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Original Research Article

Sustained Attention Outcomes of ADHD Traits and Typically Developing Participants

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ABSTRACT

Recent analyses into the prevalence of ADHD illustrate the connection between ADHD traits and eye movements. This present study explored the differences between people with ADHD traits (PWADHDT) and typically developing (TD) participants in sustained attention by measuring the number of saccades (NOS), number of fixations (NOF) and fixation duration (FD). Individuals with ADHD traits (n = 17) or without (n = 13) were examined. A saccade task and antisaccade task were utilised through a VR-created environment, designed to imitate an urban setting. The saccade task required participants to look directly at a provided stimulus, whereas the antisaccade required participants to look in the opposite direction. This experiment imitated Munoz's 2003 study and aimed to assess whether there is a link between ADHD traits and eye movements,[1] as well as outline the higher levels of hyperactivity and lower levels of inattention exhibited by the ADHD group when compared to the control group. Results revealed that PWADHD showed greater hyperactivity and lower attention, supporting the hypothesis outlined above. The findings suggested that measures of eye movement can be used as indicators for ADHD traits, and propose the continued use of innovative VR software in future experiments.

Keywords: Behavioural and social sciences; cognitive psychology; ADHD traits; saccades; fixation duration

1. INTRODUCTION

1.1 Introduction to ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is a chronic neurobehavioral disorder characterised by excessive hyperactivity and inattention which presently affects 2.8% of the world population.[2] Studies from 2015 to 2021 discovered that 5% – 7.2% of youth and 2.5% – 6.7% of adults are afflicted with ADHD, with 6% of children are affected. Although 90% of adult cases lack a history of child-onset ADHD, up to 90% of children with ADHD (CWADHD) continue to experience symptoms into adulthood. [3, 4]

Recent years have seen increased focus on and awareness of ADHD, leading to increased diagnoses: from 2007 to 2016, reports of adult ADHD increased by 123% in the USA.[5] Gendered differences have also been noted, with boys being 2.28 times as susceptible to ADHD due to heightened impulsivity and hyperactivity,[6] while females are more prone to attention deficiency.[7] The Diagnostic and Statistical Manual of Mental Disorders widened DSM-IV criteria for ADHD diagnosis, such as removing the requirement for symptoms of impairment from an early age and accommodating for comorbidity.[4, 8]

As diagnoses increase in number and complexity regarding comorbidity,[5] it has become imperative that more diagnostic methods develop. The effectiveness of 8 different vigilance and sustained attention tasks in diagnosing ADHD impairment were evaluated in a recent study.[9] The German version of the Wender Utah Rating Scale (WURS-K) and Conner's Adult ADHD Rating Scale (CAARS) were used to assess childhood and present ADHD respectively prior to the experiment. Adults with ADHD (AWADHD; N = 31), aged between 21-64 years, were assessed with DSM-5 criteria and the Weiss Functional Impairment Rating Scale (WFIRS-S) was administered to evaluate everyday impairments common among AWADHD. Task order was randomised and spaced accordingly to minimise effects of practice or fatigue, and medication was halted at least 48 hrs prior. The 8 tasks ranged from 6.5-33 minutes long and measured reaction time (RT) associated with auditory perception, detection of colour change, perception of speed, perception of movement, working memory, and response inhibition. Post-mortem analysis of the results suggested that no single variable is most sensitive in determining levels of cognitive impairment and emphasised the importance of considering unique task paradigms when assessing a multifaceted disorder such as ADHD. Sustained attention tasks have been used to measure these abnormalities in people with ADHD (PWADHD) through various stimulus-response and stimulus-inhibition experiments, and recorded patterns in saccadic eye movement, such as Munoz et al.,[1] who measured inattention with visual fixation, and hyperactivity with eye movements.

