To Mom and memory of Dad

EFFECTS OF A COLORED WALL AND A COLORED BOARD ON PERFORMANCES OF CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

The Graduate School of Economics and Social Sciences
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in

THE DEPARTMENT OF
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
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September 2019

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy in Interior Architecture and Environmental Design

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ABSTRACT

EFFECTS OF A COLORED WALL AND A COLORED BOARD ON

PERFORMANCES OF CHILDREN WITH

ATTENTION DEFICIT HYPERACTIVITY DISORDER

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Children with Attention Deficit Hyperactivity Disorder (ADHD) face many challenges throughout their educational lives. This study aims to find out whether there is a board and wall color combination that will help focus their attention in classroom environments. Therefore four experimental settings were prepared in which children with ADHD had to solve specially prepared tests on their most troublesome subjects. Results of one-way repeated measures ANOVAs showed that children with ADHD made significantly less errors in rooms where the board and wall colors were different than each other, in Coding and Matching tests. In the Pair Cancellation test participants performed significantly faster in the room in which both the board and the wall were painted red, compared to the room with white board and white walls. Although there is no significant difference between experimental settings in the reading task, it is observed that the participants with ADHD corrected their mistakes more in rooms with wall and board colors different than each other. As a result, painting the wall behind the board a different color than the board is recommended to help children with ADHD focus their attention more easily in classroom environments. With the findings of the current study it is believed that the use of color in different objects and environments in different educational activities can contribute positively to the learning abilities and mental states of children, young and adults with ADHD.

Keywords: ADHD, Classroom, Color, Framing, Red

ÖZET

RENKLİ BİR DUVAR VE RENKLİ BİR TAHTANIN DİKKAT EKSİKLİĞİ HİPERAKTİVİTE BOZUKLUĞU OLAN ÇOCUKLARIN PERFORMANSLARINA ETKİSİ

Öktem, Zeynep

Doktora, İç Mimarlık ve Çevre Tasarımı Bölümü

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Dikkat Eksikliği ve Hiperaktivite Bozukluğu (DEHB) olan çocuklar eğitim hayatları boyunca birçok zorlukla karşılaşmaktadırlar. Bu çalışmanın amacı sınıfta dikkatlerini daha iyi toplayacakları bir tahta ve duvar rengi bileşeni olup olmadığını bulmaktır. Bunun için dört deney ortamı hazırlanmış, DEHB'li çocuklar buralarda en sıkıntı çektikleri konularda özel olarak hazırlanmış testleri çözmüşlerdir. Tek Faktör üzerinde Tekrar Ölçümler için ANOVA analizleri sonucu Şifreleme ve Eşleme görevlerinde duvar ve tahta renginin farklı olduğu odalarda, aynı olduğu odalara göre anlamlı derecede daha az hata yapıldığı bulunmuştur. Çift Bulma testinde katılımcıların hızı tahta ve duvarın kırmızı olduğu odada her ikisinin de beyaz olduğu odaya kıyasla anlamlı düzeyde artmıştır. Okuma görevinde deney ortamları arasında anlamlı bir fark bulunmasa da DEHB'li katılımcı grubunun duvar ve tahta rengi farklı olan odalarda hatalarını daha fazla düzelttikleri gözlemlenmektedir. Sonuç olarak sınıflarda tahtanın bulunduğu duvarın tahtadan farklı bir renge boyanmasının DEHB'li çocukların dikkatlerini daha kolay toplamasına yardımcı olacağı düşünülmektedir. Bu çalışmadan elde edilen bulgular ışığında renk ögesinin farklı eğitim etkinliklerinde, farklı renkte nesne ve ortamların kullanımıyla DEHB'li çocuk, genç ve yetişkinlerin öğrenme güçlerine ve ruhsal durumlarına olumlu yönde katkıda bulunabileceği düşünülmektedir.

Anahtar Kelimeler: Çerçeveleme, DEHB, Kırmızı, Renk, Sınıf

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CHAPTER 1

INTRODUCTION

One of the most commonly diagnosed mental disorders in children is the Attention Deficit Hyperactivity Disorder (ADHD). Children with ADHD exhibit more frequently inattention, hyperactivity and impulsiveness in their lives compared to their non-ADHD peers. This could cause several problems in their education lives and these children often have hard time reaching their potentials. Their inability to focus and maintain attention often interferes with learning. Most of them exhibit daydreaming or excessive speaking in classroom. They often exhibit impulse control problems, and have hard time controlling their level of activity. As a result most teachers and parents complain about these situations about the child. The treatment for ADHD is usually done with psychostimulant medications. Besides the medical treatment it is also possible to facilitate lives of children with ADHD with some measures and arrangements. Studies show improvements of performance

and attention levels of individuals with ADHD with alterations providing an optimal stimulation for this group.

Classrooms are places where people spend most of their time for learning and acquiring new information. The quality of the physical environment in classrooms play an important role in this learning process, maybe even more so for the inattentive group who is more susceptible to external stimuli compared to their peers. Physical characteristics such as the room's volumetric dimensions, light, room temperature, sound, odor and color affect the well-being of the occupants of that room. Therefore providing comfort conditions for physical environment of classrooms also plays an active role in achieving the objectives of education. In a comprehensive study in UK about classroom design schemes, color is found to be one of the six design parameters and second most important affecting a pupil's learning progression (Barrett, Zhang, Moffat, & Kobbacy, 2013).

The effects of color on human emotion, mood, performance, productivity and creativity has long been studied in various research and color is considered an important design element influencing psychological and physiological human response. It is important to note that most studies on the effects of color on performance have been conducted with adult or adolescent samples and children are infrequently investigated in this subject. Although it is possible to find many recommendations for classroom color schemes on different publications, there is a lack of scientific research about the subject

and these recommendations seem to stem from common sense. A subject frequently highlighted in these discussions is the benefits of having an accent colored front wall in the classroom. In classrooms where students face one direction, having the front wall different from side and back walls is said to reduce eyestrain for students by helping the eye relax as students look up from a task. This arrangement is also said to relieve fatigue and over-stimulation and draws the attention to the front of the room where the teacher stands and the chalkboard or the whiteboard is mounted (Engelbrecht, 2003; Mahnke & Mahnke, 1987; Mahnke, 1996; Sherwin-Williams, 2013). However this suggestion lacks empirical evidence in the literature. Furthermore the effect of color in the classroom environments have not been studied for special groups such as children with ADHD. This subject requires special attention since studies have shown that color can play an important role on the performance of children with ADHD when used on testing or reading materials. For instance placing colored overlays on reading materials have been found to improve reading comprehension and recognition for children with ADHD (Iovino, Fletcher, Breitmeyer, & Foorman, 1998). Therefore it is believed that empirical studies on the color schemes in classrooms or on the benefits of an accent colored front wall in classrooms could help many children attain a higher performance in their educational lives.

1.1. Aim of the Study

This thesis aims to affirm the assertion of the benefits of an accent colored front wall in the classroom, with an experimental study conducted with children with ADHD, a special group who might be in need of more facilitating precautions in the classroom environments than their peers without the disorder. Being a relatively easy and cheap transformation in classrooms, if it is found to be helpful, could positively affect academic attainment of many children.

Painting the front wall of the classroom where the board is mounted both introduces color to the environment and visually frames the board. Its implications are first discussed with respective examples from the literature and then empirical evidence is searched with an experimental study. Two colors for walls and test boards mounted on these walls were chosen for the study; white and red. The combination of these created four experimental conditions; a room where a white board is mounted on a white wall (abbreviated as WoW referring to the phrase white on white), a room where a red board is mounted on a white wall (abbreviated as RoW referring to the phrase red on white), a room where a white board is mounted on a red wall (WoR, white on red) and a room where a red board is mounted on a red wall (RoR, red on red).

Table 1. Board and wall color combinations used in the experimental study

		WALL COLOR	
		WHITE	RED
BOARD COLOR	WHITE	WoW	WoR
	RED	RoW	RoR

This crossing of wall and board colors creates two rooms where framing can be observed, in other words where wall and board colors are different from each other (rooms WoR and RoW), two rooms where there is no framing (rooms WoW and RoR), two rooms where color is used on the testing material (rooms RoW and RoR) and two rooms where color is used as an environmental element (rooms WoR and RoR). The study aims to find the effects of framing and color when used on the testing material and in the environment on performance of the participants. In other words the effects of an accent colored front wall in classrooms on the performance of children with ADHD. The research questions of the study are as follows:

- Does having two different colors for the board and the front wall, thus a framing effect, improve ADHD students' performance on cognitive tasks?
- Does the color red on the board (testing material) improve performance on tasks creating an optimal arousal or does it decrease performance creating a fear of failure for children with ADHD?
- Does red, when used in the environment create an optimal arousal level for children with ADHD?

- Which one of these interventions is more effective for children with ADHD in terms of attentional performance in cognitive tasks?

The thesis aims to contribute to the literature on suggestions for the physical environment of children with ADHD, and on the effects of color and framing on performance. With this thesis it is aimed to verify empirically the benefits of an accent colored front wall in classrooms furthermore to investigate the effects of environmental color on children, more specifically children with ADHD, neither of which has been thoroughly studied until this time. If positive effects could be found, being a relatively cheap and easy transformation, it could improve education lives of many children by introducing color to the classroom either on a wall or on the board, a transformation which becomes easier with the increasing use of smart boards in classrooms. If no effect is found it could lead researchers in a different direction in search of precautions to be taken in the physical environment of children for improved performance.

1.2. General Structure of the Thesis

The thesis consists of seven chapters. The first chapter draws a general description of the thesis and the intentions behind such a study. Furthermore information about Attention Deficit Hyperactivity Disorder, its symptoms, prevalence rates, and implications are stated in the first introductory chapter.

Inhibitory control deficits seen in children with ADHD are also briefly explained as it will be discussed later in Chapter 3 under the subject of performance with color. As the study suggests changes in the classroom environment, other recommendations for the school environment from the literature are stated as well.

The second chapter concentrates on Cattell-Horn-Carroll (CHC) Theory of cognitive abilities. Being a comprehensive theory on intelligence, the CHC Theory is widely used in intelligence scales like Wechsler Tests, and Woodcock-Johnson Tests. This subject is considered important for the thesis because individuals with ADHD are reported to show differences compared to general population on certain aspects of cognitive ability factors and the tests used in the experimental study of this thesis are generated based on these most problematic areas for children with ADHD. Furthermore in the analysis of the data from the experimental study, participants' scores in the Wechsler intelligence scale are used as covariates for further investigation on the effects of board and wall color combinations.

The third chapter gives information from the literature on performance with color and framing since these two aspects are introduced to the classroom environment when the wall behind the board is painted an accent color. The literature on the effect of color on the performance of individuals with ADHD is scarce compared to that of normal population. Therefore the effect of color on the performance of non-ADHD samples is additionally featured in this

chapter with discussions of its implications on the ADHD population. In these experimental researches color is used either on the testing material or in the environment, and different outcomes on performance can be observed for these two situations. The respective section therefore makes the distinction of color studies accordingly which has not been generally made in discussions in the literature about the effect of color on performance. In the subject of framing, eye saccades reported to be seen in children with ADHD and effects of framing on performance of children with ADHD is presented.

The fourth chapter describes the experimental study expanding on the aim of the study, research questions and the hypotheses. Methodology and conduct of the experimental study are reported on this chapter with detailed information on how the tests were generated, the pilot study and the experimental procedure.

In the following chapter the results from the experimental study are reported with data analysis using Statistical Package for the Social Sciences (SPSS) 24.0. Results from each test are analyzed with one-way repeated measures ANOVAs with relevant intelligence scale index scores of the participants.

The sixth chapter includes the discussion of the results in the light of information from the literature previously depicted in the thesis. Last chapter draws a general conclusion of the study together with study limitations and suggestions for the classroom environment for children with ADHD. All

versions of tests used in the experimental study, and the pilot study, answer sheets, assessment sheets, and participants' scores from the tests are included in the appendices together with Bilkent University Ethics Committee approval.

1.3. Attention Deficit Hyperactivity Disorder (ADHD)

The sample group used in this study are children with Attention Deficit Hyperactivity Disorder (ADHD). This group of children encounter several difficulties in their daily lives and generally display an inferior performance compared to their peers in their academic lives. They are especially susceptible and hypersensitive to environmental stimuli, therefore positive changes in their environment can help greatly decreasing their symptoms. The following sections gives information about the definition, symptoms and prevalence of ADHD, followed by a summary of inhibitory control deficits in children with ADHD which is hypothesized to be the main cognitive deficit of children with ADHD (Barkley, 1997). Inhibition control is also linked to discussions about effects of color on performance discussed in Chapter 3. Furthermore as the study suggests changes in the classroom environment, other recommendations for the school environment from the literature are stated as well in this section.

1.3.1. Definition, Symptoms and Prevalence

Attention-Deficit Hyperactivity Disorder (ADHD), one of the most common complaints that differ in mental characteristics during childhood, is a psychiatric disorder defined by a combination of three characteristics; inattention, hyperactivity and impulsivity that is “more frequently displayed and is more severe than is typically observed in individuals at comparable level of development” (American Psychiatric Association, 2013, p.59).

Attention is the selective concentration on some phenomenon while ignoring other stimuli, thus it is also referred as the “allocation of limited processing resources” (Andersen, 1990, p.118). Attention deficiency is defined as having less of attention time and intensity than it should be according to the age of an individual. It is manifested by the inability to focus attention on a specific point, attention being easily distracted and making inattentive mistakes (Sürücü, 2016). Experts claim that everyone when doing a boring task, experience the will to do something else and that the problem with children with ADHD is that they cannot restrain this will and quit the task in hand. This is interpreted as a distraction (Sürücü, 2016). Hyperactivity is manifested by the inability to sit still for a prolonged time, fidgeting, being abnormally active, or talking too much, asking too many questions without even listening to the answers and jumping from subject to subject when talking (Şenol, İşeri, & Koçkar, 2006). Impulsivity is usually described by having no brakes. In children with ADHD the control system which makes a person to stop and

think before they do something, does not function adequately. Consequently they have difficulty to adjust their behaviors according to the situation and its consequences (Duman, Oğuz, & Top, 2009).

The findings suggest that children with ADHD also perform poorly on reading and writing issues due to perceptual problems. Some problems encountered in the school environment by children with ADHD are (Öktem 1996; Öktem & Sonuvar, 1990; Öner & Aysev 2007; Sürücü, 2016);

- Reversals when reading (i.e., "ev" for "ve", "yat" for "tay", etc.),
- transposition of letters and numbers (42 for 24, etc.),
- loss of place when reading, line to line and word to word;
- use of finger to maintain place;
- holding the book too close;
- omitting and/or confusing short words;
- short attention span;
- daydreaming in class;
- poor handwriting;
- poor motor control, clumsiness on playground or at home.

ADHD is one of the most common psychiatric diagnosis seen in children worldwide (Adam, Lucas, & Barnes, 2008; Polanczyk, Lima, Horta, Biederman, & Rohde, 2007; Thomas, Sanders, Doust, Beller, & Glasziou,

2015). Most researchers estimate that 3% to 10% of children have ADHD (Faraone, Sergeant, Gillberg, & Biederman, 2003; Öner & Aysev, 2007).

Different prevalence rates of ADHD were found in different studies conducted in Turkey. As a result of a four-year epidemiology study in İzmir the prevalence of ADHD was found to be 13.38% (Ercan et al., 2013). In a study conducted in primary school students aged 6-15 years in Sivas, the prevalence of ADHD was found to be 8.1% (Erşan, Doğan, Doğan, & Sümer, 2004), and in a study conducted in Kayseri with students between 7-15 years of age, it is reported to be 6.2% (Senol, Unalan, Akca, & Basturk, 2018). The prevalence of ADHD also varies between countries. The rates in most studies are reported for children of 7-9 years of age. In a meta-analysis of 175 studies worldwide, the prevalence of ADHD is reported to be 7.2% (Thomas et al., 2015). Nine studies in African countries, the Democratic Republic of Congo, South Africa and Ethiopia have shown the prevalence of ADHD between 5.4% and 8.7% (Bakare, 2012). While the incidence in Saudi Arabia was reported as 2.7% (Alqahtani, 2010), a meta-analysis involving Iranian children carried a very high proportion (12%) (Yadegari, Sayehmiri, Azodi, Sayehmiri, & Modara, 2018). The prevalence of ADHD in Far East countries China, Hong Kong and Taiwan is found to be 6.3% (Liu, Xu, Yan, & Tong, 2018). In a study conducted on children of school age in Brazil, a South American country, the prevalence is reported as 5.1% (Arruda, Querido, Bigal, & Polanczyk, 2015). The ratio for North America (6.2%) and European countries (4.6%) is reported similar (Polanczyk et al., 2007).

ADHD usually begins in childhood but may continue into the adult years. Approximately 30-50% of people diagnosed in childhood continue to have symptoms in their adulthood years and 2-5% of adults have ADHD (Öner & Aysev, 2007; Simon, Czobor, Bálint, Mészáros, & Bitter, 2009). It is also stated that many adults diagnosed with ADHD were not diagnosed in their childhood (Chinawa & Obu, 2015). It is claimed that the observed symptoms may vary according to age, gender, accompanying different diagnoses, familial features and environmental effects (Merrell & Tymms, 2001).

The prevalence of ADHD diagnosis was reported to be 3-6 times higher in males than in females (Adam et al., 2008, Faraone et al., 2003; Öner & Aysev, 2007). However, in recent years, the rate of male/female ratio was found to be 2.28:1 because of the increasing recognition of inattentive type of ADHD (Ramtekkar, Reiersen, Todorov, & Todd, 2010).

Three types of ADHD are defined, depending on more prominent symptoms. In the Inattentive type (ADHD-I), the child has difficulty in organizing and concluding a task, has difficulty in focusing on the details or following the instructions. While doing their day-to-day work, they are easily distracted and forget details. The second type is the Hyperactive/Impulsive type (ADHD-HI). These children are restless, have difficulty in sitting still, they talk a lot, and take action without thinking about the consequences of their behavior. The third type is the Combined type (ADHD-C). These children show

combinations of different degrees, the symptoms of the other two types (Merrell & Tymms, 2001).

There are differences in the prevalence of ADHD and the prevalence of ADHD subtypes in different studies. Based on information from clinical-based samples, it is said that the Combined type is more common than the other two types (Faraone, Biederman, Weber, & Russell, 1998; Lahey et al., 1996). However, in some international and American population-based studies the Inattentive type is found to be more common (Baumgaertel, Wolraich, & Dietrich, 1995; Gaub & Carlson, 1997; Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996); and in some cases the combined type shows a predominance (Angold et al. 2002; Ford, Goodman & Meltzer, 2003; Rohde et al., 1999). Different findings are present in the more recent studies as well. In one study, the ADHD-HI type (5%) is found to be more common than the ADHD-C (1.6%) and ADHD-I (1.5%) type (Alloway, Elliott, & Holmes, 2010), in another study ADHD-C (3.8%) shows a predominance over ADHD-I (1.7%) and ADHD-HI (0.5%) (Skounti, Giannoukas, Dimitriou, Nikolopoulou, Linardakis & Philalithis, 2010). It is reported that ADHD-C and ADHD-HI types are the least liked by their peers, and show more behavioral disorders, ADHD-C and ADHD-I experience more academic failure, and anxiety and depression is least seen in ADHD-HI type (9.2%) followed by ADHD-I (21.9%) and ADHD-C types (29.3%) (Gaub & Carlson, 1997). In the absence of treatment, children are reported to have many problems at home and at school (Barnard-Brak, Sulak, & Fearon, 2011).

Due to the problems mentioned above, it is stated that children diagnosed with ADHD will have difficulty in dealing with distractors in an ordinary classroom as a result of being hypersensitive to stimuli (Bulut, 2007). ADHD is a condition that is linked with underachievement in education (Raggi & Chronis, 2006). Children who are diagnosed with ADHD often face problems in school environments such as inability to focus and maintain attention, daydreaming or excessive speaking, inability to bear relatively uninteresting situations, inability to leave entertaining activities, difficulty in following and executing instructions, impulse control problems, inability to control the level of activity, and inequality in school performance (Sürücü, 2016).

1.3.2. Inhibitory Control in ADHD

Children with ADHD are usually described as having no brakes by parents, teachers and professionals (Kutscher, 2008; Sürücü, 2016). Barkley (1997), one of the leading names in the field, proposes that the main cognitive deficit of children with ADHD might be the deficiencies in inhibitory control which lead to secondary cognitive problems resulting in inattention, hyperactivity and impulsivity. Since this theory a number of studies concentrated on understanding the inhibitory control system in individuals with ADHD and have found significant deficiencies compared to non-ADHD groups. A study by Scheres et al. (2004) demonstrates that children with ADHD have deficits

in executive functioning like response inhibition compared to their non ADHD peers. In a test which measures interference control called the Flanker Task where the participants were shown a target stimulus surrounded on both sides with distracter stimuli on neutral, congruent and incongruent trials, children with ADHD did not differ from the control group in terms of mean reaction time however they made significantly more errors showing a lack of interference control (Scheres et al., 2004). The items in the Flanker Task consisted of an arrow as the target stimulus and squares for the neutral trials (□□→□□), arrows pointing the same direction for congruent trials (←←←←←), and arrows pointing the opposite direction of the target arrow for the incongruent trials (←←→←←). The participants were asked to specify the direction of the target arrow with keyboard arrows. Differences between ADHD and non-ADHD groups were also found in the Stroop Color-Word Test. In this test which measures interference control, color names in different colors are presented to the participants and they are asked to not read the name but to tell the color in which the word is written. The ADHD group is found to perform slower than the control children in this test (Scheres et al., 2004). The stop signal task is another task measuring inhibition control deficits in which participants are required to press a button in response to a stimulus. In a number of trials however they receive an auditory stop signal which signals the participants to withhold their response and not to press any buttons during those trials. The stop signal sometimes comes immediately after the first stimulus and sometimes the participants have to wait for a longer period of time which makes inhibition more difficult.

The studies show that children with ADHD have more difficulty inhibiting their responses than children without ADHD (Avila, Cuenca, Félix, Parcet, & Miranda, 2004; Pliszka, Borcherdig, Spratley, Leon, & Irick, 1997; Pliszka, Liotti, & Woldorff, 2000; Schachar, Mota, Logan, Tannock, & Klim, 2000; Wilcutt, Doyle, Nigg, Faraone, & Pennington, 2005). The adult population is also found to show inhibition differences in this task (Logan, Schachar, & Tannock, 1997). Researchers have demonstrated differences in inhibition of children with ADHD in another task called the Circle Tracing task where the participants are asked to trace a big circle with their fingers once in a normal speed and once as slow as they can, children with ADHD slowed down less than control children showing a difficulty in inhibition of an ongoing response (Avila et. al., 2004; Scheres et al., 2004). Other research have also shown inhibitory control deficits in children with ADHD in the Continuous Performance Test where the participants were instructed to push a button when they see an X followed by a letter A, among other letters appearing one after another on a computer screen (Avila et. al., 2004), Go/Nogo task (Neely et al., 2017) and the Matching Familiar Figures Test (Avila et. al., 2004).

These symptoms observed in children with ADHD may cause them to have significant problems in their daily and academic lives. Family members, teachers and friends living with them can also be sharers of these problems. However, it is possible to facilitate lives of children with ADHD with some measures and arrangements. In the following section, suggestions for home and at school environments in the literature will be summarized.

1.3.3 Suggestions for home and school environments

Besides treatment with psychotropic medication, children with ADHD also are reported to benefit behavioral strategies implemented in home and school environments. Experts propose simple and brief classroom rules to be printed and hang to close proximity of children with ADHD and teachers to praise these children when they follow the rules (Pfiffner, Barkley, & DuPaul, 2006). Because children with ADHD cannot concentrate on a task as much as their peers, another recommendation is to decrease the length of task demands to match their attention span and thus reduce off-task behavior of these children (DuPaul & Stoner, 2003). A strategy frequently used by teachers and parents is token reinforcement where the child gets tokens or stickers for every appreciated behavior which he/she can exchange for access to his/her preferred activity (DuPaul & Stoner, 2003). For disruptive behaviors time out strategy can be used where the child is briefly removed to a separate part of the classroom or outside. However this strategy only works if the child perceives the classroom as a positive place, otherwise it can reinforce disruptive behaviors of children with ADHD (Pfiffner et al., 2006). Making the child with ADHD to monitor and evaluate his/her own behavior i.e. self-regulation interventions is said to have positive effects of these children's academic achievement (Reid, Trout, & Schartz, 2005). Using computerized instructions have also proven to be effective for task performance and on task behavior of children with ADHD (Clarfield & Stoner, 2005; Mautone, DuPaul, & Jitendra, 2005).

For the physical setup of the classroom researchers suggest seating the child with ADHD closer to the teacher for easier control, also seating the child away from distractors as much as possible such as the door, windows, pencil sharpeners etc. however creating a minimally stimulating environment is not recommended (Reid, 1999). Surrounding the child with ADHD with behavior model peers is another suggestion to minimize inappropriate behavior (Pfiffner & Barkley, 1998). Providing two desks for the child to alter when he/she needs physical activity is another recommended measure for classrooms. Alternatively a stand-up desks and study-carrels could also be provided for individuals with ADHD (Reid, 1999). Most of these recommendations however lack empirical support (Conners, 2000). In addition students with ADHD sitting on stability balls compared to chairs are found to exhibit more attention on tasks and less hyperactivity (Fedewa & Erwin, 2011; Schilling, Washington, Billingsley & Deitz, 2003).

Determining the mental potential of children with ADHD and determining their attention span will be decisive for the measures to be taken and the methods to be applied. There are many theories aiming to explain mental levels and characteristics. In the following chapter, the most widely accepted theory of intelligence, which is the basis of mental evaluations, will be presented.

