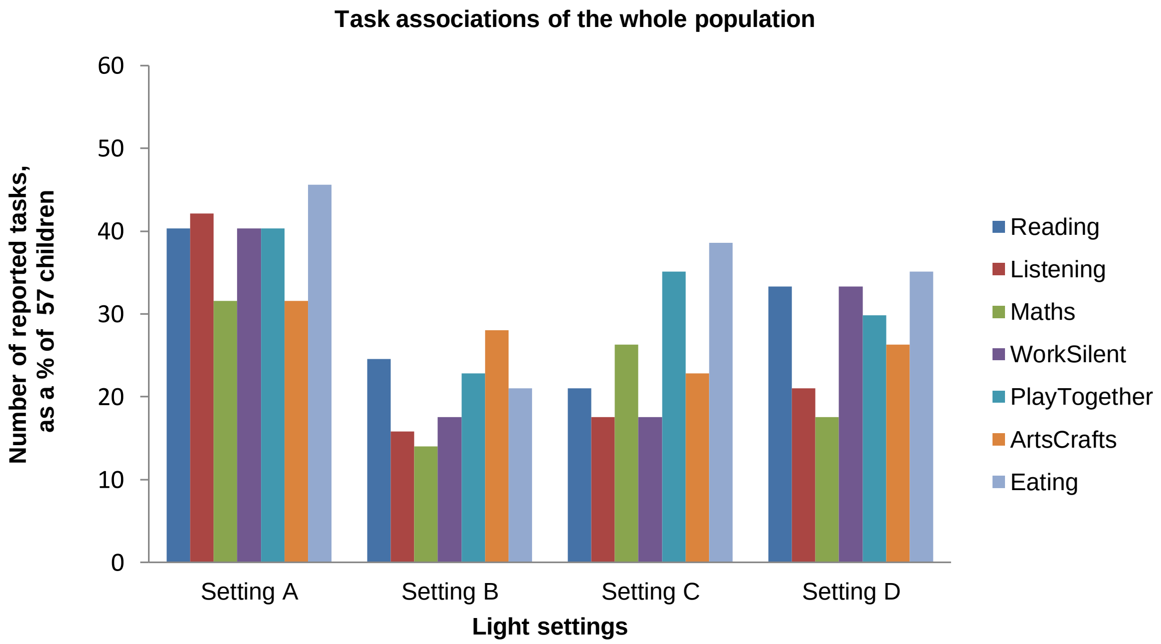

Figure 4.5 Associated tasks with each light setting as a percentage of 57 children per task per light setting

We performed a multidimensional scaling (PROXSCAL; for details see section 4.1.6.3) to explore underlying dimensions in the association of tasks with the different light settings. The Stress measure was .175, which is according to Kruskal (1964) a fair to poor goodness of fit (0 is an optimum fit). Figure 4.6 shows the perceptual map of the multidimensional scaling. The distances between variables represent the frequencies of the associated tasks.

Two underlying dimensions were found. Based on the placement of the light settings in the map, a dimension in light intensity on the x-axis and a dimension in color temperature can be approximately found on the y-axis; the more to the right in the graph means a higher light intensity and higher on the y-axis gives a higher color temperature. However, setting D does not correspond exactly in these dimensions. We tried to find other dimensions according to the placement of the tasks, but no clear dimensions were found. It was for instance thought that tasks where children have to concentrate, like Reading, Working silent and Listening, would be lying in one dimension, but Figure 4.6 does not confirm this.

Although the goodness of fit was not optimal, when comparing Figure 4.5 with Figure 4.6, the distances fit quite well with the frequencies. It can be seen in Figure 4.6 that all tasks are relatively far away from setting B, because there were fewer task associations with setting B than in the other settings, which is in line with the frequencies reported in Figure 4.5. For setting B, ArtsCrafts is the closest, which also corresponds with the highest bar in setting B of Figure 4.5. The finding of the Chi-Square tests that ArtsCrafts was the only non-significant result can also be confirmed in Figure 4.6; ArtsCrafts lies in the middle of the four light settings and thus the children did not associate arts and crafts more in one of the four light settings. Furthermore there are no clear stronger associations that show which tasks are most preferred per light setting because the tasks are all lying relatively close to each other.

Overall, we can state that all tasks are less strongly associated when exposed to setting B and that the tasks are divided across the other three light settings, where no task is really strongly associated with a specific light setting.

