



Effects of Framing and the Color Red on In-Class Performances of Children with Attention Deficit Hyperactivity Disorder

Zeynep Öktem ¹, Nilgün Olguntürk ²

Abstract

Children with Attention Deficit Hyperactivity Disorder (ADHD) face many challenges throughout their educational life. This study is to find out whether there is a combination of board and wall color 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.

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¹ Bilkent University, Faculty of Art, Design and Architecture, Department of Interior Architecture and Environmental Design, Turkey, zeynep.oktem@bilkent.edu.tr

² Bilkent University, Faculty of Art, Design and Architecture, Department of Interior Architecture and Environmental Design, Turkey, onilgun@bilkent.edu.tr

Introduction

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). 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.

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). ADHD is one of the most common psychiatric diagnosis seen in children worldwide (Adam, Lucas, & Barnes, 2008; Polanczyk, De 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 are 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 female/male 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., 1994). 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, Elliot, & Holmes, 2010), in another study ADHD-C (3.8%) shows a predominance over ADHD-I (1.7%) and ADHD-HI (0.5%) (Skounti et al., 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). 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). Almost all of these problems are within executive functions. Barkley (2011), 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, Touloupoulou, & 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) 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 and 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). Similarly, a study by Penny, Waschbusch, Carrey, and 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; Willcutt, 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, Navarro Soria, González Gómez, and García Sevilla (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.

In terms of color discrimination, ADHD children are reported to exhibit differences compared to their non-ADHD peers. In most color systems, 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). Children with ADHD are reported to exhibit blue-yellow color perception deficits (Banaschewski et al., 2006; Silva & Frere, 2011; Tannock, Banaschewski, & Gold, 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). The study conducted by Roessner et al. (2008) shows that children with ADHD makes more errors on a Farnsworth-Munsell 100 Hue Test than their typically developing peers and more so on the blue-yellow axis compared to red-green axis. Similarly when adults with ADHD were administered the same test, this group was found to make more mistakes in the color discrimination task in the blue spectrum compared to the non-ADHD group. There was no significant difference between the two groups for the colors of the red-green axis (Kim, Chen, & Tannock, 2014). 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. In the light of this information, the color to be used in this study was chosen from the red-green axis.

The treatment for ADHD is generally done with psychostimulant medications. 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 their academic performance when using color on the reading or writing materials. Colored paper is found to have a positive effect on handwriting legibility of children with ADHD (Imhof, 2004). Similarly, an adolescent

study on a copying task found out that the ADHD group, unlike the control group performed better with colored letters than with black letters (Zentall, Falkenberg, & Smith, 1985). Another study suggests that putting colored overlays on reading materials has a significant effect on reading comprehension and reading recognition of children with ADHD (Iovino, Fletcher, Breitmeyer, & Foorman, 1998). In a study among blue, red and none overlays, red was found to be the most effective overlay color for the ADHD group. Additionally, blue overlay was found to be more effective for the reading recognition task (Iovino et al., 1998).

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. Suggestions for parents are generally about home improvements since they are easier to control. Nevertheless, these children would also benefit greatly if school environments would offer a more convenient space that would reduce their symptoms and increase academic productivity.

In a study covering 751 pupils from 34 varied classrooms in seven different schools in the UK, Barrett, Zhang, Moffat, and 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%). 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).

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. In a number of studies these children are found to make more large saccades than control children (Deans, Laughlin, Brubaker, Gay, & Krug, 2010; Gould, Bastain, Israel, Hommer, & Castellanos, 2001; Munoz, Armstrong, Hampton, & Moore, 2003; Rommelse, Van Der Stigchel, & Sergeant, 2008; Ross, Harris, Olincy, & Radant, 2000). Saccades happen when an individual moves their eyes away from the target stimuli, which can cause trouble in eye fixation and experts claim that it can occur when the subject gets distracted and loses their focus (Deans et al., 2010). The ADHD group is also found to display significantly more regressive saccades where they re-read a portion of a text than do control children (Deans et al., 2010). 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).

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). One of the most researched colors is the color red with a 53% ratio in color research (Jalil, Yunus, & Said, 2012). The use of color in these experimental researches are either on the testing material or in the environment. A number of researches have shown that seeing the color red or only the word red (Lichtenfeld, Maier, Elliot, & Pekrun, 2009)

on the testing material hurts cognitive performance (Elliot, Maier, Moller, Friedman, & Meinhardt, 2007; Gnambs, Appel, & Kaspar, 2015; Maier, Elliot, & Lichtenfeld, 2008). These negative effects are often explained by the association of the color red with danger. The color of warning signs, or blood or the red pen used by teachers to correct mistakes are generally red. Mehta and Zhu (2009) in a number of experiments affirm that red creates an avoidance motivation unlike blue which creates an approach motivation. This avoidance motivation might lead to an impairment in the performance on cognitive tasks because the subjects try to avoid making mistakes (Elliot et al., 2007).