1.2 Sustained attention tasks that have recorded saccades

Saccades are unconscious eye movements between points of fixation which reflect oculomotor precision. Goto et al. executed a three-part experiment to explore the links between saccade latency and accuracy in those with ADHD and lesions - areas of damaged brain tissue - in the frontal lobe.[10] 50 total subjects in the control group were split into 4 age categories: 6-8 years, 9-11 years, 12-15 years and 20-35 years. The ADHD group consisted of 19 boys aged 6-11 diagnosed with DSM-IV criteria. The first experiment, a visually guided saccade task, measured participants' horizontal saccade latency from a fixation point to an eccentric stimulus. It found that the mean saccade accuracies for ADHD and control participants were 17.7% and 8.7% respectively, a significant difference. The second, memory guided task measured participants' saccadic accuracy and latency as they recalled the location of a stimulus while sustaining attention on a central fixation point. In this experiment, ADHD and control groups aged between 6-8 years had significantly different saccadic accuracy and ADHD participants had a generally longer saccadic latency. Lastly, the concluding antisaccade task presented participants with a stimulus and required them to estimate a point equidistant from the fixation point in the opposite direction. Here, there was a higher likelihood of directional and anticipatory errors, indicating a link between greater hyperactivity and ADHD.

To examine the influence of age in determining response inhibition, Mostofsky et al. hypothesised that CWADHD would display impaired response inhibitions, and enlisted 19 children diagnosed with ADHD from DSM IV criteria and 25 controls to investigate.[11] In the prosaccade task, participants were required to look at an LED stimulus as soon as it appeared. In the antisaccade, they estimated the distance away from the cue stimulus and looked in the opposite direction. Lastly, in the memory-guided task, participants were instructed to recall and look at the location of a stimulus which had briefly been presented. Although the results of the prosaccade task showed no significant difference in saccade latency, the percentage of directional errors in the antisaccade was too great to measure saccade latency at all. ADHD children with and without medication exhibited a rate of anticipatory and directional errors approximately 10% more often than controls; they also experienced more saccades in general. The study concludes that saccadic abnormalities in response inhibition - and therefore weaker oculomotor control - may contribute to hyperactive and impulsive behaviour observed in CWADHD. Similar findings were found in a twin study carried out by Falck-Ytter et al. which hypothesised that lower performance in an ocular fixation task would correlate with ADHD traits.[12] 240 same-gender twin pairs (mean age 11.44) were assessed for ADHD symptoms with parent ratings in Conners 3, and gift vouchers were provided (approximately $35 each child) as a reward for participation. In the task, children were required to look at a fixation target continuously for 2 minutes without distractors while the number of saccades exiting a small area around the fixation target was recorded. As expected, a strong positive correlation was found between the rate of intrusive saccades and parent-reported ADHD traits, which suggests that oculomotor response inhibition (a symptom of hyperactivity), is reduced in CWADHD. Another visual fixation experiment similarly tested and illustrated the usefulness of eye tracking methods in measuring oculomotor response inhibition of those with ADHD traits.[13] A control group of 44 children and an ADHD group of 53 children, all averaging approximately 10 years, stared at an unmoving white square for 21 seconds. The study's results found that the CWADHD were significantly more likely to experience intrusive saccades and concluded that ADHD traits interfere with the ability to sustain attention in the absence of internal or external distractions, suggesting higher levels of hyperactivity in PWADHD.

On a neuroscientific viewpoint, Ross et al. experimentally deduced the role of the prefrontal cortex in saccadic inhibition, preparation of motor response and accuracy of memory-guided saccades.[14] 13 CWADHD diagnosed with DSM-III criteria and 10 controls from ages 9-12 formed the test group. The participants were seated in front of a video monitor and asked to fixate on a presented stimulus. A cue stimulus was briefly presented shortly after and the test subjects were required to look at it once the original stimulus had disappeared. The recorded saccade latency and accuracy of memory-guided saccades across both groups were not significantly different; this suggests that difficulty in response inhibition is common in this age group. However, children with diagnosed ADHD were more likely to exhibit premature saccades than control children, showing abnormal difficulty in inhibiting hyperactive responses.