CHAPTER 2

CHC THEORY AND INTELLIGENCE SCALES

Intelligence development and related problems are some of the most studied areas over the last 50 years. The most comprehensive approach to explaining what intelligence is, is the approach known as the Cattell-Horn-Carroll Theory. The Cattell-Horn-Carroll theory of cognitive abilities is a prominent psychological theory which delivers a hierarchical model of intelligence of human cognitive abilities (Alfonso, Flanagan, & Radwan, 2005; McGrew, 2005; 2009; Schneider, & McGrew, 2012). The name of the theory comes from the surnames of its three main creators in chronological order of contribution (Ortiz, 2015). Being a comprehensive theory on intelligence, the CHC Theory is widely utilized in intelligence scales like Wechsler Tests, and Woodcock-Johnson Tests which are intelligence tests mostly implemented and normed in Turkey to measure cognitive abilities. When administered to individuals with ADHD, these tests are reported to show significant differences on certain aspects of cognitive ability factors. The tests used in

the experimental study of this thesis are thus created based on these most problematic issues for children with ADHD, with adaptations to be able to show the tests on a board and create equivalent tests for the design of the experimental study. This section gives information about the CHC Theory of cognitive abilities and show how the major intelligence scales relate to the theory, one of which, the Wechsler Intelligence Scale for Children (WISC-IV) was administered to the participants of this study. Their scores were used as covariates for further investigation on the effects of board and wall color combinations and showed significant differences.

2.1. CHC Theory and Intelligence Scales with CHC Theory Foundation

The CHC intelligence theory, which combines two psychometric-based intelligence theories, suggests a cognitive structure in the assessment of cognitive functions, in which there are large skill sets and narrow skills in their substructure (Uluç, 2016). Comprehensive tests used in the evaluation of intelligence are also based on this theory, like Wechsler Tests, and Woodcock-Johnson Tests. Comprehensive mental assessment is also guiding the identification of the mental characteristics of children and adults who show differences in their mental development. It also provides important information in determining the effectiveness of approaches to addressing mental problems. The current version of the CHC theory proposes 9 major cognitive ability factors (Flanagan, Ortiz, & Alfonso, 2007):

Crystallized Intelligence (Gc): is concerned with an individual's acquired knowledge and comprises its breadth and depth. It also measures the capacity to communicate this knowledge and, by using previously acquired experiences, the individual's ability to reason.

Fluid Intelligence (Gf): comprises the broad ability to make use of unfamiliar and new information by reasoning, solving problems and forming concepts.

Quantitative Reasoning (Gq): includes the ability to understand, form relationships and manipulate quantitative concepts and numerical symbols.

Reading & Writing Ability (Grw): is related with basic reading and writing skills.

Short-Term Memory (Gsm): is the ability to capture and hold information, to be used within a few seconds after the apprehension of the information.

Long-Term Storage and Retrieval (Glr): is the ability to store information. It is also concerned with the ability to retrieve this information later in the process of thinking.

Visual Processing (Gv): includes the perception, analysis, and synthesis of visual patterns. The ability to think with visual patterns and the capacity to

store and recall visual representations is another field of concern in visual processing.

Auditory Processing (Ga): includes the perception, analysis, and synthesis of auditory stimuli. It is also concerned with the ability to discriminate and process speech even if it is distorted.

Processing Speed (Gs): is related with the ability to maintain focused attention and execute automatic cognitive tasks especially under the exigency to maintain attention.

Decision/Reaction Time/Speed (Gt): is considered as a tenth ability in CHC Theory however it is not being assessed by any major intellectual ability test at the moment. It is related to the immediacy of a person's ability to react to stimuli or a task. Decision/Reaction Time/Speed is generally measured in seconds or fractions of seconds, unlike Processing Speed which is generally measured in intervals of 2–3 minutes.

The two major intelligence tests that incorporate CHC theory as their foundation for specifying and operationalizing cognitive abilities, and that have been used and normed in Turkey are Wechsler Intelligence Scale for Children (WISC) and Woodcock-Johnson Tests of Cognitive Abilities (WJ). The tests used for the current versions of both scales and how they relate to CHC Theory are given in the tables below:

Table 2. Tests used in Wechsler Intelligence Scale for Children WISC-IV and corresponding CHC categories (Adapted from Flanagan & Kaufman, 2009).

Verbal Comprehension Index (VCI)		
Similarities	Gf	Fluid Reasoning
Vocabulary	Gc,Glr	Crystallized Intelligence, Long-Term Storage and Retrieval
Comprehension	Gc	Crystallized Intelligence
Information	Gc, Glr	Crystallized Intelligence, Long-Term Storage and Retrieval
Word Reasoning	Gf	Fluid Reasoning
Perceptual Reasoning Index (PRI)		
Block Design	Gv	Visual Processing
Picture Concepts	Gf	Fluid Reasoning
Matrix Reasoning	Gf	Fluid Reasoning
Picture Completion	Gv	Visual Processing
Working Memory Index (WMI)		
Digit Span	Gsm	Short-Term memory
Letter-Number Sequencing	Gsm	Short-Term memory
Arithmetic	Gq, Gsm	Quantitative Reasoning, Short-Term memory
Processing Speed Index (PSI)		
Coding	Gs	Processing Speed
Symbol Search	Gs	Processing Speed
Cancellation	Gs	Processing Speed

Table 3. Tests used in Woodcock-Johnson Tests of Cognitive Abilities WJ-IV & corresponding CHC categories (Adapted from Schrank, & McGrew, 2001).

Comprehension-Knowledge (Gc)	I: Verbal Comprehension
	II: General Information
	31: Bilingual Verbal Comprehension
Long-Term Retrieval (Glr)	2: Visual-Auditory Learning
	12: Retrieval Fluency
	10: Visual-Auditory Learning-Delayed
	21: Memory for Names
	30: Memory for Names-Delayed
Visual-Spatial Thinking (Gv)	3: Spatial Relations
	13: Picture Recognition
	22: Visual Closure
	28: Block Rotation
Auditory Processing (Ga)	4: Sound Blending
	14: Auditory Attention
	8: Incomplete Words
	23: Sound Patterns-Voice
	29: Sound Patterns-Music
Fluid Reasoning (Gf)	5: Concept Formation
	15: Analysis-Synthesis
	19: Planning
	24: Number Series

	25: Number Matrices
Processing Speed (Gs)	6: Visual Matching
	16: Decision Speed
	18: Rapid Picture Naming
	20: Pair Cancellation
	26: Cross Out
Short-Term Memory (Gsm)	7: Numbers Reversed
	17: Memory for Words
	9: Auditory Working Memory
	27: Memory for Sentences

Comprehensive intelligence tests provide valuable information that cannot be otherwise identified, in areas such as training and intervention programs, clinical diagnostics and helping for the child. Many research have identified differences in intelligence scales of individuals with ADHD compared to normal population. The following section gives information about these differences which could provide a more in-depth understanding of ADHD.

2.2. ADHD Sample in Intelligence Scales

Children who are diagnosed with ADHD are often reported to face significant problems in school environments. Their inability to focus and maintain attention often interferes with learning. Most of them exhibit daydreaming or excessive speaking in classroom. They have difficulties in bearing relatively

uninteresting situations, or leaving entertaining activities. Following and executing instructions is another problematic area for these children. They often exhibit impulse control problems, and inability to control the level of activity. As a result an inequality in school performance is often observed in children with ADHD (Sürücü, 2016). Almost all of these problems are within executive functions. Barkley (2012, p. 176), one of the leading researchers in this field, defines executive functions as “abilities that allow the capacity to choose, enact and sustain actions over time towards goals, often as related to interactions with others, and usually through social and cultural appropriate means that maximize longer term welfare”. Executive functions is an integrity of several functions such as cognitive processing of information, working memory, emotion control, sustaining attention, planning, sequencing, organization, efficient time usage, flexibility, goal orientation, inhibition, and directed goal behavior (Chan, Shum, Toulopoulou, & Chen, 2008; Dixon, Zelazo, & De Rosa, 2010). Problems in executive functions cause disruptions in different fields and levels in academic and social life of the individual. It has been suggested that children, adolescents and adults with ADHD experience the foremost difficulty in focusing attention. Later, disruptions observed in cognitive areas instigated a focus on executive functions (Gropper & Tannock, 2009). Chan et al. (2008, p.213) reviewed more than twenty tests used to evaluate executive functions, and states that there is no “gold standard” in evaluating this complex structure, but evaluations can be made according to specific components. Among executive functions, working memory is the most studied cognitive skill. Cognitive skills are at the base of

executive functions and affect attention deficiency (Kasper, Alderson, & Hudec, 2012).

Research states that children with ADHD differ from their non-ADHD peers in IQ tests. Among the four major indexes of the Wechsler Intelligence Scale for Children (WISC-IV), children with ADHD are found to have the most difficulties with the Working Memory (WMI) and Processing Speed (PSI) Indexes (Mayes & Calhoun, 2007). The PSI measures the child's ability to perform simple discrimination tasks quickly (Wechsler, 2004). The WMI is a measure of short term memory that measures the child's ability to understand and hold in information and then use it within a few seconds (Wechsler, 2004). Deficits in these two indexes are also powerful predictors of learning disorders in children with ADHD (Mayes & Calhoun, 2007).

Flanagan & Kaufman (2009) administered the WISC-IV to a sample of ADHD children with and without learning disabilities, children scored lowest on the subtests of Cancellation and Coding (both in the PSI), and Arithmetic (in the WMI). Poor performance on these subtests are explained by the importance of attention, concentration, and speed that these subtests require which are "all critical areas of concern in this population" (Flanagan & Kaufman, 2009, p. 368). Similarly, a study by Penny, Waschbusch, Carrey, & Drabman (2005) investigating the performance of ADHD children in Woodcock-Johnson Tests of Cognitive Ability (3rd ed.), affirms that the inattentive symptoms of ADHD are related to slower Cattell-Horn-Carroll (CHC) ability of

processing speed which is significantly related to inattention. Other studies also point out a deficiency of processing speed in children with ADHD (Chhabildas, Pennington, & Willcutt, 2001; Ek et al., 2007; Shanahan et al., 2006; Solanto et al., 2007; Willcut, Doyle, Nigg, Faraone, & Pennington, 2005). Additional problematic areas besides processing speed found in ADHD children are working memory (Marusiak & Janzen, 2005; Muir-Broaddus, Rosenstein, Medina, & Soderberg, 2002; Skowronek, Leichtman, & Pillemer, 2008); visual processing in visual-spatial working memory tasks (Alloway et al., 2009; Marzocchi et al., 2008; Westerberg, Hirvikoski, Forsberg, & Klingberg, 2004); and long-term storage and retrieval (Cutting, Koth, Mahone, & Denckla, 2003; Muir-Broaddus et al., 2002; Solanto et al., 2007). Whether or not children with ADHD differ according to subtype in Wechsler tests is also gaining weight in research. In a study by Fenollar-Cortés et al. (2015), while there was no difference between Verbal Comprehension and Perceptual Reasoning Indexes for the ADHD Combined type, in ADHD Inattentive type Verbal Comprehension scores was found to be higher. It is suggested that the Processing Speed is affected more negatively in the ADHD Inattentive subtype.

The tests used in the current investigation are therefore created based on these most problematic areas for children with ADHD. Furthermore, their scores of the PSI and WMI are used as covariates for further investigation on the effects of board and wall color combinations.

It is known that environmental factors play an important role on the perception and attention levels of children and adults. A number of studies on the effects of environmental clues on these problems, which are the most intense for those with ADHD, are being conducted in the recent years. Color's effect on performance, attention, concentration, and speed is also an important subject discussed in literature. The following chapter summarizes the information in the literature on the effects of color and framing on performance and attention levels of subjects.

CHAPTER 3

ACCENT COLORED FRONT WALL: INTRODUCING FRAMING AND COLOR

As mentioned before the challenges experienced by children with ADHD are mostly tried to be reduced by pharmacologic treatment and behavior management (Sürücü, 2016). However appropriate changes in their environment could also be complementary for the reduction of their symptoms. These children would benefit greatly if school environments could offer a more convenient space that would help them focus their attention and increase academic performance.

Although it is possible to find many recommendations for classroom color schemes on different publications, there is a lack of scientific research about the subject and these recommendations seem to stem from common sense. A subject frequently highlighted in these discussions is the benefits of having an accent colored front wall in the classroom. In classrooms where students

face one direction, having the front wall different from side and back walls is said to reduce eyestrain for students by helping the eye relax as students look up from a task. This arrangement also relieves fatigue and over-stimulation and draws the attention to the front of the room where the teacher stands and the chalkboard or the whiteboard is mounted (Engelbrecht, 2003; Mahnke & Mahnke, 1987; Mahnke, 1996; Sherwin-Williams, 2013). To stimulate learning Mahnke (1996) recommends to have the side and back walls painted beige, sandstone or light tan and the front wall to be in medium tones of green or blue.

This thesis aims to affirm the assertion of the benefits of an accent colored front wall in the classroom, with an experimental study conducted with children with ADHD, a special group who might be in need of more facilitating precautions in the classroom environments than their peers without the disorder. Being a relatively easy and cheap transformation in classrooms, if it is found to be helpful, could positively affect academic attainment of many children. Painting the front wall of the classroom where the board is mounted both introduces color to the environment and visually frames the board. Its implications are discussed below with respective examples from the literature.

3.1. Color

The effects of color on human emotion, mood, performance, productivity and creativity has long been studied in various research and color is considered an important design element influencing psychological and physiological human response. The conceptual framework developed by Savavibool, Gatersleben, & Moorapun (2016) based on the model of aesthetic response to building attributes developed by Nasar (1994), is intended to describe how color may impact human perceptions, cognition, and affect (see Figure 1).

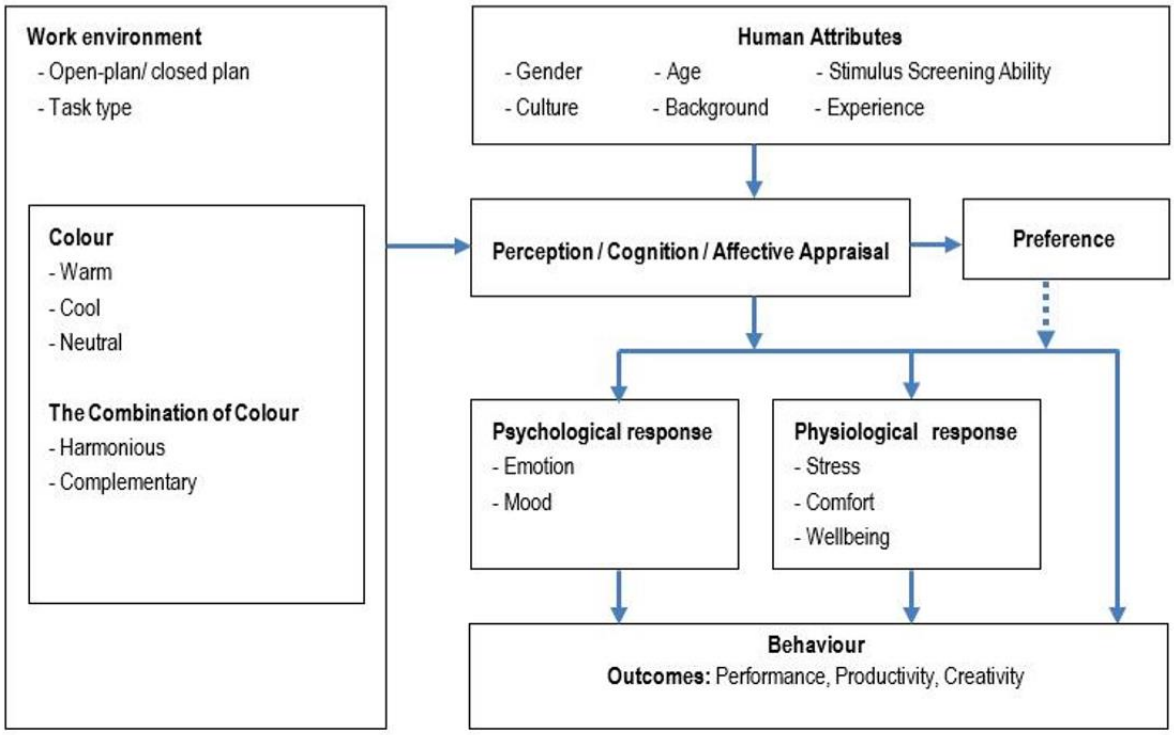

Figure 1. The conceptual framework about color interaction developed by Savavibool et al. (2016, p. 263)

In a study covering 751 pupils from 34 varied classrooms in seven different schools in the UK, Barrett, Zhang, Moffat, & Kobbacy (2013) conducted a holistic, multi-level analysis to identify the impact of classroom design on pupils' learning. According to the results of this study color is one of the six design parameters affecting a pupil's learning progression together with choice, connection, complexity, flexibility, and light. Comparing the "worst" and "best" classrooms in the sample, researchers calculated that among the six environmental factors color has an 18% proportion of increase in a pupil's learning progress which is the second most important factor after connection (26%). A cross-sectional study conducted with 210 elementary school children in Ahvaz, Iran with comprehensive questionnaires about the colors in the classroom and students' academic performance, asserts that appropriate coloring of educational environment has a significant impact on the academic achievement of pupils (Gilavand & Hosseinpour, 2016). Similarly another experimental study shows that children's off task behavior and systolic blood pressure decreased when the color of their classroom was changed from brown and off-white to blue. In this study, after changing the color of the walls to original colors, children's blood pressure gradually increased again (Grangaard, 1993).

One article about a new color scheme for a specialized school for ADHD children reports that with the color scheme used in classrooms the concentration and learning abilities of the pupils have improved (Christoffersen, 2003). These results however are excerpts from an interview

with the architect of the school Marianne T. Nielsen and are based on observations, furthermore no scientific study has been conducted to confirm the findings. Nevertheless the statement that the color combination used in the school seen in figure 2 (combinations of peach, amber, lemon and light grey for the walls, and a box arrangement in light blue and peach for the middle of the wall and all the way around the room) resulted in “less conflict, more peace and concentration, greater contentment and less aggressiveness” (Christoffersen, 2003, para. 8) is promising.

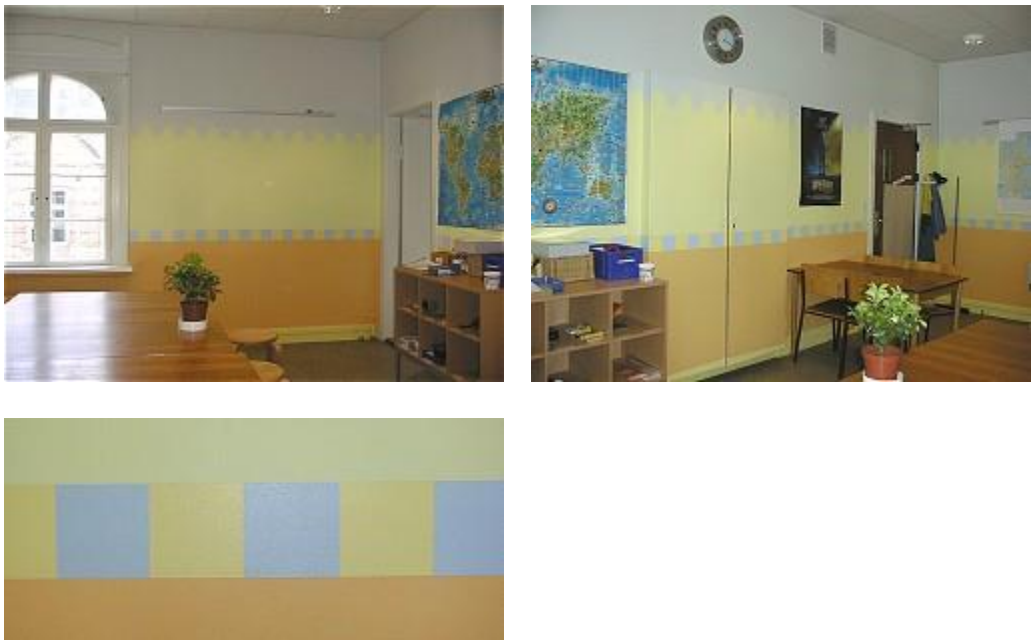

Figure 2. New color scheme for the specialized school for ADHD (www.templatenetwork.org/topaz/07/en/17.html)

This section concentrates on the effects of color on performance, specifically the color red since it is used in the experimental study of this thesis. One of the most researched colors is the color red with a 53% ratio in color research (Jalil, Yunus, & Said, 2012). The effects of red on performance will be

discussed first for the sample of individuals with ADHD. However not many studies exist concentrating on this special group therefore in the following sections the studies which investigate the effect of color red on performance of normal population will be cited together with the implications for the ADHD group.

3.1.1. Color Impairments in ADHD Population

Color vision and color discrimination in infants develop at fairly early stages after birth. However it is also true that early color vision is very limited. Adams, Courage, & Mercer (1994) found that newborns and 1-month-old infants could discriminate mainly a red colored patch. The discrimination ratio of blue, green and yellow patches were found to be substantially low. Another study by Adams (1986) suggests that although limited, newborns have the ability to discriminate chromatic from achromatic stimuli. Teller (1998) argues that infants have at least red/green color vision by 2 months postnatal. Öztürk, Shayan, Liszkowski & Majid (2013) found that categorical perception of color occur in 8-month-old infants. In terms of preference it is found that newborns look longer at stimuli with lower luminance, thus show a brightness preference; newborns, 1-month-old and 3-month-old infants prefer chromatic over achromatic stimuli; and 3-month-old infants prefer the long-wavelength (red and yellow) to short-wavelength (blue and green) stimuli, before third month infants do not show preference among different chroma (Adams,

1987). Similarly Spears (1964) demonstrated that red and blue were significantly preferred to gray in 4-month-old infants.

Color perception in human beings is attained through photoreceptors that are neurons which detect light. Two major types of photoreceptors exist in human eyes which are the rods and cones. Rods are photoreceptors which are very sensitive but they are slow. At light levels where the cones come into play and attain optimal functioning the response of rods saturates. Cones are less sensitive photoreceptor however they function faster. They have the ability to adapt to the brightest lights and it is almost impossible to saturate the cones (Gouras, 2009). Cones function according to the energy they absorb. Different wavelengths might produce similar energy levels absorbed by the cones. Here perceiving wavelength contrasts becomes important to detect objects when there is minimal energy contrast reflected from them. Therefore vision occurs by combining both energy and wavelength contrasts (Gouras, 2009). Perception of wavelength contrast occurs thanks to three cone photoreceptor types which are maximally sensitive to long, middle and short wavelengths in the perceived light spectrum (Tannock, Banaschewski, & Gold, 2006). These create two systems that function distinctively; the red-green system and the blue-yellow system. In the red-green system long and middle wavelength cone signals are antagonistic and differentiated from each other. The blue-yellow system operates by differentiating short wavelength cone signals from a combination of long and middle wavelength cone signals (Tannock, Banaschewski, & Gold, 2006). According to wavelength, colors

are sequenced from shortest to longest wavelength as violet (380–450 nm), blue (450–485 nm), cyan (485–500 nm), green (500–565 nm), yellow (565–590 nm), orange (590–625 nm), and red (625–740 nm) (Bruno & Svoronos, 2005). In most color systems similarly, colors are located in two axes, blue-yellow and red-green. These axes were created by Ewald Hering in 1920, with the idea that opposite colors are never perceived together like a reddish green or a bluish yellow (Shevell, 2014). Figure 3 shows these two axes in the Natural Color System (NCS), a color model based on the aforementioned color opponency hypothesis and how human beings perceive color (NCS, n.d.).

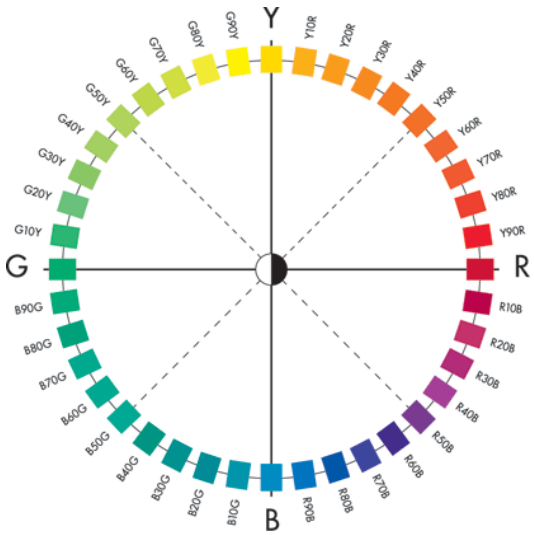

Figure 3. Blue-yellow and red-green axes in NCS System (https://ncscolour.com/about-us/how-the-ncs-system-works/)

In terms of color discrimination, ADHD children are found to exhibit some differences compared to their non-ADHD peers. ADHD children are reported to exhibit blue-yellow color perception deficits related with abnormalities in retinal dopaminergic function (Banaschewski et al., 2006; Tannock et al.,

2006). A study investigating color discrimination in children with and without ADHD indicates that children with ADHD make more blue-yellow errors but not more red-green errors compared to children without ADHD on a Farnsworth-Munsell 100 Hue Test (Banaschewski et al., 2006). Similarly the study conducted by Roessner et al. (2008) shows that children with ADHD make more errors on a Farnsworth-Munsell 100 Hue Test then their typically developing peers and more so on the blue-yellow axis compared to red-green axis. The study also investigates the color perception deficits for children with chronic tic disorder (CTD) who are also reported to have blue-yellow color perception deficits and the comorbid group of children with ADHD and CTD. The results show that the group having both conditions represent an additive model for color perception deficits (Roessner et al., 2008). In another study a computer game design was implemented to children with and without ADHD, where hints and information boards in the game were painted red and green colors in one version of the game and blue and yellow colors in another (Silva & Frere, 2011). The study shows that although the use of blue/yellow colors decreased the performance of all participants, a greater decrease was detected for ADHD children where tasks requiring attention were most affected.

Color processing problems are also found in ADHD on tasks requiring rapid and/or continuous processing of colored stimuli. A number of studies found out that children and adolescents with ADHD are slower relative to their normally developed peers on the Rapid Automatized Naming Test and

Stroop Color Word Test, although they do not show slower naming for letters, words or digits (Brock & Knapp, 1996; Carte, Nigg & Hinshaw, 1996; Houghton et al., 1999). Lawrence et al. (2004) report that ADHD children, when performing Wisconsin Card Sorting Task according to color stimuli, had more difficulties and took more trials to deduce the rule.

