The Effects of Different Navigation Techniques on Distractibility of ADHD and Non-ADHD Individuals In Virtual Reality

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As more efforts are being put towards research for treatment of ADHD, several researchers have turned towards VR as a method of potentially diagnosing or treating individuals with ADHD. While VR technology works to become more inclusive and accessible, it is being increasingly being recognized as a powerful tool with abilities to help treat those with disabilities. The goal with this study was to use prior research on VR as a treatment for ADHD, and attempt to identify a method of navigation that would benefit individuals with ADHD. Because distractability and lack of attention is one of the most common symptoms experienced by people with ADHD, finding a method of navigation to assist people work in VR could be a useful component in using this technology as a treatment. This study used 12 participants in a repeated measures study to identify if there was a statistical difference between using a quest-marker or line to navigate through an environment in VR. Out of the 12 participants, 6 had ADHD, and 6 did not. The 6 that did not have ADHD were used as a control group. To determine which method of navigation yielded the best results, we tested the time it took to reach the objective, the time spent delayed by a distraction, as well as asking each individual which method they preferred and why. Ultimately, the speed in which it took individuals to complete the course did not significantly vary for each method of navigation. The standard deviations for both the line and quest-marker were to great to identify any significant difference. However, when asked which method was preferred, 11 out of 12 participant chose the line. These findings suggest that there is no significant difference between these methods of navigation regarding performance, though one of the methods was perceived as easier by the test subjects.

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1 INTRODUCTION

Attention-Deficit/Hyper-Activity Disorder (ADHD) is an increasingly recognized and diagnosed neurodevelopmental disorder that can have significant impacts on affected individual's daily lives. According to the DSM-5, ADHD is classified by 5 or more behaviors creating a pattern of inattention or hyperactivity. The DSM-5 lists a variety of behaviors related in inattention such as failing to give close attention to details in school or work, failing to follow through with tasks such as chores or homework, and an avoidance or dislike for engaging in tedious, mentally strenuous efforts such as preparing reports, homework, and reviewing lengthy papers [1].

While ADHD can be treated through stimulant medications such as Ritalin or Adderall, many choose to treat ADHD through behavioral methods such as therapy. This can be due to a variety of reasons, such as the cost or side effects of medication, though it is becoming increasingly clear that research into behavioral methods of treatment are of paramount importance in this field [11] . Due to the importance of behavioral treatments, we sought out to test the

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relevance of virtual reality in ameliorating ADHD symptoms. There have been several attempts to aid those with mental health disorders such as post traumatic stress disorder (PTSD), phobias, autism spectrum disorder, eating disorders, etc. While there have been varying levels of success in treating these disorders, the prospect of using VR to treat symptoms of ADHD seems to be promising [8].

The intention behind this study was to design a system in which a user would use different methods of navigation within VR. They would be expected to reach an objective as quickly as possible, while also dealing with various distractions we had implemented. Our goal was to determine which method of navigation would most benefit individuals with ADHD complete a task. As virtual reality becomes more prevalent as a method to consume media as well as for educational purposes, accessibility is an important issue to focus on. A great deal of research has been done on making VR accessible to those with physical disabilities such as a study intended to create a user interface that is more accessible to those with visual impairments. This study adaptive zoom, inverted colors, and auto-reading [19]. While these are great steps, there is more work to be done in making VR more inclusive towards those with mental or learning disabilities, While there is a great body of research concerning using VR as a diagnostic tool for ADHD or as an intervention, we found they often lacked the detail of using navigation methods best suited for those with ADHD. This experiment aimed to contribute to this body of research by providing potential methods to create more accessible technology through providing optimal navigation methods.

Research indicates that around 3-10% of children are diagnosed with ADHD while only 1-6% of adults continue to struggle with ADHD. Symptoms of ADHD in adults include hyperactivity, inattention, disorganization, and irritability. A study suggests that medications such as selective serotonin re-uptake inhibitors (SSRIs) do little to relieve symptoms of ADHD in adults. Stimulant medications seem to be most effective in providing relief. However, consistently taking these medications often does have side effects, therefore, cognitive behavioral therapy and other methods of alternative treatments are sought out [20]. Because adults have often already gone through several treatment options, our study intends to focus on this group of individuals to identify the most beneficial forms of navigation to assist those with ADHD when using virtual reality as a form of treatment or otherwise.