Vakil et al. utilised the Stroop test to explore the attention difficulties prevalent in AWADHD regarding eye movement.[15] The Stroop test, popularised in 1935 by John R. Stroop, tests selective attention and interference control by presenting conflicting stimuli and requiring participants to isolate relevant information. An experimental group of 60 volunteers, split evenly into PWADHD and controls, were presented with a coloured rectangle and word ("yellow", "blue", or "red" etc) simultaneously on a screen. They reacted by pressing a key in the corresponding colour of the rectangle on a keyboard. When the rectangle and word conveyed the same colour, it was considered the "congruent condition", and when mismatched the "incongruent condition". Analysis of behavioural results revealed that the controls exhibited higher accuracy and speed than the ADHD group regardless of the condition. Contradictory to previous experiments, the ADHD group's overall fixation time on both distractor and target stimuli was longer than controls'. However, although fixations were measured, the Stroop test is inherently a selective attention assessment and does not evaluate sustained attention. Thus it is vital to extend research into fixations in sustained attention tasks, which little literature has covered.

1.3 Tasks which have recorded fixations

Caldani et al. explored the fixation capabilities of CWADHD by recording the number of saccades made in varying postural conditions.[16] The experiment involved a group of 42 children, half of which were diagnosed with ADHD with DSM-5 criteria. They performed a simple fixation task and one with a distractor, either sitting, standing on a stable platform or an unstable one. In the first task, the subjects fixated on a white circle presented a short distance away for 30s. In the second, a white smile target sporadically appeared and subjects needed to inhibit saccades towards the distractor. Both visual tasks highlighted a higher number of saccades and more time spent looking outside the fixation target for CWADHD, suggesting that PWADHD are more prone to inattention than controls.

Seernani et al. aimed to clarify behavioural and oculomotor consistencies within ADHD and TD children with a visual search task.[17] An ADHD group of 23 diagnosed by ICD-10 criteria and a TD group of 29 were told to firstly stare at a fixation cross on the left of a screen until a grid with paired words appeared on the right. Within the pairs was a cue word which they found and responded to on a response pad that mirrored the arrays of the grid. Although the difference between groups was not significant, the experiment found that ADHD children had longer reaction times, contrasting with past studies. These contradictions and the lack of abundant literature on fixations urge further research.

Papageorgiou et al. found in a follow-up longitudinal study that differences in infants' mean fixation duration are related to behavioural and attentional control in childhood.[18] The combined eye-tracking data of previously-published tasks from infants (N = 120) of average age 7.69 months was newly analysed to deduce fixation durations. It was found from the pre-existing data that fixation duration was negatively correlated with number of fixations. The participants' parents were contacted to fill in questionnaires which measured effortful control, surgency and hyperactivity-inattention on behalf of their children. For the latter, the hyperactivity-inattention scale from the parent report edition of the Strengths and Difficulties Questionnaire was used to evaluate such traits. The analysis showed that reported effortful control was negatively correlated with hyperactivity-inattention. The study recognises that ADHD is heavily interlinked with this behavioural trait and concludingly suggests that fixation duration in infancy is connected with developing ADHD. However, these conclusions may be flawed due to experimental limitations such as the use of subjective external observation.

A study focused on exploratory eye movements investigated differences in fixative behaviour among ADHD (n = 30) and TD (n = 26) subjects between ages 9-20.[19] Diagnoses were performed through interviews based on DSM-III criteria and all children were monetarily compensated with an unstated amount. While participants stared at a white stimulus on a screen in front of them, they were asked one of three different questions about an image, which was presented shortly after. The image remained onscreen for 8 seconds freely observed by the children, who answered the question after it disappeared. The experimental results revealed that the ADHD group had slightly shorter mean fixation duration regardless of what the question asked them to recall (global, focal and counting aspects). It was concluded that although the difference in fixation durations was small, the nature of the task was ill-fitted to measure focus as it did not require effortful problem-solving. Furthermore, the experiment only measured movements from one eye, which may limit its validity. Additionally, the subjects taking antidepressants (Zoloft and Prozac) were not required to halt their dosages for the study; therefore, their performance may have been inorganic.