Tannock et al. (2006) offers two classes of explanation for these kinds of perceptual deficits in ADHD children; psychological and neurobiological. The psychological explanation claims that the slow color naming is relevant to developmental immaturity just as young children find it harder to name color rather than shapes or animals. Another psychological explanation is that color names unlike digits, shapes or letters do not have sharp, clear boundaries and thus requires an effortful semantic processing (Tannock et al., 2006). The neurobiological explanation favors the fact that people with ADHD had smaller anterior superior white matter volumes in both hemispheres. Tannock et al. (2006) also hypothesizes that hypo-functioning of the central dopaminergic system in individuals with ADHD will be accompanied by hypo-functional retinal dopamine, thus resulting on detrimental effects on visual function-especially on the short wavelength of blue-yellow color perception.

In the light of this information, the color to be used in this study was chosen from the red-green axis. The following section shows studies reporting performance improvements in ADHD samples with various stimulants. Color

is found to be an important stimulant in such studies creating an optimal arousal for children with ADHD. The color red is one of the colors mostly used and showed positive effects on performance in these studies, one of the reasons which the color red is chosen for this study within the red-green axis.

3.1.2. Improvements with Stimulants Such As Color for the ADHD Population

The treatment for ADHD is generally done with psychostimulant medications (Sürücü, 2016). Besides these, additional precautions in home and school environments of these children show some positive effects on their attention levels. For instance, several studies show improvements in the academic performance of individuals with ADHD when using color on the reading or writing materials. These positive effects are evaluated in line with the optimal stimulation theory developed by Zentall (1975; 2005) which will be discussed in detail below (see Vostal, Lee, & Miller, 2013 for a review).

The positive effects of color on cognitive performance of children with ADHD include better reading and comprehension scores, decreased number of errors in various tasks like mathematical equations or memory tasks, increase in speed and better handwriting abilities. A study researching about the effect of colored paper on the handwritings of children with ADHD show some improvements with colored paper as opposed to plain white paper

(Imhof, 2004). In this study children with ADHD and control group were shown a text including problematic words from German language and they were asked to copy it either on white paper or on a colored paper of their choice from a collection of papers in pastel to fluorescent colors. The children copied an equivalent text one week after the first trial, on papers they have not used for the first copying task. It is important to note that the researchers made sure that all children used colored paper before the study for different tasks in school to mitigate the novelty effect. The handwriting samples were examined by raters on five categories namely letter formation, alignment, slant, spacing and neatness. The handwriting of children with ADHD was rated to be neater and to contain fewer poorly marked letters and fewer line transgressions on colored paper. Control group as opposed to the ADHD group did not show any significant differences on any rating category. The author shows similarities with previous research conducted by her and colleagues, and reports that children with ADHD performed significantly better by making less mistakes and taking their time to finish the work when color stimulation was added. Although not statistically confirmed the researchers add that the teachers reported that the handwritings of children with ADHD seemed to be improved on colored paper. These effects were not observed in the control group (Imhof, 1995; Imhof & Scherr, 2000, as cited in Imhof, 2004, p. 192). The researchers claim that added external color stimulation might have an unspecific effect on attention regulation and behavioral inhibition in children with ADHD facilitating graphomotor coordination. Another explanation for the positive effects of colored paper on

overall legibility suggested by Imhof (2004) is color mitigating the strong contrast of black letters on white paper thus reducing visual stress. However the author claims that the observed positive effects more likely are the results of added stimulation for children with ADHD, by giving examples of other studies which found improvements for the ADHD group using external stimulations that are also mentioned in this section.

The positive effects of external stimulations are generally explained with the optimal stimulation theory on individuals with ADHD (Zentall, 1975; Zentall & Zentall, 1983) which suggests that “hyperactive children […] respond favorably to an increase in sensory input and stimulant drug therapy” (Zentall & Zentall, 1983, p.446). Although the theory dates back many years, recent studies show some results in favor of external stimulation aiding children with ADHD in their performance. One of these studies comprises two experimental designs in which children with ADHD were asked to solve mathematical equations on high and low stimulation conditions (Lee & Zentall, 2002). In the first study math problems were shown either on a grey computer screen with black numbers or on a colored screen with colored numbers and animation effects. The researchers found that in the high stimulation alternative children with ADHD performed better, they solved more equations and did so more correctly. Their level of activeness also dropped in the high stimulation condition. The second study used the same high and low stimulation conditions but in a competing way such that children had to solve equations on a different screen but were allowed to look at the

other screens which showed either a grey background or some cartoons with animation effects. This time children scored more poorly on the high stimulation condition showing that added external stimulation could be beneficial for children with ADHD if the stimulation is related to the task and not competing with it. In the first study where children could experience the stimulation and complete the task simultaneously they performed better (Lee & Zentall, 2002). Another study presented either no screen or a screen that showed colorful pictures to children with ADHD and control children while listening to a sequence of letters through headphones. Participants were asked to press the spacebar when they hear the letter A followed by the letter X. Children with ADHD performed equally with control group only on the high-stimulation condition (Zentall & Meyer, 1987). On another study by Zentall, Falkenberg and Smith (1985) adolescents with and without ADHD were given a copying task from a booklet of low-stimulation black letters or high-stimulation colored letters. The results show that the ADHD group made less errors and performed better in the high-stimulation condition. The control group did not show a significant difference between high and low stimulation conditions (Zentall, Falkenberg, & Smith, 1985). The authors assert that unlike children without ADHD, hyperactive children are less tolerant of lower levels of arousal and in such conditions seek to find their own sources of stimulation like talking or fidgeting in class and by using task related stimulations it is possible to see improvements in these children’s behavior and performance (Lee & Zentall, 2002).

In some studies environmental stimulation is provided by white noise. Such a study is conducted by Söderlund, Sikström and Smart (2007) with twenty one children with ADHD and twenty one children in the control group. These children listened to simple sentences which they should remember as much as possible at the end of the session. The sentences were read from a CD either with white noise on the background or with no noise. The results show that the ADHD group recalled more sentences with the white noise condition. Another study administered a Go/Nogo task with and without white noise where participants have to press a button in the Go condition (an x appears on the screen) and not to press the button in the Nogo condition (a + sign appears on the screen). The researchers found that exposure to white noise reduced omission rate in children with ADHD, equating their performance to those in the control group (Baijot, et al., 2016). Similarly a study by Greenop and Kann (2007) shows that while listening to a favorite music of their choice both children with ADHD and children without ADHD were more accurate in a mathematics test. The authors agree with the optimal stimulation theory however claim that it may not be specific to only the ADHD group. With a narrower sample (n=3) Lee & Asplen (2004) also administered a mathematics test with and without color added as a stimulant to test papers and found out that added stimulation and novelty increased the overall task persistence for the majority of students studied.

In a study by Zentall, Grskovic, Javorsky, and Hall (2000), students with attention deficits and control group received two types of texts. One with

black letters on white paper and one with black letters on white paper but this time some lines of text highlighted in different colors with magic markers. The highlighted portions of the text were non-informational that is the highlights were not done according to the important portions of the text but rather on the last two thirds of each text. The results show that children with attention deficits reached a similar level of reading accuracy with the control group in the color added condition, and that they read worse in black letters condition and improved on the second administration with the colored condition where the control group showed a decline in performance (Zentall et al., 2000).

Another study by Iovino, Fletcher, Breitmeyer, & Foorman (1998) is considered an important finding for children with ADHD and its suggestions are widely used with this population. The authors found out that putting colored overlays on reading materials has a significant effect on reading comprehension and reading recognition of children with ADHD. The study consists of putting red or blue colored overlays or no overlays on the reading material of the subjects. The authors claim that red overlay was found to be the most effective overlay color for the ADHD group. The color red compared to the non-ADHD group significantly improved the performance of children with ADHD in the reading comprehension and reading recognition performance. Additionally, blue overlay was found to be more effective than the no overlay condition for the reading recognition task (Iovino et al., 1998).

Figure 4. Colored overlays (mycolorisgenius.com)

Colored overlays are experimented with other specific groups as well. Ludlow, Wilkins & Heaton (2006; 2008) showed benefits of colored overlays on reading abilities of children in the autism spectrum. Bouldoukian, Wilkins & Evans (2002) found improvements of colored overlays on people with specific learning difficulties. In an extensive study with 233 children aged 8-12 years, the researchers found that more than one third of children read more quickly with colored overlays (Scott, et al., 2002). Long term use of colored overlays were also found to be effective. Reading speed of children who used the overlays for more than three months is reported to be increased (Wilkins, Lewis, Smith, Rowland, & Tweedie, 2001). Similarly, for children who used the overlays for more than three months, improvements are reported on their performance on the Developmental Eye Movement test which is used to identify anomalies of horizontal scanning behavior (Northway, 2003). Colored overlays or Irlen filters are extensively used with children with dyslexia. Irlen filters are special colored glasses or contact lenses used to decrease visual stress. In a study with children with and

without dyslexia, green filters are found to be more effective for reading speed for children with dyslexia. The eye-tracking study to observe the eye saccades of the sample in this research also shows that this group had the shortest fixation time in the green filter condition as opposed to yellow and no filter conditions. Children without dyslexia did not show any significant improvements between conditions (Razuk, Perrin-Fievez, Gerard, Peyre, Barela, & Bucci, 2018). Although many researchers support the use of colored filters or overlays for people with dyslexia some studies fail to find significant improvements (Palomo-Álvarez & Puell, 2013; Ritchie, 2010; Ritchie, Della Sala, & McIntosh, 2012). Singleton & Trotter (2005) claim that in their study only dyslexic students with high visual stress exhibited significant improvements in reading speed and conclude that it is possible that not all people with visual stress experience the same set of symptoms or respond the same way to the treatment. Visual stress symptoms can be light sensitivity, headache and watery eyes when reading, excessive blinking, inability to sustain attention and poor visual focus. Some visual stress sufferers also report blurring or movement of print, missing lines and individual words, losing one's place when reading, or doubling of text. Colored overlays and colored filters or lenses are believed to decrease visual stress and increase visual comfort on a number of patients (Malins, 2009). Colored background for writing is found to be helpful for handwriting of children without complaints as well. A study conducted in Taiwan used two media to assess the handwriting quality of 31 children in 6th grade elementary school; paper and tablets. The results show that the handwriting

were assessed to be better both subjectively and objectively when writing on paper and when the background color was red (among white, yellow, green and blue) (Yang, Hsu, & Huang, 2014).

These studies suggest that an improvement in these children's lives is possible through carefully selected color schemes. As students with ADHD experience sensory overload and process visual stimuli intensely, they are reported to experience color sensitivity whilst learning in educational settings (Freed & Parsons, 1997). However, the effects of environment color have not been thoroughly studied for this group. The literature on the effect of color on the performance of individuals with ADHD is scarce compared to that of normal population. Therefore the effect of color on the performance of non-ADHD samples is featured in the following section with discussions of its implications on the ADHD population.

3.1.3. Color & Performance in Non-ADHD Population

Besides framing the board, painting the front wall of a classroom introduces color to the environment. The effect of color on performance has been largely studied in the past but there is still a vast body of knowledge waiting to be explored (see Elliot, 2015). The use of color in these experimental researches are either on the testing material or in the environment. This section will first review studies that used color on the testing material,

followed by research on the use of color in the environment. This distinction is not generally made in discussions of color studies except for a few exceptions, and all studies are evaluated together. However different outcomes on performance can be observed when the color is used on testing material or in the environment. The respective sections therefore makes the distinction of color studies accordingly and summarizes the studies conducted on the effects of color on performance in the literature.

3.1.3.1. Color on testing material

When red is used on the testing materials a number of researches have shown that seeing the color red hurts cognitive performance. One of these studies conducted six experiments with undergraduate and high-school students in the United States and in Germany (Elliot, Maier, Moller, Friedman, & Meinhardt, 2007). In the first experiment the researchers gave the participants an anagram test of six pages on which a participant number was written with either red, green or black ink. The experimenter asked the participants to check their participant number after solving the practice test with no color manipulation and before starting the real anagram test with color manipulation to ensure the perception of color on the test sheets. The participants were also instructed that they would receive feedbacks of their performances. The results show that the participants in the red condition performed significantly worse than those in black and green conditions. When queried about the color of participant number on their sheets most

participants remembered it correctly however none of the participants guessed that the study was about color and performance. In the second experiment an analogy test was given to participants, again with a practice test with no color manipulation and a real test with color manipulation. The color manipulation involved the title “Analogies” written on colored rectangles of 12.7x18.4 cm dimensions on the front page of analogy booklets. The color of the rectangles were either red or green or had no color with only the title written on white paper. In this experiment contrary to the first one, the exposure to color was brief, approximately five seconds. The participants after seeing the cover page continued to solve analogies on the other pages of the booklet. Even with a limited exposure to color the performance of the participants have been negatively affected by the color red. On this experiment also it is found that the participants were mostly aware of the color of their test booklets however could not guess the purpose of the experiment. On the third experiment high-school students received the same analogy test but they were instructed that it is an IQ test and the experimenters made sure that color exposure was shorter, approximately two seconds. Red and green colors were used again in this experiment however white color was replaced with a gray rectangle. Similar to previous experiments the performance of the participants on the red condition was found to be significantly worse than those in gray and green conditions. The results of the fourth experiment show very similar effects. High-school students on a number-based task on experiment 4 solved significantly fewer items in red condition compared to green and gray conditions as utilized in

the previous experiment. Experiments 5 and 6 concentrate on the avoidance motivation assertedly caused by the color red which will be discussed in detail later in this chapter. The previous four experiments show that when the color red on the testing material was perceived before an achievement task, even very briefly, it impairs performance relative to green or an achromatic color like white, grey or black, and even if the participants were not conscious of the situation, the detrimental effects of red can still be observed (Elliot et al., 2007).

A similar research investigating the effect of red on performance examines these effects in a repeated color exposure experimental design on a memory task (Gnambs, Appel, & Kaspar, 2015). In this study 191 secondary school students received an instructional booklet about medieval dining habits. On the front cover and subsequent pages of the booklet a rectangle in either red or grey color was printed, and the title was written on this rectangle. After studying the booklet children played computer games unrelated to the research for 20 minutes and then were given a test booklet again with red or gray rectangles on the cover and subsequent pages. The test booklet contained open-ended questions about the medieval dining habits that the participants have studied on the instructional booklet. This design have resulted in four experimental conditions; (1) participants who received red instructional booklets and grey test booklets, (2) those who received gray instructional booklets and red test booklets, (3) those who received both booklets in gray, and (4) those who received both booklets in red. The

researchers also took into account the genders of the participants. The results show gender differences with boys having significantly lower scores with repeated exposure to red (condition 4) and girls having lower scores in conditions where they received only one booklet in red (conditions 1 and 2). Repeated exposure to red or gray did not result in a significant difference on performance of girls. The authors assert that exposure to red color seems to hurt performance and claims that the gender differences in performance might be explained with differences in color preferences for boys and girls (Gnambs, Appel, & Kaspar, 2015).

An interesting study by Lichtenfeld, Maier, Elliot & Pekrun (2009) shows even the perception of the word red undermines performance. Four experimental studies conducted with German high school students showed the word red to the participants in different settings. In the first experiment the participants were grouped into two and received identical analogy tests with only one exception; one group had the word “red” written on the cover of the booklet (“rot” in German), and the other had the word “place” written on the cover (“ort” in German). In the second experiment the participants were again given an analogy test with multiple choices. The only difference between booklets was that in one of them the answer to a sample question was Red-alder and in the other it was Grey-alder. The sample question showed the analogy “if hound is to animal, ___ is to plant”. The third experiment sought an even more subtle manipulation in which the word red or grey were added to the copyright information located on the bottom right corner of the introductory

pages of a numeric IQ test as “© Hografe Series of Tests Red, 1978” in 10 pt Arial font. In all of the aforementioned experiments participants in the red condition are found to perform significantly worse than others. A final experiment aiming to make connections with worry, mood and general arousal, conducted the same design with manipulation on the copyright information but used the words red and green. The participants performed worse on the red condition and reported more worry on a self-evaluation form. Mood and general arousal were not found to be significantly different between red and green condition groups (Lichtenfeld et al., 2009). The negative influence of red was replicated in a Chinese study where red also have positive connotations in the culture however in an idioms test written in red or blue letters on a computer screen participants performed worse in the red condition (Shi, Zhang, & Jiang, 2015).

These negative effects are often explained by the association of the color red with danger. The color of warning signs, traffic lights or blood or the red pen used by teachers to correct mistakes are generally red. Thus Elliot et al. (2007) claim that these learned associations between red and danger of failure might explain the drop in performance in competitive contexts. According to the authors this fear of failure also activates an avoidance motivation where the subject tries to avoid making mistakes which in turn undermines performance (Elliot et al., 2009). The relationship between red and avoidance motivation will be discussed further in this chapter.

The results are not always replicable in other studies nonetheless. There are a good number of studies which found no detrimental effect of red on cognitive performance. In one of these studies 200 adult participants from the UK were given five ability tests. Their table numbers were written on the booklets with either red or green colored pens in a 1.4x4.8 cm rectangle as in the first experiment by Elliot et al. (2007). The researchers found no significant effect of color on performance or self-rated ability before and after adjusting for intelligence scores of the participants. The authors argue that this difference from previously cited articles might stem from the size and participant age differences because other studies have used high school students and comparably smaller size samples for their experiments (Larsson & Stumm, 2015). Another study conducted with undergraduate students investigated the color effect on three studies, the participants took exams once with the cover page in red or green color, and twice with the whole exam booklet in green or red colors. The first two exams were considered a high-stakes exam because they affected students' course grade, the third one was a low-stakes exam to measure a baseline for the course. The researchers also used students' GPA and a baseline test on white paper as covariates to control for potential preexisting differences between red and green condition groups. In neither study there was an effect of color on performance. The researchers assert that because the students were familiar with the subject and had higher motivation caused by grade anticipation the characteristics of the participants were different and this might have offset the negative effects of red on intellectual performance

(Arthur Jr., Cho, & Muñoz, 2016). A similar study with two hundred and four undergraduate students investigated the effect of red and green colored exam papers which revealed no effect on performance. An analogous study using white and pastel colored papers by the same authors showed no significant difference between color conditions either (Martinez, Oberle, & Thomson Jr., 2010). Another study with undergraduate students used red and green colored exam sheets in an exam which affects students' course grade. The results show no significant differences in performance or self-reported anxiety between conditions. The authors of the study state that the difference might arise from the fact that most studies which have found a detrimental effect of red on performance were conducted in a laboratory setting and the participants were given tasks that they have not prepared for before which might have increased their anxiety levels. Furthermore the test results did not have any implications for the participants unlike a genuine course exam which would affect their course grade. Finally in a laboratory setting authors claim that the context and the presentation of color to participants is different than the actual field and this might affect participants' psychological processes and performance (Smajic, Merritt, Banister, & Blinebry, 2014). Studies which have found no significant effect of red on performance are generally explained by Elliot & Maier's (2012) Color-in-Context theory which suggests that color carries meaning and affects psychological functioning and these meanings and effects are context-specific. Therefore the detrimental effects of red could be seen in a context

where fear of failure is sensed more and the studies which did not find any significant effects may have failed to create such a context.

A prevalent view about the color red is that it creates an **avoidance motivation** which in turn harms performance. The series of experimental studies by Mehta & Zhu (2009) shed some light into the understanding of this avoidance motivation assertedly caused by red. In the first study participants were given anagrams on red, blue or neutral backgrounds on a computer screen. The words used in the anagrams were prepared under three groups with three items in each group. The groups were words that have an avoidance association like “prevent”, words that have an approach motivation like “adventure” and neutral words that do not connote any motivation like “computer”. The researchers have found that participants who viewed the anagrams on red background performed faster on items with an avoidance motivation. Similarly those who viewed the anagrams on blue background solved the approach related items faster and those in the neutral background did not show any difference of speed between word groups. In the second study participants were asked to report their preferences among two brands of which they read the descriptions on a computer screen with either blue or red background. The descriptions highlighted either avoidance or approach related characteristics of the two brands. For instance two brands for toothpaste, one preventing cavities (avoidance motivation) and the other whitening teeth (approach motivation) were presented to the participants. The results show that participants in the blue condition reported a greater

preference for approach-oriented brands than those in red and neutral color conditions. In terms of performance the researchers found that for a detail-oriented task like a memory task in which participants memorize and asked to recall words that they see on a computer screen with red, blue or neutral backgrounds, those in the red condition performed better than those in blue condition. Additionally the participants in blue condition made more false recalls than those in red or neutral color conditions. The researchers assert that red facilitates people's attention to details. Nonetheless in a task that requires creativity where participants are asked to generate as many uses for a brick as they can think of, the amount of answers did not differ among conditions however the answers in the blue condition were rated to be more creative than those in red and neutral conditions. On further experiments participants in the red condition performed better than those in blue and neutral conditions on a task where they were required to find the subtle differences among two texts, and those in the blue condition performed better on a Remote Associates Test where the participants were asked to find a target word using the stimulus words they have been given (e.g. "Shelf", "Read," and "End" as stimulus words and "Book" as the target word). In the study which assesses both creativity and attention to details where the participants were asked to create a children's toy using drawings of twenty different parts, the designs in the red condition were judged to be more practical and appropriate, showing attention to details and, those in the blue condition were judged to be more original and novel, reflecting creativity. In a different study, when encountered with two ads of an item participants are

found to favor ads which reflect specific details of the item in red condition and, favor ads including remotely related associations for the item in the blue condition. One example of such ads is the one for a camera where one ad shows specific product details like its lens and the other shows a road sign, a dining table in a restaurant, and a map which requires the viewer to make an association with travel and the camera. In the light of these experiments the authors conclude that red is a more favorable color for attention requiring tasks and blue enhances creativity (Mehta & Zhu, 2009).

In the series of experiments using red on test materials conducted by Elliot et al. (2007) the last two experiments were realized to propound the avoidance motivation hypothesized to be caused by the color red. The researchers gave a booklet to participants with either red, green or grey rectangles on the cover page and the title “Analogies” was written on these colored rectangles. On the next page there were two samples of an analogy task followed by a statement indicating that the participant may choose between easy and moderately difficult analogies to solve next. The statement further explained that the participant had a 90% chance to solve the easy analogies and 50% chance to solve the moderately difficult analogies. The participant then was asked to choose the amount of easy and difficult items summing up to a total of ten questions. The results show that participants in the red condition chose a greater number of easy questions then the participants in grey and green conditions. The other study measured asymmetrical activity in the frontal cortex with electroencephalography (EEG) to show avoidance motivation

which causes greater right, relative to left, frontal cortical activation. As hypothesized by the researchers the participants who viewed red prior to the test, color manipulation presented similar to the previous experiment but on a computer screen, exhibited more asymmetrical and relative right frontal activation than those in the green and grey conditions showing an avoidance motivation in participants in the red condition (Elliot et al., 2007). Another article concentrates on the behavioral differences of participants when encountered with the color red in two separate experiments (Elliot, Maier, Binser, Friedman, & Pekrun, 2009). In the first experiment the participants were taken in a room where they were given instructions about what they are going to do for the experiment. One group were told that they would take either a vocabulary or an analogy test. This group was considered to be in an achievement context because they were told that their performance in the test was going to be evaluated. The other group were told that they were going to rate vocabulary or analogy tests considering how much other students would like the questions. This group was considered to be in a non-achievement context, they were not asked to answer the test question but only rate them. All participants were given a binder and were told that the name of the test they would be taking or rating i.e. either vocabulary or analogies test was written in the binder and instructed to open the binder and check for the title. The title “Analogies” was written on a colored rectangle in either red or green inside the binder. The participants were later told that they will continue the experiment in another room and escorted out. Participants found a “please knock” sign on the door of the other room in which they were

going to take or rate the test. The study aimed to count the number of knocks on the door as a measure of avoidance motivation. The researchers hypothesized that fewer knocks would demonstrate avoidance behavior. The results show that participants in the achievement context group knocked on the door significantly less than those in the green condition in the achievement context. Participants in the non-achievement context did not show any differences. The researchers conclude that in an achievement context seeing the color red creates an avoidance motivation (Elliot et al., 2009). The second experiment was conducted with participants wearing body movement sensors, seated in front of a computer screen. They were told they are going to take an IQ test and were shown sample questions on the computer screen. Following this session participants saw the title of the test on either red, green or grey rectangles. The researchers aimed to measure the body movements upon seeing color on the screen and, found that compared to participants in the green condition those in the red condition moved their body away from the screen when color was presented which according to the authors is a manifestation of avoidance behavior (Elliot et al., 2009).

Researchers claim that task difficulty is also a consideration in performance tasks. In a study on the effects of red, blue and gray background on simple and difficult proofreading tasks, it is found that participants performed better in red condition on the simple detail-oriented task. Contrarily performance of the participants in the blue condition was found to be higher in the difficult

task. The authors claim that in the difficult task, avoidance motivation's positive impact on performance caused by red was offset by the negative effect of high arousal. On a secondary experiment the researchers administered the participants a simple and difficult creativity task which is a Chinese version of Remote Associates Task used in Mehta & Zhu's (2009) study. It is found that blue color both in simple and difficult creativity task enhanced performance of the participants. Similar to the first experiment no significant difference between gray and red conditions were found in this experiment suggesting that red may have a "facilitating effect" in some tasks but does not have an "interference effect" on cognitive performance (Xia, Song, Wang, Tan, & Mo, 2016, p. 5).

Although avoidance motivation has not been thoroughly investigated in children with ADHD, many studies suggesting impulsivity and inhibitory control deficit in these children (Avila et al., 2004; Barkley, 1997; Chamberlain et al., 2011; Pliszka et al., 1997; 2000; Schachar et al., 2000; Scheres et al., 2004; Wilcutt, et al., 2005) give rise to the thought that avoidance motivation might be useful to stop them from making mistakes and restrain their impulsivity. Researchers assert that impulsive approach increases with stronger tendency to approach incentive cues and impulsivity is related to the sensitivity of the approach system (Carver, Johnson, & Joormann, 2014). Therefore besides the optimal stimulation theory, the performance improvements seen in studies using red with ADHD samples might be also caused by this avoidance motivation. As Mehta & Zhu (2009)

demonstrated avoidance motivation could be beneficial for detail-oriented tasks and tasks that require attention, which is one of the most troubled areas for children with ADHD. Therefore caution and avoidance motivation might be a desirable outcome for the inattentive group; however, no scientific research about this phenomenon on ADHD sample has been realized.

