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Research Article

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The on-task Attention of Individuals with Autism Spectrum Disorder-An Eye Tracker Study Using Auticare

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ABSTRACT

Introduction: Autism Spectrum Disorders (ASD) are characterized by atypical patterns of behaviors and impairments in social communication. Traditional intervention approaches often require extensive fund support and well-trained therapists to address core deficits. Hence, emerging technology such as virtual reality (VR) has the potential to offer useful technology enabled intervention systems. In this paper, an innovative Extended reality, Artificial Intelligence, virtual reality-based skill training platform called Auticare was used.

Aim/Objective: This study explores the on-task attention on two virtual reality based cognitive scenarios of individuals with Autism spectrum disorder (ASD) and typically developing (TD) groups.

Methodology: 220 participants (ASD = 200, TD = 20) took part in a series of attention tests, which involved ball picking and putting in a basket and an alphabet learning scenario. We captured four eye-gaze parameters, which includes time to first fixate, first fixation duration, average fixation duration, and the sum of fixation count. The eye tracking data were analyzed to determine the on task attention of the user while performing VR based cognitive scenarios. Performance data, eye tracking indices and physiological features indicated the on-task attention of the individuals with ASD.

Results: In the results we observe the comparison in the eye tracking parameters of ASD and TD group. This gives insight into the attention patterns of the participants of the study in each cognitive VR scenario.

Conclusion: It is concluded that virtual reality skill training is a promising medium for skill training of individuals with Autism.

Key Words: Attention, Auticare, Autism spectrum Disorder, Eye tracker, Virtual reality

INTRODUCTION

Autism Spectrum Disorder (ASD) is a spectrum-based disorder that occurs in early childhood due to neurological disorders, and its symptoms include abnormal social skills, communication skills, interests and behavior patterns (center for disease control and prevention, 2022). Currently, there are no effective drugs to treat the disease, but long-term educational intervention can gradually improve children with ASD, which prevent lifelong disability. Therefore, the development of technical tools to help and train children with ASD has been identified as a priority research domain.[7] Among which, VR based systems for ASD intervention are coming to light. It is well known that tracking eye gazing information in VR intervention training will provide valuable information of the trainee's status, such as trainee's attention information. With the eye tracking embedded HMD becoming more accessible, in our current research, we aimed to develop a VR system that utilizes the eye tracking information to conduct attention training for users with ASD.

The current research study is carried out using Auticare, an Extended reality, Artificial intelligence and virtual reality based inclusive learning platform for individuals with ASD, neurodevelopmental disorders and special education. As an emerging technology VR integrated training programs have been developing and show a positive impact on the life of ASD patients. It allows the ASD patients to be trained in a real-world which could be manipulated and the patients can be adapted to any situation, overcome their limitations based on their unique capabilities. Due to limited empirical evidence, more research and intervention models should be needed by

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using VR integrated technology. It is essential to prove the potential of this technology to support the life skill learning of people with ASD and it must be developed as a tool that helps them to make their own life easier.

It is important to identify activities that appeal to the special needs and ability of individuals with intellectual and developmental disabilities (IDD) for enhancing their participation level.[6] A study was conducted on children with autism, to assess the performance of children on joint attention tasks using an Avatar mediated virtual reality technology.[5] The study results revealed that using VR integrated technology, the performance scores and focus area of attention of participants can be measured accurately. Another case study contributed to the importance of the development of a VR tour system to explore methods of therapy for individuals with intellectual and developmental disabilities and help them in dealing with everyday social situations.[1] Another study involved creating virtual environments to help IDD individuals get more comfortable with skills for independent living, enhance cognitive performance, and finally improve social skills.[4]

A study that involved designing a VR experience to support the cognitive development of IDD individuals.[8] The participants demonstrated significant cognitive improvement in terms of their abilities to perform certain tasks. The findings of this study suggested that VR-based experiments can be used in treating IDD individuals. The developed prototype of an attention enhancement system using virtual reality technology and EEG biofeedback possesses the ability to improve the attention span of children and adolescents with behavioral or cognitive problems and help them learn to perform certain tasks.[3] The immersive Virtual Reality was found to supplement the training and keep it interesting and also found that both VR EEG Biofeedback and VR cognitive training has a great effect on attention enhancement. A study conducted on sex difference in Autism spectrum Disorders which showed a significant male bias in terms of prevalence, with roughly four affected males for every one affected female.[9] The stability of this finding across time and populations clearly suggests that sex-specific biological variables play a role in ASD causation.