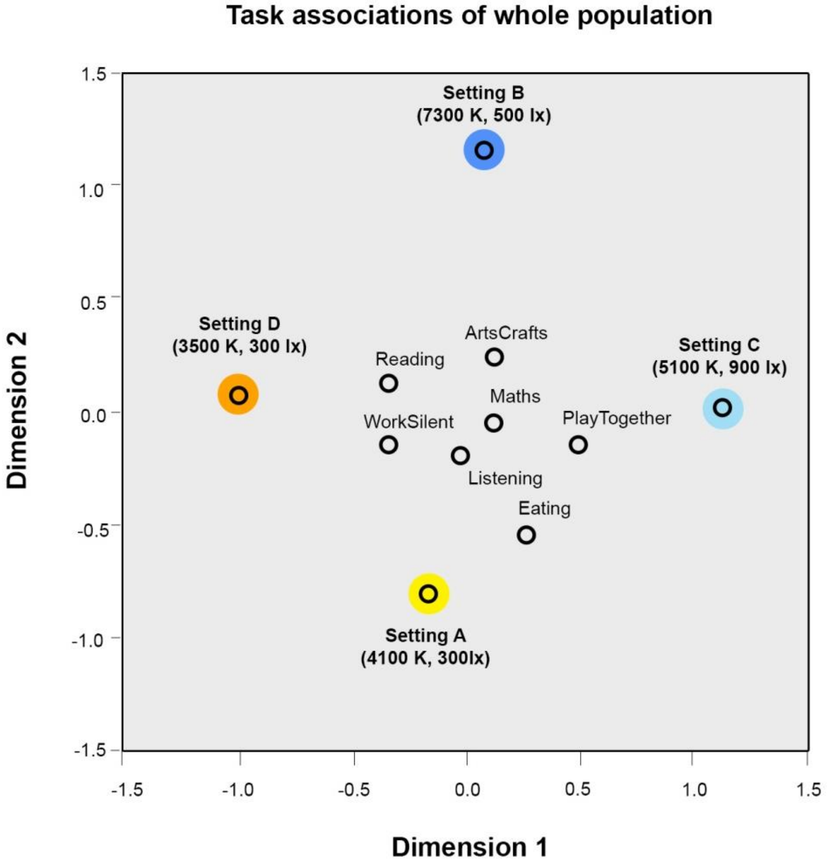

Figure 4.6. Multidimensional scaling of the task association assignment

4.3 Comparing results between children with and without autism

4.3.1 Pleasantness

For both the data with autistic children and the data with children without autism, a non-parametric related samples analysis (Friedman Anova) was performed to analyze the effect of light setting on the rated pleasantness (Smileyometer). For the ASD group, the test was not significant, $\chi^2_F(3) = 1.71$, $p > .05$, which means that children did not rate the four settings differently on pleasantness. Neither was the test significant for the non-ASD group, $\chi^2_F(3) = 4.41$, $p > .05$, indicating that there was no significant difference in rated pleasantness by the non-ASD children between the four light settings. Concluding, children with autism as well children without autism did not rate a specific light setting significantly more pleasant than the other light settings.

4.3.2 Headache

As we already did with the whole population, Chi-Square tests were performed to analyze the relationship between the light settings and Headache and Tiredness.
In the group of children with autism, in 31 of the 136 cases (22.8%) a headache sticker was used. The effect of light setting on Headache was found significant, $\chi^2(3) = 4.14$, $p<.05$, meaning that there is a significant difference in associated headache by children with ASD across the four light settings. In Table 4.7 can be seen that of all associated headache, 38.7% was during setting C.

Table 4.7 Number of associated headaches by children with ASD with the four different light settings

Light setting	**Number of associated headache by ASD**		
	No	Yes	Total
Setting A (4100 K, 300 lx)	28	6 (19.4%)	34
Setting B (7300 K, 500 lx)	27	7 (22.6%)	34
Setting C (5100 K, 900 lx)	22	12 (38.7%)	34
Setting D (3500 K, 300 lx)	28	6 (19.4%)	34
Total	105	31 (100%)	136

In the group of children without autism, in 15 out of 92 cases (16.3%) a headache sticker was used. The effect of the light setting on Headache was found significant too, $\chi^2(3) = 6.61$, $p<.01$, indicating that the associated headache by children without autism, was significant different between the light settings. In Table 4.8 can be seen that the most headaches were associated with exposure of setting B and C. Only one child associated a headache with setting A.

Table 4.8. Number of associated headaches by children without ASD with the four different light settings

Light setting	**Number of associated headache by non-ASD**		
	No	Yes	Total
Setting A (4100 K, 300 lx)	22	1 (6.7%)	23
Setting B (7300 K, 500 lx)	17	6 (40.0%)	23
Setting C (5100 K, 900 lx)	17	6 (40.0%)	23
Setting D (3500 K, 300 lx)	21	2 (13.3%)	23
Total	77	15 (100%)	92

For both the ASD group and the non-ASD group, children associated the most headaches with setting B and C, the settings with the highest color temperature and intensity. Children with ASD associated in total more headaches (22.8%) than children without ASD (16.3%), yet this was not significantly different, $\chi^2(1) = 1.44$, $p>.05$.

4.3.3 Tiredness

Besides Headache, Chi-Square tests were performed to investigate the relation between the light settings and Tiredness. In the group of children with autism, in 29 out of 136 cases (21.3%) a tiredness sticker was used. The effect of Light setting on Tiredness was significant, $\chi^2(3) = 5.04$, $p<.05$, which means that the associated tiredness by children with autism is significantly different between the four light settings. As can be seen in Table 4.9, most tiredness was associated with setting A and D, only 10.3% of the tiredness stickers were used in setting B.

Table 4.9. Number of associated tiredness by children with ASD with the four different light settings

Light setting	**Number of associated tiredness by ASD**		
	No	Yes	Total
Setting A (4100 K, 300 lx)	24	10 (34.5%)	34
Setting B (7300 K, 500 lx)	31	3 (10.3%)	34
Setting C (5100 K, 900 lx)	27	7 (24.1%)	34
Setting D (3500 K, 300 lx)	25	9 (31.0%)	34
Total	107	29 (100%)	136

A significant effect of Light setting on Tiredness was found too in the group of children without autism, $\chi^2(3) = 7.08$, $p<.01$. This indicates that there is a significant difference in associated tiredness by children without autism between the different light settings. In 14 out of 92 cases (15.2%) children associated a light setting with tiredness. Table 4.10 shows that 50% of all associated tiredness was with setting D. Only one child associated tiredness with setting C.

Table 4.10. Number of associated tiredness by children without ASD with the four different light settings

Light setting	**Number of associated tiredness by non-ASD**		
	No	Yes	Total
Setting A (4100 K, 300 lx)	19	4 (28.6%)	23
Setting B (7300 K, 500 lx)	21	2 (14.3%)	23
Setting C (5100 K, 900 lx)	22	1 (7.1%)	23
Setting D (3500 K, 300 lx)	16	7 (50%)	23
Total	78	14 (100%)	92

In the ASD group as well as the non-ASD group, tiredness was most associated with setting A and D, the light settings with the lowest color temperature and intensity. Children with autism more often used a tiredness sticker (21.3%) than children without autism (15.2%), however this was not significantly different, $\chi^2(1) = 1.34$, $p>.05$.

When summarizing the effect of the light settings on Headache and Tiredness in the ASD and non-ASD group, we can say that only small differences between the two groups can be observed. Headache is in both the ASD and the non-ASD group associated the most with the settings with a higher color temperature and illuminance (setting B: 7300 K, 500 lx; setting C: 5100 K, 900 lx). Tiredness is most associated in both groups with settings A and D, which have relatively low color temperatures and illuminance (setting A: 4100 K, 300 lx; setting D: 3500 K, 300 lx).
Children with autism use in general more headache and tiredness stickers than children without autism do, but these differences between the groups were not significantly different. In both groups, children used more often headache than tiredness stickers, however this was also not significantly different (ASD: $\chi^2(1) = .86$, $p>.05$. non-ASD: $\chi^2(1) = .04$, $p>.05$.)