Another field of study that aims to explain the effects of red on performance focuses on local/global processing. The test which assesses local and global processing in individuals is called the Navon task, created by David Navon in 1977. In Navon task subjects are shown a large letter made up of smaller letters as shown in Figure 5. In general it is found that participants perform faster in global tasks where they are asked to identify the large letter and ignore the small letters. For the local task on the other hand where the participants are asked to identify the small letters which make up the large letter, reaction times increase and the processing is subjected to a “global precedence” or a global processing bias where people automatically process the global dimension first, identified by Navon (1977, p. 353) with the phrase “forest before trees”.

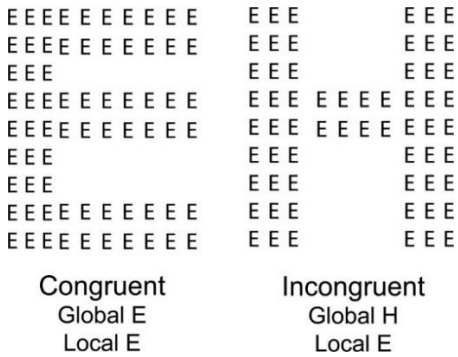

Figure 5. An example of a Navon task stimulus (Watson, 2013: 3).

Maier, Elliot, & Lichtenfeld (2008) conducted a series of experiments to investigate the mediation of the negative effect of color red on performance. With a similar study with Elliot et al. (2007)'s experiment mentioned previously (experiment 4), they found that seeing red prior to an IQ test undermines performance. The researchers went on exploring the mediation of these negative effects with a new design in which they look for local or global processing. The task they administered to the participants to measure local and global processing of the individuals consisted of figures which the participants were asked to compare and match. An example of these items is the task to match the target figure; a triangle composed of square elements with one of the comparison figures; either a square composed of squares (which represents local processing) or a triangle composed of triangles (which represents global processing). In other words local processing corresponds to the local details of the target figure (squares), and global processing corresponds to the global details of the target figure (triangle). The researchers claim that the selection of local processing items indicates a more constricted attentional focus. The results of this experiment showed that participants who had seen red prior an IQ test exhibited more local processing compared to those who had seen gray prior to the test. A third experiment aims to establish a link between performance and local processing. The participants were given the global-local processing tasks used in the previous experiment. One group were told to concentrate on the local details and the other group was asked to choose the comparison figure which represents global details of the target figure. The results show that

participants who worked with local details performed worse on an IQ test than those who concentrated on the global details. Together with the previous experiment the authors claim that seeing red results in local processing which in turn undermines intellectual performance. The last experiment is a combination of prior experiments in which participants completed the local/global processing task with color manipulation like in the second experiment and then took an IQ test. Participants who have seen red as opposed to those who have seen gray prior to taking the tests are reported to make local processing selections and performed worse on the IQ test.

It is important to note that children and adults with ADHD are reported to show some differences with the normal population on the Navon task. Therefore the findings of previous experiment by Maier, Elliot, & Lichtenfeld (2008) should be discussed with caution for individuals with ADHD. It is reported that individuals with ADHD do not show a global processing bias and exhibit local interference compared to normal population (Kalanthroff, Naparstek, & Henik, 2013; Song & Hakoda, 2012; 2015). A recent study by Kalanthroff, Naparstek, & Henik (2013) shows the effects of an auditory stimulus to reinstate the global processing bias in adults with ADHD. Comparing adults with and without ADHD, the researchers have found that the ADHD group without an alerting sound, did not show a global processing bias as opposed to the control group. In other words while the control group performed significantly faster in the global task, adults with ADHD show no

difference in performance between local and global tasks. However when an alerting sound accompanied the task, the researchers have found that global bias increased in the control group and was reinstated in the ADHD group. That is to say with the presence of an alerting cue, participants with ADHD showed global processing bias which interfered with local processing while the contrary interference was significantly less which brought the ADHD group's performance similar to that of the control group. Consequently the researchers claim that the reason we do not see a global precedence in individuals with ADHD might be the low levels of arousal typically encountered in this population (Kalanthroff, Naparstek, & Henik, 2013). Therefore it can be argued that stimuli which create high levels of arousal could be beneficial for individuals with ADHD. As discussed previously in the section about improvements with stimulants for the ADHD sample, red is considered to be an arousing color and hypothesized to create optimal arousal for the inattentive individuals. Experts indicate that added stimulation would be most beneficial for this group of children especially during tasks that require sustained attention (Zental, Falkenberg, & Smith, 1985). Considering that the medication which decreases ADHD symptoms are psychostimulants (Sürücü, 2016), it is not surprising that studies using external stimulation have also revealed positive effects on motor activity and academic performance for people with ADHD.

3.1.3.2. Color on Environment

When red is introduced as an environment color rather than on testing materials, different results can be observed on performance. Although fewer studies have been conducted about the effects of environment color on cognitive performance, the findings do not suggest a detrimental effect of red. To begin with, differences on performance among chromatic and achromatic working places are reported where participants who solved problem-solving and proofreading tests in a chromatic room performed significantly better and faster than those in an achromatic room (Öztürk, Yılmazer, & Ural, 2012). One study demonstrated that the subjects made fewer errors in a red office on a proofreading task compared to a white office (Kwallek, & Lewis, 1990). Another study with 675 participants investigated the effects of nine office colors (all walls painted in red, white, green, orange, yellow, blue, beige, gray or purple) on subjects' performance on a proofreading task, mood, and color preference. The results showed that participants made significantly less proofreading errors in the red and blue offices than in the white office which was interestingly rated as the least distracting and among the most preferred colors for working by the participants (Kwallek, Lewis, Lin-Hsiao, & Woodson, 1996). In a more recent study students with low writing ability received higher achievement scores on a journaling task in a red environment compared to a blue environment (Johnson & Ruiter, 2013). Subjects completing a proofreading task in red and blue rooms performed faster in the red room but with lower accuracy. This combination, according to the authors is a well-

established indicator of heightened arousal in the central nervous system (Küller, Mikellides, & Janssens, 2009). Therefore these findings are explained in line with arousal theory which suggests that there is an optimum level of arousal for everyone and performance is in its best on this optimum level. Lower or higher levels of arousal cause a decrease on performance and red being a stimulant color creates a heightened arousal for the subjects (Küller, Mikellides, & Janssens, 2009; Kwallek & Lewis, 1990; Kwallek, Woodson, Lewis, & Sales, 1997; Stone, 2003; Walters, Apter, & Svebak, 1982). The arousing effect of red is also acknowledged by subjective evaluations of participants who were exposed to red, green and blue light (Rajae-Joordens, 2010). In a study by De Korte, Kuijt & Van Der Kleij, (2011) heart rate variabilities of participants were measured while performing a creativity task in three different rooms decorated in three colors. The authors claim that decreased variance in heart rate is an indication of high arousal and participants in the red room showed low heart rate variance and idea originality was assessed to be greater compared to green and blue rooms. The effects of colors on human physiology has been studied for many years. In a research by Jacobs & Hustmyer (1974), participants were presented red, yellow, green, and blue colors for 1 minute and their galvanic skin response (GSR), heart rate and respiration were recorded. The results show that participants demonstrated a significant increase in GSR when red was presented compared to blue and yellow. No significant difference in heart rate, and respiration was observed. Galvanic skin response is used as a measure of emotional arousal intensity by tracking the changes in sweat

gland activity (Farnsworth, 2018). Therefore the authors conclude that red is a more arousing color than blue and yellow (Jacobs & Hustmyer, 1974). A more recent study shows an increase in heart rate of participants who performed a reading and comprehension task in red and yellow rooms (Al-Ayash, Kane, Smith, & Green-Armytage, 2016). The study examined the effects of vivid red, vivid blue, vivid yellow, pale red, pale blue, and pale yellow color conditions in private study spaces. Additional results show that participants performed significantly better in vivid colored rooms although vivid red and vivid yellow colors were not evaluated as appropriate colors for learning by the majority of participants. The authors conclude that vivid colors are more arousing than pale colors and in terms of hue long wavelength colors like red and yellow are more arousing than short wavelength colors like blue. Another interesting finding of the study is that participants who rated the pale color conditions to be more positive exhibited increased learning in the vivid color conditions. Therefore it could be said that preference and performance does not always go hand in hand. The authors claim that although the participants evaluated the pale color conditions as more calm and relaxing and thus appropriate for learning environments, colors with arousing properties stimulate neural activity and could be more suitable for learning (Al-Ayash, Kane, Smith, & Green-Armytage, 2016).

These results are not always replicable. One study assessing the effects of color on the environment reports no significant difference in performance on a number of cognitive tasks carried out in pink, red, blue and white

environments (Von Castell, Stelzmann, Oberfeld, Welsch, & Hecht, 2018). The color manipulation was realized with colored wooden booths placed on the tables of high school students while performing cognitive tasks, namely numerical reasoning, visual memory, cued recognition of categories, mental rotation, and cued recognition of word pairs. There were no significant difference between color conditions in any of the cognitive tasks. Only on the mental rotation task red and pink conditions were found to be slightly better. By referring Elliot et al. (2007)'s study which showed decrease in performance when seeing red on testing materials, the authors claim that when encountered on test material participants might have associated red with red marks on an exam paper signaling failure, however when the color is perceived in the environment no such association takes place (Von Castell et al., 2018). Similarly no effects of wall color is found in a study investigating participants' performance in a typing task and self-rated anxiety, depression, and arousal scores in red, blue-green and white rooms (Ainsworth, Simpson, & Cassell, 1993). In studies examining the color effect used as an environmental element white is generally used as a control color for walls. The same approach is also applied in the current study.

Most research on the effects of environmental color on cognitive performance have been conducted with adults. The children sample is used in one extensive study where the subjects completed test booklets in the presence of a colored screen and a grey screen (Brooker & Franklin, 2016). In this study, exposure to color was rather limited compared to other studies which

use color as an environmental element and not on testing material; A3 size colored boards were put in front of the subjects while taking the tests. The results show a significantly worse performance in the presence of red screen. Writers claim that children might have associated red with failure as in the aforementioned studies (e.g. Elliot et al., 2007; Gnambs et al., 2015; Lichtenfeld et al., 2009; Maier et al., 2008) and had lower scores in the presence of the red board (Brooker, & Franklin, 2016).

The current study aims to explore the effects of the color red used as an environment color on the performance of children with ADHD which has not been tested before. Furthermore, by using different colored wall and boards, the effect of framing on performance will also be analyzed.

3.2. Framing & Eye Saccades in ADHD

Having a different colored wall behind the board, in a sense creates a frame around the board which could be beneficial for children with ADHD. The ADHD population is found to have visual differences compared to non-ADHD individuals not only in color vision but also in terms of eye fixation revealed by eye tracking studies. In a research by Deans, Laughlin, Brubaker, Gay, and Krug (2010) which uses eye movement tracking method to quantify vision anomalies in children with ADHD and children with Reading Disorder (RD) a brief reading task on a computer screen was presented to the

subjects between the ages of 6 and 12. The study shows that both the ADHD group and RD group showed shorter fixations compared to the Control group, meaning that they focused their gaze on a particular target for a shorter time. These two groups also showed fewer left to right saccades and more regressive saccades than the Control group. Regressive saccades happen when the eye moves from right to left showing that the individual has re-read a portion of a text. Additionally the ADHD group is reported to display significantly more vertical saccades compared to the Control group, meaning that they moved their eyes from the target stimuli upwards or downwards more frequently which usually occurs when the subject gets distracted (Deans et al., 2010). In the light of this information on the reading test of the current experimental study the words that the participant children has re-read are counted and analyzed separately than the words that they have misread.

Munoz, Armstrong, Hampton, and Moore (2003) compared ADHD children and adults with respective control groups in a study where the subjects were administered three visual tracking tasks. In the first task called the pro-saccade task, subjects were asked to look at a focal point and then shift their gaze to a new eccentric stimulus. In the second task, called the anti-saccade task they were asked to look at the opposite direction of the eccentric stimulus. The third task required the participants to fix their gaze on the target stimulus that stayed for a longer period of time and reappear either on the same or a different spot. The ADHD group was found to make slower saccades in the pro-saccade task and they showed longer reaction times.

The anti-saccade task reveals that the ADHD group made more errors than the Control group and had difficulty inhibiting looking at the target stimulus. The third task showed more intrusive saccades in the ADHD group, that is children and adults with ADHD made more unnecessary rapid shifts in eye position during this task than did the Control group (Munoz et al., 2003). A similar task conducted with adults with ADHD show similar results. Adults with ADHD are found to make more anticipatory (premature) saccades in pro-saccade task than the Control group. Additionally in the anti-saccade task adults with ADHD fail more in the inhibition of gazing towards the target stimuli on a significant level (Feifel, Farber, Clementz, Perry, & Anllo-Vento, 2004).

In a memory-guided saccade task which measures visuo-spatial working memory and disinhibition with children with ADHD, research has found that these children displayed significantly more anticipatory and intrusive saccades than controls. In the memory guided saccade task the subjects are first shown a point on a screen and are asked to memorize its location. Afterwards they are required to look at a central point on the screen for either three or seven seconds and are asked to look at the location where the previous point was when the central point disappears. Anticipatory saccades happen when the subject looks towards the target while the central point is lit and intrusive saccades are saccades towards another location during the same period. Children with ADHD were also found to be less accurate and making more intrusive saccades during the seven seconds delay period as

opposed to three seconds. The researchers suggest that longer delay periods impose some weight on working memory and inhibitory processes (Rommelse, Van der Stigchel & Sergeant, 2008). On a similar task which uses one second or three second delay periods, young adults with ADHD are found to make more premature saccades than the control group although they did not show a difference in the latency and spatial accuracy of remembered saccades (Ross, Harris, Olincy, & Radant, 2000).

Other eye movement tracking research show similar results with children with ADHD. In a study where the participants were asked to look at a stimuli for about 30 seconds and follow the stimulus which bounced back and forth on the screen, children with ADHD had difficulty inhibiting the tendency to look away from the target stimuli and made larger saccades than the Control group (Gould, Bastain, Israel, Hommer, & Castellanos, 2001). Even on medication, children with ADHD are reported to display significantly more directional errors on the anti-saccade task and significantly more anticipatory errors compared to the Control group (Mostofsky, Lasker, & Cutting, 2001). More recent studies also found microsaccades in adults who reported more ADHD like traits like inattention and hyperactivity in the Adult ADHD Self-Report Scale (Panagiotidi, Overton, & Stafford, 2017).

The framing effect in this study is hoped to lower the large saccades of ADHD children and help them to re-focus their gaze on the board. No scientific data exists about whether a framed reading material diminishes

these saccades; however, a mother of a boy diagnosed with ADHD reports in her book that brightly colored placemats put underneath the reading material helped her child to focus his attention more since the placemat visually frames the child's work (Boring, 2002).

CHAPTER 4

EXPERIMENTAL STUDY

4.1. Aim of Study

The current study aims to explore the effects of different wall and board color combinations on the performance of children with ADHD in cognitive tasks that they show the most deficiencies. The color red is chosen because of blue-yellow color deficiency in children with ADHD. Furthermore as suggested in optimal arousal theory by Zentall (1975; 2005) the color red may help to create an optimal arousal for children with ADHD thus enhance their attentional performance. The color white is chosen as a control color like most studies using color on the environment. When thinking about walls that have no color on, one mostly considers that the walls are white. The effect of color red on performance, and avoidance-approach motivation although has been studied extensively with non-ADHD population, there are limited studies concerning the ADHD group. Furthermore most color studies are conducted

with adolescents and adults, and the effect of color on children's performance is yet to be explored. By using different colored wall and board, the effect of framing on performance of children with ADHD will also be analyzed. The experimental study aims to investigate the effects of an accent colored main activity wall in classrooms as recommended by a number of specialists in the field (Engelbrecht, 2003; Mahnke & Mahnke, 1987; Mahnke, 1996; Sherwin-Williams, 2013). These effects however have not been empirically studied before. This experimental study aims to provide information on the use of such walls in classroom environments, and find out whether or not it improves the performances of the occupants in such an environment.

4.2. Research Questions

The study will investigate the effects of framing and the color red on cognitive performance of children with ADHD in an experimental setting. Framing and color are introduced to the environment by painting the main wall of the classroom an accent color. The research questions are as follows:

- Does having two different colors for the board and the front wall, thus a framing effect, improve ADHD students' performance on cognitive tasks?
- Does the color red on the board (testing material) improve performance on tasks creating an optimal arousal or does it decrease performance creating a fear of failure for children with ADHD?

- Does red, when used in the environment create an optimal arousal level for children with ADHD?
- Which one of these interventions is more effective for children with ADHD in terms of attentional performance in cognitive tasks?

4.3. Hypotheses

1. Framing effect: Rooms RoW and WoR

In Rooms RoW and WoR, by using different colors for the board and the wall, the board is differentiated from the background. According to Boring (2002) framing the study material helps children with ADHD to concentrate more. ADHD group are found to make more saccades and regressions compared to non-ADHD group (Deans, et al., 2010; Gould, et al., 2001; Ross, et al., 2000; Rommelse, Van, & Sergeant, 2008; Munoz, et al., 2003). Framing the board could help ADHD children to focus their attention on the task given on board, decreasing the times where children look elsewhere.

Hypothesis 1: The framing effect seen on Rooms RoW and WoR will help children with ADHD to focus more on the board and lead to a better performance on tasks (i.e. less errors, more correct answers).

2. Red on the testing material: Rooms RoW and RoR

Studies made with colored overlays and colored paper show a significant improvement for ADHD group's reading accuracy and rate, and reading comprehension (Iovino et al., 1998), as well as handwriting (Imhof, 2004). It is also found that color-added stimulation reduced activity and errors for participants with attention-problems unlike the non-ADHD group in story-copying tasks (Zentall, Falkenberg, & Smith, 1985), and spelling tasks (Zentall, 1986). In the colored overlay study red is found to be the most effective overlay color compared to blue overlay and none overlay (Iovino et al., 1998). Researchers claim that the reduction of visual stress as color mitigates strong contrasts of black print and thus provides less visual stress and tiring could be the reason for this improvement (Imhof, 2004). Also it is widely accepted that additional environmental stimulation has positive effects on motor activity and academic performance for people with ADHD (Iovino et al., 1998; Zentall & Shaw, 1980; Zentall & Zentall, 1983).

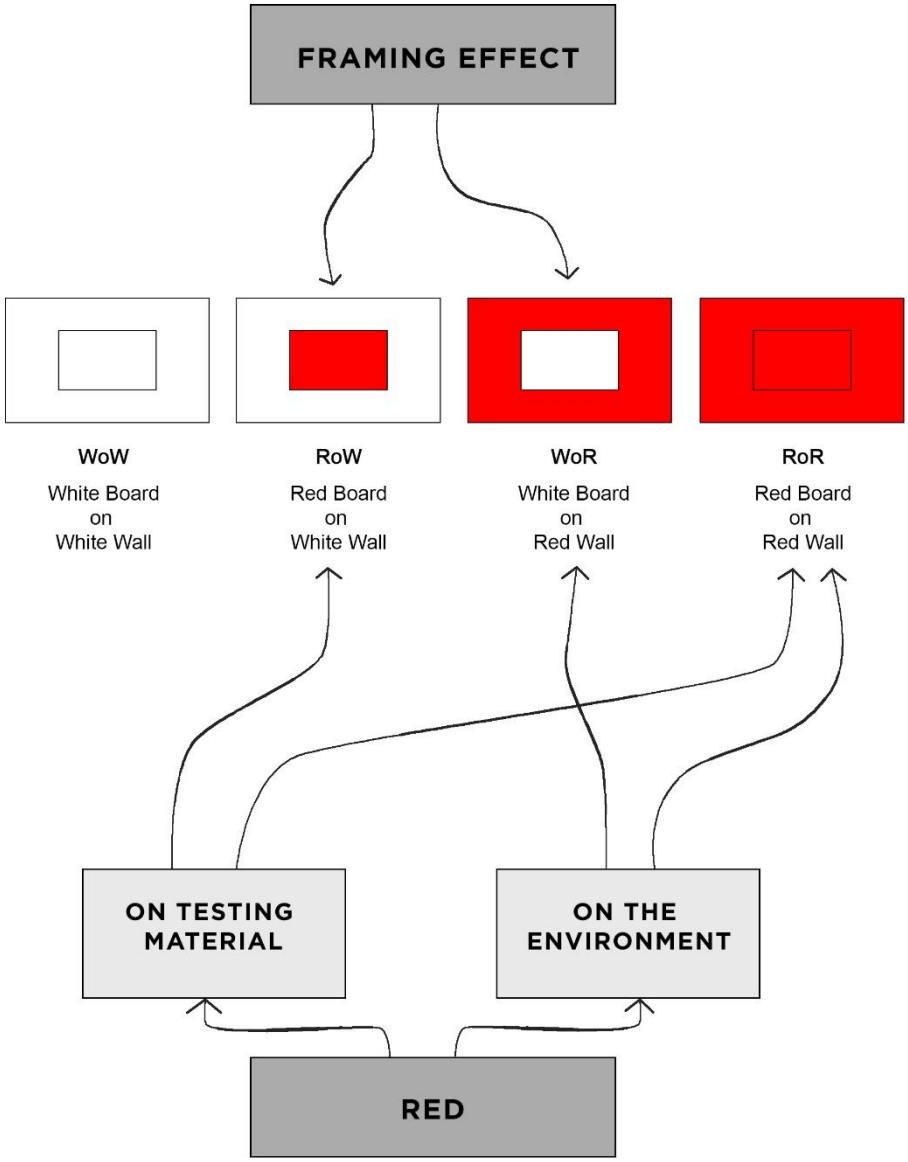

Figure 6. Board and wall color combinations used in the study and relevant topics from the literature

On the other hand in a number of studies red is found to hurt performance of non-ADHD population when used on testing material (Elliot et al., 2007; Gnambs et al., 2015; Lichtenfeld et al., 2009; Maier et al., 2008; Shi et al., 2015). These studies are mostly conducted with adolescents and adults. The negative effects of red on performance is associated with the fear of failure

and danger evoked by the color red. Experts claim that this in turn creates an avoidance motivation which hampers cognitive performance. Other studies which show no detrimental effect of red (Arthur Jr. et al., 2016; Larson & Stumm, 2015; Martinez et al., 2010; Smajic et al., 2013) are generally explained by Elliot & Maier's Color-in-Context theory (2012) which asserts that the detrimental effects of red may be seen in contexts where the fear of failure is sensed more. In this study because children are going to be tested alone and do not have the chance to compare their testing conditions with other participants and because they will be showed all rooms and explained the procedure beforehand, it is hypothesized that the color red will not create a context where the fear of failure hampers performance. Furthermore some other studies show an increase in performance in red conditions while solving detail-oriented tasks which require attention (Mehta & Zhu, 2009; Xia et al., 2016). Researchers assert that red may have a facilitating effect or no effect on performance nevertheless does not have an interference effect on cognitive performance (Xia et al., 2016).

Hypothesis 2: The color red on the board seen on Rooms RoW, and RoR will enhance performance for children with ADHD, reducing strong contrast with black lettering and provide less visual stress. Red will not cause a fear of failure because of experimental design of this study, furthermore will create an optimal arousal for children with ADHD, and increase their attention levels.

3. Red on the environment: Rooms WoR and RoR

Arousal theory suggests that there is an optimum level of arousal for everyone and performance is in its best on this optimum level. Lower or higher levels of arousal cause a decrease on performance.

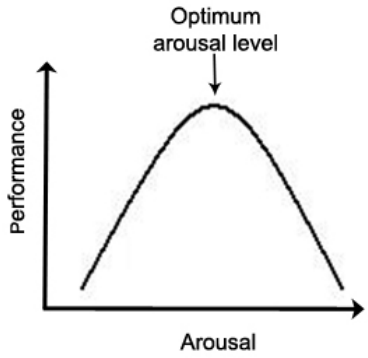

Figure 7. Graphic showing performance over arousal levels. Lower or higher levels from optimal arousal cause a decrease on performance (commons.wikimedia.org/wiki/File:Inverted_u.jpg)

The color red is said to be a stimulant color and create a heightened arousal (Kwallek, et al., 1997; Küller, Mikellides, & Janssens, 2009; Kwallek, & Lewis, 1990; Stone, 2003; Walters, Apter, & Svebak,1982). A number of studies have found that seeing red in the environment increases performance for the subjects (Kwallek & Lewis, 1990; Stone, 2003; Johnson & Ruiter, 2013; Kwallek, 1997). The findings are explained in line with the arousal theory, suggesting that red creates an optimal level of arousal for the participants. According to Zentall, Falkenberg, & Smith (1985) arousal theory would predict that added stimulation would be most beneficial for hyperactive children especially during those tasks that involve considerable repetition and monotony (e.g., sustained attention tasks). Furthermore additional

environmental stimulation has positive effects on motor activity and academic performance for people with ADHD (Iovino et al., 1998; Zentall & Shaw, 1980; Zentall & Zentall, 1983). Similarly the drugs which decrease ADHD symptoms are psychostimulants (Sürücü, 2016). In other words with added stimulation ADHD children perform better and their symptoms decrease.

Hypothesis 3.a: ADHD sample might benefit a higher level of arousal with the added stimulation to the environment. Thus the Rooms WoR, and RoW might increase performance creating an optimal arousal level.

Hypothesis 3.b: Too much red (Room RoR) might create too much arousal than the optimal level which might decrease performance. Similarly no added stimulation (Room WoW) might cause less arousal than the optimal level, again causing a decrease in performance.