The goal of this study was to determine a method of navigation in VR that would best suit the needs of individuals with ADHD, primarily focusing on adults with ADHD. The navigation method with the greatest level of success combating inattention could have implications of creating more accessible technology for individuals with ADHD.

2 RELATED WORKS

Previous studies regarding ADHD and VR primarily focus on diagnosing children with ADHD through VR as well as the possibility of using VR as an intervention. While this study does not focus on using VR as a diagnostic tool, the research gathered assisted our efforts in building an environment in VR that could test and combat inattentive behaviors in individuals with ADHD.

In a study titled "A study on the system for treatment of ADHD using virtual reality", the intention was to treat individuals diagnosed with ADHD in a reformatory through virtual reality therapy. The method the authors used to determine improvement of the subjects' inattentive behaviors was through detection of errors of omission. It was concluded that the individuals who participated in the study improved more than those who were not [11]. This suggests that there could be significant benefits to using VR as a method to assist with ADHD symptoms. This study also assisted in our effort to choose dependent variables to measure the subjects' performance. A control group was used in this study which we found to be a crucial step to determining the effectiveness of the intervention.

Using a meta-analysis, we were able to understand the effects of several papers regarding virtual reality based interventions. The paper analyzed four studies that were all aimed at finding the effectiveness of VR as an intervention for individuals with ADHD. The authors examined omission errors, commission errors, correct hits, reaction time, and perceptual sensitivity. These were all used as dependent variables in previous studies to measure the test subjects' performance. It was determined that for omission errors, correct hits, and perceptual sensitivity, there was a significant effect. There was a moderate effect regarding commission errors and reaction time [17]. This information is necessary to understand which variables may have the best possibility for capturing the performance of an individual in virtual reality environments. Further, this allowed us build an environment that could measure these results.

A different study analyzed the concept of using a virtual reality classroom to assist in ADHD symptoms. The authors constructed a classroom environment through virtual reality that served to improve the attention of children with ADHD [15]. The context of this study greatly differs from our own, though it demonstrates how VR can be an effective tool in assisting ADHD. Our study aims to complement studies such as this by adding navigation to continue to assist behavioral therapies being conducted for individuals with ADHD. The authors of the study used controlled distractions to continuously acclimate the children to focusing in an environment with distractions [15]. This further contributes to understanding the background of our experiment.

A study titled "ADHD assessment and testing system design based on virtual reality" created a classroom inside of VR and had participants take a test. In this study distractions were split up into 3 groups; pure audio, pure visual, and a combination of both [10]. These distractions were performed at semi-random times over the course of the test. Data was collected using an eye-tracker as well as an EEG. This study concluded that it was possible to diagnose people with ADHD using VR technology, as well as determining that collecting eye and EEG recordings improves the accuracy of the test[10]. Eye tracking is a common way of tracking distractability in VR. In a study it was observed that a persons gaze will be less focused on a particular target when a distraction has just occurred and that the participant's gaze will slowly focus back on the previous task once the distraction has stopped. It was concluded that the more that the eyes were moving around and not focused, the greater chance that they performed less well on the given task [18].

Additional research was done on VR as a diagnostic tool for ADHD in a study titled "Is a Virtual Reality Test Able to Predict Current and Retrospective ADHD Symptoms in Adulthood and Adolescence?" As shown by the title, this study examined current and retroactive symptoms. Using correct answers, omission, and commission errors, the authors were able to determine that the results were significant. Using VR to predict current and retroactive symptoms through the metrics listed above did yield significant results [2]. This gave us a larger body of research to build our study off of. Because the intention of our study was to build off of current tools, this helped us understand another field in which VR is being used to help individuals with ADHD.

Beyond researching VR and ADHD, it was necessary to review information regarding the efficacy of different methods of navigation in VR. The two methods used in this study were a gaze-directed steering method, as well as a pointing method. They identified these methods as two of the most efficient methods of navigation. Through their study, the authors also concluded that the pointing method of navigation yielded the best results. The subjects were able to complete their navigation faster and with fewer errors [4]. We gained a background in understanding different methods of VR navigation, as well as which could lend itself to improved performance. Our goal is to use this information to determine if we discover similar results in individuals with ADHD while the navigation is also paired with distractions. This study served as a baseline for understanding the efficacy of certain navigation techniques in VR.