Objectives of the study

The present study aims to explore the factors affecting attention patterns of individuals with ASD, to check the effectiveness of VR simulated Technology on measuring the attention deficits of children with ASD, to find out the effectiveness of eye-tracking studies on attention patterns of children with ASD, to find the values of AFD, SFC, TTFF and FFD of the participants, and to understand the differences in the attention patterns of individuals with ASD and TD. To find the efficacy of cognitive skills training using virtual reality for individuals with ASD, To find the relationship if any between gender and level of autism of individuals with ASD, to find the efficacy of the product Auticare for skill training.

TTFF (Time to first fixate): Measures the time it takes to look at the first Area of Interest (AOI) in the stimuli.

FFD (First fixation duration): Gives the total time of first look at AOI.

AFD (Average fixation duration): It gives the mean value of the entire fixation duration for each AOI and throws light into how each of the participants gives attention to stimuli.

SFC (Sum of fixation count): Estimates the number of looks made on each AOI throughout the viewing time

Formula

Total AFD= Total duration of fixations (all AOIs) / total number of fixations (all AOIs)

AFD of AOI = Sum of fixation durations of the specific aoi / sfc

Purpose of the study

Recognizing the eye gazing patterns is critical. When people look at different objects, their eyes will stay on some objects for a long time. On the other hand, people's eyes may just glide through each object. The question is how to distinguish these objects, if they attract people's attention, and how to check out people's eye patterns from these distracting objects. For autistic individuals with impaired communication, eye-tracking software is especially important for understanding how they focus on the world around them.

Methodology

Type of research

A quantitative approach has been employed for the present study as we have focused on quantifying the collection and analysis of data.

Population

The participants of the study were taken from various special education institutes across Kerala. We obtained prior informed consent from the parents/guardians of all participants. A total of 220 children between the age group of 6 and 18 years participated in the study. Among these 200 children with ASD, diagnosed by clinicians and satisfied the diagnostic criteria for ASD according to the ISAA (Indian Scale for assessment of Autism) as mild or moderate were taken for the present study. And twenty of the children were TD children. We recruited the TD participants from mainstream schools.

Materials

For the study we have used an Extended reality, Artificial intelligence and Virtual reality-based product called Auticare. Auticare is a skill training platform for individuals

with special needs. Auticare comprises of both software and hardware, which includes HTC Vive pro eye kit, leap motion (hand tracking sensor), laptop and tablet. Applied Behavior analysis and Cognitive Behavior Therapy based VR skill training activities have been applied to ASD.

Virtual Reality Environment (VRE)

The virtual environments are intimate and immersive for children, so they easily pay attention to the environment itself. For the present study, we have used two cognitive virtual reality-based scenarios which include ball picking putting in basket and Alphabet learning scenario. The environments are designed and scripted by therapists and special educators specifically for individuals with special needs. The ball picking scenario includes the avatar in the VRE welcoming the user to the scenario and giving instructions about the task. The scenario consists of various balls of various colors and sizes. The user has to pick each ball and put it in the basket kept nearby. The scores for each of the correct responses are coded. The Alphabet scenario involves the avatar teaching the child each alphabet along with their interaction. For both of the scenarios, the areas of interest are fixed.

Hardware and Software Configurations

The System hardware consists of Head Mount Display along with Eye tracking hardware which is included in the Vive Pro Eye. A tablet is provided to the therapist to remote control the hardware. Initially the therapist logs into the system and selects the patient profile which is created beforehand. Then the therapist selects a scenario for the therapy and it is launched.

The Eye tracker data along with other metrics is recorded on a session which the therapist could manually start. Once started, the data will be recorded in the system and after the recording session is stopped, it is saved to the server. This data can be visualized in the Web dashboard by the therapist. The Eye data collected include TTFF, FFD, AFD of AOIs, SFCs of AOIs.

Statistical Analysis

For the statistical analysis, first we have used Pearson correlation test between the factors, gender and level of autism. Second, we conducted a Pearson correlation test for the average performance score of our sample set (N =220) and level of Autism. We used analysis of variance (ANOVA) to compare the means of performance scores between groups (ASD and TD).

RESULTS

Below is a summary table of the surveys carried out following the guidelines corresponding to the research work:

This table gives the average comparative value of the eye tracker components ASD and TD group. The various eye tracker components include TTFF, FFD, AFD and SFC.

Relationship between gender and level of Autism

Hypothesis

H0 - There is no significant relationship between gender and level of Autism.