4.3.4 Task association

For both the ASD and the non-ASD group we performed a multidimensional scaling (PROXCAL) to explore underlying dimensions in the association of tasks with the four light settings (see Figure 4.7 and Figure 4.8). The goodness of fit Stress measure for the ASD group was fair to poor (0.15), and for the non-ASD group poor (0.25).

When comparing Figure 4.7 and Figure 4.8 it can be observed that the dimensions are rotated, which indicates that the most variance was find in different dimensions. As in the multidimensional scaling of the whole population, dimensions can only be found in color temperature (x-axis) and light intensity (y-axis), where the color temperature of setting D does not correspond exactly on the y-axis.

In the map of children with ASD (Figure 4.7) the tasks are positioned relatively far away from setting B and the rest of the tasks are spread between setting A, C and D. In the map of the children without autism (Figure 4.8) this pattern is not the same. Here tasks appear to be a bit further away from setting D, and Eating and PlayTogether seem to be positioned closer to Setting A and C respectively. Arts and crafts and Listening are positioned in the middle of the four light settings, suggesting that children did not associate Arts and crafts with one light setting more than another.

From figure 4.9 and 4.10 it can be observed that children with ASD used more task stickers than children without ASD and that both groups associated the least tasks with setting B.

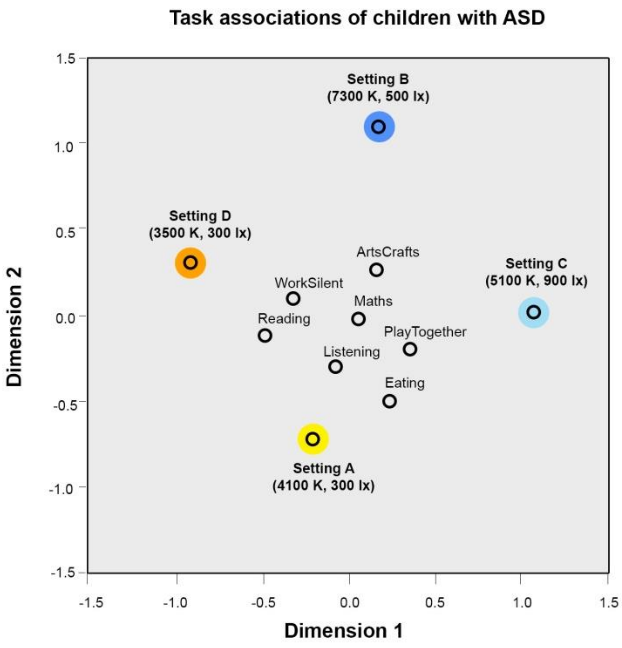

Figure 4.7 Multidimensional scaling of the task association assignment of children with ASD

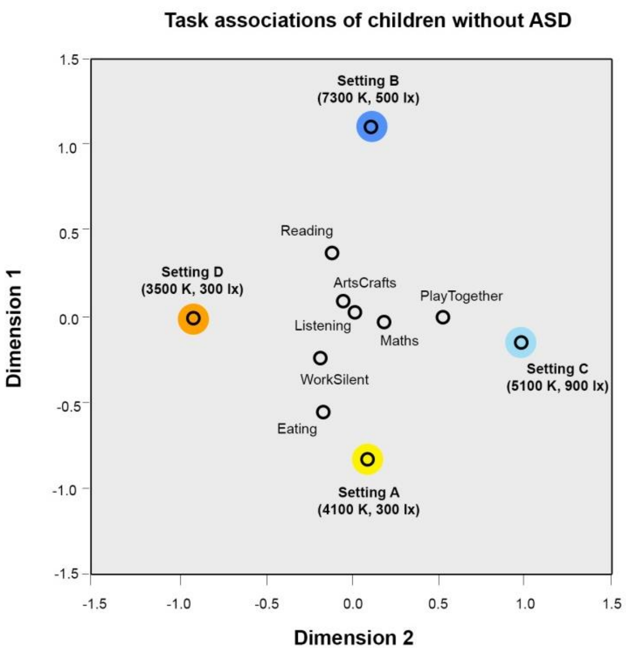

Figure 4.8 Multidimensional scaling of the task association assignment of children without ASD

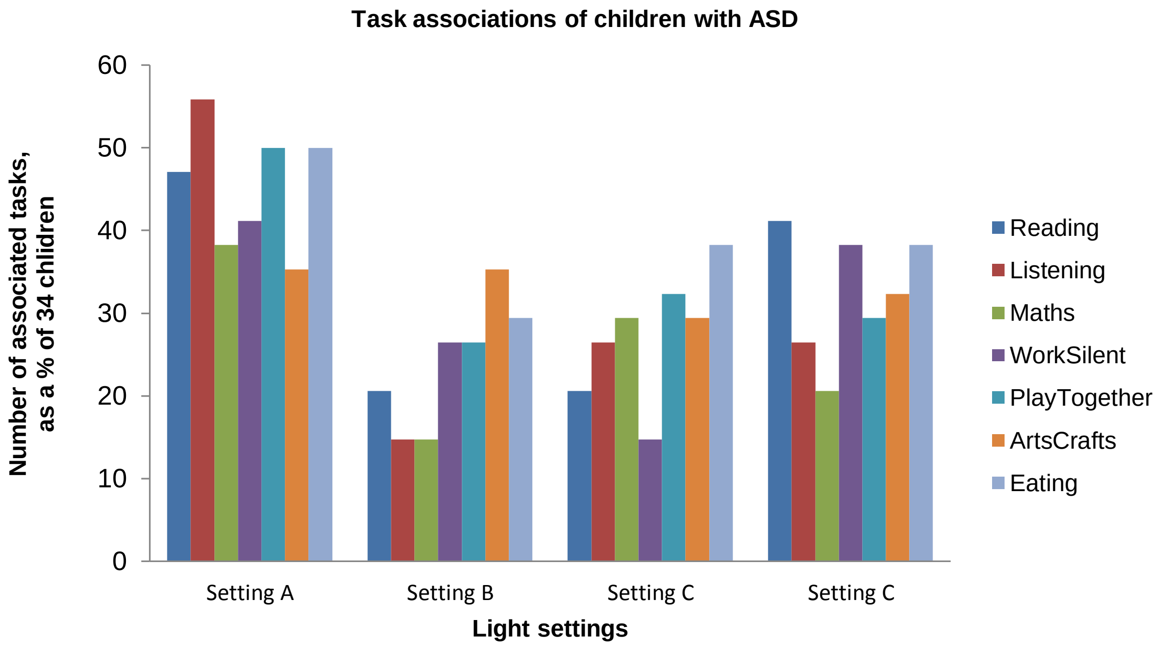

Figure 4.9 Associated tasks with each light setting as a percentage of 34 children with ASD per task per light setting