1.4 Eye tracking technology

Advanced eye tracking technology has become an increasingly popular tool for measuring saccades due to its objective assessment of ADHD traits. Levantini, et al. surmises the versatility of eye tracking systems in the clinical field, particularly in visual fixation, saccade and antisaccade, and countermanding tasks that measure oculomotor control.[20] In a more novel direction, the paper suggests the potential of eye movement tracking to record fluctuations in pupil size and investigate emotionally salient stimuli. However, it acknowledges limitations, such as the inability to consider peripheral perception and difficulties in monitoring eye movement in naturalistic settings.

Merzon et al. emphasised the importance of using VR technology to recreate scenarios which more effectively emulate stimulus-rich real life surroundings, contributing to a more precise experimental analysis.[21] A control (N = 36) group and an ADHD (N = 37) group (diagnosed by DSM-IV criteria) were between ages 9-13 years. The experiment recorded visual fixation duration, saccade duration and saccade amplitude of control and ADHD groups in two VR settings: EPELI, where participants performed miscellaneous everyday tasks in an apartment; and Shoot the Target (STT), where participants located and “shot” targets by orienting their gaze at them. The experimental analysis suggested that EPELI’s naturalistic VR setting accommodated for aberrant eye movements that were triggered by varying factors across the duration of the task; instead of utilising focal processing on a static stimulus, the dynamic stimuli in EPELI’s tasks allowed participants to naturally switch between ambient and focal processing.

1.5 The Present Study

As presented above, some studies that measured visual fixation have drawn incompatible results.[17-19] We have considered that different task paradigms have specific strengths and therefore may produce varying conclusions. Additionally, literature exploring visual fixations in PWADHD is extremely limited. Thus, we recognise the need for further experimental study and have incorporated analysis of both saccades and visual fixation in our task.

This paper was based on Munoz et al. who hypothesised that PWADHD experienced difficulties in saccadic suppression and explored the influence of ADHD on saccadic reaction time.[1] In that study, 294 total participants were sorted into 4 groups: control or ADHD, and within that adult (18-59yr) and children (6-16yr). ADHD traits were assessed with DSM-IV criteria, Brown Attention-Deficit Disorder Scale (BADDS) for adults and Conner Parent’s Rating Scales (CPRS) for children. The first experiment was pro-saccade and explored the saccadic reaction time of ADHD and control participants by presenting LEDs positioned to the left and right of a central focal point, which required participants to look at the stimulus; the mean SRT was noticeably longer in the ADHD group than the control group. The second utilised an anti-saccade approach and required participants to look in the opposing direction when presented with an eccentric stimulus; ADHD traits were correlated with increased pre-emptive and directional errors. The third measured the frequency of intrusive saccades during prolonged visual fixation; the mean rate of intrusive saccades in the ADHD group was significantly above the control group. The findings from all stages suggest that decreased oculomotor control and erratic responses form part of ADHD traits, which is commonly characterised by similarly hyperactive behavioural indicators.

The existence of contradictory papers specifically regarding sustained attention and reaction time outcomes urges further research into this topic.[15, 17] The present study aims to identify the difference in eye movements between PWADHD and TD people in sustained attention tasks, and consequently to understand if eye movements can be indicative of ADHD traits. It is hypothesised that the ADHD subjects will exhibit higher levels of hyperactivity and lower levels of inattention than the control group, which the study will quantify in terms of number of saccades (NOS), number of fixations (NOF) and fixation duration (FD): The ADHD group will have a significantly higher number of saccades (H1), higher number of fixations (H2) and shorter mean fixation duration (H3). Hyperactivity has been operationally defined as NOS, as inconsistencies in oculomotor inhibition have been linked with saccadic eye movements. [1, 10-13, 16, 18, 20, 21] Differences in NOF and FD indicate discrepancies in attentional capacity as the inability to fixate begets inattention. Thus, the present study holistically analyses all aspects of ADHD.

2. MATERIALS & METHODS

2.1 Participants

Through UCL SONA, thirteen controls (Mean age: 22, SD: 2.121, 5 Females and 8 Males) and seventeen PWADHD (Mean age: 23.65, SD: 3.390, 7 Females and 10 Males) were recruited by Dr Kazazi. Symptoms of inattention and hyperactivity were self-reported in all PWADHD. The study was approved by UCL Research Ethics Committee (6252/002). Participants were compensated with £15 following the experiment including travel expenses within the M25 area. Participants received a consent form to sign and an information sheet before the experiment. Considering the total of 30 participants, the power analysis states that there is an 80% chance of detecting a trend.