Another journal titled "Evaluating the Performance of Virtual Reality Navigation Techniques for Large Environments" proved useful for our study by providing information regarding VR. The paper examines a study that was conducted in which participants are asked to complete multiple objectives and tasks inside a large virtual environment in a VR headset. The participants are given different navigation methods to assist them with finding and completing the objectives. This information was beneficial to constructing our study since our study aims to understand the effects of navigation within VR for individuals with ADHD. The study found that a variant of flight was useful for navigating the large world but allowing the participant to choose the method they preferred was the best option [5].

Another journal that assisted us in determining additional methods to collect data from our participants was "A Comparison of Virtual Reality Classroom Continuous Performance Tests to Traditional Continuous Performance Tests in Delineating ADHD: a Meta-Analysis". Some of the tests conducted were used to see if the researchers would be able to tell which participants had ADHD and which didn't simply from their behavior. The study also examined if a VR environment was more effective at alleviating the symptoms of ADHD compared to a 2D flat screen. The study determined that VR, at the time of the study, may not have the capabilities to simulate the real world sufficiently to analyze how it could be beneficial to those with ADHD. Additionally, the study was unable to find a significant difference between 2D and 3D [13].

To understand how people navigate through environments, particularly environments in VR, examining the navigation abilities of different animals can prove useful. In a study titled "A Toolset for Navigation in Virtual Environments", the authors studied the aviation patterns and navigation ability of birds. While avian navigation is not fully understood, it is known that birds use landmarks to determine their path. Through this, a hypothesis has been formed that humans make cognitive maps of their environments through a variety components. These include landmarks, edges, paths, nodes, and districts [6]. This study gave us information on how humans best navigate their natural environments, and therefore how to translate that knowledge to a virtual environment.

In our study, one of the main features was auditory distractions. In a paper we utilized for this study it was concluded that if an individual only hears audio, the type of audio they hear effects their response [3]. Another paper stated that unnatural soundscapes were perceived by participants as unpleasant and when audio is introduced it increases realism inside of the virtual world [7]. A reason why we focused on auditory distractions more than visual distracts was because, according to our research audio is easier to control and could elicit an expected response [12] if the sounds were correctly produced.

A final study we examined used gaming in virtual reality as a method to treat children with ADHD. It used a brain-computer interface intended to assist with symptoms of ADHD. The authors of this study received statistically significant results using 5 subjects regarding this game interface used to reduce symptoms of ADHD. While the study was small, there was promise for greater results using this technology [16]. Our study uses a game style interface in which users navigate in. The results of this study suggested there could be significant benefits for using a game interface for the treatment of ADHD.

3 METHODOLOGY

To begin this process, we designed a game environment in VR using Unity. We used two forms of navigation to traverse the world. The first form of navigation implemented is a "Quest Marker". It uses an arrow that appears at the top of the user's screen, pointing to the location of the objective. The second form of navigation used was a line displayed in the scene that displays a path between where the player starts and the objective the player must find. Our distractions played audio/visual effects once the participant walks within a certain radius of the distraction and the participant was *distracted* if the participant was looking close to the distraction and was inside the radius of the audio/visual effect. The auditory distractions were a few random noises that we recorded to be played while a user was navigating the map.

The visual distractions included some blocks in the way as well as a colorful, winding map. We prioritized auditory distractions due to the results of a study which indicated that irrelevant sounds affect the short term memory and attention of adults with ADHD [14].

Participants alternated between using the pointer or line as a navigation method first to combat order effect. One map was consistently the first map participants navigated through, while the other map was consistently the second environment. The environments were created to be open but also closed off. This was achieved by having patches of different colored trees scattered across the grassy map to inhibit the field of vision of the participant. The trees were placed between the start and end points intentionally so that the participant could not immediately see the objective. Participants could use the controller placed in their right hand to turn 45 degrees, while the controller in their left hand allowed them to move forward and backward. Through other studies, we determined that natural walking would be the best method of locomotion for our study. Along with reducing confounding variables, it would reduce motion sickness, and allow the user to reach the objective in a more natural way [9]. Many of our participants had limited experience in VR, so natural walking appeared to be the most convenient form of locomotion.

One mechanism of data collection was a timer which would be started when the participant walked through a transparent screen between the spawn and map areas and would be stopped when the player reached the goal. Our goal was represented by an invisible area that would check if/when the player entered it.