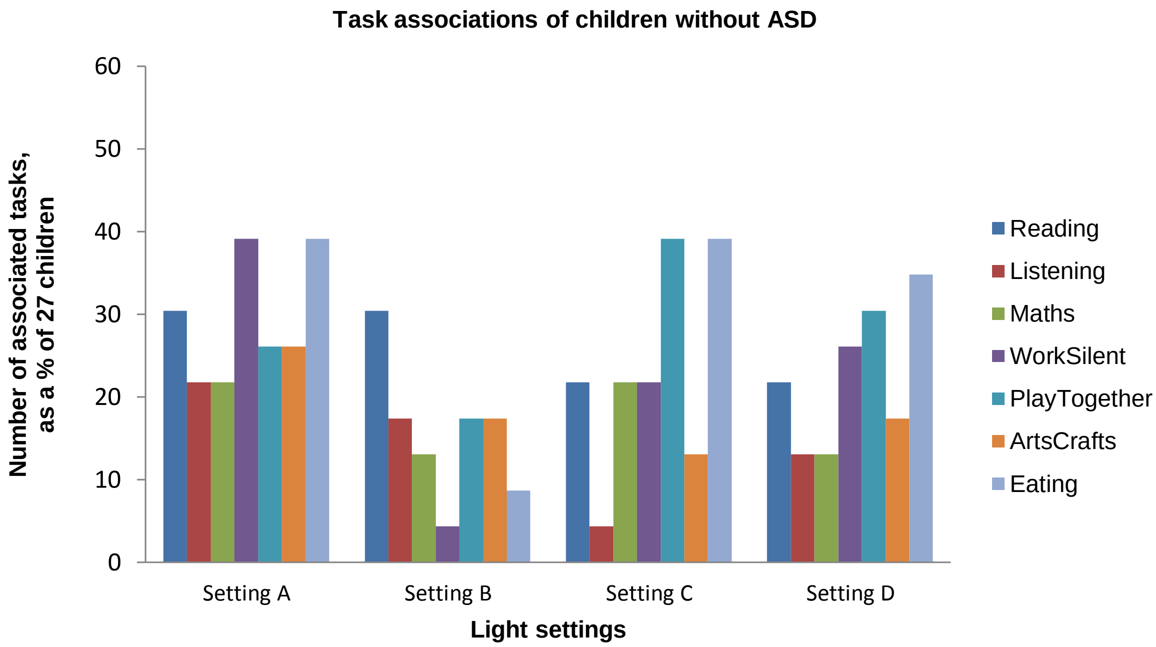

Figure 4.10 Associated tasks with each light setting as a percentage of 27 children without ASD per task per light setting

4.4 Discussion

The goal of the association assignment study was to investigate the rated pleasantness across the different light settings and the associated tasks by the children with the four light settings. In this section, the results (of pleasantness, headache and tiredness, and task association) and the methodological limitations will be discussed.

4.4.1 Pleasantness

The effect of the light setting on the pleasantness was not found significant, suggesting that children did not rate a specific light setting more pleasant than the other light settings. From the unstructured interviews with the children after the assignment, it also appeared that children had different, sometimes contradicting opinions about the lights:
Children during setting C: 'I like this light the most'; 'I get a headache of this light'
Children during setting B: 'I prefer less bright light'; 'During this light I fall asleep'; 'I like this blue light the most'.

In previous studies investigating the effects of light, light settings were never rated with the Smileyometer. However, the pleasantness measurements of our study might show similarities with the 5-point rating scale that Barkmann et al. (2012) used in their study. Children had to rate all the seven classroom light settings from (0) very poor to (5) very good. Although the average ratings per light settings were reported and looked quite similar, Barkmann et al. (2012) did not report whether the ratings across the light settings were significantly different or not. It would be interesting to compare this study where the general population was used with our study where special education children were used.

When comparing the results of the children with autism and the children without autism, the light setting had no significant effect on Pleasantness, both for the ASD group as the non-ASD group. This suggests that autistic children as well as non-autistic children did not prefer one light setting more than another. Since the possible hyper- or hyposensitivity of autistic children for light, autistic children could react more extreme on light compared to non-autistic children, which could influence their preferences. Yet our results do not show this thought.

4.4.2 Headache and tiredness

A significant effect was found of the light setting on the use of headache and tiredness stickers of all children, suggesting that the children associated headaches with setting B and C (setting B: 7300 K, 500 lx; setting C: 5100 K, 900 lx) and tiredness with setting A and D (setting A: 4100 K, 300 lx; setting D: 3500 K, 300 lx). Differences of associated headache and tiredness with the light settings between the ASD and non-ASD group were only subtle. In total autistic children associated more headaches and tiredness than the non-autistic children, but this was not significant.

Children associated most headaches in the settings with the highest light intensity. In some previous research, the influence of high intensity light on headaches is discussed. Winterbottom and Wilkins (2009) concluded that glare produced by too bright fluorescent lighting can cause discomfort and headaches. In the classroom lighting study of Barkmann et al. (2011), 'one male student and one female student in the secondary school class complained of headaches caused by the Concentrate light' (5800 K, 1060 lx). However, since our study measured *associated* headaches and not current experienced headaches it cannot be concluded that light setting B and C really induced headaches.

Tiredness was most associated in the setting with the lowest intensity (illuminance). A lot of previous researchers suggest that a high illuminance can reduce subjective tiredness (Badia, Myers, Boecker, & Culpepper, 1991; Rüger, Gordijn, Beersma, de Vries, & Daan, 2006). However, no studies tested in the opposite direction whether low illuminance also really increases tiredness.