2.2 Design

Normal hearing and vision were first required in participants. After this, they undertook the ASRS.[22] To remove potential ordering effects, the tasks were counterbalanced thus: if the ID of the participant was an even number, the order of tasks was VR tasks then ASRS, if it was odd, the order was ASRS then VR tasks. There was a brief opportunity before the tasks began for users to ask the experimenter questions and read instructions, and perform practice runs. Data from the eye tracking measures formed the dependent variables.

2.3 Materials

The VR saccade task was constructed in Unity in C# programming language, and materials were sourced from the Unity Asset store: 3D materials downloaded include a city landscape, appropriate sound effects such as traffic and intermittent talking, stationary vehicles and buildings. A moving plane 3D model was also utilised. For a naturalistic social environment, animated human avatars created in DAZ3D were made to talk and walk around the user, who was placed in the centre of the scene. There was a park in front of the users which was bordered by two roads (one on the left and one on the right) and housed a lamp in the middle. A pupil labs eye tracker attached to the lenses of the HTC Vive Pro VR headset and an adjacently connected Looxid Link EEG mask attached to its forefront were both connected to an Alienware m15 Ryzen Edition R7 laptop. Prior to the tasks' commencement, headset and eye tracker calibration was implemented to ensure high accuracy in the data. The antisaccade and saccade tasks featured the same setup and used the same assets built in C# Unity programming language. The same equipment and calibration procedure were also used.

2.4 Measures

The 2005 Adult ADHD self-report scale (ASRS) was also revised in 2017 to fit DSM-5 criteria, which was a step towards recognising variability in ADHD. The ASRS is an 18-question questionnaire used to evaluate an individual's ADHD traits.[23] Its design is based on stepwise logistic regression and machine learning, and created with reference to the World Health Organisation Composite International Diagnostic Review. The refined 2017 version with 6 questions was developed in 2017 to simplify the process while retaining a highly specific threshold applicable to the general population.[22] Whereas the ASRS cannot perform a medical diagnosis, it has been widely used in treatment settings.

2.5 Procedure

Participants started the prosaccade task in front of a virtual city environment, facing a park with roads on the left and right sides. Randomly coloured cars would drive past the users one at a time on either road. In randomised order, 25 cars were presented on each side, totalling 50 cars. The duration of each car's appearance was 1.15 seconds and the interval between consecutive cars was also 1.15 seconds. At a designated time within the exercise, an audible plane passed in the virtual sky. Participants were required to look towards the presented car and press a button on the VR controller which corresponded with the side the car drove. For example, given a car passed the user on the right, users were to look to the left road and press the controller's left button. In the space between two cars' appearance, the user stared at the lamp in the park before them. Prior to the task, participants were allowed practice. The procedure of this task is based on Munoz et al. and measured visual, sustained attention, taking 3:20 minutes.[1] Furthermore, the antisaccade task was also based on Munoz et al. and featured the same virtual setting with a park and roads. In a similar counterbalanced order, 50 cars drove down the right or left road with random colouration. The duration of each car's presence and delay in between consecutive cars was the same as the prosaccade task. However, participants needed to look in the opposite direction of the presented car and press the opposite option on the controller; if the car was presented on the right side, participants were required to look left and press the left button. Similarly, when there was no car stimulus they looked at the forefront lamp. Again measuring visual sustained attention, the task was 3:20 minutes long and sufficient practice was undertaken by users prior to the task.

3. RESULT

3.1 ASRS Results

Table 1. ASRS results for 2 groups: controls and PWADHDT.

	Controls			PWADHDT		
	Mean	**SD**	**Number**	**Mean**	**SD**	**Number**
ASRS	10.50	2.902	14	16.00	2.18	17

Note. An Independent samples t-test was conducted ($p < 0.05$), rendering the groups significantly different on the basis of ADHD traits.

3.2 Saccade Task Results

H1: The ADHD traits group will have a significantly higher number of saccades.