Prior to building our code, we finalized our variables as well as methods of testing. Our independent variable was modifying the method of navigation, as well as using individuals who had been diagnosed with ADHD and some who had not been. We wanted to determine if there was a difference between individuals with ADHD and those without, and we also wanted to test if there were performance differences between the navigation methods. We collected 12 participants, 6 with diagnosed ADHD, and 6 without. We determined that within subject testing would yield the best results as we could see each individual's performance with both methods of navigation. To prevent order effects, we randomized which method of navigation was used first. Some individuals used the pointer method with map 1 and the navigation line with map 2, while some individuals had the inverse experience. Our goals with changing the order which individuals used to navigate the maps was to prevent confounding results. Using two different map environments helped prevent participants from becoming too familiar with the layout of the map. Additionally, it was anticipated that the second round of testing would be easier as the participant would have some experience with the VR setup. We wanted to confirm that the results from this test were caused by the method of navigation rather than experience with the map and process of the experiment.

As for determining a participant's performance, we measured the time an individual took to navigate through the environment, the time they spent on distractions, as well as how many distractions effectively stalled the individual. As we were deciding on how to best track performance, [21] reviewing some previous related studies helped us determine that time to complete the task as well as error rates were some of the most effective methods of measuring their performance. We were able to measure these through using a timer within the code to measure how long it took each participant to get from the beginning to the objective. We also implemented code to track how frequently the participant became distracted and how long they were distracted. In addition to tracking their performance, we surveyed each test subject on their experience with each of the navigation methods. This provided us with a better understanding of the difficulty each test subject perceived with both methods of navigation.

Alongside building the virtual reality environment, we worked on constructing questionnaires to recruit subjects as well as mitigate confounding variables. To collect subjects, we inquired about whether or not they were diagnosed with ADHD, as well as personal details to understand the demographics of our test subjects better. The day of the experiment, we had each test subject complete a questionnaire prior to participating in the experiment. This questionnaire asked questions such as whether or not they had previous experience in VR, and if they had ADHD, had they taken medication that day? We asked several questions which would allow us to see any random or confounding variables. They proceeded to navigate through map 1 with their randomly assigned first navigation method. After the participant completed the first round of testing they were asked to complete a short survey on how difficult they felt the activity was as well as what they felt would have made it easier. The second round of testing began in map 2 with the other method of navigation. Finally, the test subject filled out a final questionnaire on the difficulty, as well as which test round they felt was easiest. Each participant was asked why they felt that the round they chose was easier. The information we collected aided our understanding of the test subject's thoughts on the experiment.

We collected parametric data from each participant regarding their completion time, how many distractions stalled them, and the amount of time each distraction effectively distracted them. Additionally, we collected some categorical data through the questionnaires we provided to each test subject. This aided us in understanding their perception of the difficulty. While looking at the statistics of which method of navigation proved the best results, it is also important to take into account how people felt about their experience with the navigation methods.

4 RESULTS

We gathered 12 participants between the ages of 19 and 37 for this study. Of those participants, 6 had ADHD and 6 did not. Of the 6 with ADHD, only one took prescribed medication for their symptoms. To gauge our participants experience with VR, as well as understand any confounding variables, we asked them to complete a questionnaire prior to the experiment. When asked how much experience they had with VR, 3 participants said they had over 16 hours of experience, 1 said they had 6-10 hours of experience, 4 said they had 1-5 hours of experience, and 4 said they had no experience with VR. This information was helpful as we could understand how quickly they would take to understand some of the controls of the VR controllers. Additionally, we asked participants if they had consumed any caffeine or other stimulants the day of the experiment. To this question 8 people responded no while 4 people responded yes. Because medication for ADHD are stimulants, this was important to know for the individuals with ADHD, even if they were not taking medication, this could improve their performance. Of the 4 participants who had consumed caffeine or other stimulants, 3 of those participants have been diagnosed with ADHD. While this might not have contributed to their performance, this was still important information to know.