4.4. Methodology

The experimental study was conducted with 48 boys who were diagnosed with ADHD Combined type, between the ages 7 and 9. They were all administered Wechsler Intelligence Scale for Children (WISC-IV) for mental evaluation by specialists. The participants took equivalent tests in four experimental conditions namely WoW Room with a white board on a white wall, RoW Room with a red board on a white wall, WoR Room with a white board on a red wall, and RoR Room with a red board on a red wall, in a

counterbalanced order. These rooms were created by painting red and white the walls of two rooms separated by a curtain. Red and white colored boards were mounted on the walls of these two rooms with equivalent tests printed on them. The equivalent tests created for this experiment were Reading Test, Coding test, Pair-Cancellation Test and Matching Test, all of which were prepared on the most troublesome areas for children with ADHD. Detailed information on how they relate to Processing Speed and Working Memory Indexes of Wechsler Intelligence Scale for Children and how the equivalency between tests is ensured is reported in this section together with detailed information on the sample used for the study.

4.4.1. Sample

The participants in the study consisted of 50 children who were diagnosed with ADHD and had mental evaluations in another concurrent study which received the necessary permits from both the parents and the children. Two children were excluded from the study, one because of severe learning disability and one because of an IQ score below 70 in the Wechsler Intelligence Scale for Children (WISC-IV). The first group of children (n=24) participated in the study within a two weeks period, after an intermission of two months the second group of children were taken in the experiment (n=26) to increase the sample size and to replace counterbalanced order of two participants excluded from the study. The sample was formed solely from

male participants to exclude the effect of gender on the test results and because there was not enough female student application since ADHD is about 2.28 times more likely to be diagnosed in boys than in girls (Ramtekkar et al., 2010). All participants are children with ADHD Combined type. They were also instructed not to use any medication that will affect their attention when they were being assessed. All participants had normal or corrected to normal vision.

The mean age was found to be 99.38 months (SD = 11.987). All participants attended school; 12 of which attended 2nd grade, 19 attended 3rd grade, and 17 attended 4th grade. It has been reported that there are few extensive studies on the development of executive functions according to ages in school-age children (Pureza, Gonçalves, Branco, Grassi-Oliveira, & Fonseca, 2013). When talking about the developmental characteristics of school-age children, there is no exact agreement about the age groups. In some studies investigating executive functions, age groups were used as 6-7, 8-10 and 11-12 years old (Pureza et al., 2013). In different researches, age groups are constructed as Early Childhood (5-6 years), Middle Childhood (7-9 years), Late Childhood (10-12 years) and Early Adolescence (13-14 years) (Brocki & Bohlin, 2004). Attention control seems to occur during infancy and in early childhood it improves quickly. Cognitive flexibility, goal setting and information processing, goes through an important period of development between the ages 7 and 9. These are generally matured by the age of 12 (Anderson, 2002). The education system in Turkey known as 4+4+4 brings a

new approach to this classification. The reason for the inclusion of 2nd-4th grade children to the current study is that in the 2nd grade literacy has been formed and children in the 5th grade will be moving to a different school system. In our study, the age of the children did not give any significant findings.

The participants were administered the Wechsler Intelligence Scale for Children (WISC-IV) for mental evaluation by specialists, for a concurrent study in Hacettepe University. Their scores for Verbal Comprehension Index (M = 102.21, SD = 10.431), Perceptual Reasoning Index (M = 97.23, SD = 13.016), Working Memory Index (M = 93.71, SD = 9.656), Processing Speed Index (M = 95.50, SD = 12.379) and Full Scale IQ scores (M = 98.67, SD = 10.186) were used for further investigation in this study.

4.4.2. Assessment Tools

The tests used in the study were prepared under expert supervision, and difficulty levels, visibility and legibility of the tests were confirmed with ten children in a pilot study prior to the experiments. A Matrix task inspired by the Matrix Reasoning test in Perceptual Reasoning Index of Wechsler Intelligence Scale for Children (WISC-IV) was also prepared however it was found to be too difficult and frustrating by the children in the pilot study therefore it was omitted in the real study. Other changes done on the tasks

after the pilot study are reported below under corresponding task definitions. Four tasks were prepared to measure the performance of the participants in different experimental conditions; reading, coding, pair cancellation and matching. Apart from the Reading task the tests were created based on the most problematic areas for children with ADHD; the Processing Speed Index and the Working Memory Index. Reading in children with ADHD is also reported to be deficient in some cases.

The reading test required children to read out loud a paragraph written on the board (see Appendix A-B). This test measures the subject's ability to read effectively. As ADHD children are known with making inattentive mistakes, adding or omitting letters, missing suffixes or prefixes, or reversing syllables while reading (Öktem, 1996; Öktem & Sonuvar, 1990; Öner & Aysev 2007; Sürücü, 2016) this test was aimed to see whether the different wall and board color combinations helped to reduce these problems. The equivalence of the test was attained with paragraphs prepared with equal length and difficulty. The reading test was assessed on four features; total reading time, words that the participant misread but corrected afterwards, words that the participant misread but did not correct, and total number of misread words.

The Coding test consisted of symbols corresponding to each letter of the Turkish alphabet (see Appendix C-D). The symbols were derived from the runic alphabet which was used to write various Germanic languages before the adoption of the Latin alphabet ("Runes", 2014). The participants were

required to write “TÜRKİYE” on their answer sheets using the symbols they see on the board (see figure 8). This test was inspired by the Coding sub-test which is used in every edition of Wechsler Tests. This sub-test measures the “skills in learning the coding process, visual-motor speed and complexity, motor coordination and attention” (Wechsler, 2004) and is a part of the Processing Speed Index where ADHD children are found to have the most difficulties (Chhabildas et al., 2001; Ek et al., 2007; Flanagan & Kaufman, 2009; Mayes & Calhoun, 2007; Penny et al., 2005; Shanahan et al., 2006; Solanto et al., 2007; Willcutt et al., 2005). In the pilot study it has been noted that because of the page design, children had difficulties to find whether the symbol below or above the letter corresponds to the correct answer. Therefore an empty space has been added between rows. For the equivalence of tests, same symbols are used for the correct answers of each test because drawing of different symbols may be of different difficulty. For all tests the word “TÜRKİYE” is used as the key word for symbols. However in each test different symbols correspond to different letters in the word. The places of the correct letters are kept the same in each test, and the letters are distributed randomly to these places. When scanning an image, some places are known to be looked first so the correct letters for the word TÜRKİYE are located on the same location in the matrix but in a random order. The coding test was assessed on two features; completion time and the number of incorrect answers.

Figure 8. Participant solving the Coding test in WoR room. His face is intentionally blurred for privacy reasons (personal archive of Zeynep Öktem)

The board for Pair Cancellation test showed a series of dog, cat and ball drawings on a random order and asked the participants to count the instances where a cat is followed by a ball on each row (see Appendix E-F). This test required the participant to look attentively at the board for a rather long period of time (see figure 9). This test was inspired by the Cancellation sub-test in Wechsler Intelligence Scale for Children (Wechsler, 2004) and Pair Cancellation sub-test in Woodcock-Johnson Achievement Tests

(Woodcock, Mather, & McGrew, 2001) in the Processing Speed Index. The original tests measure executive functions, attention and concentration, perceptual speed, processing speed, attention and concentration, and vigilance (Wechsler, 2004). Because this task necessitates the child to continually keep in mind the rule (cat followed by a ball), it also requires working memory skills. The test equivalence was attained by randomly altering the rows of cats, dogs and balls for each test. As participants are required to finish the test and not given a time limitation, equal number of rows were scanned by the participants. The pair cancellation test was assessed on four features; completion time, number of incorrect answers where the participant counted more instances than the correct answer, number of incorrect answers where the participant counted less instances than the correct answer, and total number of incorrect answers. If a child with ADHD counts less instances than the correct answer, it might be an indication of inattention where he misses the correct instances. When he counts more instances on the other hand, this might point to impulsivity where he counted the instances that did not abide the rule.

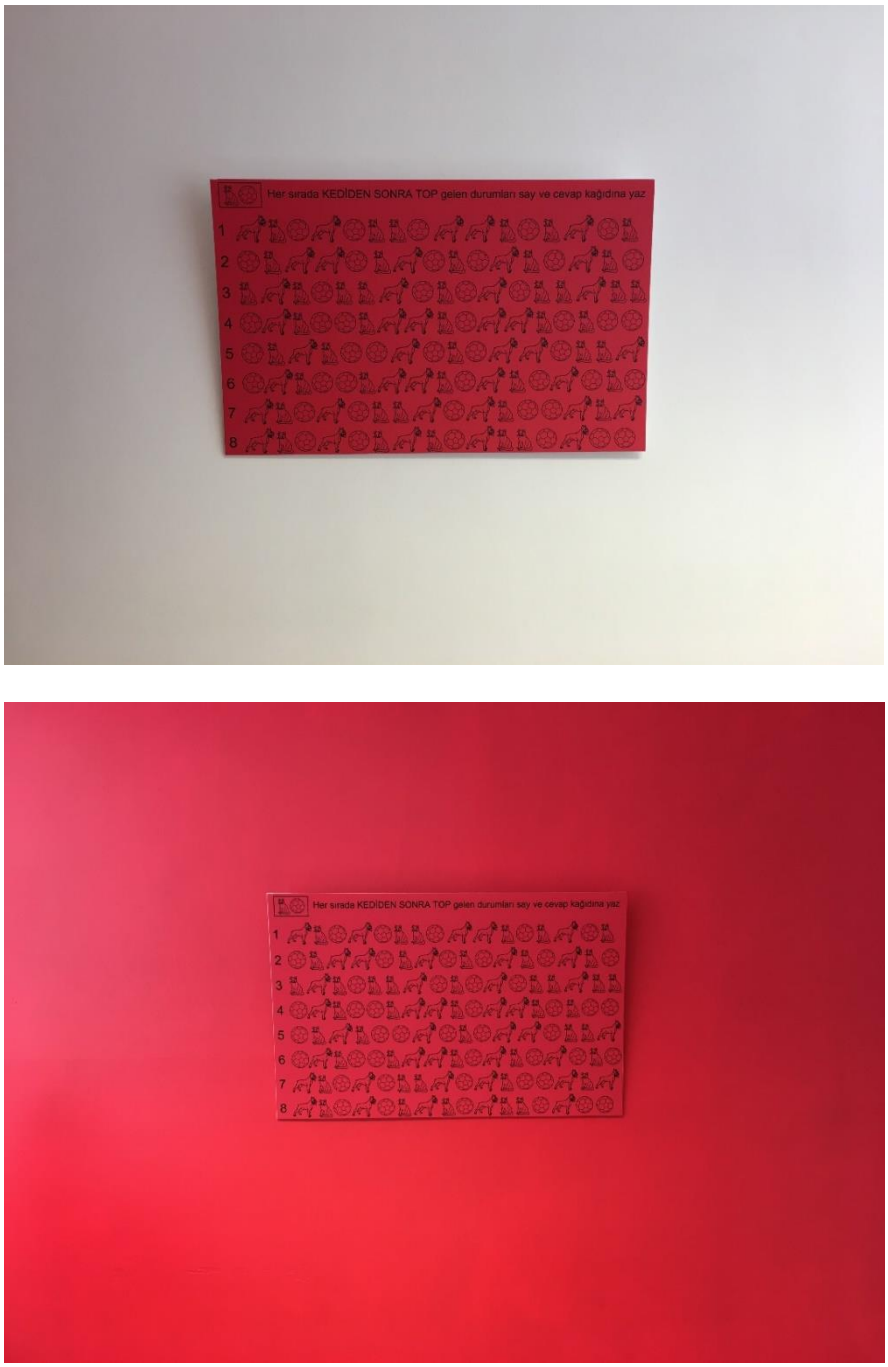

Figure 9. Pair Cancellation test in RoW and RoR rooms (personal archive of Zeynep Öktem)

The matching test required the participant to match the items on the left column with the ones on the right column (see figure 10). The items were made of three letters and three numbers, an example would be “bbd252”.

The letters chosen for the test are b, d, and p since these are the most confused letters due to their mirror images (see Appendix G-H). Likewise the numbers 2 and 5, and 6 and 9 are mostly troublesome for children with ADHD and learning disabilities, and thus selected for the test. The test is inspired by the Matching test used in a study by Ödemiş, Yener, & Camgöz (2004). This test, because it requires the subject to keep in mind the number and letter sequence while scanning the right column, can be interpreted as related to Working Memory.

Figure 10. Participant solving the Matching test in WoR room. His face is intentionally blurred for privacy reasons (personal archive of Zeynep Öktem)

For the test, participants were given three minutes and were asked to match as many as they can during this time. In the matching test the items were generated in three groups; those that have same letter sequencing and different number sequencing (eg. bbd965 & bbd252), those that have same number sequencing and different letter sequencing (eg. dbp256 & bdd256), and those that are unique in letter and number sequencing. The items in respective groups are then randomly assigned according to the same order for test equivalence. The place of the correct answer on the right column, whether it is above or below the misleading item was also carefully adjusted for each test. The items in respective groups are randomly assigned according to the rule below:

1. Unique
2. Unique
3. Same number (below)
4. Same letter (above)
5. Unique
6. Same letter (below)
7. Same number (above)
8. Unique
9. Unique
10. Same number
11. Same letter
12. Unique
13. Unique
14. Same letter
15. Same number
16. Same number
17. Same number
18. Same letter

The terms below and above refer to the place of the correct answer in the second column. Below items are placed below the matching pair which is the incorrect answer on the right-hand side column. For instance for the item dbp256 in Test A, the correct answer is placed below the item bdd256 on the right-hand side column. The matching test was assessed on three features; number of incorrect answers, number of correct answers and total number of answers.

The four tasks created for the experiment and their corresponding intelligence scale indexes in which the children with ADHD are found to have the most problems are shown in figure 11. Processing Speed and Working Memory Indexes correspond to Coding, Pair-Cancellation and Matching tasks. For the reading task research stating difficulties in reading and those showing improvements in reading with added stimulation are listed.

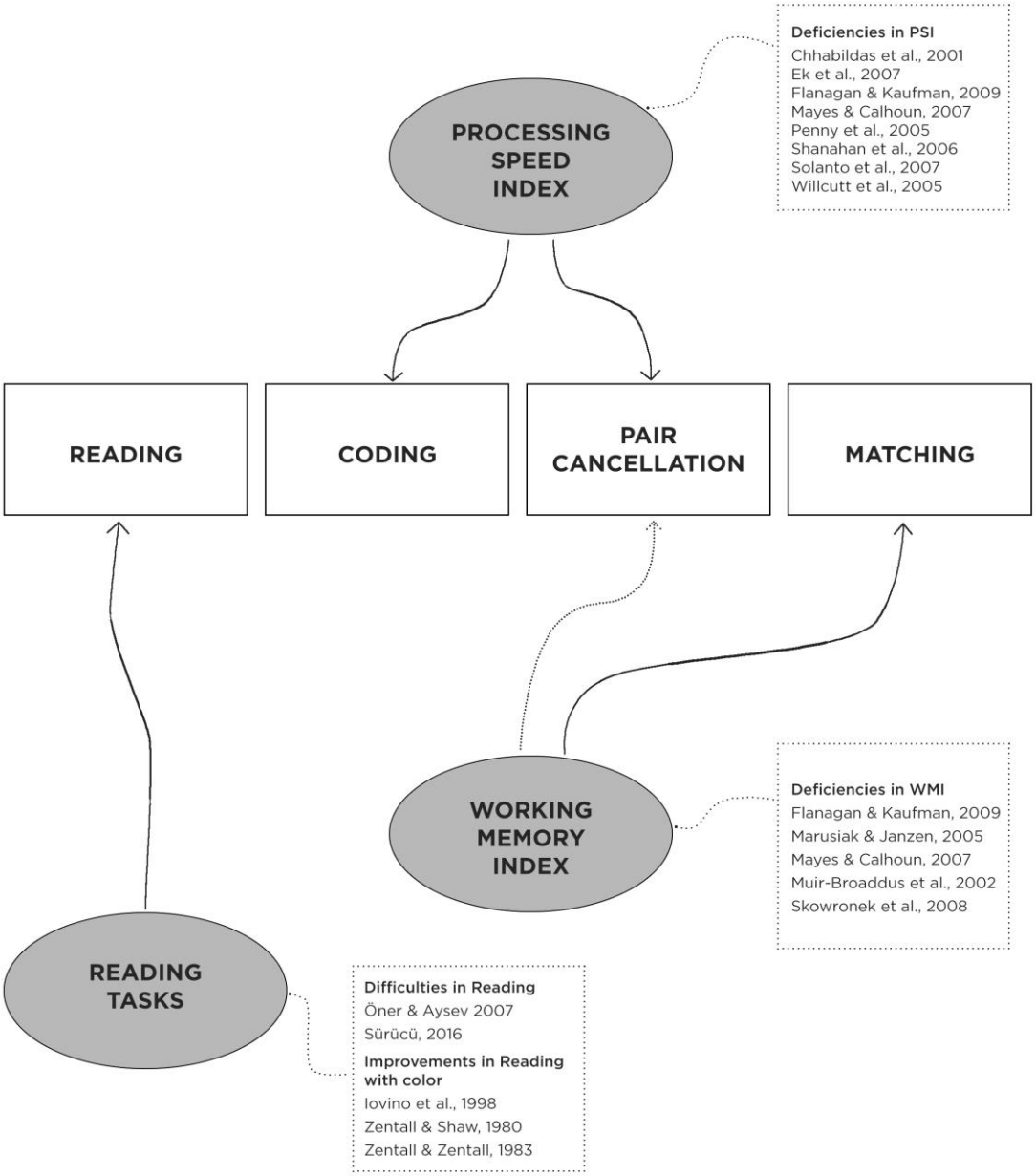

Figure 11. Tasks used in the study and corresponding intelligence scale indexes with information from the literature.

4.5. Conduct

In order to test ADHD children's performance in classroom environments that have different colored board and wall combinations, a rectangular room was divided into two with a white curtain. The first room had all walls painted white, in the second room the front wall where the boards are mounted was painted red (NCS 1070R). All windows were closed using white panels and white curtain to eliminate the effect of natural light and two identical light sources illuminated the two rooms from an equal distance in order to achieve an even lighting condition in both rooms. Fluorescent lamps with 6500 K color temperature were used for the ambient illumination. Measured by Minolta Illuminance Meter, the illuminance level on the working surface was 525 lx and 300 lx on the board.

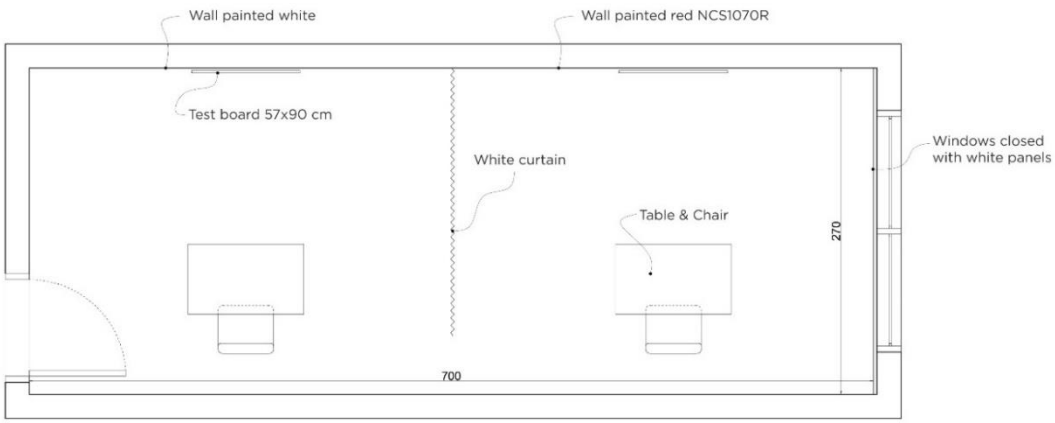

Figure 12. Plan of the two experimental rooms

Participants were seated 220 cm away from the boards on identical tables and chairs. 57x90 cm boards with test items printed on them were prepared in white and red (NCS 1070R) colors. These boards were mounted in turn on

the front walls of the two rooms. This settlement created four experimental conditions: a white board on a white wall (WoW), a red board on a white wall (RoW), a white board on a red wall (WoR) and a red board on a red wall (RoR) seen in Figure 13. Parents were informed about the experiment and gave consent for their children to take part in the study.

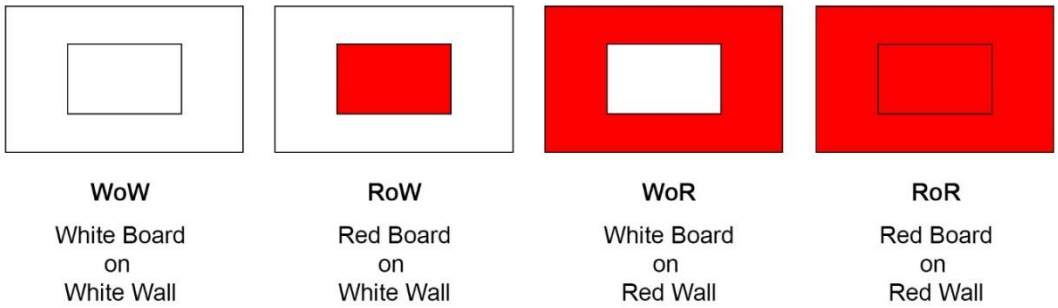

Figure 13. The four experimental conditions: WoW, RoW, WoR and RoR

Upon entering the testing place, participants and parents who gave consent for participation were shown the two rooms and were explained the procedure. Children were instructed beforehand with an example of each test and told what was expected from them in these tests. After this information is given, participants were asked again if they still would like to participate in the study. They were taken in the study after giving this consent. Each participant took equivalent tests in the four experimental setting. The order of the experimental conditions was counterbalanced. Upon finishing a test in one experimental condition the child was taken to another room where he played an entertaining game of quoits and smashed empty eggshells to collect points which at the end rewarded them with a little present like ball shaped pencil sharpeners, key chains or plastic dinosaurs.

The study was approved by Bilkent University Ethics Committee. (Ethics Committee no: 2018_08_08_01).

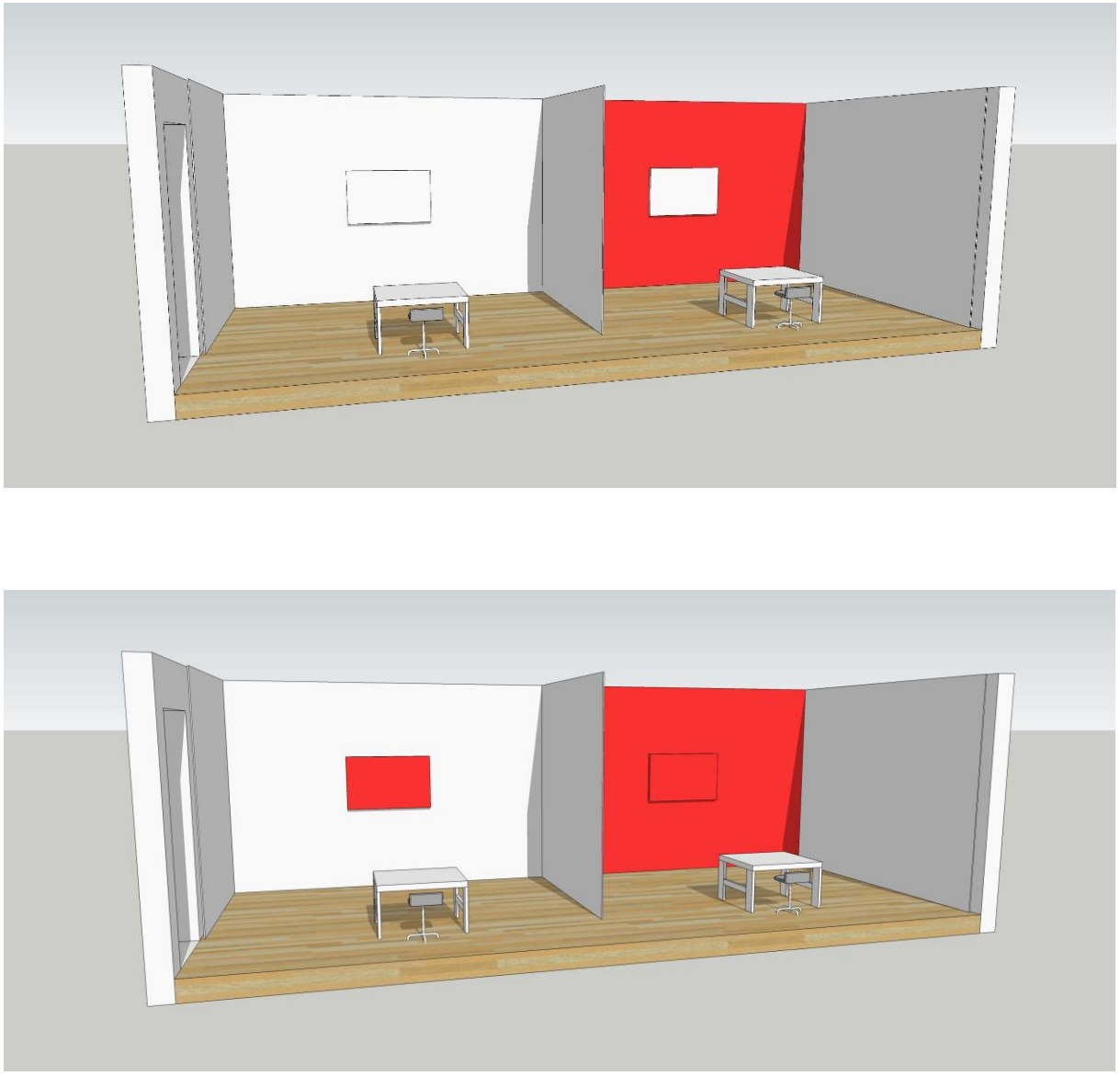

Figure 14. 3D representation of experimental conditions WoW and WoR on top, RoW and RoR on the bottom

CHAPTER 5

DATA ANALYSIS OF THE EXPERIMENTAL STUDY

The data from the experimental study consists of test scores of 48 boys who were diagnosed with ADHD Combined type, between the ages 7 and 9. They were all administered Wechsler Intelligence Scale for Children (WISC-IV) for mental evaluation by specialists. The equivalent tests created for this experiment were Reading Test, Coding test, Pair-Cancellation Test and Matching Test, all of which were prepared on the most troublesome areas for children with ADHD. In general participants' incorrect answers and finishing times were assessed in these tests. Additionally in the Reading test children's misread words which they corrected afterwards and those that they did not correct were assessed separately since self-correction is a desirable quality for these children while reading. Similarly in the Pair-Cancellation Test apart from completion time and total number of incorrect answers, number of incorrect answers where the participant counted more instances than the correct answer, and the number of incorrect answers where the participant

counted less instances than the correct answer were assessed separately since these may show impulsivity or inattention respectively.