Descriptive statistics in Table 2 revealed that in general, controls had a lower average NOS and approximately half the variability of the PWADHDT group. No outliers were found in the data through use of box and whisker plots. The Shapiro-Wilks test indicated normally distributed data ($p > 0.05$) while the independent samples t-test ($p < 0.05$) and Mann-Whitney U test ($p = 0.029$) showed a significant difference between group outcomes (Table 3). This is graphically demonstrated in Figure 2, where the error bars of confidence interval 95% indicate reasonable certainty. These findings support H1.

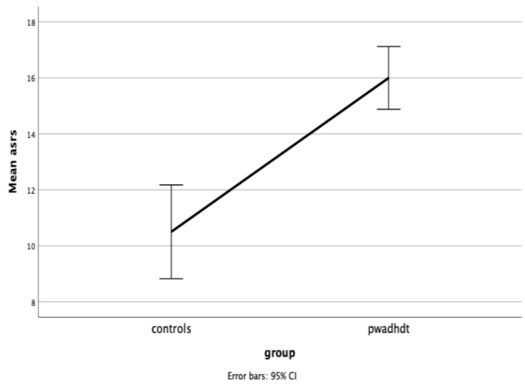

Figure 1. ASRS outcomes for control and PWADHDT groups.

Table 2. Descriptive Statistics for NOF, NOS, FD.						
	Controls			**PWADHDT**		
	Mean	**SD**	**Number**	**Mean**	**SD**	**Number**
NOS	29.00	17.54	11	56.82	33.40	17
NOF	230.60	142.14	10	510.00	273.90	15
FD	123.44	6.88	9	110.51	6.18	16
Note. NOS stands for the number of saccades, NOF the number of fixations and FD the fixation duration.						

H2: The ADHD traits group will have a significantly higher number of fixations.

From the descriptive statistics, PWADHDT had more than double the NOF as controls, and experienced greater variability (Figure 3 visually presents this through longer error bars). The data was found to be normally distributed (Shapiro-Wilks: $p > 0.05$) and significantly differed (Mann-Whitney U test: $p = 0.013$; independent samples t-test: $p < 0.05$). This indicates that H2 is supported.

H3: The ADHD traits group will have a significantly shorter fixation duration.

Results (Table 2) confirm that the PWADHDT group had lower fixation duration with reduced variability (see Figure 4 for a visual depiction) while Table 3 illustrates its significance. Thus, H3 is accepted.

2.3 Antisaccade Task Results

H1: The ADHD traits group will have a significantly higher number of saccades.

Descriptive statistics in Table 4 indicated that the PWADHDT group exhibited more than double the saccades of the controls and roughly twice the variability. The use of box and whisker plots revealed no outliers. Shapiro-Wilks demonstrated normally distributed data ($p > 0.05$) and the independent samples t-test ($p < 0.05$) and Mann-Whitney U test ($p = 0.022$), indicating a significant difference in the outcomes between groups. This is visually represented in Figure 5, where the error bars with confidence interval 95% show the reliability of data, supporting H1.

H2: The ADHD traits group will have a significantly higher number of fixations.

Table 4 affirms that there was a difference in number of fixations across the PWADHDT and control groups, with the controls' mean NOF amounting to less than half of the PWADHDT group's mean NOF (as seen in Figure 6). A normal distribution was identified through Shapiro-Wilks ($p > 0.05$)

Table 3. Hypothesis results for 2 groups: controls and PWADHDT.					
Hypothesis	**Outliers**	**Shapiro-Wilk**	**Independent t test**	**Mann-Whitney U test**	**Hypothesis met?**
(H1): The ADHD traits group will have a significantly higher number of saccades.	None	($p = 0.071$)	($p = 0.008$)	($p = 0.029$)	**Approved**
(H2): The ADHD traits group will have a significantly higher number of fixations.	None	($p = 0.059$)	($p = 0.003$)	($p = 0.013$)	**Approved**
(H3): The ADHD traits group will have a significantly shorter fixation duration.	None	($p = 0.468$)	($p < 0.001$)	($p < 0.001$)	**Approved**