H1- There is significant relationship between gender and level of Autism

As per Pearson correlation test, when the obtained significance value p is less than 0.01, we will reject the null hypothesis, therefore there is a significant relationship between gender and level of Autism. Here the level of Autism involves Mild, moderate and severe categories according to the ISAA (Indian scale for Assessment of Autism) scale. The correlation test proved a significant relationship between levels of Autism and Gender. Thus, the findings prove that Males are severe on the level of Autism when compared to females.

Relationship between average performance score of ASD and TD with level of Autism.

Hypothesis

H0- There is no significant relationship between average performance score of ASD and TD with level of autism.

H1-There is a significant relationship between average performance score of ASD and TD with level of autism.

As per Pearson correlation test, when the obtained significance value p is less than 0.01, we will reject the null hypothesis, therefore there is a significant relationship between average performance score of ASD and TD with level of autism. This means that greater the severity in the level of Autism, lower will be the performance scores. Here the findings prove that the performance scores are greater for individuals with Mild autism when compared to moderate and severe ASD individuals. The study also proves that there is a significant difference in the average performance scores of ASD and TD group. The performance scores of TD is comparatively greater than ASD.

The relationship between Level of Autism and Performance Score of ASD

Hypothesis

Ho- there is no significant relationship between level of autism and performance score of ASD.

H1- there is a significant relationship between level of autism and performance score of ASD.

Significance level is less than 0.01 so we reject the null hypothesis therefore there is a significant relationship between level of autism and performance score of individuals with

ASD. This proves that performance scores are higher for individuals with Mild autism when compared to moderate and severe categories.

Figure 1 Represents the graph showing relationship between level of autism and gender. From the graph it is seen that males are more severe on the level of autism when compared to females.

Figure 2 Represents the heat map of the alphabet learning scenario. It depicts where the user is fixated the majority of the time during the task.

Figure 3 Represents the alphabet learning task environment. As the user starts the session, the eye tracker data will start recording.

Figure 4 Represents the ball picking task environment. As the user starts the session, the eye tracker data will start recording.

DISCUSSION

This study has been carried out to understand the factors affecting attention patterns of individuals with ASD, to check the effectiveness of VR simulated Technology on measuring the attention deficits of children with ASD, to find out the effectiveness of eye-tracking studies on attention patterns of children with ASD, to find the values of AFD, SFC, TTFF and FFD of the participants, and to understand the differences in the attention patterns of individuals with ASD and TD, to find the efficacy of cognitive skills training using virtual reality for individuals with ASD, To find the relationship if any between gender and level of autism of individuals with ASD, to find the efficacy of the product Auticare for skill training.

Two cognitive Virtual reality scenarios in Auticare:

1. Ball picking and putting in basket
   The scenario begins with the user entering a virtual room. To the right of the user he/she will be able to see an avatar to the right side. As soon as the user locks eye with the avatar, the avatar starts the conversation with the user by greeting and introducing oneself. This in turn gives the child the opportunity to highly engage with avatar modeling and improving greeting behavior in social interaction. After the introduction, the avatar will be providing step wise instructions to do the respective task. In this scenario the avatar guides the child to find the different colored balls in front of them and ask them to pick and put in the basket kept nearby. The users are positively reinforced with visual reinforcements after each successful attempt and are encouraged to do better after every failed attempt by the avatar. The scores are automatically stored in the AI cloud platform, along with that the attention distribution pattern based on AOIs generated using four eye-gaze measures, TTFF, FFD, AFD AND SFC are computed. The list of AOIs range from ball, basket, toy basket, poster, roof, ceiling lamp, chair, door, floor, plant, toy, table. Scoreboard and window
2. Alphabet learning scenario
   In this scenario, the avatar guides the child on each alphabet with their corresponding objects. The user is guided to interact with each object while learning the alphabets. The responses are automatically stored in the AI cloud platform, along with that the attention distribution pattern based on AOIs generated using four eye-gaze measures, TTFF, FFD, AFD and SFC are computed. The list of AOIs range from wall stickers, buzzer, window outside, wall side, wall front, door, wall design, roof, cupboard, door, table, apple. Ball, cat, dog, elephant, flower, Glass, hat, ice cream, jar, kite, lamp, mango, Nest, orange, parrot, queen, rocket, sun, Tap, Umbrella, violin, watch, xylophone, yacht, zebra.