These aforementioned experimental studies use the color red on testing materials and are realized with adult or adolescent samples and do not include special groups like ADHD. Caution and avoidance motivation might be a desirable outcome for the inattentive group; however, this has not yet been tested. The studies which did not find an effect of the color red on cognitive performance (Larsson & Stumm, 2015; Martinez, Oberle, & Thompson Jr., 2010; Olsen, 2010) are generally explained by Elliot and Maier's color-in-context theory (2012) which suggests that 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.

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. One study demonstrated that the participants made fewer errors in a red office on a proofreading task compared to a white office (Kwallek & Lewis, 1990). 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). Participants completing a proofreading task in red and blue rooms performed faster in the red room but with lower accuracy (Küller, Mikellides, & Janssens, 2009). 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 participants (Küller et al., 2009; Kwallek & Lewis, 1990; Kwallek, Woodson, Lewis, & Sales, 1997; Stone, 2003; Walters, Apter, & Svebak, 1982). In the case of children with ADHD, experts indicate that added stimulation would be most beneficial for this group of children especially during tasks that require sustained attention (Zentall et al., 1985). Considering that the medication which decreases ADHD symptoms are psychostimulants (Sürücü, 2016), it is not surprising that several studies of environmental stimulation have also revealed positive effects on motor activity and academic performance for people with ADHD (Iovino et al., 1998; Zentall & Shaw, 1980; Zentall & Zentall, 1983).

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 participants 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 participants 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.

Method

Participants

The participants in the study consisted of 48 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. 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.

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). 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 the mental evaluation and 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.

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 the experiments. Four tests were prepared to measure the performance of the participants in different experimental conditions; reading, coding, pair cancellation and matching. The reading test required children to read out loud a paragraph written on the board. This test measures the participant'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 (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. 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. 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, Doyle, Nigg, Faraone, & Pennington, 2005). 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.

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. This test required the participant to look attentively at the board for a rather long period of time. 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). The original tests measure executive functions, attention and concentration, perceptual speed, processing speed, attention and concentration, and vigilance (Wechsler, 2004). 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 participant. 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.

The matching test required the participant to match the items on the left column with the ones on the right column. 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 (Öktem, 1996). 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 Ödemis, Yener, and Camgöz (2004). 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 matching test was assessed on three features; number of incorrect answers, number of correct answers and total number of answers.

Procedure

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 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. 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 1. Parents were informed about the experiment and gave consent for their children to take part in the study.

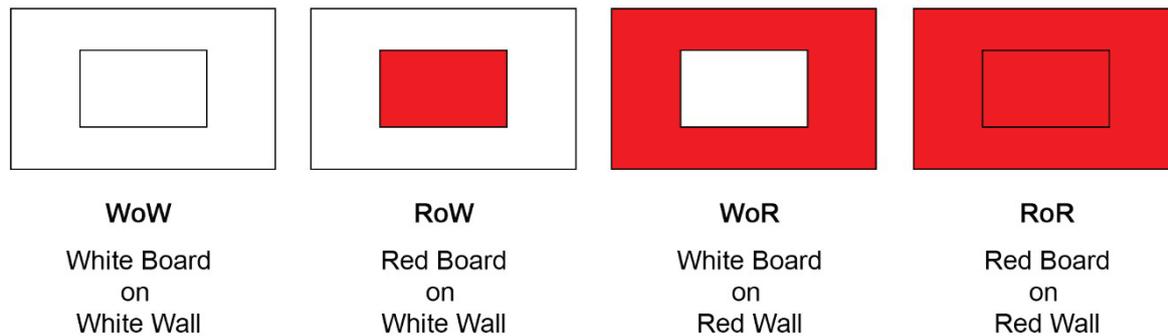


Figure 1. The Four Experimental Conditions: WoW, RoW, WoR and RoR

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.

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

Results

The results are analyzed with one-way repeated measures ANOVA. 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. The cases where PSI and WMI scores create a difference when used as a covariate are reported below.

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 ($\epsilon = 29.750$, $F(3, 124) = .238$, $p > .05$, $\mu = .005$), on the number of misread words corrected afterwards ($\epsilon = .89$, $F(3, 139) = .38$, $p > .05$, $\mu = .008$), on the number of misread words not corrected afterwards ($\epsilon = 1.766$, $F(3, 123) = .362$, $p > .05$, $\mu = .008$), or on the total number of misread words ($\epsilon = .292$, $F(3, 135) = .045$, $p > .05$, $\mu = .001$). Figure 2 provides the mean values for reading time measured in seconds. Figure 3 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.