Through our tests, our findings suggest there is no statistical difference between using the quest-marker (pointer) or line to navigate. The time in which it took participants to reach the objective had large deviations and therefore was not able to indicate any significant difference between the two methods of navigation. In Figure 1, the time in which it took each individual to complete the course is shown. This figure demonstrates that the greatest factor regarding completion time was whether or not that round was the individual's first or second round. The first round for both the pointer and the line overall took more time than the second round. While we tried to remove confounding variables by changing the environment in which participants were navigating between rounds, the issue of learning how to navigate still consumed time. Participants needed time to become accustomed to the controls as well as the navigation process. Several of our subjects had limited experience with VR, and the time it took them to learn how to navigate meant that their first round of the experiment took each individual slightly longer on average. On average, the first round with the pointer took approximately 13 seconds longer than the second round using the pointer. Regarding navigation with the line, participants spent an extra 1 second on the first round versus the second round with the line. The fact that the first

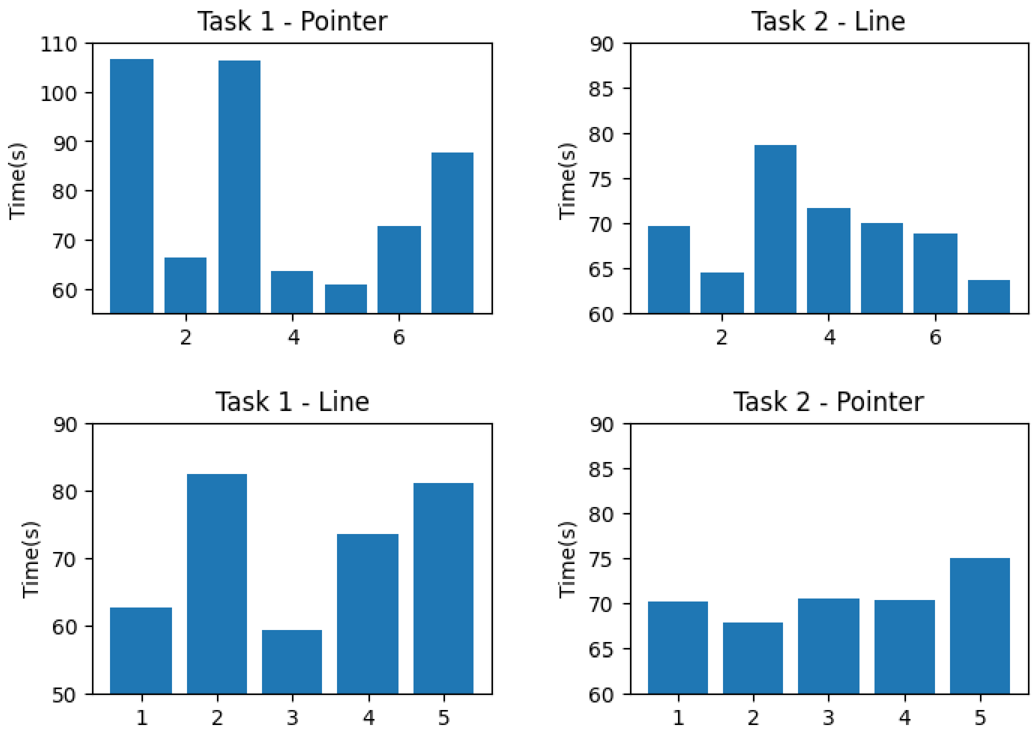

Fig. 1. Times taken to complete the levels in seconds

round with the pointer took an extra 13 seconds indicates that gaining experience of navigation, as well as learning how to use the pointer took more time than becoming accustomed to the line as a method of navigation.

By examining the data from Figure 3, it is also clear that there are is no statistical difference in performance between the participants who had ADHD and those who did not. With the pointer, participants who had ADHD had an average of 69.43 seconds to reach the objective. With the line, they spent an average of 71.78 seconds. For the participants who did not have ADHD, they spent an average of 86.09 seconds on the round where they used the pointer, and an average of 69.09 seconds with the line. These results do not differ drastically, and it appears that the average time for those without ADHD using the pointer exceeded the average time for participants with ADHD.

4.1 Data

As shown in Figure 1, the average time participants took to reach the objective with the pointer exceeded the average time participants took using the line. On average, the first round of testing with the pointer was 88.13 seconds and the second round with the pointer had an average of 75.02 seconds to complete. Examining the data for the line method, the first round took participants 66.31 seconds while the second round took 65.39 seconds. This appears to indicate that the line method of navigation yielded better results, though by examining Figure 2, it can be concluded that there