Participants took four equivalent tests in each board and wall color conditions; white board on white wall (WoW), red board on white wall (RoW), white board on red wall (WoR), and red board on red wall (RoR). The order of these rooms were counterbalanced, and the order of the tests were fixed. The results were analyzed with one-way repeated measures ANOVA in Statistical Package for the Social Sciences (SPSS) 24.0 program. Children's Processing Speed Index (PSI) and Working Memory Index (WMI) scores from WISC-IV Wechsler Intelligence Scale for Children were also used as a covariate in one-way repeated measures ANCOVA since the tests were prepared mostly in these more problematic areas for children with ADHD. All scores from the tests and the cases where PSI and WMI scores create a difference when used as a covariate are reported in this chapter.

5.1. Reading Test

The reading test was assessed on four features; (1) total reading time, (2) words that the participant misread but corrected afterwards, (3) words that the participant misread but did not correct, (4) total number of misread words. A one-way repeated measures ANOVA was conducted to compare the effects of different board and wall color combinations on these four features in WoW, RoW, WoR and RoR conditions. There was not a significant effect

of board and wall color combinations on total reading time (ε= 29.750, F(3, 124)=.238, p>.05, μ=.005), on the number of misread words corrected afterwards (ε= .89, F(3, 139)=.38, p>.05, μ=.008), on the number of misread words not corrected afterwards (ε= 1.766, F(3, 123)=.362, p>.05, μ=.008), or on the total number of misread words (ε=.292, F(3, 135)=.045, p>.05, μ=.001). Figure 15 provides the mean values for reading time measured in seconds. Figure 16 shows the mean values for corrected and not corrected misread words. Although a significant difference could not be found, it is worth to remark that the participants corrected their mistakes by re-reading more in RoW and WoR conditions, in other words in rooms where the wall and board colors are different, providing a framing effect of the board. Experts assert that although it is not always possible for children with ADHD to avoid making mistakes, it is a desirable quality if they could realize their mistakes and correct them in their academic life.

Table 4. Reading time in seconds in the Reading Test

	Mean	Std. Deviation	N
WoW	41.88	12.767	48
RoW	41.46	13.086	48
WoR	40.83	15.341	48
RoR	41.08	15.074	48

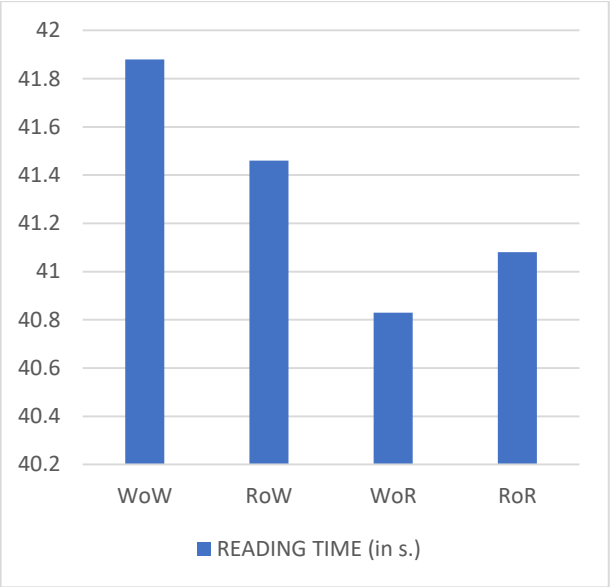

Figure 15. Mean values for reading time measured in seconds

Table 5. Total number of misread words in the Reading Test

	Mean	Std. Deviation	N
WoW	2.92	2.112	48
RoW	2.85	2.193	48
WoR	2.81	2.472	48
RoR	2.83	2.253	48

Table 6. Number of words that the participant misread but corrected afterwards in the Reading Test

	Mean	Std. Deviation	N
WoW	.83	.996	48
RoW	.96	1.254	48
WoR	.98	1.082	48
RoR	.83	1.117	48

Table 7. Number of words that the participant misread but did not correct in the Reading Test

	Mean	Std. Deviation	N
WoW	2.08	1.944	48
RoW	1.90	2.076	48
WoR	1.83	2.107	48
RoR	2.00	2.212	48

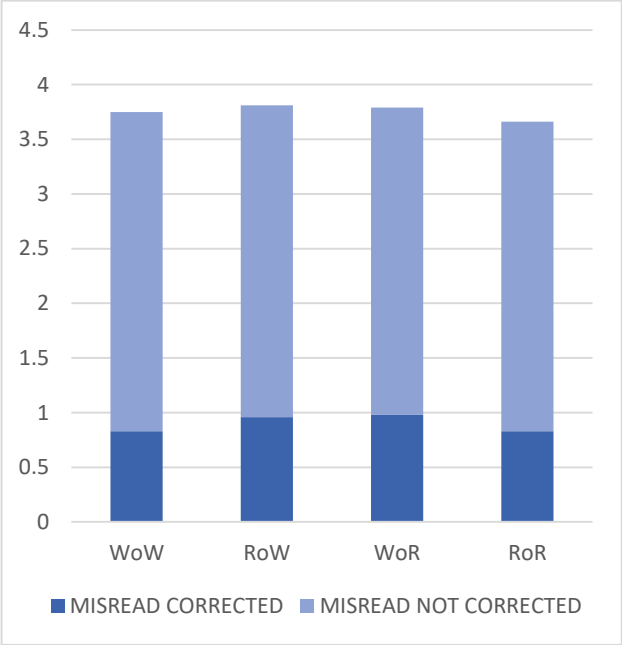

Figure 16. Mean values for words that the participant misread but not corrected afterwards, words that the participant misread but corrected afterwards, and total number of misread words in the Reading Test

5.2. Coding Test

The coding test was assessed on two features; (1) completion time, and (2) number of incorrect answers.

A one-way repeated measures ANOVA was conducted to compare the effects of different board and wall color combinations on the completion time and incorrect answers in the coding test in WoW, RoW, WoR and RoR conditions. No significant effect of board and wall color combinations could be found on completion time (ε=1359.224, $F(3, 128)=.998$, $p>.05$, $\mu=.021$). There was a significant effect of board and wall color combinations on incorrect answers (ε=9.708, $F(3, 114)=7.27$, $p<.001$, $\mu=.134$). Pairwise Comparisons with Bonferroni adjustment for multiple comparisons have shown that WoW condition (M=1.06, SD=1.156) is significantly different than RoW (M=.54, SD=.651) and WoR (M=.56 SD=.741) conditions, and has the highest incorrect answer rate among all conditions. On the other hand there is no significant difference between WoW (M=1.06, SD=1.156) and RoR (M=.92, SD=1.145) conditions. RoR (M=.92, SD=1.145) condition is found significantly different than RoW condition (M=.54, SD=.651) which has the lowest rate of incorrect answers among all conditions. The pilot diagram for the number of incorrect answers in board and wall color combinations is shown in Figure 17. Analyses suggest that the number of incorrect answers in the coding test can be 14% explained with the change of board and wall color combinations. In this test it can also be observed that Processing Speed scores of participants as a covariate has a significant effect on the outcome ($F(1,46)=5.2$, $p<.05$).

Table 8. Completion time in seconds in the Coding Test

	Mean	Std. Deviation	N
WoW	99.58	33.858	48
RoW	92.25	27.791	48
WoR	96.52	35.136	48
RoR	97.38	29.189	48

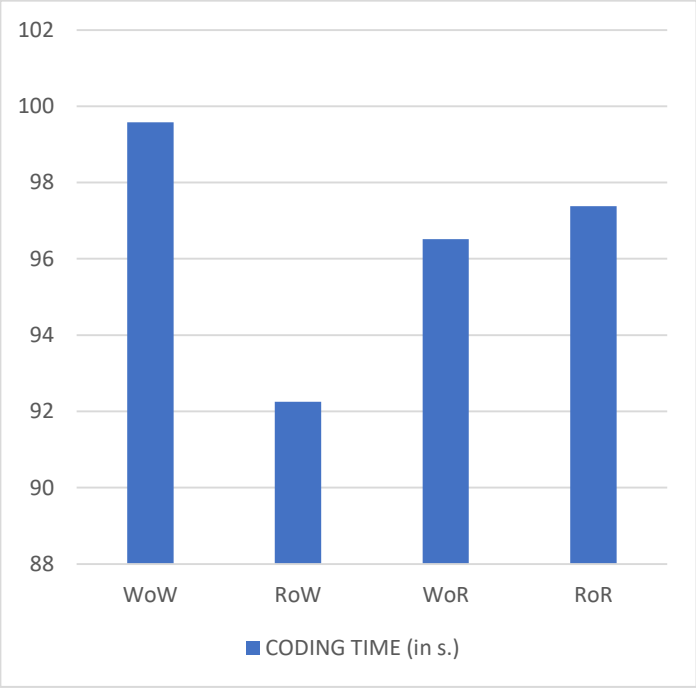

Figure 17. Mean values for coding time measured in seconds.

Table 9. Number of incorrect answers in the Coding Test

	Mean	Std. Deviation	N
WoW	1.06	1.156	48
RoW	.54	.651	48
WoR	.56	.741	48
RoR	.92	1.145	48

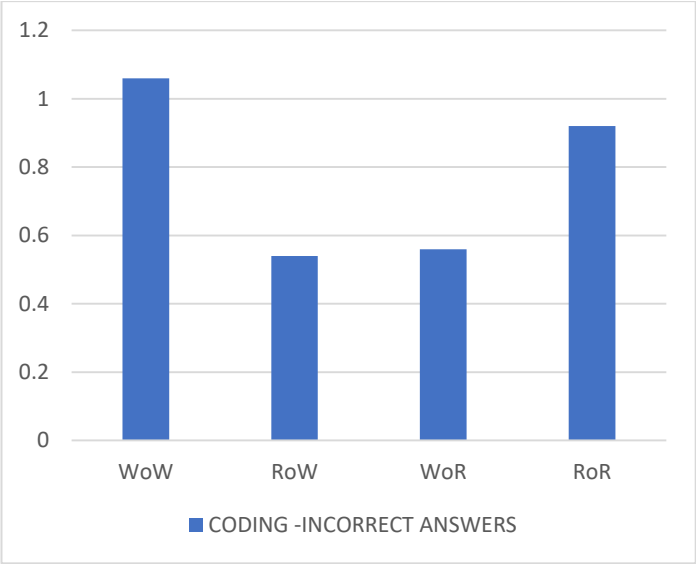

Figure 18. Mean values for incorrect answers in the coding test.

5.3. Pair Cancellation Test

The pair cancellation test was assessed on four features; (1) completion time, (2) number of incorrect answers where the participant counted more instances than the correct answer, (3) number of incorrect answers where the participant counted less instances than the correct answer and (4) total number of incorrect answers.

A one-way repeated measures ANOVA was conducted to compare the effects of different board and wall color combinations on the completion time of the test in WoW, RoW, WoR and RoR conditions. A significant effect of board and wall color combinations on the completion time has been found (ε=1572.292, $F(3, 134)=3.193$, $p<.05$, μ=.064). Pairwise Comparisons with Bonferroni adjustment for multiple comparisons showed that participants performed significantly faster in RoR condition ($M=80.27$, $SD=24.875$) than in

WoW condition (M=87.75, SD=29.154). The pilot diagram for the completion times in board and wall color combinations is shown in Figure 19.

As a result of the one-way repeated measures ANOVA, no significant effects of board and wall color combinations were found on the number of incorrect answers where the participant counted more instances than the correct answer (ε=.125, F(3, 120)=.168, p>.05, μ=.004), on the number of incorrect answers where the participant counted less instances than the correct answer (ε=.104, F(3, 138)=.048, p>.05, μ=.001), or on the total number of incorrect answers (ε=.229, F(3, 137)=.084, p>.05, μ=.002).

Table 10. Completion time in seconds in the Pair Cancellation Test

	Mean	Std. Deviation	N
WoW	87.75	29.154	48
RoW	86.67	27.887	48
WoR	85.23	23.365	48
RoR	80.27	24.875	48

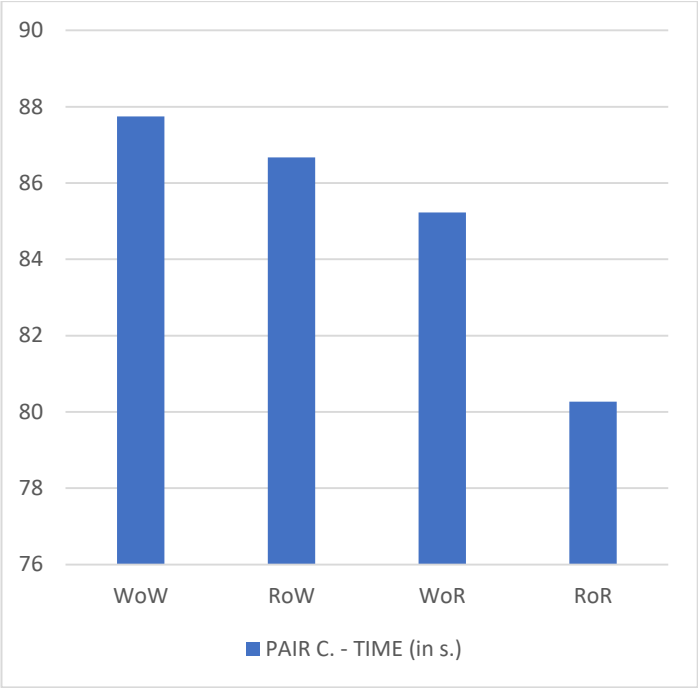

Figure 19. Mean values for pair cancellation time measured in seconds.

Table 11. Number of incorrect answers where the participant counted more instances than the correct answer in Pair Cancellation Test

	Mean	Std. Deviation	N
WoW	.73	1.455	48
RoW	.71	1.320	48
WoR	.71	1.383	48
RoR	.77	1.403	48

Table 12. Number of incorrect answers where the participant counted less instances than the correct answer in the Pair Cancellation Test

	Mean	Std. Deviation	N
WoW	.77	1.077	48
RoW	.75	1.120	48
WoR	.71	1.166	48
RoR	.73	1.300	48

Table 13. Total number of incorrect answers in the Pair Cancellation Test

	Mean	Std. Deviation	N
WoW	1.50	1.650	48
RoW	1.46	1.557	48
WoR	1.42	1.596	48
RoR	1.50	1.738	48

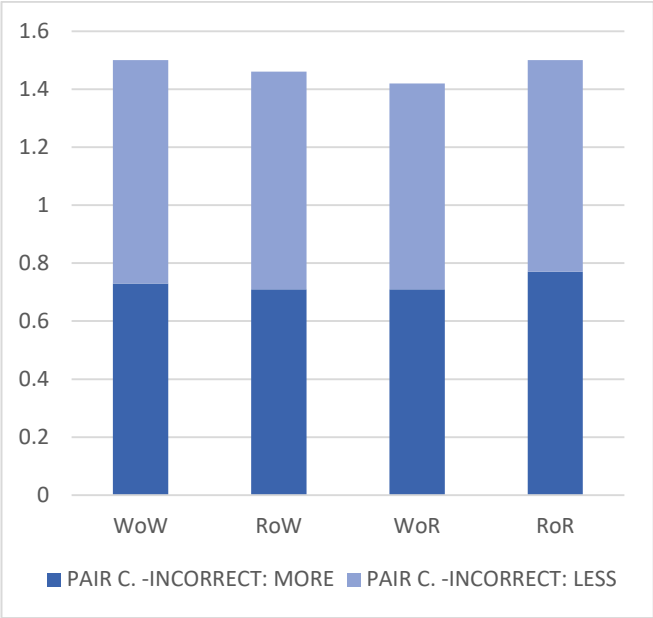

Figure 20. Mean values for number of incorrect answers where the participant counted more instances than the correct answer, number of incorrect answers where the participant counted less instances than the correct answer and total number of incorrect answers in the pair cancellation test.

5.4. Matching Test

The matching test was assessed on three features; (1) number of incorrect answers, (2) number of correct answers, and (3) total number of answers.

A one-way repeated measures ANOVA was conducted to compare the effects of different board and wall color combinations on the total number of incorrect answers in the matching test, in WoW, RoW, WoR and RoR conditions. There was a significant effect of board and wall color combinations on the number of incorrect answers (ε=12.474, $F(3, 122)=3.261$, $p<.05$, μ=.065). However, there is no significant difference between the number of incorrect answers given in different board and wall color combinations (i.e WoW, RoW, WoR and RoR conditions) at $p<.05$ level.

The significant difference between board and wall color conditions are visible after controlling for Working Memory scores, that is when participants' scores in the Working Memory Index in the Wechsler Tests were used as covariate. A one-way repeated measures ANCOVA was conducted to determine a statistically significant difference between WoW, RoW, WoR and RoR conditions, on the number of incorrect answers in Matching test, controlling for Working Memory scores of the participants. There is a significant effect of board and wall color combinations on the number of incorrect answers after controlling for Working Memory scores ($F(3, 126)=7.266$, $p<.01$, μ=.136).

After controlling for Working Memory scores, pairwise comparisons with Bonferroni adjustment for multiple comparisons showed that WoR condition (M=1.63, SD=1.231) was significantly different than WoW (M=2.27, SD=1.8) and RoR (M=2.19 SD=1.593) conditions, and has the lowest incorrect answer rate among all conditions. On the other hand there is no significant difference between WoR (M=1.63, SD=1.231) and RoW (M=1.90, SD=1.341)

conditions. The pilot diagram for the number of incorrect answers in board and wall color combinations is shown in Figure 21. Analyses suggest that the number of incorrect answers in the coding test can be 13% explained with the change of board and wall color combinations when working memory scores are controlled.

Table 14. Number of incorrect answers in the Matching Test

	Mean	Std. Deviation	N
WoW	2.27	1.795	48
RoW	1.90	1.341	48
WoR	1.63	1.231	48
RoR	2.19	1.593	48

Table 15. Number of correct answers in the Matching Test

	Mean	Std. Deviation	N
WoW	6.92	3.332	48
RoW	6.98	3.504	48
WoR	7.00	3.128	48
RoR	6.56	3.045	48

Table 16. Total number of answers in the Matching Test

	Mean	Std. Deviation	N
WoW	9.19	2.958	48
RoW	8.88	3.431	48
WoR	8.63	2.980	48
RoR	8.75	3.172	48

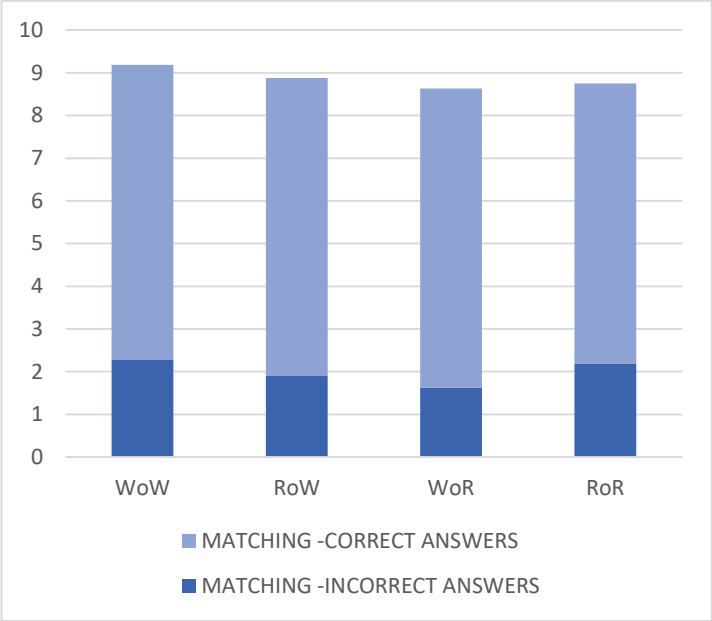

Figure 21. Mean values for number of incorrect answers, number of correct answers, and total number of answers in the matching test

For the number of correct answers, and total number of answers in the matching test, a one-way repeated measures ANOVA was conducted with and without PSI and WMI as covariates. No significant effect of board and wall color combinations was found on the number of correct answers (ε=6.021, $F(3, 138)$=.367, $p>.05$, μ=.008) nor on the total number of answers (ε=8.391, $F(3, 133)$=.517, $p>.05$, μ=.011).

CHAPTER 6

DISCUSSION

The main purpose of this study was to demonstrate the effects of an accent colored front wall in classrooms on the performance of children with ADHD. This suggestion although have been mentioned in the literature has not been tested before. Furthermore research on the effects of color on children's performance could be identified as scarce. With the ADHD population those studies which investigated color's effect are the ones which used color on testing or reading material and the effects of color when used as an environmental element is unknown. The study aimed to fill these gaps in the literature.

Painting the wall behind the board in the classroom both introduces color to the environment and visually frames the board. The experimental setting of the study provided means to investigate the effects of framing and the color red both when it is used on the test material and on the environment. The crossing of wall and board colors created two rooms where framing can be

observed, in other words where wall and board colors are different from each other (rooms WoR and RoW), two rooms where there is no framing (rooms WoW and RoR), two rooms where color is used on the testing material (rooms RoW and RoR) and two rooms where color is used as an environmental element (rooms WoR and RoR). When the repeated test scores of children with ADHD are analyzed significant differences have been found. These findings will be discussed in connection with the hypotheses mentioned in Chapter 4.

6.1. Discussion of Findings of the Experimental Study

The first hypothesis was that the framing effect seen on Rooms RoW and WoR would help children with ADHD to focus more on the board and lead to a better performance on tasks. They were expected to make less errors and have more correct answers. Significant differences found in the number of incorrect answers in Coding and Matching tests may indicate the importance of framing the board for the attention levels of children with ADHD.

In the Coding test, the ADHD sample in the study made significantly less errors in RoW and WoR conditions than in WoW condition. These former two conditions are the ones where wall and board colors were different from each other, thus provide a framing effect for the board. Similarly children made significantly less errors in RoW condition than in RoR condition which provides no framing effect as both the wall and board are painted red.

In the Matching test a significant effect of board and wall color combinations on the number of incorrect answers may be observed as well. After controlling for Working Memory scores of the sample, WoR condition was found significantly different than WoW and RoR conditions, having the lowest incorrect answer rate among all conditions. On the other hand, there is no significant difference between WoR and RoW conditions both providing a framing effect.

These findings showing that the sample made less errors in conditions where the board and wall colors were different than each other support the idea that children with ADHD may benefit from a framing effect on their study materials as Boring (2002) suggested. This improvement in performance may be due to framing decreasing the large saccades of ADHD children found in a number of studies (Deans et al., 2010; Gould et al., 2001; Munoz et al., 2003; Rommelse et al., 2008; Ross, et al., 2000) where children with ADHD move their eyes away from the target stimuli causing an interruption in fixation.

Although no differences could be found, it is worth mentioning that in the reading test children corrected their mistakes more in the RoW and WoR conditions which provide again a framing effect. Due to their impulsivity and inattentiveness, preventing mistakes is not always easy however noticing these mistakes and correcting them is a desired quality for children with ADHD.

The second hypothesis was that the color red on the board seen on Rooms RoW, and RoR would enhance performance for children with ADHD, reducing strong contrast with black lettering and provide less visual stress. It was hypothesized that red would not cause a fear of failure because of the experimental design of this study, furthermore it was expected that it would create an optimal arousal for children with ADHD, and increase their attention levels. In the Coding test in term of number of errors RoW condition was found to be better than WoW condition yet so was the WoR condition which used a white board. Furthermore children made significantly less errors in RoW condition compared to RoR condition both of which used the color red on the testing material. Therefore it can be said that the significant difference in this case stems from the framing effect. Similarly in the Matching test no significant difference between WoR and RoW conditions were observed. These two both provided a framing effect with one having a red board and the other a white one. Consequently it can be said that the color red had no effect when used on the testing material, contrary to some previous research which suggest that seeing red hurts performance (Elliot et al., 2007; 2009; Gnambs et al., 2015; Lichtenfeld, et al., 2009; Maier et al., 2008; Shi et al., 2015).

The results can be interpreted in line with previous research which found no effect of color red on performance when used on a testing material (Arthur Jr. et al., 2016; Larsson & Stumm, 2015; Martinez et al., 2010; Smajic et al., 2014). The findings of this study are in line with the statement by Xia et al. (2016, p.5), claiming that red may have a “facilitating effect” in some tasks

but does not have an “interference effect” on cognitive performance. Furthermore none of these aforementioned studies were realized with children nor with people who has ADHD. The effect of hue is investigated with the ADHD sample in the colored overlay study by Iovino et al. (1998) which examines the effects of red, and blue overlay and none overlay on performance. In this research red is found to be the most beneficial overlay color for children with ADHD.

In this respect it is important to note that in the current study, regardless of where red is used, be it on the board or on the wall, or both, when color was introduced to the environment a better performance was observed compared to the WoW condition in three of the four tests administered to the participants. In the Coding test children made significantly less errors in RoW and WoR conditions than in WoW condition; in the Matching test there were significantly less incorrect answers in WoR condition than there were in WoW condition; in the Pair-Cancellation test children performed faster in the RoR condition than in the WoW condition. Therefore it can be argued that a positive effect of red is present, or at least it does not have a detrimental effect on performance in this case. Thus the study supports the research findings which state that children with ADHD perform better in presence of optimal stimulus if the stimulation is related to the task and not competing with it (Baijot, et al., 2016; Greenhop & Kann, 2007; Imhof, 2004; Iovino et al., 1998; Lee & Asplen, 2004; Lee & Zentall, 2002; Söderlund et al., 2007; Yang et al., 2014; Zentall, 1975; 1986; 2005; Zentall et al., 1985; 2000; Zentall & Meyer, 1987; Zentall & Zentall, 1983). The color red being an

arousing color may have stimulated the children with ADHD compared to no stimulus WoW room which had white walls and a white board.