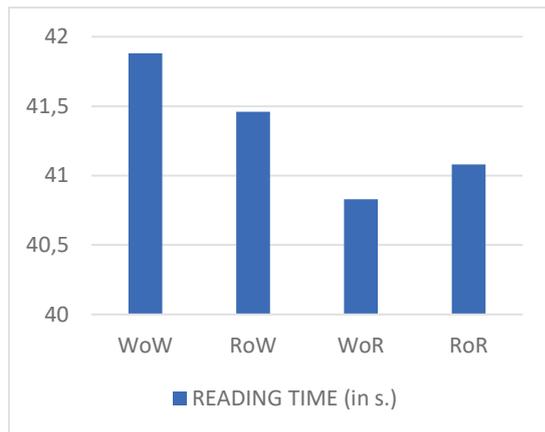


Figure 2. Mean values for reading time measured in seconds.

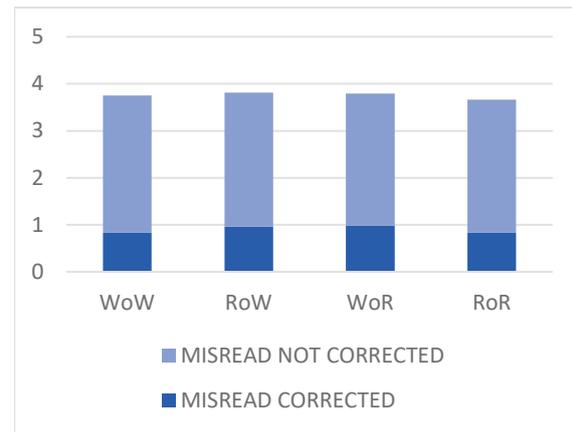


Figure 3. Mean values for words that the participant misread but not corrected afterwards, words that the participant misread but corrected afterwards, and total number of misread words in the reading test.

Coding Test

The coding test was assessed on two features; (1) completion time, and (2) 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 ($\epsilon = 1359.224$, $F(3, 128) = .998$, $p > .05$, $\mu = .021$). There was a significant effect of board and wall color combinations on incorrect answers ($\epsilon = 9.708$, $F(3, 114) = 7.27$, $p < .001$, $\mu = .134$). 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 5. 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 ($F(1,46) = 5.2$, $p < .05$).

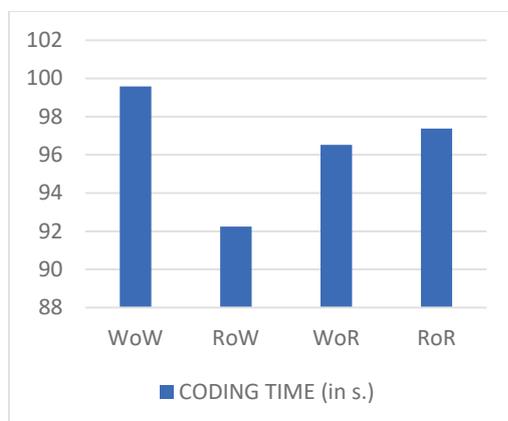


Figure 4. Mean values for coding time measured in seconds.

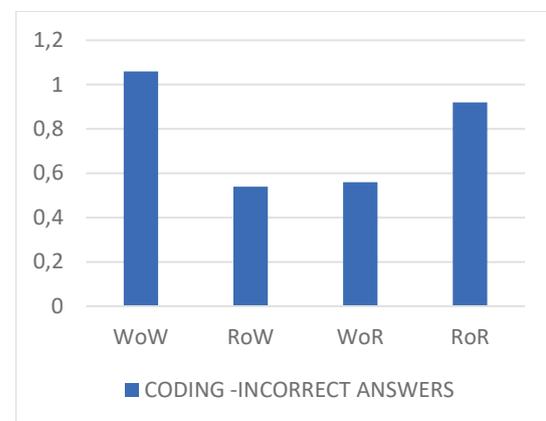


Figure 5. Mean values for incorrect answers in the coding test.

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 ($\epsilon = 1572.292$, $F(3, 134) = 3.193$, $p < .05$, $\mu = .064$). 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 6.

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 ($\epsilon = .125$, $F(3, 120) = .168$, $p > .05$, $\mu = .004$), on the number of incorrect answers where the participant counted less instances than the correct answer ($\epsilon = .104$, $F(3, 138) = .048$, $p > .05$, $\mu = .001$), or on the total number of incorrect answers ($\epsilon = .229$, $F(3, 137) = .084$, $p > .05$, $\mu = .002$).