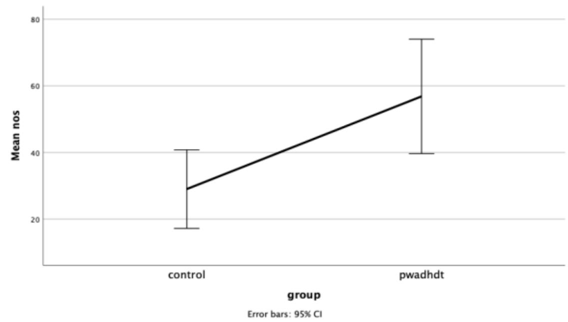

Figure 2. NOS - saccade task.

and significance was found in the Mann-Whitney U test ($p = 0.012$) and independent samples t-test ($p < 0.05$). Therefore, H2 is supported.

H3: The ADHD traits group will have a significantly shorter fixation duration.

Results in Table 4 and Table 5 confirm a significantly shorter mean FD of the PWADHDT group compared to the TD group, an outcome graphically visualised in Figure 7. Hence, H3 is approved.

3. DISCUSSION

The increasing worldwide diagnoses of ADHD require matched progression of study into its methods of diagnosis and characteristics. Furthermore, the contradictions in papers exploring visual fixations evidence a lack of literature. Based on Munoz's 2003 study, this experiment's saccade and antisaccade tasks aimed to investigate the link between ADHD traits and oculomotor response inhibition, comparing the number of saccades, fixations, and fixation duration in PWADHDT and TD controls. Data in these measures lacked any outliers and was normally distributed, as assessed by Shapiro-Wilks. Regardless, both parametric and non-parametric tests

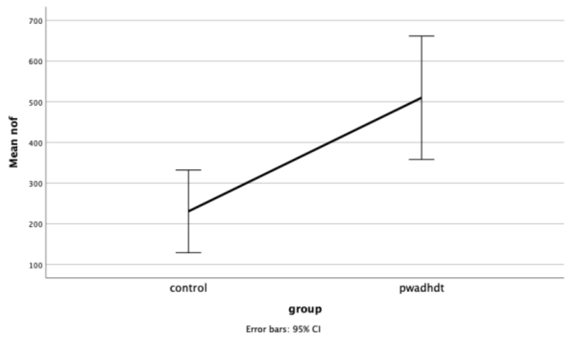

Figure 3. NOF - saccade task.

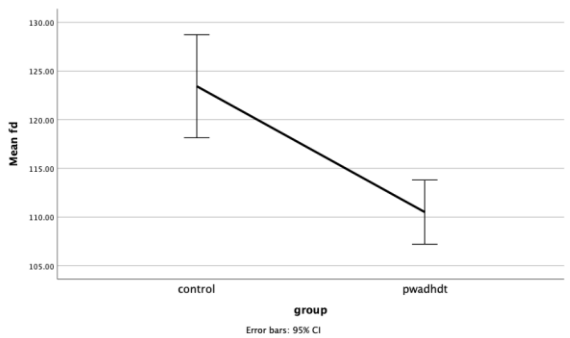

Figure 4. FD - saccade task.

(Independent t-test and Mann-Whitney U test respectively) were reported. In the results, the PWADHDT group exhibited a significantly higher number of saccades and fixations, and significantly shorter fixation duration, supporting H1, H2 and H3. These findings align with previous studies that have linked erratic eye movement with the lack of oculomotor control found in PWADHD,[1,10-13, 16, 18, 20, 21] and conflict with Vakil's 2020 study,[15] adding to the limited literature which explores fixation duration. Recurring significant links between saccadic eye movement and ADHD traits indicate the potential for a novel method of diagnosis.

