Understanding How ADHD Affects Visual Information Processing

Yahya Alqahtani(✉), Michael McGuire(✉), Joyram Chakraborty(✉), and Jinjuan Heidi Feng(✉)

Department of Computer and Information Sciences, Towson University, Towson, USA
{yalqahl, mmcguire, jchakraborty, jfeng}@towson.edu

Abstract. Attention Deficit Hyperactivity Disorder (ADHD) is a condition that is characterized by impulsivity, age-inappropriate attention, and hyperactivity. ADHD is one of the most prevalent disorders among children. For a significant number of children whose condition persists into adulthood, ADHD leads to poor social and academic performance. In this paper we present preliminary results of an experiment that investigates how ADHD affects visual information processing under three information presentation methods (textual, graphical, and tabular). The efficiency and accuracy of both the neurotypical group and the group with ADHD were significantly impacted by different information presentation methods. However, the neurotypical group and the group with ADHD showed different patterns in their perceived interaction experience with the three information presentation methods. The result provides insights that might help designers and educators develop or adopt more effective information representation for people with ADHD.

Keywords: ADHD · Information presentation methods · Visual information processing

1 Introduction

One of the most common mental disorders that affect children and adults is Attention-deficit/hyperactivity disorder (ADHD) [1]. People with ADHD experience different symptoms including short attention span, hyperactivity and impulsivity [1]. According to the Centers for Disease Control and Prevention (CDC), the estimated number of children and adolescents who have ADHD is 6.1 million, which counts for 9.4% of children 2 to17 years old [2]. Until today, the real cause of ADHD hasn't been identified and the focus of the treatment is to reduce its symptoms [2]. Treatment for ADHD usually combines psychological and medical interventions. Medical interventions seek to reduce hyperactivity and impulsivity as well as to enhance the ability to focus, learn and work [3]. Although ADHD causes long-term impact on a large number of children and adults, existing research on information technology based solutions to support people with ADHD is rather limited [4].

Analyzing data presented in various forms is crucial for both academic and professional performance as well as everyday life. Different information presentation

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methods can substantially affect task performance. To date, there is no research conducted that investigated the effect of ADHD and information presentation methods on visual interaction when processing data. To fill this gap, we conducted an experiment to better understand the relationship between ADHD and information presentation methods in the context of visual information processing. The specific information presentation methods investigated in the study are textual presentation, graphical presentation, and tabular presentation. The result of the study provides insight on how people with ADHD interact with different information presentation methods as well as their subjective perception regarding the interaction experience.

2 Related Research

2.1 ADHD

ADHD has been established as a brain disorder that affects the development and functioning of both children and adults. The disorder is characterized by inattention because the afflicted individual is unable to sustain attention and is not persistent when performing tasks. It is also presented as hyperactivity because the individual is restless and frequently moves, including excessive mannerisms such as tapping and fidgeting and excessive talking. Impulsivity is yet another characteristic, which is manifested as acting hastily often without prior thought, being intrusive in social situations and interrupting others excessively. [1] ADHD is a prevalent neurobiological condition among children and its behavioral influences are most noticeable in school-age children as it affects between 5% and 8% of these children [5].

In children, ADHD is observed with various behavioral attributes including having a short attention span as these children lose attention after short durations. This problem may lead to poor academic performance, especially in the subjects or activites that require sustenance of attention. It has been reported that children with ADHD underperform in reading and mathematical tasks [5].

2.2 Computer-Based Solutions to Support People with ADHD

Most of the previous work in assistive technologies regarding users with ADHD focused on monitoring or extending the users' attention span or supporting specific daily routines [6, 7]. For example, Beaton et al. developed a reflective mobile application to help young people with ADHD better understand their engagement levels during their daily tasks. The application was used together with an electroencephalographic (EEG) device to collect data about user-specific task engagement. The task engagement data was further analyzed with geographic and temporal data so that the degree of engagement could be interpreted in the context of time and location [6].

Dibia introduced FOQUS, a smartwatch application designed to help people with ADHD increase their attention span and reduce anxiety. The app has functionalities such as Pomodoro time management technique, meditation techniques, positive messages and health tips. 10 participants with ADHD used the application during an evaluation study and eight of those participants reported reduced level of anxiety [7].