Tiredness was associated in the ASD group mostly with setting A (34%) and setting D (31%), the light settings with a warm color temperature. Long (2010) states that warm light is the best for children with autism since it creates a calm atmosphere, however our study suggest that children associate negative feelings as tiredness in the warm light settings. Though, again, we cannot conclude that the warm light settings also really induced tiredness since our results were based on associations and not especially current experiences. On top of that might the tiredness sticker not be interpreted by all children as a negative feeling.

4.4.3 Task association

From the map that was created with the multidimensional scaling, it was observed for the whole population that most tasks were positioned quite in the middle of the map, which suggests that no task is really strong associated with a specific light setting. Underlying dimensions were found in light intensity (on the x-axis) and color temperature (on the y-axis), based on the placement of the light settings in the graph, yet setting D did not correspond exactly. Other dimensions according to the placement of the tasks were not found. No clear differences between the ASD and non-ASD group were observed.

The map from the multidimensional scaling might show that all tasks are less associated with setting B. Possible explanation for the less task associations with setting B could be because other tasks than the tasks displayed on the stickers were associated with setting B, though the tasks on the stickers were specifically chosen by the researchers because they were often done in the classroom and expected as familiar by the children. More probable is that the children did not like setting B and therefore do not want to do any task in that light setting and so did not associated any task in that light setting. A teacher also confirms this: 'It could be, that when the children are exposed to the light they like the most, they chose the task they like the most, instead of the task that fits the best with light'. However, the result from the effect of the light settings on pleasantness does not confirm that the children do not prefer the setting B.

4.4.5 Method evaluation

The data of Pleasantness (Smileyometer stickers) was, in the whole population, as well as in the ASD group as in the non-ASD group, not normally distributed. In the statistical analysis (4.1.6.1) possible causes such as rare half scale points and the influence of the age of the children were already discussed.

Although the data of the children which the teachers rated as not meaningful were removed from the sample, the non-normal distribution and extreme scores might show that it is still too difficult for the children to express their emotion by choosing one sticker out of a scale of five. This could also be noted by the 13 cases where children chose two Smileyometer stickers next to each other which caused scores like 4.5. Even though teachers thought the children would be able to use the Smileyometer scale in a meaningful way, the fact that children with ASD have difficulties with interpreting emotions (Begeer et al., 2006) might have caused difficulties for the children with autism to use the smiley stickers.

More research should be done on other scales and ways of asking emotions to find the best method for children in special education. We think interviewing the children should be considered, because the few unstructured discussions with the children after the assignment already suggested different reasons for their answers:

Researcher: ‘Why do you prefer the setting B the most?

‘Blue is my favorite color’ (Child of group 8)

‘Because I have in my room at home also this light’ (Other child of group 8)

Because the results of the associated headache and tiredness confirmed our expectations, it can be suggested that all the children had no much difficulty with interpreting and using the headache and tiredness sticker. An important note is that for both headache and tiredness it should be taken into account that the children were asked about their association with the lights and not especially their feeling at that moment, specifically because the children were only exposed to the light for a few minutes. Next to that are the numbers of using the headache and tiredness sticker quite high; in 20.2% of all cases, children used a headache sticker and in 18.6% of all cases, children used a tiredness sticker. The existence of the headache and tiredness stickers might have provoked the children to use one of the stickers and think they associate a headache or tiredness.

Considering the results of the multidimensional scaling it is difficult to say something about the usefulness and reliability of the task stickers. The fact that no clear dimensions on task characteristics were found (for example all concentration tasks lie in one dimension), could be caused by different interpretations of the stickers. One child might see Arts and crafts as easy and fun, while another child can interpret it as a difficult concentration task. Furthermore, although the sample size of all groups were big enough to find dimensions (higher than N=15; Rodgers, 1991), the poor Stress measures (All: .175; ASD: .15; Non-ASD: .25; Kruskal, 1964) can be a cause for the absence of clear dimensions.

In some groups, the assignment instruction for the children went slightly different than planned. Although teachers received beforehand an e-mail with instructions, it can be expected that the instructions went in all groups a bit different because teachers have their own way of teaching. However, when looking back, some parts of the instruction that went different across the groups possibly influenced the results.

At first teachers were asked to instruct the children with the question ‘Which feeling fits with this light? and ‘Which task fits the best with this light?’. However, often the teachers asked ‘How do you feel now with this light?’ and ‘What do you like to do most with this light?’. These are only small differences of formulating a question, but the meaning can be quite different. ‘What do you like most with this light?’ can cause children using more stickers of their favorite task in general, instead of sticking the sticker with the task that fits best with the specific light.

Another part of the instruction that went different across the groups was the amount of stickers the children were allowed to use per light setting. The researcher's instruction was that children were allowed to use as many stickers as they wanted, for instance to indicate that the light was annoying and also associated with a headache, and that both doing mathematics and reading fitted with the light. Yet, because 'using as many stickers as you want' was a too much freedom for some children, teachers made the rule that only one emotion sticker and one task sticker was allowed per light setting. This caused quite some missing data in the pleasantness scale, as children already used a headache or tiredness sticker and were not allowed to also use a pleasantness sticker.
On top of that, some children, especially the children with autism who had a high need for structure and knowing what is happening, were confused that the order of the light settings for the association task was not the order of the light setting buttons on the panel. It was annoying for them that they did not know which light setting would be on when: 'I want to know which light this is; how can I otherwise know what I feel?' (child with ASD in group 7).
Last, teachers were asked to do the instruction themselves after the researcher entered the classroom, however, in two cases the teacher asked the researcher to do the instruction.