The third hypothesis was about the use of color red in the environment rather than on testing material. It was hypothesized that the ADHD sample might benefit a higher level of arousal with the added stimulation to the environment. Consequently the Rooms WoR, and RoW were expected to increase performance creating an optimal arousal level. This assumption was made due to previous studies that used red as an environmental element and demonstrated an increase in performance of the participants (De Korte, Kuijt & Van Der Kleij, 2011; Johnson & Ruiter, 2013; Kwallek, & Lewis, 1990; Kwallek et al., 1996; Rajae-Joordens, 2010) or an increase in speed (Küller, Mikellides, & Janssens, 2009). As Al-Ayash et al. (2016) claim colors with arousing properties stimulate neural activity and could be more suitable for learning.

In the current study as discussed previously rooms which had red either as a wall color or board color show a significant increase in performance compared to all white condition which is in line with the aforementioned studies using color in the environment. The reason why a decrease in performance is not seen in these studies could be explained as Von Castell et al. (2018) put it, when encountered on test material participants might associate red with red marks on an exam paper signaling failure, however when the color is perceived in the environment no such association takes place. Elliot and Maier’s color-in-context theory (2012) although does not

make the distinction of place of use of red, explain the difference in performance similarly, saying that those studies which did not found a detrimental effect of red failed to create a context where the fear of failure or danger is sensed. Therefore it can be argued that the association of red with failure or danger might be sensed more when encountered on a more personal material like test books or answer sheets. If the environment is perceived as a shared space and not specifically altered for one person, it is likely that it does not evoke feelings of avoidance, danger, or failure like in the case of the current study. In the experimental study it was hypothesized that because children were going to be tested alone and do not have the chance to compare their testing conditions with other participants and because they were going to be showed all rooms and explained the procedure beforehand, the color red would not create a context where the fear of failure hampers performance. It can be said that this hypothesis was confirmed since no detrimental effect of red could be found in the study.

This result does contradict however with one study which used red not on the test material but as an environmental element. In the study by Brooker & Franklin (2016) researchers had put colored boards in front of children in a classroom and found out that those who solved questions in front of a red board had lower scores. In this study introduction of color was not on the testing material however different colored boards were randomly assigned to children in a classroom which might be perceived as more personal thus might have created a fear of failure in those who were assigned the red boards.

In hypothesis 3 another assumption was made stating that too much red in Room RoR might create too much arousal than the optimal level which might decrease performance. Similarly it was hypothesized that no added stimulation (Room WoW) is associated with less arousal than the optimal level, again causing a decrease in performance. It is true that WoW room, despite its name, did not wow the participants, they performed worse compared to more stimulant rooms. However in terms of finishing times of the tests a significant difference between wall and board color combinations is observed in the Pair Cancellation test. The results show that children finished the test significantly earlier in RoR condition than in WoW condition. Number of correct or incorrect answers did not show a significant difference. Although not statistically significant, it is observed that speed increases as the amount of red in the environment increases. This finding may be interpreted parallel to the Arousal Theory, and several studies which define red as an arousing color (Küller et al., 2009; Kwallek & Lewis, 1990; Kwallek, Lewis, & Robbins, 1988; Stone, 2003; Walters et al., 1982). Specialists claim that added stimulation in the environment has positive effects on academic performances of children with ADHD (Iovino et al., 1998; Zentall et al., 1985; Zentall & Shaw, 1980; Zentall & Zentall, 1983). Similarly, the medications that decrease ADHD symptoms are psychostimulants (Sürücü, 2016). Other studies also found that seeing red in the environment resulted in an increase of speed (Küller et al., 2009). In this study it can be said that the ADHD sample benefited a higher level of arousal with the added stimulation to the

environment and performed faster. Thus the hypothesis that too much red would hamper performance is rejected.

Significant differences between board and wall color conditions found on Pair Cancellation, Coding and Matching tests but not on the Reading test might be because the first three were prepared according to the most problematic areas for ADHD children in IQ tests; Processing Speed Index (Chhabildas et al., 2001; Ek et al., 2007; Mayes & Calhoun, 2007; Penny et al., 2005; Shanahan et al., 2006; Solanto et al., 2007; Willcutt et al., 2005) and Working Memory Index (Marusiak et al., 2005; Mayes & Calhoun, 2007; Muir-Broaddus et al., 2002; Skowronek et al., 2008). Thus, the changes in the environment might be beneficial for more difficult tasks and not automatic skills like reading.

To sum up significant differences between the board and wall color combinations in all tests in the study except for the reading test, demonstrate that color plays an important role in learning spaces. This study may be a contribution to findings indicating color as one of the most important design parameters for classrooms (Barrett et al., 2013). The findings of this study are parallel to the remarks of several authors who discuss the importance of a different colored main activity wall in classrooms, stating that it reduces eyestrain, relieves fatigue and over-stimulation and draws the attention to the front of the classroom (Engelbrecht, 2003; Mahnke, 1996; Mahnke & Mahnke, 1987). Furthermore, this study adds to the literature which states that the ADHD population is susceptible to color and show improvements in

academic performance with color (Falkenberg & Smith, 1985; Imhof, 2004; Iovino et al., 1998; Zentall, 1986; Zentall & Zentall, 1983). It is hoped that this study adds to the sparse literature of children with ADHD and color.

6.2. Implications for Environmental Design

The quality of the physical environment in classrooms play an important role in the learning process of its occupants, maybe even more so for the inattentive group who is more susceptible to external stimuli compared to their peers. Providing comfort conditions for physical environment of classrooms plays an active role in achieving the objectives of education. Unfortunately there are a limited number of empirical studies about an ideal color scheme of a classroom. In a comprehensive study in UK about classroom design schemes, color is found to be one of the six design parameters and second most important affecting a pupil's learning progression (Barrett, Zhang, Moffat, & Kobbacy, 2013). Similarly in the current study different wall and board color combinations have shown different effects on the performances of the participants.

The findings of the study show an increase of performance especially when the color of the wall and the board were different than each other, that is framing the board with a different wall color is likely to improve performance causing less mistakes. In one task finishing time of the task is found to be shorter with the red color used in the experimental study. It is hypothesized

that red being an arousing color increased speed of the participants as also suggested in the literature (Küller et al., 2009; Kwallek & Lewis, 1990; Kwallek, Lewis, & Robbins, 1988; Stone, 2003; Walters et al., 1982).

It could be said that painting the front wall of a classroom an accent color, because it provides the framing of the board and introduces color to the environment could be a helpful solution for classrooms. A white board on a white wall could be described as being rather dull and lacking added stimulus in a classroom environment which could have helped children with ADHD for their academic performance. Beeing a rather inexpensive transformation painting the front wall of a classroom is easily applicable in education environments. In terms of the choice of color for the front wall, in the current study only the color red has been tested which has not caused a decrease in performance, contrary to some previous research using red on testing material. Future research about other colors to be used for the front wall would be valuable for education environments. Furthermore with the increasing use of smart boards in classrooms, background color of the board could be more easily used and experimented for better performance of the pupils. The current study is conducted with male participants with an ADHD Combined type diagnosis. Because these children generally have education in the same classroom with their non-ADHD peers, it is necessary to determine how framing and color affects other children that do not have ADHD, in order to generalize the study findings.

CHAPTER 7

CONCLUSION

Children with Attention Deficit Hyperactivity Disorder face many challenges in their academic lives. As one of the most commonly diagnosed childhood disorders the prevalence of ADHD is said to be between 3% to 10% of population (Faraone, Sergeant, Gillberg, & Biederman, 2003; Öner & Aysev, 2007). Children with ADHD often exhibit inability to focus and maintain attention. They have hard time dealing with distractors and reported to be hypersensitive to stimuli. Therefore in classroom environments teachers often complain about their daydreaming or excessive speaking, and fidgeting. Children with ADHD have hard time leaving entertaining activities and are unable to bear uninteresting situations, much more so than their non-ADHD peers. Because of their inability to pay attention and concentrate they have difficulty in following and executing instructions (Sürücü, 2016). Subsequently ADHD is a condition that is linked with underachievement in education (Raggi & Chronis, 2006). Most children with ADHD have impulse control problems. Some theories suggest that the main cognitive deficit of children with ADHD is the deficiencies in inhibitory control which lead to secondary cognitive

problems resulting in inattention, hyperactivity and impulsivity (Barkley, 1997).

Children with ADHD are reported to show differences compared to their non-ADHD peers not only in these behavioral aspects but also in terms of perception and cognitive characteristics. For instance they are found to have deficits in blue/yellow color perception (Banaschewski et al., 2006; Silva & Frere, 2011; Tannock et al., 2006). They also exhibit color processing problems on tasks requiring rapid and/or continuous processing of colored stimuli (Brock & Knapp, 1996; Carte, Nigg & Hinshaw, 1996; Houghton et al., 1999; Lawrence et al., 2004).

In intelligence scales most noticeable difference of children with ADHD compared to normal population is their lower scores on Processing Speed Index (Chhabildas et al., 2001; Ek et al., 2007; Mayes & Calhoun, 2007; Penny et al., 2005; Shanahan et al., 2006; Solanto et al., 2007; Willcutt et al., 2005) and Working Memory Index (Marusiak et al., 2005; Mayes & Calhoun, 2007; Muir-Broaddus et al., 2002; Skowronek et al., 2008). The tests used in this study, except from the reading test are therefore prepared on these most problematic areas.

The treatment for ADHD is usually done with psychostimulant medications. These children are also found to respond positively to added stimulation to tasks they engage in. Researchers assert that unlike children without ADHD, hyperactive children are less tolerant of lower levels of arousal and in such

conditions seek to find their own sources of stimulation like talking or fidgeting in class, and by using task related stimulations it is possible to see improvements in these children's behavior and performance (Lee & Zentall, 2002). In a study by Imhof (2004) handwritings of children with ADHD were rated to be neater and to contain fewer mistakes when colored paper was used, hence the author claims that added external color stimulation might have an unspecific effect on attention regulation and behavioral inhibition in children with ADHD facilitating graphomotor coordination. Colored overlays are also found to aid children with ADHD's reading comprehension and reading recognition (Iovino et al., 1998).

These findings bring to mind whether the same principle would work in a classroom environment. Unfortunately there are not many empirical studies about an ideal color scheme of a classroom. A number of authors recommend having an accent colored front wall in the classroom to reduce eyestrain and relieve fatigue and to draw the attention to the front of the classroom (Engelbrecht, 2003; Mahnke & Mahnke, 1987; Mahnke, 1996; Sherwin-Williams, 2013). However this suggestion lacks empirical evidence in the literature. Furthermore the effect of color in the classroom environments have not been studied for special groups such as children with ADHD. One example of change of color scheme in a specialized school for ADHD children; improving concentration and learning abilities of the pupils (Christoffersen, 2003) is promising yet this information is based on observations, and no scientific study has been conducted to confirm the findings.

This thesis aims to affirm the assertion of the benefits of an accent colored front wall in the classroom, with an experimental study conducted with children with ADHD, a special group who might be in need of more facilitating precautions in the classroom environments than their peers without the disorder. The findings of the study show an increase of performance especially when the color of the wall and the board were different than each other, that is framing the board with a different wall color is likely to improve performance causing less mistakes. In one task finishing time of the task is found to be shorter with the red color used in the experimental study. It is hypothesized that red being an arousing color increased speed of the participants as also suggested in the literature (Küller et al., 2009; Kwallek & Lewis, 1990; Kwallek, Lewis, & Robbins, 1988; Stone, 2003; Walters et al., 1982).

It could be said that painting the front wall of a classroom an accent color, because it provides the framing of the board and introduces color to the environment could be a helpful solution for classrooms however it is important to note that the findings obtained from this study are based on male participants with an ADHD Combined type diagnosis, who attend 2nd, 3rd and 4th grades, by using the color red. Children diagnosed with ADHD have education in the same classrooms with children without similar problems. Therefore in order to actualize the study findings, it is necessary to determine how framing and color affects other children that do not have ADHD. Considering the fact that the school boards were black and green in

the previous years and in the following years whiteboards were mainly used in classrooms, it would be useful to test the color and frame effects using different colors.

In this study, participants were used as their own controls because of the different ratios of ADHD components in different individuals and different cognitive levels. The time allocated to a child is approximately two hours including the breaks. This study can be repeated in a larger sample in children's natural environments, that is the classes. In addition to this, gender variable should be investigated in children with and without ADHD complaints. How the different types of ADHD react to the frame/color effect is also worth investigating.

In the present study, the reading test consists of a four-sentence paragraph. The results could have been different if the reading passage was longer, the eyestrain could have come into play. For further studies a longer reading passage might be given on different colors to see the effects of long-term exposure and reading comprehension could also be assessed as in the study of Iovino et al. (1998). This study could be repeated with colors other than red, perhaps medium tones of green or blue as recommended by Mahnke (1996).

The color red should be approached with caution considering the studies which report a decrease in cognitive performance when red is seen before or during a task performance (Elliot et al., 2007; 2009; Gnambs et al., 2015;

Lichtenfeld, et al., 2009; Maier et al., 2008; Shi et al., 2015). Hence the effects of red on non-ADHD children's performance should also be carefully studied since they often share a classroom. This color, which is highly stimulating, may induce excessive stimulation in people without ADHD.

As a conclusion, children with ADHD may benefit from a change in color scheme in their classrooms especially in tasks where they have the most difficulty. The framing effect provided by different colored boards and walls are recommended for less errors. The color red seems to create a heightened arousal for children with ADHD thus they might perform faster in such environments. However long-term exposures to these environments should be studied to see whether the effects would last. Furthermore the color red could show different results on non-ADHD children's performance and might provide excessive stimulation or create a fear of failure or avoidance motivation. Research about the effects of red used as an environmental element on children would greatly contribute to these discussions. Furthermore whether or not the observed findings are affected by the gender variable can be tested in subsequent studies. With the spreading use of smart boards in classrooms, different background colors could also be tested to see color's effect on children's concentration and academic performance. With the findings of the current study it is believed that the use of color in different objects and environments in different educational activities can contribute positively to the learning abilities and mental states of children, young and adults with ADHD.

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APPENDIX A

READING TEST A-B

Sermin, Bircan ve Serhat bebekliklerini bile birlikte geçirmişlerdi. Aileleri de çok iyi dostlardı. Yaz tatilinde kullanılmayan bir depoyu bu arkadaşlara verdiler. Çocuklar, deponun badanasını yapıp, sandıklardan sedirler yaptılar. En sevdikleri ve okumak istedikleri kitapları getirip, paylaştılar.

Selin, Banu ve Serhan ayrılmaz üçlü olarak anılırdı. Datça'nın pazarına babalarının hazırladığı badem, susam, domates, biber gibi ürünleri götürüp tezgahta sergilerlerdi. Küçücük bedenlerinden beklenmeyen derecede büyük işler beceriyorlardı. Satış yapıp sepetleri boşaldıkça keyiften dört köşe oluyorlardı.

APPENDIX B

READING TEST C-D

Defne, Bedri ve Selda böceklerle ilgili çalışma grubundaydılar. Bu konuda bilimsel deneyler yapıp, bunların sunumunu yapacaklardı. Öncelikle bu konuda bildiklerini ve bilmeleri gerekenleri paylaştılar. Ansiklopediden bilgiler edindiler. Bahçeden buldukları tırtıl, salyangoz ve solucanı bir kavanoza koydular.

Serdar, Serpil ve Bedir sınıf arkadaşıydı. Bu derste sınıftakilere yurdumuzun yemeklerini tanıtacaklardı. Yanlarında tattırmak için pestil ve peksimet de getirmişlerdi. Birer küçük bidonda tahin ve pekmez sıralarını bekliyorlardı. Kuru üzüm, kayısı ve ceviz rengarenk tabaklara konulmuştu.

APPENDIX C

CODING TEST A-B

Aşağıdaki sembolleri kullanarak cevap kağıdına TÜRKİYE yaz

A	N	M	F	R	H	S
ᛕ	ᛇ	ᛟ	ᛝ	ᛗ	ᛉ	ᛗ

İ	I	T	Z	L	Ö	Ç
ᛊ	ᚺ	ᛞ	ᚠ	ᚳ	ᛜ	ᚲ

G	P	O	J	Ş	U	E
ᛏ	ᚱ	ᚦ	ᚨ	ᛝ	ᚢ	ᛖ

Ü	C	B	K	V	Y	D
ᛋ	ᚹ	ᛉ	ᛘ	ᛒ	ᚢ	ᛁ

Aşağıdaki sembolleri kullanarak cevap kağıdına TÜRKİYE yaz

J	V	Ç	U	Y	Z	Ö
ᛏ	ᛗ	ᚱ	ᚺ	ᛋ	ᚲ	ᚠ

R	B	Ü	N	H	C	G
ᚢ	ᛒ	ᛘ	ᛝ	ᚢ	ᚦ	ᛁ

I	D	A	O	F	Ş	İ
ᛕ	ᛇ	ᛟ	ᛇ	ᚳ	ᛝ	ᛞ

K	P	L	T	M	E	S
ᛖ	ᚹ	ᚠ	ᛗ	ᛜ	ᛊ	ᛉ

APPENDIX D

CODING TEST C-D

Aşağıdaki sembolleri kullanarak cevap kağıdına TÜRKİYE yaz

F	V	Ş	Ö	İ	B	G
ᛁ	ᚠ	ᛏ	ᛉ	ᛘ	ᛒ	ᛝ

T	C	K	Ç	S	D	M
ᛊ	ᚴ	ᚲ	ᚷ	ᚹ	ᚦ	ᛗ

A	P	H	J	N	Z	Y
ᚨ	ᛈ	ᚺ	ᛟ	ᚾ	ᛉ	ᛦ

E	I	L	R	O	Ü	U
ᛖ	ᛣ	ᚦ	ᛇ	ᚱ	ᛞ	ᚢ

Aşağıdaki sembolleri kullanarak cevap kağıdına TÜRKİYE yaz

I	J	F	U	K	D	C
ᛗ	ᚨ	ᚠ	ᛗ	ᛖ	ᚦ	ᛏ

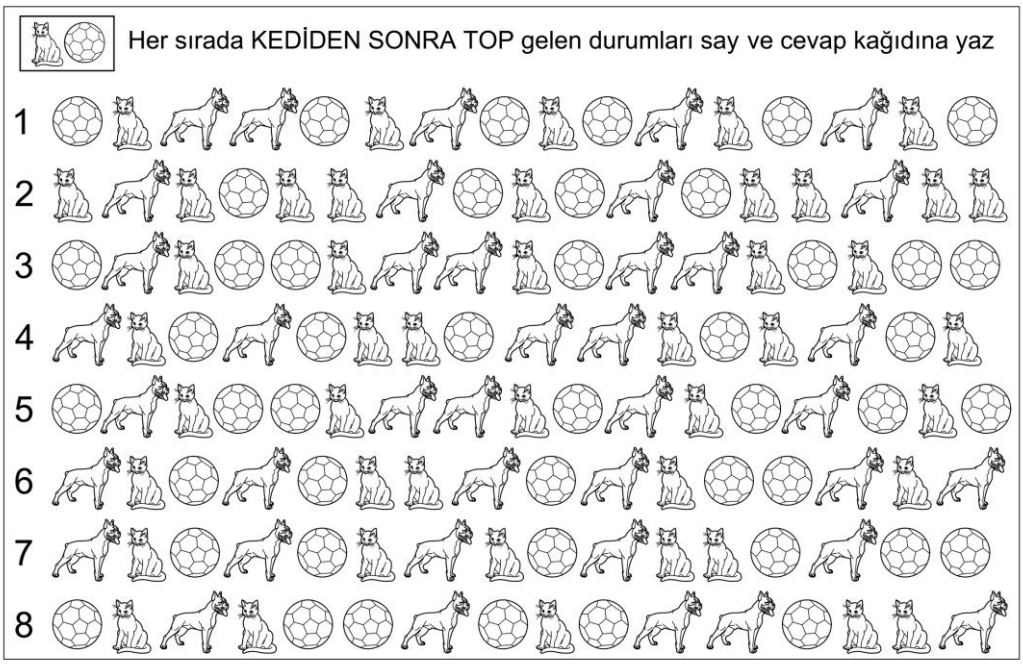
Y	Ş	E	Ö	H	N	V
ᛘ	ᛈ	ᛦ	ᚠ	ᚲ	ᚴ	ᛁ

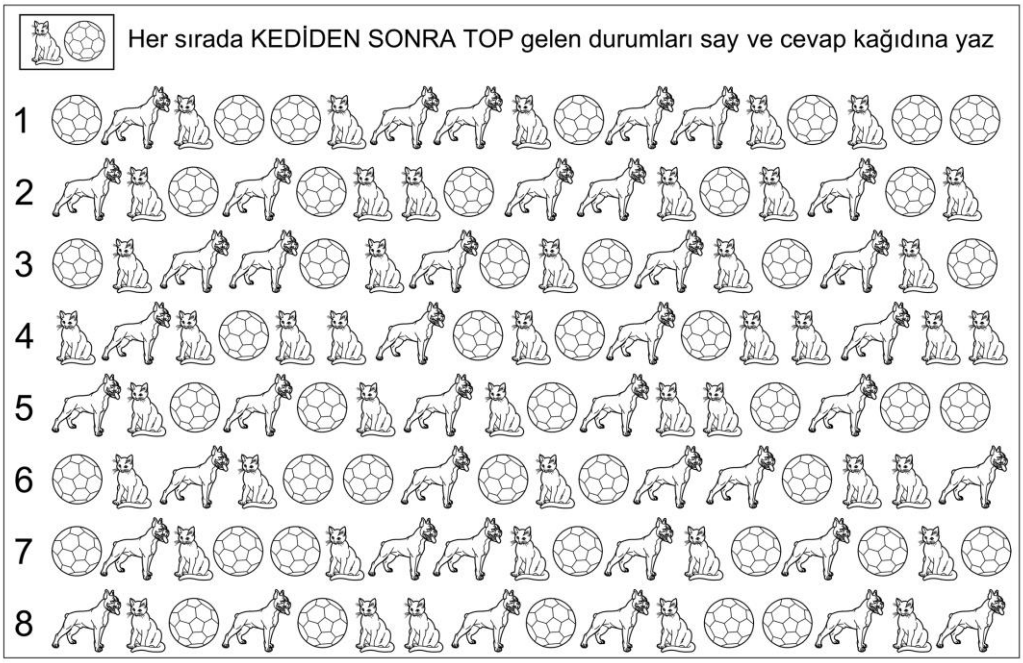
P	O	L	S	A	Ç	Ü
ᛈ	ᛝ	ᚢ	ᛉ	ᚱ	ᚷ	ᚲ

R	B	Z	İ	M	T	G
ᛞ	ᚺ	ᚷ	ᛊ	ᛒ	ᛇ	ᛣ

APPENDIX E

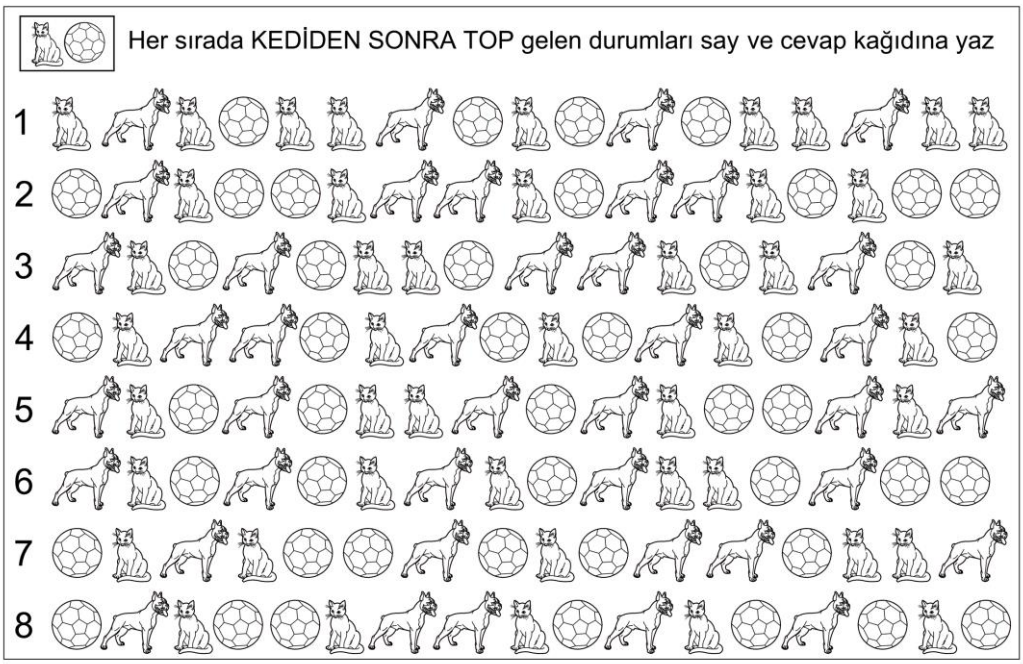
PAIR CANCELLATION TEST A-B

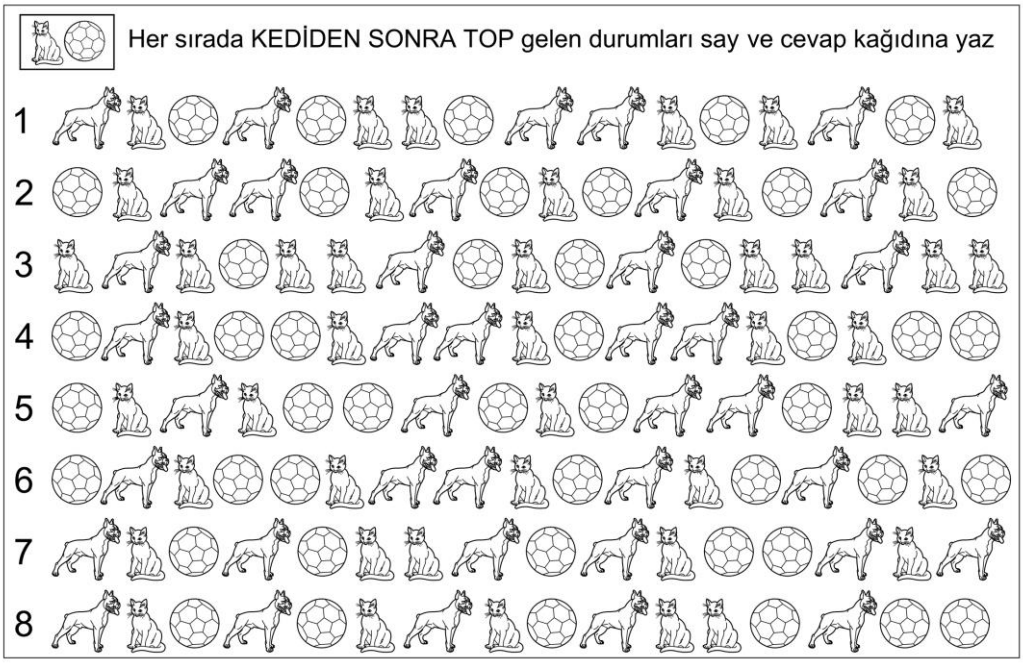




APPENDIX F

PAIR CANCELLATION TEST C-D





APPENDIX G

MATCHING TEST A-B

1.	bpp952	A.	pdd625
2.	dbd696	B.	pbp266
3.	dpb625	C.	bbd965
4.	pdb996	D.	ddp522
5.	pbp266	E.	bdd256
6.	pdb296	F.	bbd252
7.	bdd256	G.	dpb625
8.	bpb596	H.	dbp256
9.	ppb669	I.	dbd696
10.	bbd252	J.	pdb996
11.	pdd625	K.	bdb669
12.	ddp522	L.	bpp952
13.	bbd965	M.	bpb596
14.	dbp256	N.	pdb296
15.	bdb669	O.	ppb669