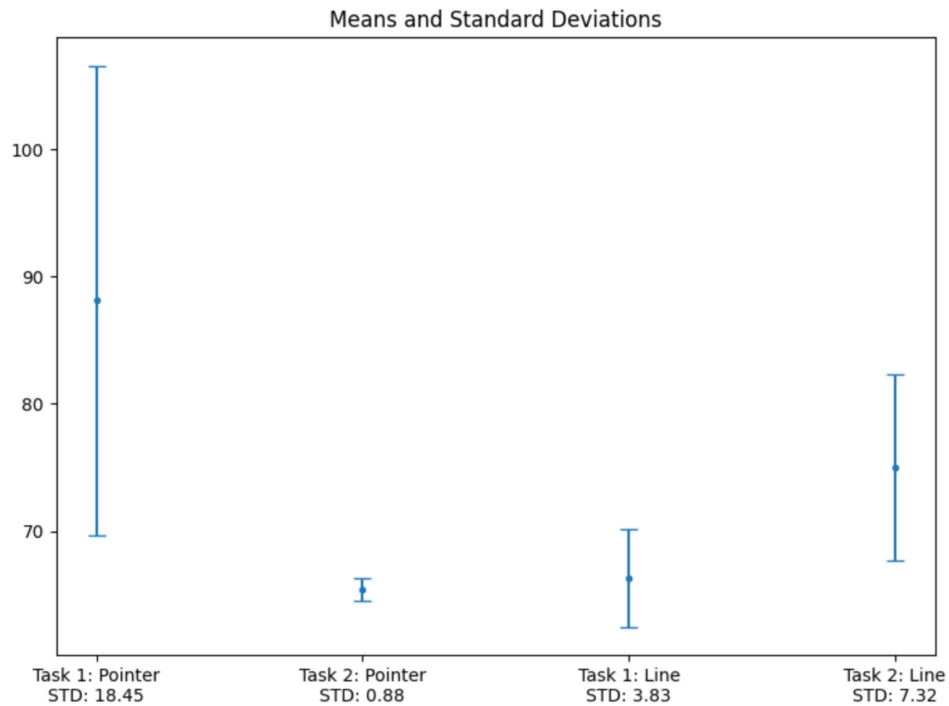

Fig. 2. This graphs shows the average time it took for each group to complete the tasks along with the group's standard deviations

is no significant difference. While participants took around 10 seconds less on average using the line as a method of navigation, the standard deviation is large. For the first round of experimentation using the line, the standard deviation was 3.83 seconds, while for the second round with the line, the standard deviation grew to 7.32 seconds. In regards to the standard deviation of using the pointer for navigation, the first round had a standard deviation of 18.45 seconds. Even though the second round with the pointer only had a standard deviation of 0.88 seconds, it is clear by looking at the averages and standard deviations of the other three rounds that these differences in average have no significant value due to the variation between participants being so large.

The same issue occurs when examining the difference in performance between participants with ADHD and those without. While the averages are different by almost 10 seconds, the standard deviations are too great to consider any statistical significance. The standard deviation for participants with ADHD when using the pointer came to 0.63 seconds, and for the line it was 2.18 seconds. While these are relatively small standard deviations, the standard deviations for the participants without ADHD was far greater and removed the possibility of a statistically significant difference between the ADHD and non-ADHD participants. The standard deviation for participants without ADHD using the pointer was 18.57 seconds, and for the line was 1.39 seconds. Because of this variation, there was no statistical significance.

While the data regarding the time each participant took to reach the objective did not show any significant difference, the questionnaires participants took showed clear preferences. 11 out of the 12 participants said they found the line