In summary, the effect of light was not significant on the rated pleasantness of the whole population, neither in the ASD group or non-ASD group separately. This suggests that there is no difference between the preference of light by children with or without autism. Because of a non-normal distribution and sometimes inconsistent answers, the Smileyometer might not be the best way to all children in special education to ask about their emotions. The result that headaches are mostly associated with settings with the high color temperature and intensity, and that tiredness is mostly associated with the low color temperature and intensity settings, confirm our expectations. It should be noted that our results are based on associations and not especially current experiences.
Most tasks were positioned in the middle of the multidimensional scaling map, suggesting that no task is really strong associated with a specific light setting. Tasks were less associated with setting B; children maybe did not like this setting, although this was not confirmed by the results of the pleasantness scale. Dimensions were found in the intensity and color temperature of the light settings, but no dimensions were found in task characteristics. Furthermore no clear differences in task associations between the ASD and non-ASD group was found.
Although no clear effects of light were found, the small unstructured interviews and the apparent headache and tiredness results showed that children have a clear own opinion about the light.

5. General Discussion

5.1 Discussion

In this research we tried to answer the question:
What is the effect of different classroom light settings on the behavior and emotions of children with Autism Spectrum Disorders?

We explored the effect of four classroom light settings on the behavior of special education children through an observation study where children in their classroom were observed by teachers during two weeks while they were exposed to two different light settings each day. Children's rated pleasantness and associated tasks with the light settings were measured with a playful assignment while they were shortly exposed to the four different light settings.
Results showed no significant effects of different light settings on the classroom atmosphere and associated emotions and tasks of children in special education. We found significant effects of light setting on associated headaches and tiredness. Headaches were most associated in the light settings with a high intensity and color temperature (setting B, 7300 K, 500 lx; and setting C, 5100 K, 900 lx), tiredness was most associated in the light settings with a low intensity and color temperature (setting A, 4100 K, 300 lx; and setting D, 3500 K, 300 lx). No clear pattern of associated tasks with specific light settings could be observed. Children with Autism Spectrum Disorders (ASD) did not show clearly different behavior or emotions compared to the other children in special education.

5.1.1 Interpretation of results

The two studies of our research investigated the effect of classroom light settings on the children from different perspectives: teachers observed the behavior of children and children gave their own opinion about the light. The observations of the teachers and the opinion of the children both did not show a clear preference for one of the four light settings; the classroom atmosphere was not different across the light settings and the children did not rat a specific light setting as more pleasant.
The fact that the least tasks were associated by the children with setting B might indicate that the children did not prefer that setting; however, this was not confirmed by the atmosphere or pleasantness measurements. The associated headaches with setting B and C and the associated tiredness with setting A and D maybe suggests that all light settings were not preferred; yet there might be a discrepancy between associating the headaches and tiredness and really experiencing these. The only few reported complains of the children about the light in the observation study might also indicate that the negative opinions about the light settings indicated through the headache and tiredness associations are less extreme than they suggested. Thus, our research cannot conclude a clear preference for a light setting.

Previous research showed effects of light on for instance the performance of children such as reading speed and communication, but measurements on children's behavior, their emotions or opinions are mostly lacking. Classroom atmosphere and the opinion of children about the different light settings are measured in one classroom lighting, the study of Barkmann et al. (2012). In their study the effect of light setting is not found to be significant on classroom atmosphere and the children's light ratings appear to be similar across light settings (not statistically tested), which confirms our results.

However, the way of measuring is limited compared to our study where classroom atmosphere was measured multiple times and where a method to ask children's opinion was specifically designed for this purpose.

The preference for a specific light setting might be an indication for the behavior or functioning of people. Research with adults showed that well-being and task performance can be influenced via the preference of a light setting (Veitch et al., 2008). Therefore, the children's pleasantness ratings of the association study might predict their behavior in the observation study. However, since both the results from the pleasantness rating and the behavior was not significantly affected by the light setting, it is difficult to conclude whether the light preference influenced the behavior, and a psychological pathway was involved here.

The results of the task association did not conclude that specific tasks are associated with specific light settings. The different interpretations of the pictograms by the children can be a cause of this. However, it can also be the case that children just do not associate a task with a specific light setting since before the experiments started the light settings were not used yet in a systemized way.

The results discussed above were results of all the children that participated in the studies since differences between the ASD and non-ASD children separately were only small. Autistic children can be hyper- or hyposensitive for light and are soon distracted by environmental cues, which causes them experiences sooner discomfort of the light. From this it might be expected that children with autism react more extreme on light compared to children without autism. However, our results do not provide evidence for these considerations.

Although no clear differences were found between light settings on children with and without autism, our results suggest that children have often a clear opinion about the light and different preferences for light settings. The small unstructured interviews after the association assignment showed different reasons for choosing different light settings. Additionally, the associated headaches and tiredness with the light settings also indicate that children have an opinion about the light settings.

5.1.2 Method evaluation

The design and methods used in both studies of this research are unique compared to other studies that investigated effects of classroom lighting on children. It investigated classroom behavior intensively during two weeks and involved the children's opinion. Data was gathered from two viewpoints: the teachers' observation and the children's experience. The observation scheme in the first study and the association assignment were especially designed for this purpose.

Limitations of the research should be taken into account when validating the results.
In both studies teachers and sometimes also children were not blind for the light settings. In the first instance the teachers were in the observation study not told to which light setting the children were exposed, but soon the problem arose that after shutting off the light while for instance watching television, the teachers did not know which light setting to put on again. Therefore, after the first day of the experiment, the number of the light setting was written down on the observation schemes by the researcher. Besides that, although the light panel was taped in both studies, the teachers and children

still often noticed which light setting was on; especially the blue-looking light (setting B) and the yellow-looking light (setting D) were often noticed. Potential expectancy biases are, however, unlikely as the teacher reported no clear differences in atmosphere between the light settings.
Furthermore, it should be added that groups did use different light settings (setting A or D) as standard setting before the studies at the Talentencampus started. This could cause that children are more used to a specific light setting and this might influence their behavior and emotions.

Besides that, as described in the study-setting, the sizes and window designs of all classrooms were different. The measurements were done in spring, seven of the eight days had primarily overcast sky (where 4 days had a lot of rain), 1 day was sunny and the average temperature was 12°C. The different size, window design and the weather cause different daylight contributions to the classrooms. In addition, the flexible light system dims the artificial lights automatically if the classroom has sufficient light from outside. The teacher of group 7 confirmed this: 'If there is a lot of sunlight, you do not really notice a lot of the artificial light in the classroom'. Because of the daylight contribution, the intensity of the four light settings was probably not the same across the day and across the groups. This situation could also cause smaller differences between the four light conditions.