Researchers also developed games such as Tarkeezy that makes use of eye tracking technologies to develop engaging behavioral therapy programs. The system captures a user's eye gaze while playing the game and the data is used as an control element in the game's interactive interface [8].

More recently, Asiry et al. designed a system with an adaptable user interface to extend attention span for children with ADHD. In this study, children's attention during reading is tracked through two modalities: their eye movement captured via a webcam and the location of pointing via a mouse. Whenever the system senses that the user is hovering on a pre-defined Area of Interest, one color scheme would be applied to that area in an attempt to keep the user attentive to the content. A user study was conducted involving 21 students with ADHD aged between 10 to 12. It was found that 'highlighting', 'contrast', and 'sharpening' all significant affect the attention span of children with ADHD. However, the 'highlighting' scheme had the highest effect among the three schemes [9].

Analyzing data presented in various forms are crucial for both academic and career development as well as everyday life. It has long been discussed that different information representations such as tables and graphs could affect information processing and decision-making [10]. Given the reported difficulty that people with ADHD experience in reading and mathematical skills [5], insight on how people with ADHD interact with different information representations may help understand the challenges they experience in related tasks. To date, there is no previous research examining this specific topic. Therefore, we conducted a controlled user experiment as the first attempt to start filling this gap.

3 Method

3.1 Experiment Design

In this study we adopted a split-plot design that consists of both between-group and within-group variables. The between-group independent variable is the condition of the participants: the neurotypical group and the group with ADHD. The within-group independent variables are the information presentation methods and the difficulty of the questions. Three information presentation methods were investigated in this study: the textual method, the tabular method, and the graphical method. Participants answered 3 groups of questions with different levels of difficulty based on the visual information presented to them.

Participants' performance was measured through the time it took to complete the task, the quality of the answers provided by the participants, and satisfaction and preference ratings collected through a post-test questionnaire. We also collected the participants' eye movement data through a Tobii X2 60 system to better understand the visual scanning patterns while interacting with different information representations.

3.2 Participants

Twenty-four participants took part in the study. Twelve participants had no cognitive or perceptual impairments and twelve participants were diagnosed with ADHD. The neurotypical participants were recruited through email announcement and flyers. The participants with ADHD were recruited via email announcement through a student support group on campus. In the neurotypical group, three participants were female and nine were male. In the group with ADHD, six were female and six were male. All participants were native English speakers. The age for all participants was between 20 to 24 except for one neurotypical participant who was between the age of 25-30 and one participant with ADHD between the age of 18 to 20. All participants were university students with different majors.

3.3 Scenario and Tasks

During the study, the participants viewed health-related information presented in different methods and answered questions based on the information presented. Health-related information was chosen as the context of the tasks because people constantly browse and search health-related information on the Web. We developed imaginary data for four counties regarding smoking, high cholesterol, diabetes and high blood pressure and their occurrence among four ethnic groups. The amount of information contained in each country was the same. For each country, we developed three questions for participants to answer based on the data presented. The level of difficulty of the questions varied based on the amount of information needed to answer the question. The easy questions required the participant to navigate the information about a specific ethnic group in order to find the answer. For example, in order to answer the following question, the participant only needed to navigate to the data about the male Asian group.

> "Among Asian males, which of the 4 health related conditions has the highest percentage of occurrence?"

The medium level questions required the participant to find information about a specific gender. For example, in order to answer the following question, the participant needed to find relevant data about all female ethnic groups.

> "Among all female groups, which ethnic group and condition has the highest percentage of occurrence."

The difficult questions required the participant to look at all groups to find the answer. For example, in order to answer the following question, the participant needed to find data about all ethnic groups, both male and female.

> "Among all groups, which ethnic group and condition has the smallest difference between male and female?"

The quality of an answer was measured using a numeric rating with three possible values: 0, 0.5, and 1. For the easy questions, the answer only consisted of one specific health condition. An answer with the correct condition would receive a quality rating of 1. An incorrect answer would receive a quality rating of 0. The answer for a medium or

difficult question consisted of two components: one specific health condition and one specific ethnic group, each contributing 0.5 point towards the quality rating. An answer containing both the correct health condition and the correct ethnic group would receive a quality rating of 1. An answer containing the correct health condition but the incorrect ethnic group, or vice versa, would receive a quality rating of 0.5. An answer containing incorrect health condition and incorrect ethnic group would receive a rating of 0.