From the results, it is clear that the average time to first fixate (TTFF) for alphabet learning and ball picking tasks for ASD is greater than the TD group. This shows that the ASD subjects take more time to first fixate on the area of interest when compared to the TD group. Thus, the study has thrown insight into understanding the on-task attention of the user. This helped to know the reaction time of the user and the total time taken to finish a particular task. The FFD, AFD and SFC average values for ASD group is less when compared to the TD group. This shows that the on-task attention for individuals with ASD is less when compared to the TD group. The Sum of Fixation counts (SFC) enabled in understanding the total amount of time fixated on each area of interest in each of the Virtual reality scenarios. These findings emphasize the potential for the use of eye-gaze measures to identify attention impairment in children with ASD. This product Auticare, thus enables to find the attention deficits and distractions of the user with ASD. Since this study also gives the eye tracking report of the TD group, it helps in a comparative analysis of performance in the VR scenarios. From the study it is also observed that all the participants in the ASD group participated in the VR skill training. They were very enthusiastic to perform their task in the virtual reality environment. The eye tracking measures gave a detailed report of the attention patterns of the ASD group and how it varies with the TD group. The eye gaze measures of participants in the ASD group helped to generate a heat map of their eye movement and hence helped the therapist to map the progress of each individual with ASD. Auticare, proved to be an assistive aid for the therapist to carry out the therapy sessions in a productive manner. All the performance metrics tapped were stored in each patient behavior data dashboard. This enabled the therapist to prepare an Individualized Education plan. Auticare also enabled therapy sessions to be fun and enabled parental involvement, as they could track each progress of

their kid. The attention parameters received from the eye tracker system fostered adding, removing or even creating a hierarchy of virtual reality objects according to their areas of interest. This enabled them to increase their learning curve and better improve their skills in a safe immersive platform.

In the results, in relation to Gender and levels of autism, it is understood that males are more severe on the level of autism when compared to females. According to the Center for disease control and prevention (2021), approximately 1 in 44 children in the U.S. is diagnosed with an autism spectrum disorder (ASD), according to 2018 data. 1 in 27 boys identified with autism 1 in 116 girls identified with autism. Boys are four times more likely to be diagnosed with autism than girls. The severity of symptoms was also seen in boys compared to girls in the present study.

In the results, in relation to Relationship between average performance score of ASD and TD with level of Autism**,** it is evident that there is a correlation between the performance scores of ASD group and level of autism.

In the results, Tests of Between- Subjects Effect The relationship between Level of Autism and Performance Score of ASD, it is understood that there is a significant relationship between level of autism and performance scores of ASD. Greater the performance scores in the cognitive VR scenarios, lower degree of autism. The participants of the ASD group with Mild autism level scored higher in ball picking and putting in basket and Alphabet learning VR scenario.

CONCLUSION

This study helped to put forward the effectiveness of the Virtual Classroom for the assessment and rehabilitation of attention deficits using Auticare. This study shows that VR can be used in the assessment of attention as well as cognitive training and can offer better predictive information regarding performance in the real environment. The subjects of the study actively participated in the two cognitive VR scenarios, Alphabet learning and ball picking and putting in basket. The present study showed the efficacy of virtual reality training using Auticare. The eye tracking parameters of ASD and TD group gave a comparative report on the attention patterns while performing each activity in Virtual reality. The reports on various areas of interest of the participants also helped to create virtual reality objects hierarchy. The preliminary results of this study are promising and show the feasibility and efficacy of Virtual reality skill training using Auticare. It is also concluded that there is a significant relationship between gender and level of autism as males tend to show higher degrees of autism in terms of its severity when compared to females. It is also concluded that the time to first fixate is considerably higher for the ASD group when compared to the TD. The on-task attention on each cognitive VR scenario was greater for the TD group when compared to the ASD. The present study thus enabled us to get a heat map on the eye data of the participants which enabled the researchers to study the attention deficits in individuals with ASD using Auticare. This study will be beneficial for future studies since it details important data about eye tracking parameters and hence do further research on other skill areas like social, self-care and behavioral scenarios.

Conflict of Interest

The authors declare no conflict of interest.

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Author's Contributions

Joanna James: Conceived and designed the analysis, wrote the paper.

Sathyanarayanan AR: Set the objectives of the study and collected the data.

BobinChandra: Contributed for collecting data and analysis.

Table 1: Represents the average value of eye tracker components of ASD And TD group.