In the observation study, as discussed in section 3.4.2, teachers mentioned a lot of external factors such as change of weather and schedule that influence the behavior of the children. The question is whether, next to the possible influences of the external factors, the light setting still had an effect on the behavior and atmosphere in the classroom. The results of our observation study suggest the light setting did not have an effect. However, it cannot be just concluded that the external factors caused the fact that no significant effect of light setting on behavior and atmosphere was found. Possibly a combination of external factors and the light setting cause the behavior and atmosphere in the classroom.

To overcome the problem of daylight contribution and some external factors, a laboratory experiment with a more controlled setting might an option. However, it would also lack all benefits of a field study like the natural daily environment, which is especially for children with ASD important, since they have difficulties to adapt to new environments (Autism Research Institute, 2013).

Another possible limitation of our research was the reliability of the pleasantness scale. As already discussed in section 4.4.5, it should be considered whether all children were able to use the Smileyometer scale since the data was not normally distributed and some inconsistent answers were given. Our method of using an association assignment was a good start, but more guidance and interviewing to investigate the reasoning of the children will probably improve the validity of the results.

Concluding the evaluation of the methods; in both studies teachers and children were not blind for the light settings and daylight contribution in the different classrooms maybe made the differences between light settings smaller. The observation scheme in the first study showed a good reliability, the association assignment in the second study gave some useful insights into children's opinion, but should be developed further. The methods were unique since the measurement scheme and assignment were especially designed for this purpose, and the experience and opinion of the children themselves were involved.

5.1.3 Practical implications

Since the research revealed no significant effects of different light settings on the classroom behavior and atmosphere and children's associated emotions, no recommendations of using a specific light setting can be given. However, results of the small unstructured interviews and the apparent headache and tiredness associations did show that the children have a clear opinion about the light.

Some light settings were associated with negative feelings. Headache was associated with the settings with the highest color temperature and intensity (setting B and C) and tiredness was associated most with the settings with the lowest color temperature and intensity (setting A and D). However, since results were based on associations and possibly not current experiences, and only a few children or teachers had negative remarks about the light, we expect the light settings will not obstruct the functioning of the children.

With this in mind, teachers of the Talentencampus Venlo can start experimenting with the different light settings of the flexible light system in their classroom. Teachers can try using different light settings for different tasks, as the autism expert from the school suggested that different light settings might bring more structure during class (A. van Gastel, personal communication, April 24th, 2013). However, as Long (2010), Vogel (2008), Winterbottom and Wilkins (2009) concluded, children (with and without autism) often have different needs and therefore the teachers should by all means always use the light settings with care.

Our general advice of experimenting with the light settings in all groups, so also the groups with a high percentage of autistic children, deviates from the suggestions for classroom lighting for children with autism of Long (2010). She advises a light with low color temperature and intensity; yet her recommendations are based on a literature study and only little empirical evidence, while our study investigated both behavior and emotions in a real-life situation. More research should be done in future to add more insights to the field of classroom light settings on autistic children and to elaborate on our explorative study.

For future research, several aspects could be taken into account. First, a more controlled setting, preferably with the same classroom lay-out across groups and controlling for daylight (for instance by using blinds or performing the study in winter) would be beneficial. Our method of using a sticker association assignment was a good start, but more guidance and interviewing to investigate the reasoning of the children will probably improve the validity of the results. Next to that, it would be interesting to test long term effects and perhaps also investigate school performance of children instead of merely exploring behavior and emotions. Moreover, no measurements were done in this research with the general children population because the classrooms in the normal education of the Talentencampus Venlo did not have the flexible light system installed. It would therefore be interesting to compare effects of light on children with autism in special education groups with normal education groups.

5.2 Conclusion

This explorative research showed no clear effects of different light settings on the classroom atmosphere, subjective pleasantness and associated school activities of children in special education. Children's associations of headaches and pleasantness with a specific light setting were found significant. Headaches were associated with light settings with a high color temperature and intensity (setting B, 7300 K, 500 lx; and setting C, 5100 K, 900 lx) and tiredness was associated with light settings with a low color temperature and intensity (setting A, 4100 K, 300 lx; and setting D, 3500 K, 300 lx). Children with Autism Spectrum Disorders did not clearly show different behavior or emotions compared to the other children in special education.

Although the results suggests that children do not have an explicit preference for a specific light setting, the small unstructured interviews and the apparent results of associated headache and pleasantness indicate that the children have a clear opinion about the light. Considering the only few negative remarks that were given about the light and the fact that the effects of the light settings on headache and tiredness were based on associations and not current experiences, we expect the light settings will not obstruct the functioning of the children. Therefore we advise the teachers to start experimenting with the light settings in their own classroom.

This research built upon the knowledge about light effects on human functioning, classroom light effects, and the knowledge about the potential role of light exposure on the behavior and perception of children with Autism Spectrum Disorders. Since this was the first explorative study of classroom light effects on children's behavior and emotions in special education, more research is needed in future.

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Appendix

Appendix A – Pictures of the classrooms

Classroom 1

Classroom 2

Classroom 3

Classroom 4

Classroom 5

Classroom 6


Classroom 7


Classroom 8


Classroom 9

Appendix B – Light settings scheme

Group

1

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting C	setting B	setting D	setting A	setting D	setting B	setting C	setting A
Afternoon	setting A		setting C		setting A	setting D		setting B

2

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting C	setting A	setting D	setting C	setting B	setting B	setting D	setting A
Afternoon	setting D		setting B		setting C	setting A		setting C

3

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting B	setting D	setting A	setting B	setting C	setting C	setting A	setting D
Afternoon	setting A		setting C		setting B	setting D		setting B

4

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting D	setting C	setting B	setting D	setting A	setting A	setting B	setting C
Afternoon	setting B		setting A		setting D	setting C		setting D

5

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting A	setting B	setting C	setting A	setting D	setting D	setting C	setting B
Afternoon	setting C		setting D		setting A	setting B		setting A

6

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting B	setting C	setting A	setting D	setting A	setting C	setting B	setting D
Afternoon	setting D		setting B		setting D	setting A		setting C

7

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting C	setting A	setting D	setting C	setting B	setting B	setting D	setting A
Afternoon	setting D		setting B		setting C	setting A		setting C