3.4 Information Representation

We developed three sets of webpages that present the same amount of information in three different information presentation methods: textual, graphical, and tabular (Figs. 1, 2 and 3). The three information presentation methods were chosen because they are the most commonly adopted methods to present visual content.

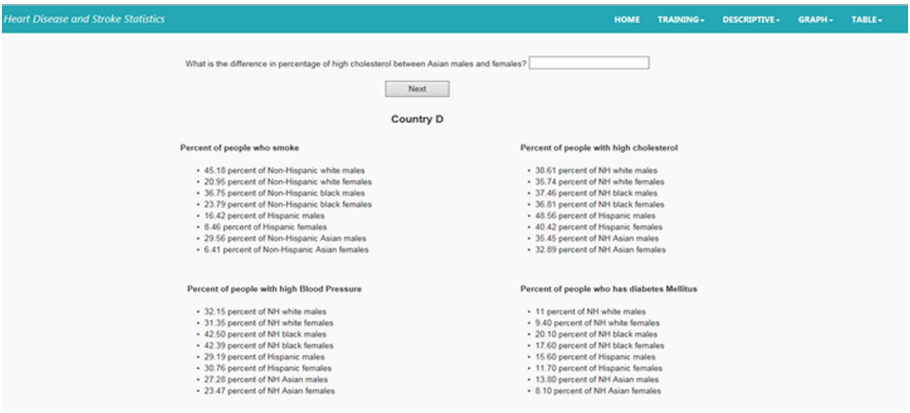

Fig. 1. A webpage presenting the health-related data in the textual method

3.5 Procedure

At the beginning of the study, the participants completed a training session that exposed them to all three information presentation methods. Following the training session, each participant reviewed the health information of three countries presented in three conditions (textual, graphical and tabular) and answered questions based on the information. Under each condition, they viewed the data of a specific country and answered one easy question, one question of medium level difficulty, and one difficult question. Both the order of the information presentation methods and the countries were counterbalanced to control the learning effect. Participants completed a demographic and satisfaction questionnaire at the end of the study. At the end of the experiment, all participants were awarded a $20 gift card for their time and effort.