Variable	ASD (n=200)	TD (n=20)
Age	14.06yrs	13.75 yrs
Gender		
Male	141	14
Female	59	6
Eye Tracking Measures		
Alphabet learning scenario		
TTFF (ms)	2387.101012	577.159075
FFD (ms)	107.154462	584.6006
AFD (ms)	483.9418159	538.5654
SFC	6.87432798	11.31136533
Ball Picking Scenario		
TTFF (ms)	2441.339283	546.731645
FFD (ms)	350.4242713	480.705095
AFD (ms)	479.3830561	743.6429
SFC	9.369924406	18.99892857

Table 2: Correlation between Gender and Level of Autism

		Gender	LOA
Gender	Pearson correlation	1	-410
	sig.(2- tailed)		<.001
	Sum of squares and cross- products	35.955	-24.465
	covariance	.181	-123
	N	200	200
LOA	Pearson correlation	-410	1
	sig(2- tailed)	<.001	
	Sum of squares and cross- products	-24.465	99.195
	covariance	-123	.498
	N	200	200

Table 3: Correlation between Average Performance Score and Level of Autism

		Performance score for ASD	LOA
Pearson score for ASD	Pearson correlation	1	-.310
	sig.(2-tailed)		<.001
	Sum of squares and cross-products	2317024074.7	-190932.456
	covariance	10580018.606	-871.838
	N	220	220
LOA	Pearson correlation	-.310	1
	sig.(2-tailed)	<.001	
	Sum of squares and cross-products	-190932.456	163.382
	covariance	-871.838	.746
	N	220	220

Table 4: Tests of between- Subjects Effects

Dependent variable: performance score for ASD

Source	Type 3 sum of squares	df	Mean square	F	sig.	Partial Eta squared
Corrected Model	643868895.0	3	214622965.01	27.707	<0.001	.278
Intercept	726770354.08	1	726770354.08	93.824	<0.001	.303
LOA	643868895.04	3	214622965.01	27.707	<0.001	.278
Error	1673155179.6	216	7746088.795			
Total	2493969464.3	220				
Corrected Total	2317024074.7	219				

a. R squared = 278(Adjusted R Squared = .268)

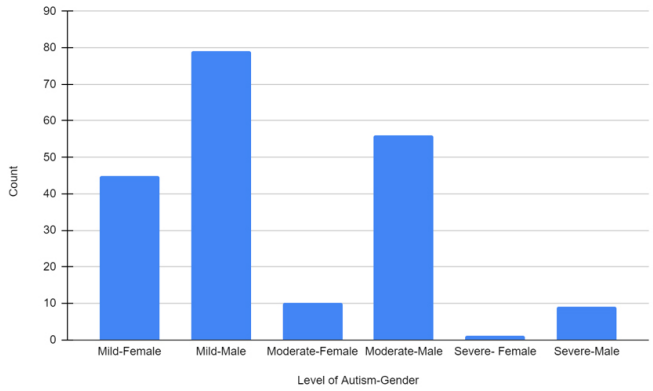

Figure 1: Represents the relationship between level of autism and gender.

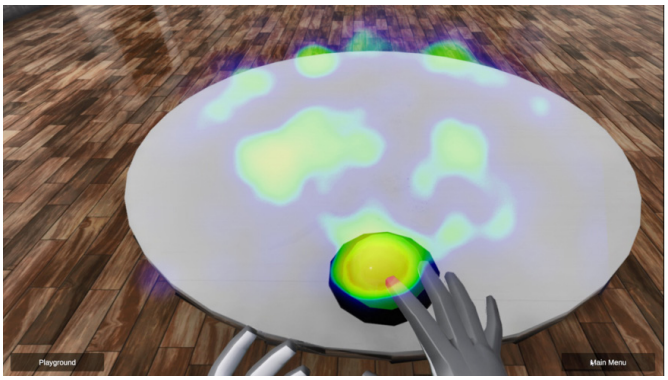

Figure 2: Represents the heat map of the alphabet scenario.

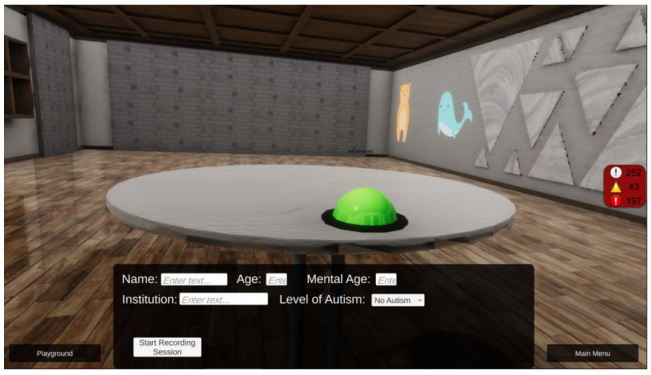

Figure 3: Represents alphabet learning scenario.

Figure 4: Represents ball picking scenario.

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