8

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting A	setting D	setting C	setting B	setting C	setting D	setting A	setting B
Afternoon	setting B		setting A		setting B	setting C		setting D

9

	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Morning	setting D	setting A	setting B	setting C	setting B	setting A	setting D	setting C
Afternoon	setting C		setting D		setting C	setting B		setting A

Appendix C – Elements and specifications of the flexible light system

Elements of the SchoolVision System. A: the SchoolVision light. B: the light sensor. C: the control panel. Reprinted from Koninklijke Philips Electronics N. V. (2010). Retrieved August 22, 2013, from http://www.lighting.philips.com/pwc_li/gb_en/connect/tools_literature/FINAL_Schools%20Segment %20Brochure_Int%20version%20june%202010.pdf

Type	**TCS477 (surface-mounted, light surface, Dynamic Lighting)**
Light source Fluorescent:	3 x MASTER TL5 / G5 / 49 W
Lamp color combination	827/452
Color temperature	2x 17,000 K; 1x 2700 K
Ballast	Electronic, 220 - 240 V / 50 - 60 Hz: - High Frequency Regulator, DALI (HFD)

Specifications of the SchoolVision system. Adapted from *SchoolVision – the lighting solution that enhances children's learning* (p. 2). Retrieved August 22, 2013, from http://download.p4c.philips.com/l4bt/3/334089/schoolvision_tcs477_surface_moun_334089_ffs_aen.pdf

Appendix D - Observation scheme - morning

(translated from Dutch)

Date
Group

Fill this observation scheme out at the end of the morning.
The questions are about a *general* view of the class *compared with an average morning.*
You can indicate at the end of this paper the exceptions of individuals on the general behavior or atmosphere in the group. Don't think too long about filling out this observation scheme.

The children in the classroom were, compared to an average morning:

o more movable	o a bit more moveable	o moved as on an ordinary morning	o were sitting a bit stiller	o were sitting stiller

The children in the classroom were, compared to an average morning:

o more social to each other	o a bit more social to each other	o social as on an ordinary morning	o a bit less social to each other	o less social to each other

The children in the classroom were, compared to an average morning, during individual tasks:

o better concentrated	o a bit better concentrated	o concentrated as on an ordinary morning	o a bit less concentrated	o less concentrated

The children in the classroom listened, compared to an average morning, during instructions:

o better	o a bit better	o as on an ordinary morning	o a bit worse	o worse

The atmosphere in the class was, compared to an average morning:

o quiter	o a bit quiter	o as on an ordinary morning	o a bit more restless	o more restless

The atmosphere in the class was, compared to an average morning:

o better	o a bit better	o as on an ordinary morning	o a bit worse	o worse

How many children showed these behaviors?

... children showed exceptional externalized behavior, namely:

... children showed exceptional internalized behavior, namely:

... children complained about the light, namely:

... gave positive remarks about the light, namely:

Where there factors today that made the day different than normal? What where these factors? (for instance the weather, events, visitors)

Other remarks:

Appendix E – Teacher instructions for Emotion- and Association Task

(translated from Dutch)

Dear teacher,

Last week I made an appointment with you to do a task in the classroom with the children for my light research. Below you will find an explanation of the task.

The task takes about 20 minutes. The goal of the task is that the child indicates during every light setting what feeling and task fits the best to the light. To keep it as clear as possible for the children, the teacher will explain the task. I am in the classroom to change the light, help the children and explain things if they are still unclear.

The teacher introduces Josien and explains the task to the children:
'Josien is from the university in Eindhoven and investigates the light in the classroom. She wants to know what you feel and think about the light in the classroom and therefore we will now do a fun small task. The teacher and Josien will help you if needed.'

'You all get one booklet. One page is meant for one sort of light. Josien changes the light four times. You have to stick stickers on the page about which feeling and which task you think fits the best with the light. Stick the green stickers in the green box and the blue stickers in the blue box.'

'The task is about what you think, so every answer is correct. Therefore you should make the task alone and not together with your classmates.'

Josien distributes the booklets and gives everyone a blue and green sticker strip.
The children write their name on the front page.
When needed, the teacher explains the various pictograms on the stickers so everyone knows the meaning of the stickers.

Josien sets light 1.
The children turn the front page and see the page with number 1.
Which feeling fits with this light? Stick the blue stickers that fit with this light in the blue box. And **which task fits the best with this light?** Stick the green stickers in the green box.

If all children are finished, Josien sets light 2 and gives to all children a new blue and green sticker strip.
The children turn the page so they see number 2. Which feeling fits with this light? Stick the blue stickers that fit with this light in the blue box. And which task fits the best with this light? Stick the green stickers in the green box.

This procedure will be repeated for light 3 and 4.

After light 4 there is the possibility for the children to say out loud what they thing about the task and the lights. Was the task easy or difficult? Do the lights clearly differ? Which light do you like the most?
When all children are finished with the last page the booklets will be collected and Josien leaves the classroom.

Children can possibly write or draw things next to the stickers if they think this makes their choice more clear or when certain feelings or tasks are not displayed on the stickers.
Children are allowed to stick more than one sticker in one box.
Most import is that it is clear to the children that the task asks their own opinion and that all answers are correct. It should be a pleasant task to do and I'm grateful that they will help. If the task doesn't succeed totally it is not a very big problem. It is finally the goal of this task to explore whether children in the Special Education have certain feelings with light and whether they can express these feelings.

After school time I want to come by for some questions:

- What is the indication of the children? (ASD or not)
- What do you think about the light changes the last two weeks and what do you think about the task with the children today?

Due to privacy reasons I will remove the name of the children on the front page before leaving the school.

You can always e-mail or call me for questions,

Josien

Appendix F – Scheme light settings emotion- and task- association assignment

Group	1	2	3	4
3	Setting C	Setting D	Setting B	Setting A
4	Setting C	Setting A	Setting B	Setting D
5	Setting A	Setting C	Setting D	Setting B
6	Setting B	Setting A	Setting C	Setting D
7	Setting B	Setting D	Setting C	Setting A
8	Setting A	Setting B	Setting D	Setting C
9	Setting D	Setting B	Setting A	Setting C