1.	dbd696	A.	ddp522
2.	pbp266	B.	pdd625
3.	dbp256	C.	pdb296
4.	bbd965	D.	ppb669
5.	bpp952	E.	bdd256
6.	pdb996	F.	pbp266
7.	bdd256	G.	bbd965
8.	bpb596	H.	dpb625
9.	bdb669	I.	dbd696
10.	bbd252	J.	dbp256
11.	pdd625	K.	pdb996
12.	ddp522	L.	bdb669
13.	pdb296	M.	bpb596
14.	dpb625	N.	bbd252
15.	ppb669	O.	bpp952

APPENDIX H

MATCHING TEST C-D

1.	bpb596	A.	dbp256
2.	ddp522	B.	bbd252
3.	pdd625	C.	bpp952
4.	bbd252	D.	pdb296
5.	pbp266	E.	dbd696
6.	pdb996	F.	ddp522
7.	dbp256	G.	dpb625
8.	bpp952	H.	pdb996
9.	ppb669	I.	bdd256
10.	bbd965	J.	bpb596
11.	dpb625	K.	pdd625
12.	dbd696	L.	bbd965
13.	pdb296	M.	bdb669
14.	bdd256	N.	pbp266
15.	bdb669	O.	ppb669

1.	bpp952	A.	bbd252
2.	ddp522	B.	pbp266
3.	ppb669	C.	bdd256
4.	bbd252	D.	dbd696
5.	bpb596	E.	bpp952
6.	pdb296	F.	bdb669
7.	dpb625	G.	pdb996
8.	dbd696	H.	dpb625
9.	pdd625	I.	ddp522
10.	bbd965	J.	dbp256
11.	bdd256	K.	pdb296
12.	pbp266	L.	ppb669
13.	pdb996	M.	pdd625
14.	dbp256	N.	bpb596
15.	bdb669	O.	bbd965

APPENDIX I

ANSWER SHEET

No:	BdBt	BdKt	KdBt	KdKt
Tarih:	1	2	3	4

1 Tahtadaki sembolleri kullanarak buraya TÜRKİYE yaz

2 Her sırada kediden sonra top gelen durumları say ve buraya yaz

1)
2)
3)
4)
5)
6)
7)
8)

3 Sol taraftaki maddeleri sağ taraftakilerle eşleştir

1)	11)
2)	12)
3)	13)
4)	14)
5)	15)
6)	16)
7)	17)
8)	18)
9)	19)
10)	20)

APPENDIX J

ASSESSMENT SHEET

Denek no:
Adı Soyadı:

Tarih:
Doğum Tarihi:

TEST 1

TÜRKİYE Süre: _____ D: _____ Y: _____

EŞLEME D: _____ Y: _____

KEDİ-TOP D: _____ Y: _____

OKUMA Süre: _____ D: _____ Y: _____

Selin, Banu ve Serhan ayrılmaz üçlü olarak anılırdı. Datça'nın pazarına babalarının hazırladığı badem, susam, domates, biber gibi ürünleri götürüp tezgahta sergilerlerdi. Küçücük bedenlerinden beklenmeyen derecede büyük işler beceriyorlardı. Satış yapıp sepetleri boşaldıkça keyiften dört köşe oluyorlardı.

TEST 2

TÜRKİYE Süre: _____ D: _____ Y: _____

EŞLEME D: _____ Y: _____

KEDİ-TOP D: _____ Y: _____

OKUMA Süre: _____ D: _____ Y: _____

Sermin, Bircan ve Serhat bebekliklerini bile birlikte geçirmişlerdi. Aileleri de çok iyi dostlardı. Yaz tatilinde kullanılmayan bir depoyu bu arkadaşlara verdiler. Çocuklar, deponun badanasını yapıp, sandıklardan sedirler yaptılar. En sevdikleri ve okumak istedikleri kitapları getirip, paylaştılar.

TEST 3

TÜRKİYE Süre: _____ D: _____ Y: _____

EŞLEME D: _____ Y: _____

KEDİ-TOP D: _____ Y: _____

OKUMA Süre: _____ D: _____ Y: _____

Serdar, Serpil ve Bedir sınıf arkadaşıydı. Bu derste sınıftakilere yurdumuzun yemeklerini tanıtacaklardı. Yanlarında tattırmak için pestil ve peksimet de getirmişlerdi. Birer küçük bidonda tahin ve pekmez sıralarını bekliyorlardı. Kuru üzüm, kayısı ve ceviz rengarenk tabaklara konulmuştu.

TEST 4

TÜRKİYE Süre: _____ D: _____ Y: _____

EŞLEME D: _____ Y: _____

KEDİ-TOP D: _____ Y: _____

OKUMA Süre: _____ D: _____ Y: _____

Defne, Bedri ve Selda böceklerle ilgili çalışma grubundaydılar. Bu konuda bilimsel deneyler yapıp, bunların sunumunu yapacaklardı. Öncelikle bu konuda bildiklerini ve bilmeleri gerekenleri paylaştılar. Ansiklopediden bilgiler edindiler. Bahçeden buldukları tırtıl, salyangoz ve solucanı bir kavanoza koydular.

APPENDIX K

ETHICAL COMMITTEE APPROVAL

Bilkent Üniversitesi
Akademik İşler Rektör Yardımcılığı

Tarih : 8 Ağustos 2018

Gönderilen : Zeynep Öktem

Tez Danışmanı : Nilgün Olguntürk

Gönderen : Fatma Taşkın
İnsan Araştırmaları Etik Kurulu Başkanı

Konu : *"Effects of ..."* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 8 Ağustos 2018 tarihli görüşme sonucu, *"Effects of an accent colored main activity wall in classrooms and a colored board for children with ADHD"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri, ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmesine karşı gelmektedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Etik Kurul Üyeleri:

Ünvan / İsim	**Bölüm / Uzmanlık**	**İmza**
1. Doç.Dr. Fatma Taşkın	İktisat	
2. Prof.Dr. Erdal Onar	Hukuk	
3. Prof.Dr. Haldun Özaktaş	Elektrik ve Elektronik Müh.	
4. Doç.Dr. Işık Yuluğ	Moleküler Biyoloji ve Genetik	
5. Yrd.Doç.Dr. Gül Günaydın	Psikoloji	
Yd.1.Doç.Dr. Çiğdem Gündüz Demir	Bilgisayar Mühendisliği	(yedek üye)
Yd.2. Yrd.Doç.Dr. A.Barış Özbilen	Hukuk	(yedek üye)

Kurul karar/toplantı No: 2018_08_08_01

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

APPENDIX L

DATA FROM EXPERIMENT

							WoW														RoW														
V1	YAS	SK	AAY	ÇB	İH	TÖZP	S1	OS1	OH1	OG1	OT1	TRS1	TRH1	KTS1	KTF1	KTA1	KTT1	EH1	ED1	ET1	S2	OS2	OH2	OG2	OT2	TRS2	TRH2	KTS2	KTF2	KTA2	KTT2	EH2	ED2	ET2
1	109	98	97	100	97	86	2	40	0	3	3	68	0	67	0	0	0	2	7	9	3	30	0	0	0	54	0	64	0	0	0	2	11	13
2	107	108	89	85	100	98	2	31	1	1	2	57	0	69	0	0	0	4	8	12	3	38	0	5	5	102	0	64	0	4	4	2	10	12
3	103	86	85	100	118	94	3	30	2	2	4	110	1	72	0	4	4	0	9	9	1	31	0	2	2	175	0	158	0	3	3	0	5	5
4	104	128	106	109	103	117	4	25	3	1	4	135	0	61	0	0	0	0	12	12	3	22	2	0	2	80	0	60	0	1	1	2	5	7
5	97	98	91	100	88	93	2	52	3	0	3	110	1	63	0	0	0	1	9	10	1	64	4	0	4	97	0	70	0	3	3	5	1	6
6	101	108	74	91	85	87	1	36	2	0	2	91	1	83	0	1	1	0	5	5	2	39	1	1	2	75	1	69	1	1	2	3	6	9
7	97	102	91	100	97	97	4	31	7	1	8	121	1	64	0	2	2	5	7	12	1	34	7	1	8	99	2	90	2	2	4	2	3	5
8	114	104	91	94	97	96	1	26	3	0	3	104	0	99	0	2	2	0	5	5	3	24	3	0	3	100	0	60	0	1	1	0	9	9
9	90	110	100	94	100	102	1	29	3	1	4	164	3	79	4	1	5	1	6	7	4	17	1	0	1	107	1	77	4	0	4	0	4	4
10	92	90	113	109	112	106	4	50	5	4	9	82	0	63	0	1	1	1	13	14	3	44	3	2	5	78	0	69	0	2	2	2	13	15
11	117	104	109	100	106	106	1	40	1	0	1	64	0	73	0	1	1	1	10	11	2	38	2	2	4	71	1	54	0	0	0	2	10	12
12	116	102	94	103	88	96	3	23	0	1	1	89	0	83	4	0	4	0	14	14	2	27	0	2	2	118	0	125	4	1	5	0	12	12
13	83	100	104	91	91	97	2	62	2	1	3	180	1	116	0	1	1	2	2	4	4	65	2	1	3	85	2	126	0	0	0	3	4	7
14	86	104	91	97	106	99	3	23	3	1	4	84	1	56	0	1	1	4	6	10	1	25	3	1	4	162	0	84	0	2	2	0	4	4
15	115	106	77	97	88	90	4	36	3	1	4	68	2	57	0	0	0	5	8	13	1	58	2	4	6	70	1	67	0	0	0	0	7	7
16	105	88	98	106	103	97	2	45	7	0	7	83	0	73	0	0	0	1	9	10	4	37	2	1	3	82	0	78	0	0	0	1	10	11
17	100	106	102	103	97	103	4	60	0	1	1	81	0	92	0	0	0	1	9	10	3	72	1	0	1	101	0	86	0	0	0	2	6	8
18	102	86	77	79	94	78	3	29	6	0	6	94	2	62	3	1	4	1	9	10	4	25	10	0	10	95	1	90	3	0	3	5	10	15
19	91	118	100	97	112	110	2	48	1	0	1	106	0	98	0	0	0	0	4	4	1	46	0	1	1	115	0	78	0	0	0	1	2	3
20	118	104	94	97	85	94	3	23	0	0	0	86	0	55	0	0	0	3	9	12	4	26	0	0	0	82	0	45	0	0	0	1	14	15
21	90	102	91	88	100	94	4	50	5	0	5	177	3	74	6	0	6	2	7	9	2	62	4	0	4	109	1	80	6	0	6	3	5	8
22	117	108	104	113	94	107	4	28	0	0	0	57	0	61	0	0	0	2	11	13	2	28	2	0	2	97	0	65	0	1	1	3	10	13
23	83	94	102	91	115	100	3	42	0	2	2	54	3	66	0	1	1	4	6	10	2	42	1	1	2	80	1	95	0	0	0	4	7	11
24	90	96	100	91	91	94	2	53	2	0	2	150	0	130	0	1	1	0	7	7	4	52	1	1	2	154	1	90	0	0	0	0	6	6
25	118	108	126	109	88	112	1	33	1	1	2	86	0	67	0	1	1	0	9	9	2	25	0	1	1	54	0	56	0	0	0	0	11	11
26	105	98	98	85	97	102	3	35	0	0	0	101	0	68	0	0	0	4	6	10	1	39	0	0	0	92	0	65	0	1	1	2	5	7
27	104	108	98	103	91	101	4	41	3	0	3	116	1	78	0	0	0	3	8	11	2	45	1	0	1	109	1	85	2	0	2	2	5	7
28	88	96	98	106	129	107	2	50	5	1	6	63	0	55	0	1	1	0	5	5	1	49	4	0	4	71	0	48	0	0	0	1	2	3
29	99	110	109	78	79	104	1	45	2	2	4	170	2	152	3	0	3	4	4	8	3	46	2	3	5	96	0	122	2	0	2	3	4	7
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31	103	96	98	79	80	97	3	55	0	3	3	103	1	134	0	3	3	4	1	5	1	54	0	3	3	110	1	132	0	1	1	3	0	3
32	84	112	111	85	80	106	4	68	0	0	0	130	2	132	5	0	5	5	5	10	1	50	0	0	0	93	1	129	3	0	3	4	5	9
33	86	88	102	91	85	90	2	68	4	0	4	66	2	123	1	0	1	3	10	13	4	60	5	1	6	87	0	118	1	1	2	2	12	14
34	84	90	83	77	97	82	2	48	2	1	3	125	2	77	1	0	1	5	3	8	3	45	3	1	4	120	1	72	0	0	0	4	5	9
35	93	98	100	79	118	110	1	43	2	0	2	68	0	60	0	1	1	4	5	9	3	40	1	0	1	71	0	58	0	0	0	3	5	8
36	108	102	102	94	85	102	1	61	2	2	4	105	3	122	0	0	0	2	3	5	4	42	3	0	3	88	0	96	1	0	1	1	8	9
37	83	116	96	80	103	106	2	37	0	1	1	64	0	78	0	1	1	5	3	8	3	32	0	0	0	70	0	72	0	0	0	2	8	10
38	85	98	87	85	118	95	3	58	3	1	4	70	0	61	0	5	5	4	3	7	2	54	2	0	2	78	0	52	0	3	3	4	4	8
39	84	98	89	100	80	85	1	36	0	0	0	92	4	129	0	0	0	0	4	4	3	40	0	3	3	78	2	118	0	0	0	1	4	5
40	83	92	91	94	112	95	3	45	4	0	4	47	1	62	1	0	1	2	6	8	2	44	4	1	5	56	2	60	0	1	1	1	5	6
41	95	76	89	91	82	83	1	67	5	0	5	103	2	130	0	1	1	2	6	8	4	64	6	1	7	87	1	107	1	1	2	1	13	14
42	110	98	94	103	85	94	4	28	1	2	3	129	0	116	0	0	0	0	15	15	2	22	3	0	3	133	1	98	0	2	2	1	12	13
43	85	102	72	100	85	86	2	56	0	0	0	90	2	108	0	1	1	2	9	11	1	39	1	0	1	68	1	105	0	0	0	2	7	9
44	98	92	81	97	88	86	4	53	0	0	0	156	0	82	2	1	3	1	13	14	3	48	1	0	1	82	0	78	1	0	1	1	13	14
45	118	106	109	82	88	102	3	36	1	1	2	96	1	80	2	0	2	3	2	5	4	38	1	2	3	61	0	73	1	0	1	1	4	5
46	116	126	132	89	82	127	1	36	1	1	2	97	3	132	1	1	2	5	3	8	2	55	2	0	2	67	1	128	1	0	1	2	8	10
47	90	116	128	77	103	121	4	30	1	1	2	55	1	67	1	2	3	5	5	10	1	33	0	0	0	48	1	73	0	4	4	3	5	8
48	107	120	115	82	82	112	1	35	2	0	2	119	2	144	0	0	0	4	3	7	4	39	1	1	2	74	0	133	0	0	0	2	7	9

							WoR														RoR														
V1	YAS	SK	AAY	ÇB	İH	TÖZP	S3	OS3	OH3	OG3	OT3	TRS3	TRH3	KTS3	KTF3	KTA3	KTT3	EH3	ED3	ET3	S4	OS4	OH4	OG4	OT4	TRS4	TRH4	KTS4	KTF4	KTA4	KTT4	EH4	ED4	ET4
1	109	98	97	100	97	86	4	30	0	0	0	60	0	67	0	0	0	4	11	15	1	43	2	2	4	76	0	79	0	0	0	0	4	4
2	107	108	89	85	100	98	1	33	0	1	1	83	0	84	0	3	3	0	7	7	4	30	0	3	3	83	0	55	0	5	5	4	11	15
3	103	86	85	100	118	94	2	36	4	1	5	127	0	92	0	2	2	0	6	6	4	27	2	0	2	97	1	60	0	2	2	1	4	5
4	104	128	106	109	103	117	2	24	0	0	0	102	0	64	0	2	2	0	8	8	1	25	0	0	0	124	0	63	0	3	3	0	4	4
5	97	98	91	100	88	93	3	65	4	0	4	92	1	73	0	1	1	3	6	9	4	61	8	0	8	99	0	63	0	0	0	4	6	10
6	101	108	74	91	85	87	4	36	0	3	3	66	1	67	0	0	0	3	7	10	3	38	0	1	1	52	1	66	0	0	0	3	8	11
7	97	102	91	100	97	97	2	38	7	1	8	81	3	75	0	2	2	3	7	10	3	29	3	2	5	115	2	95	0	1	1	0	10	10
8	114	104	91	94	97	96	4	21	1	0	1	83	0	91	0	0	0	0	6	6	2	23	6	0	6	102	0	64	0	2	2	0	9	9
9	90	110	100	94	100	102	2	25	6	0	6	167	1	93	4	1	5	0	6	6	3	26	2	2	4	120	1	68	4	0	4	0	7	7
10	92	90	113	109	112	106	2	40	1	3	4	112	0	76	0	2	2	4	7	11	1	47	1	1	2	99	0	71	0	0	0	3	4	7
11	117	104	109	100	106	106	3	38	0	2	2	39	1	44	0	0	0	2	13	15	4	39	1	1	2	57	0	36	0	0	0	3	12	15
12	116	102	94	103	88	96	4	25	0	0	0	102	0	80	4	0	4	0	14	14	1	28	1	2	3	106	0	120	4	0	4	0	7	7
13	83	100	104	91	91	97	3	65	2	3	5	168	1	98	0	0	0	3	3	6	1	90	5	1	6	159	1	143	1	4	5	2	1	3
14	86	104	91	97	106	99	4	30	3	2	5	86	0	69	0	0	0	2	4	6	2	22	4	0	4	105	0	74	0	0	0	3	5	8
15	115	106	77	97	88	90	3	47	4	3	7	61	1	64	0	0	0	3	6	9	2	46	2	4	6	73	2	54	0	0	0	4	11	15
16	105	88	98	106	103	97	1	45	7	1	8	125	0	109	1	0	1	0	6	6	3	45	5	2	7	67	0	76	0	0	0	1	9	10
17	100	106	102	103	97	103	1	75	5	1	6	103	0	102	0	0	0	3	4	7	2	63	0	0	0	119	0	87	0	0	0	3	5	8
18	102	86	77	79	94	78	1	41	6	1	7	148	1	93	3	0	3	1	8	9	2	29	6	0	6	140	0	93	5	0	5	3	7	10
19	91	118	100	97	112	110	4	34	0	0	0	110	0	64	0	0	0	2	3	5	3	40	0	0	0	72	0	71	1	0	1	0	5	5
20	118	104	94	97	85	94	2	32	2	2	4	67	0	56	0	0	0	1	9	10	1	32	0	2	2	65	0	70	0	0	0	0	5	5
21	90	102	91	88	100	94	3	56	2	1	3	89	3	98	6	0	6	2	7	9	1	70	9	0	9	125	1	99	6	1	7	0	6	6
22	117	108	104	113	94	107	1	40	0	2	2	102	0	83	0	0	0	3	8	11	3	27	2	0	2	58	0	65	0	1	1	2	12	14
23	83	94	102	91	115	100	1	56	2	1	3	117	1	95	0	1	1	1	5	6	4	42	2	0	2	62	3	72	1	0	1	1	6	7
24	90	96	100	91	91	94	1	90	4	1	5	195	0	102	0	6	6	2	3	5	3	55	2	0	2	78	1	108	0	1	1	1	6	7
25	118	108	126	109	88	112	3	26	1	0	1	48	0	49	0	0	0	0	12	12	4	26	0	1	1	44	0	53	0	0	0	0	15	15
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27	104	108	98	103	91	101	3	31	0	0	0	120	1	82	1	0	1	2	7	9	1	38	0	3	3	111	1	84	0	1	1	3	4	7
28	88	96	98	106	129	107	3	60	4	1	5	59	0	45	0	1	1	1	6	7	4	48	4	1	5	82	0	42	0	0	0	0	1	6
29	99	110	109	78	79	104	2	32	1	0	1	162	0	118	1	1	2	3	5	8	4	35	3	0	3	142	0	108	2	0	2	4	4	8
30	117	110	79	97	80	90	1	28	1	2	3	122	2	145	2	1	3	3	2	5	2	26	1	2	3	162	3	114	0	2	2	3	7	10
31	103	96	98	79	80	97	2	49	1	4	5	121	1	118	0	2	2	3	2	5	4	54	0	4	4	100	1	112	1	1	2	4	2	6
32	84	112	111	85	80	106	2	53	0	0	0	148	1	122	4	0	4	2	9	11	3	64	0	0	0	124	2	118	3	0	3	5	5	10
33	86	88	102	91	85	90	3	65	4	1	5	53	1	120	0	1	1	2	12	14	1	68	5	0	5	91	3	122	0	0	0	4	4	8
34	84	90	83	77	97	82	4	52	2	0	2	97	1	63	1	0	1	3	7	10	1	41	3	0	3	114	3	67	1	0	1	4	4	8
35	93	98	100	79	118	110	2	37	1	0	1	66	0	58	0	1	1	3	4	7	4	48	0	0	0	54	0	48	1	0	1	4	3	7
36	108	102	102	94	85	102	2	44	0	0	0	70	0	105	0	0	0	0	6	6	3	60	2	1	3	99	1	96	1	0	1	1	7	8
37	83	116	96	80	103	106	1	24	0	0	0	81	0	75	0	1	1	2	2	4	4	29	1	0	1	83	0	59	0	0	0	4	8	12
38	85	98	87	85	118	95	1	50	2	1	3	63	1	62	0	3	3	2	4	6	4	50	0	0	0	81	0	50	0	5	5	4	5	9
39	84	98	89	100	80	85	4	32	0	2	2	71	1	105	0	0	0	0	6	6	2	38	1	0	1	87	4	102	1	0	1	1	4	5
40	83	92	91	94	112	95	4	40	3	0	3	63	1	59	0	0	0	0	9	9	1	41	4	0	4	74	3	53	0	1	1	1	6	7
41	95	76	89	91	82	83	3	57	5	2	7	109	0	123	0	0	0	1	14	15	2	62	3	1	4	114	2	105	1	0	1	1	12	13
42	110	98	94	103	85	94	1	22	2	2	4	122	1	107	1	0	1	1	10	11	3	27	0	1	1	131	1	91	0	0	0	2	13	15
43	85	102	72	100	85	86	4	43	0	0	0	71	0	92	0	1	1	1	11	12	3	45	0	0	0	75	1	87	2	0	2	2	9	11
44	98	92	81	97	88	86	1	52	0	0	0	111	0	84	2	0	2	2	5	7	2	47	0	0	0	141	0	74	1	1	2	2	8	10
45	118	106	109	82	88	102	2	26	0	0	0	59	1	79	2	0	2	1	4	5	1	31	1	0	1	89	3	78	0	0	0	2	3	5
46	116	126	132	89	82	127	4	28	0	2	2	84	0	88	2	0	2	0	12	12	3	26	1	2	3	106	0	99	1	0	1	4	5	9
47	90	116	128	77	103	121	3	21	0	1	1	57	1	67	0	2	2	2	6	8	2	25	1	1	2	63	1	56	0	3	3	5	6	11
48	107	120	115	82	82	112	3	24	1	0	1	81	0	122	0	0	0	1	8	9	2	29	2	0	2	113	2	124	0	0	0	3	6	9

YAS: Age in months

SK: Verbal Comprehension Index Scores

AAY: Perceptual Reasoning Index Scores

ÇB: Working Memory Index Scores

İH: Processing Speed Scores

TÖZP: Intelligence Scores in WISC-IV

OS: Reading time in seconds

OH: Reading incorrect - not corrected

OG: Reading incorrect - corrected

OT: Reading incorrect - total

TRS: Coding time in seconds

TRH: Coding incorrect

KTS: Pair-Cancl. time in seconds

KTF: Pair Cancl. incorrect - more instances than correct answer

KTA: Pair Cancl. incorrect - less instances than correct answer

KTT: Pair Cancl. incorrect - total

EH: Matching - incorrect answers

ED: Matching - correct answers

ET: Matching - total number of answers