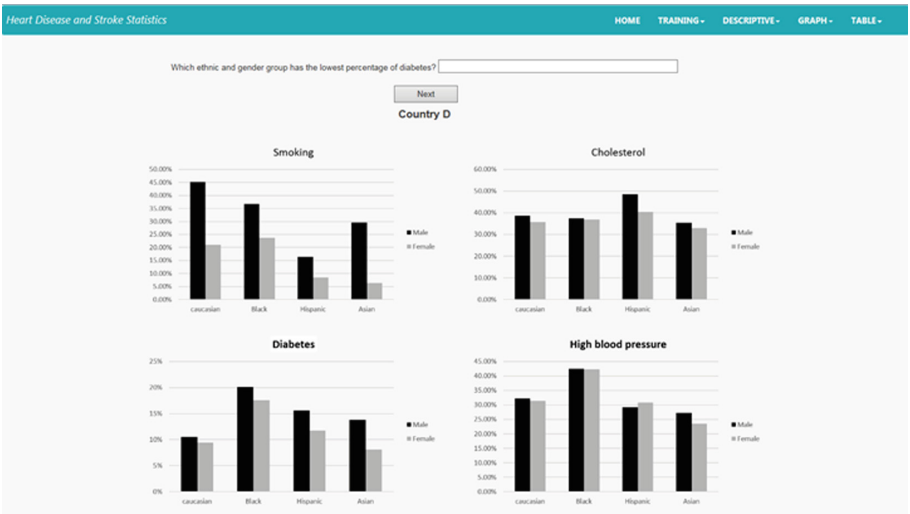

Fig. 2. A webpage presenting the health-related data in the graphical method

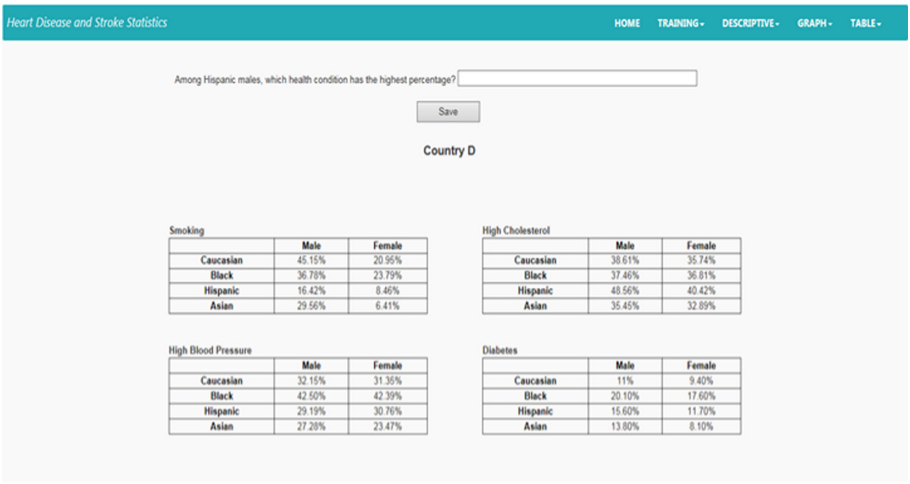

Fig. 3. A webpage presenting the health-related data in the tabular method

4 Results

We conducted a Repeated Measures Analysis of Variance (ANOVA) test with task completion time as the dependent variable and participant condition, information presentation method, and question type as the independent variables. The results suggest that both information presentation method and type of questions have significant effect on task completion time ($F(2, 44) = 42.62$, $p < 0.001$; $F(2, 44) = 7.93$, $p < 0.001$). There is a significant interaction effect between information presentation

method, types of questions and task completion time ($F(4, 88) = 10.19$, $p < 0.001$). No significant difference is observed in task completion time between the neurotypical participants and the participants with ADHD ($F(1, 22) = 1.21$, n. s.). As indicated in Fig. 4, participants in both groups spent significantly longer time completing the tasks when the information was presented in text as compared to a graph or a table.

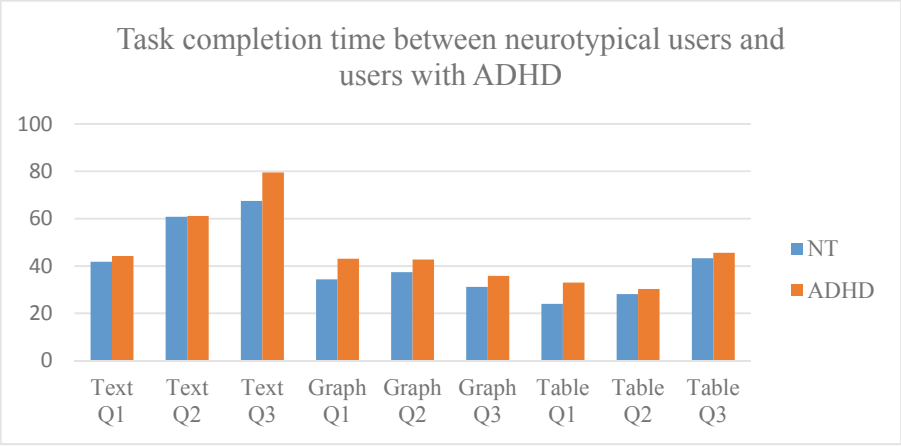

Fig. 4. Task completion time (in seconds) of both participant groups

A Repeated Measures Analysis of Variance (ANOVA) test was also conducted with answer quality ratings as the dependent variable and participant condition, information presentation method, and question type as the independent variables. No significant difference was observed in the quality of answers between the neurotypical participants and the participants with ADHD ($F(1, 22) = 0.59$, n. s.). Both the information presentation method and the type of questions have significant effect on the quality of the answers ($F(2, 44) = 6.23$, $p < 0.005$; $F(2, 44) = 12.29$, $p < 0.001$). There was significant interaction effect between information presentation method, types of questions and quality of the answers ($F(4, 88) = 6.00$, $p < 0.001$). As demonstrated in Fig. 5, neurotypical participants had lower-quality answers when the information was presented in text as compared to table. For participants with ADHD, no significant difference was observed in the answer quality ratings among the three information presentation methods.