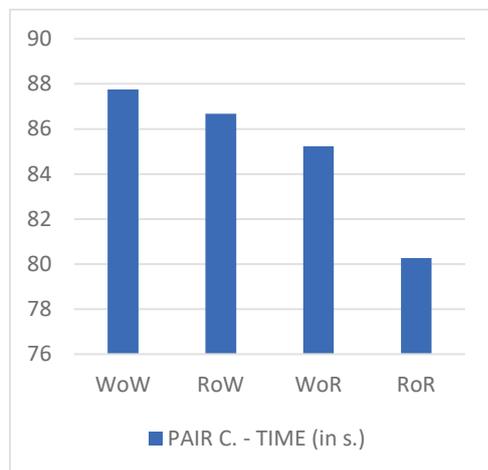


Figure 6. Mean values for pair cancellation time measured in seconds.

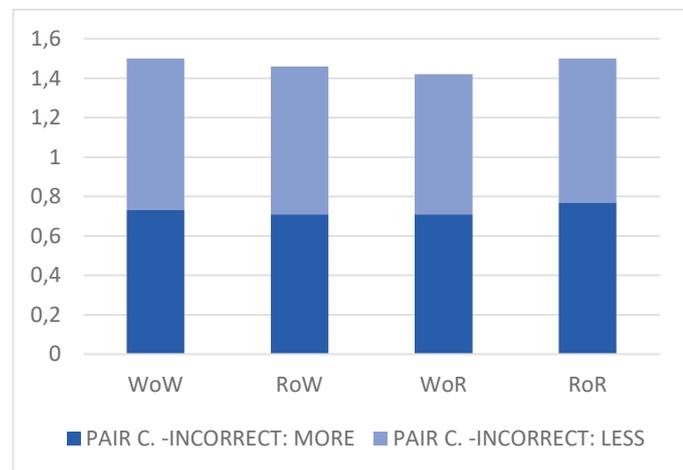


Figure 7. Mean values for number of incorrect answers where the participant counted more instances than the correct answer, number of incorrect answers where the participant counted less instances than the correct answer and total number of incorrect answers in the pair cancellation test.

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 ($\epsilon = 12.474$, $F(3, 122) = 3.261$, $p < .05$, $\mu = .065$). 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. 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 ($F(3, 126) = 7.266, p < .01, \mu = .136$).

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 8. 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.

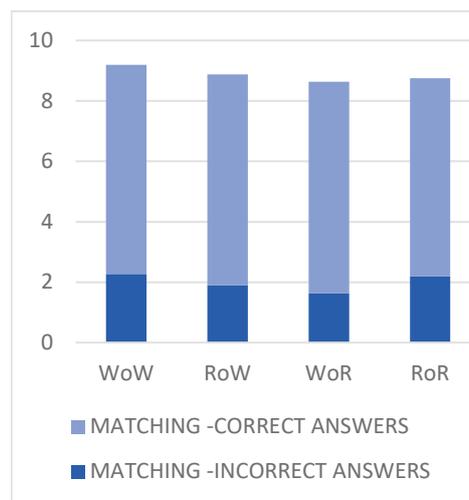


Figure 8. Mean values for number of incorrect answers, number of correct answers, and total number of answers in the matching test

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 ($\epsilon = 6.021, F(3, 138) = .367, p > .05, \mu = .008$) nor on the total number of answers ($\epsilon = 8.391, F(3, 133) = .517, p > .05, \mu = .011$).

Discussion

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 (Imhof, 2004; Iovino et al., 1998; Zentall, 1986; Zentall & Zentall, 1983; Zentall & Shaw, 1980; Zentall, Falkenberg, & Smith, 1985). It is hoped that this study adds to the sparse literature of children with ADHD and color.

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 are 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 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 significant 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.

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, several studies 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 ADHD children (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.

Contrary to some previous research which suggest that seeing red hurts performance (Elliot et al., 2007; Gnambs et al., 2015; Lichtenfeld et al., 2009; Maier et al., 2008), in this study no negative effect of color red have been found on performance. None of these aforementioned studies were made with an ADHD sample and the color red is used in the testing material thus the difference might stem from the fact that in this study red was used as an environmental stimuli and with ADHD children. The effect of hue is investigated with the ADHD sample in the colored overlay study by Iovino et al. (1998) which investigates 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. The findings are also in line with studies which used red as an environmental condition and found positive effects on performance (Johnson & Ruiter, 2013; Kwallek et al., 1997; Kwallek & Lewis, 1990; Stone, 2003). It can be argued that Elliot and Maier's color-in-context theory (2012) might explain the difference in performance when red is used on the testing material or on the environment. 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. The study by Brooker and Franklin (2016) where exposure to red boards is found to hurt performance for children could be explained in this direction. Introduction of color is not on the testing material however different colored boards are

randomly assigned to children in a classroom which might be perceived as more personal thus create a fear of failure.

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 & Janzen, 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.

Limitations, Conclusion and Suggestions

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).

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 class 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 in the previous years and green in the following years, 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.

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 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. 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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