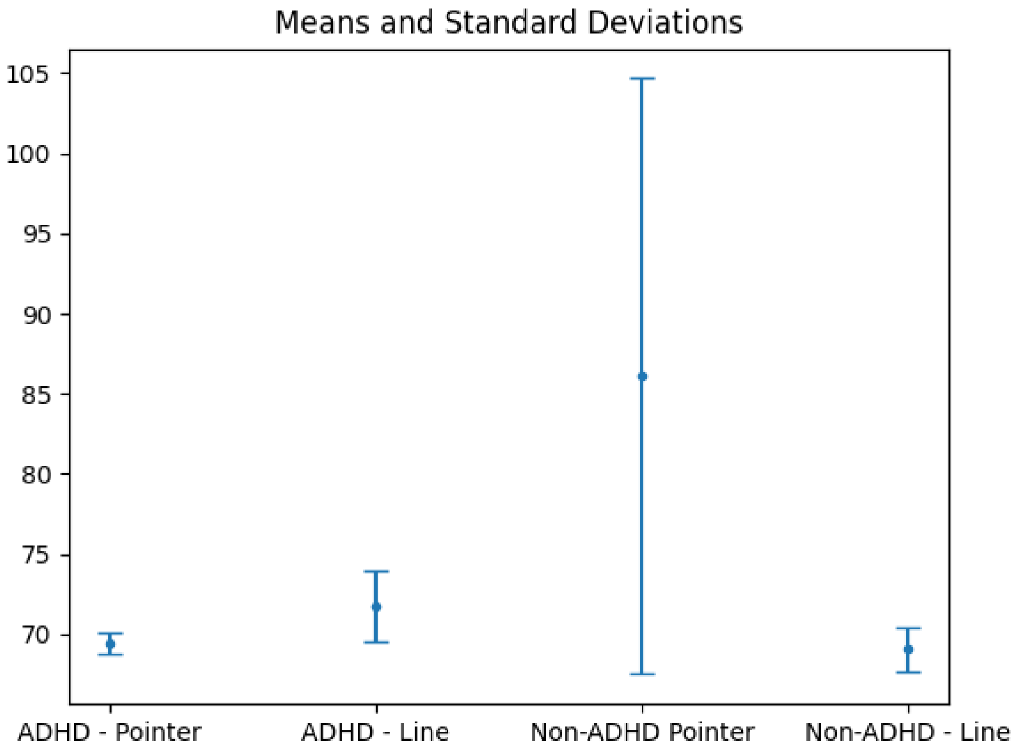

Fig. 3. The means and standard deviations for ADHD/Non-ADHD and type of pointer

to be easier to follow. The one who preferred the pointer claimed they felt more pressure to follow the line closely as opposed to the pointer. The other participants claimed that being able to see where they were going ahead helped them and made the course feel easier. Additional data collected in the questionnaires participants took after each round included what they felt was most difficult about completing the course. Several participants mentioned the auditory distractions as being slightly disorienting. This demonstrates a personal preference of the use of the line as a navigation method. While there was no statistical difference in the performance of the participants using the pointer or line for navigation, several participants preferred the line as a method of navigation. However, it is important to note that these results cannot be extrapolated for every circumstance.

Unfortunately, an error was committed in the experimentation process which impaired our ability to do proper data analysis. In our experiments, 7 participants used the pointer as their first method of navigation while only 5 participants used the line as their first method. The participants who used the pointer first were classified as G1 while the participants who used the line first were G2. Because these two groups were uneven, we could not run ANOVA tests on the data to get further information. This impaired the validity of our conclusion, though despite not having results from an ANOVA test, we could still determine that the results were not significantly different from one another and would have a p-value larger than 0.05.

Participants	Has ADHD	Task 1 time(s)	Task 2 time(s)	Time Spent Distracted(s)	Navigation Group
1	Yes	106.58	69.67	0	G1
2	Yes	66.26	64.51	0	G1
3	No	62.48	70.14	0	G2
4	Yes	106.28	78.59	4	G1
5	Yes	82.34	67.70	11	G2
6	Yes	59.32	70.48	0	G2
7	Yes	63.68	71.66	8	G1
8	No	60.86	70.06	0	G1
9	No	73.46	70.34	2	G2
10	No	72.74	68.80	4	G1
11	No	80.96	74.88	97	G2
12	Yes	87.66	63.58	2	G1

Table 1. This table shows the data collected from each of the participants.

4.2 Findings

The results we collected from this experiment were ultimately inconclusive. The time taken for each of the participants to reach the objective is shown in Figure 1 which demonstrates that the average time to complete the course while using the line is less than the average time using the pointer. However, when looking closer at the data, it is clear that because of the large standard deviations, there is no relation between the completion time of the tasks and the type of navigation technique used. The graphs in column one in Figure 1 have the largest variation of times while having different methods of navigation. The same is true for the second column where the times are more tightly grouped. This was again shown in the difference between participants with ADHD and those without. One of the largest issues faced in this study was the fact that we had 7 participants in G1 and 5 participants in G2. This meant we could not do proper ANOVA testing. Without this data our results suffer, though even without the ANOVA test, it was evident that because of the standard deviations sizes, our data still did not support one method of navigation have statistically improved performance over the other. Despite there being no significant difference in results based on the navigation, there was a preference for the line method of navigation. It should be noted that while there was an overwhelming preference for the line, this sample size was not large enough to determine preference for the population we were studying.

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