At the end of the study, participants ranked their preference for the three information presentation methods. The graphical method was the most preferred among the neurotypical participants (6 out of 12) while the tabular method was the most preferred among the participants with ADHD (8 out 12). Regarding the least preferred method, 9 out of 12 neurotypical participants chose the textual method and 2 chose the graphical method. Interestingly, 7 participants with ADHD chose the graphical method and 4 chose the textual method. A Chi-squared test suggests that the difference in the preference rankings between the 2 groups is significant ($X^2(1) = 4.70$, $p < 0.05$).

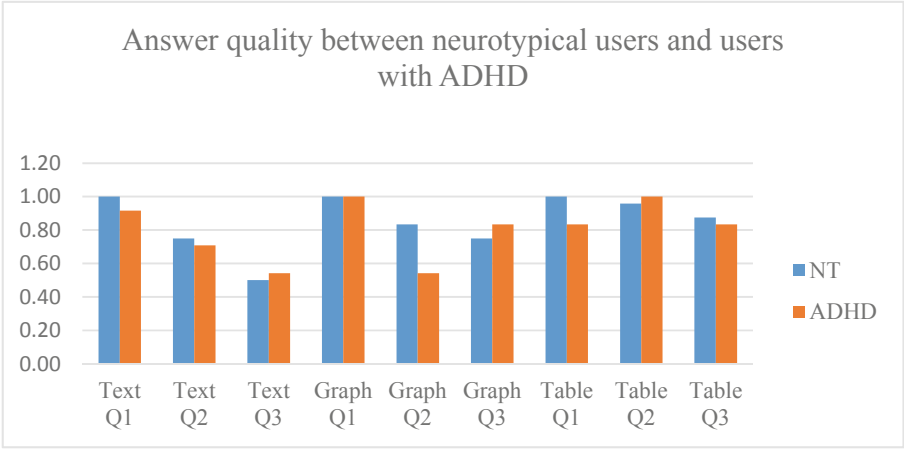

Fig. 5. Answer quality ratings of the neurotypical group and the group with ADHD

The preference rankings of the neurotypical group was consistent with their performance measures while the rankings of the participants with ADHD was not, suggesting that the perceived satisfaction of the participants with ADHD might be influenced in a larger extent by additional factors besides task performance measures collected in this study.

5 Discussion and Conclusion

We examined the impact of three information representations on visual information processing for people with ADHD through a controlled experiment. Compared to the neurotypical participants, the participants with ADHD spent similar amount of time to answer the questions and produced answers of similar quality. For both the neurotypical participants and the participants with ADHD, the textual method required significantly longer time to answer the questions than the tabular method and the graphical method. However, there was a difference in the impact of information representation on the quality of answers between the two groups. The quality ratings of the participants with ADHD were similar among the three information representations while the neurotypical participants had higher ratings in the tabular condition than the textual condition.

There is also significant difference between the two groups of participants in the subjective preference rankings. 9 of the 12 neurotypical participants chose the textual method as the least preferred method, which was consistent with the task performance results. In contrast, only 4 of the participants with ADHD chose the textual method and 7 chose the graphical method as their least preferred method, which was inconsistent with the task performance results. In the future, we will analyze the eye tracking data to examine the visual scanning patterns of the participants. We hope that the eye tracking

data will help explain the inconsistency between the performance measures and the perceived satisfaction of the participants with ADHD.

This study provides preliminary understanding regarding how people with ADHD interact with different information presentation methods. However, the results need to be interpreted with caution because of the small sample size. In addition, we didn't collect information about the medication usage of the participants due to IRB restrictions. Some of the participants with ADHD might have taken medication on the day of the study, which could have affected their performance. We are planning a future study involving a larger number of participants with ADHD. We are also revising the IRB application so that medication and other health-related information relevant to task performance could be collected.

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