A limitation of this experiment was the relatively small participant number. Although a G*Power test revealed an 80% chance of significant results, a higher number of participants would have increased this likelihood. Furthermore, the mean age of participants in the PWADHDT group and control group differed by approximately two years, creating a potential confound in the experiment outcome as the manifestation of ADHD traits are known to shift with age.[10, 18] Similarly, the uneven number of female and male participants may have affected experiment outcomes due to known gendered differences in PWADHD.[7]

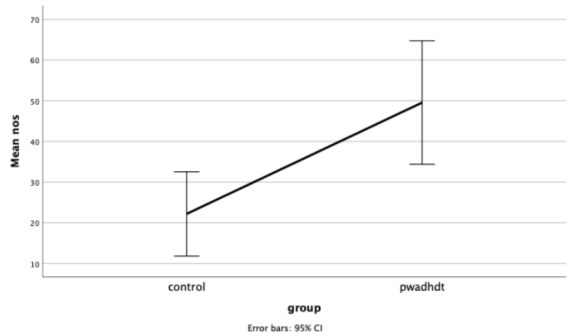

Figure 5. NOS - antisaccade task.

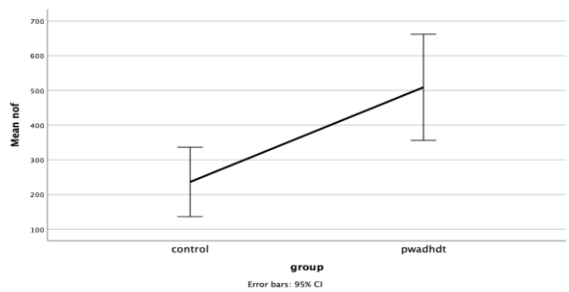

Figure 6. NOF - antisaccade task.

This study contributes to the increasing awareness of ADHD by researching the connection between erratic eye movements and ADHD traits, identifying a potentially new method of diagnosis which may increase testing accessibility.

Future studies may consider examining hyperactivity by testing response inhibition with stimuli relating to different senses, or reaction which requires differing movements. Different facets of attention deficiency may also be tested, such as reaction time. This will yield a more holistic understanding of ADHD and explore alternative, novel methods of diagnosis.

4. CONCLUSION

This study investigated the link between eye movement and ADHD traits, employing a TD control group and ADHD traits group differentiated by ASRS score. It found significant differences in number of saccades, number of fixations and fixation duration, which point towards a deficiency in oculomotor control and response inhibition in those with ADHD traits. This posits the measuring of eye movements as a potential diagnostic method for ADHD.

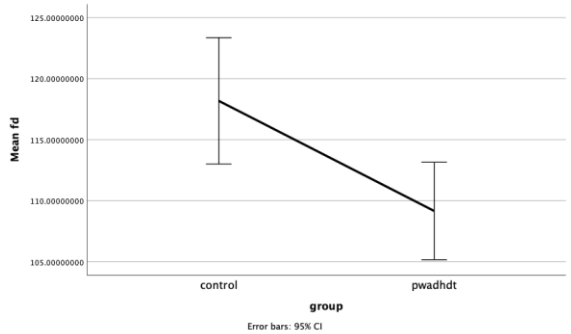

Figure 7. FD - antisaccade task.

Table 4. Descriptive Statistics for NOF, NOS, FD.

	Controls			PWADHDT		
	Mean	**SD**	**Number**	**Mean**	**SD**	**Number**
NOS	22.20	14.50	10	49.56	28.49	16
NOF	236.18	148.91	11	508.77	252.89	13
FD	118.18	8.15	12	109.16	7.77	17

Note. NOS stands for number of saccades, NOF the number of fixations and FD the fixation duration.

Table 5. Hypothesis results for 2 groups: controls and PWADHDT.

Hypothesis	Outliers	Shapiro-Wilk	Independent t test	Mann-Whitney U test	Hypothesis met?
(H1): The ADHD traits group will have a significantly higher number of saccades.	None	($p = 0.070$)	($p = 0.004$)	($p = 0.022$)	Approved
(H2): The ADHD traits group will have a significantly higher number of fixations.	None	($p = 0.052$)	($p = 0.004$)	($p = 0.012$)	Approved
(H3): The ADHD traits group will have a significantly shorter fixation duration.	None	($p = 0.152$)	($p = 0.005$)	($p = 0.015$)	Approved

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: I would like to thank Dr Fjorda Kazazi, who collected data, implemented experimental methodology and provided analysis software and code while guiding me through the basics of data analysis.

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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