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Original Article

Physiotherapy Section

Effects of Video-based Gesture Gaming on Hand Functions in Autistic Population: A Quasi-experimental Study

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ABSTRACT

Introduction: Autism is a complex neurodevelopmental disorder with broad spectrum of intricacies and challenges, affecting 1 in 100 individuals, as estimated by World Health Organisation (WHO). Symptoms mainly are related to behavioural abnormalities, motor control deficits and social communication issues. Video gaming technology are emerging as valid tool in the intervention protocols for autism, by showing significant improvements in motor strength and executive functions.

Aim: To evaluate the impact of gesture gaming on dexterity, grip strength and working memory in individuals with autism.

Materials and Methods: A quasi-experimental study was carried out at Krupanidhi College of Physiotherapy Outpatient Department (OPD) in Bengaluru, Karnataka, India. The duration of the study was one year, from June 2022 to June 2023. Subjects were selected primarily based on the Childhood Autism Rating Scale. Thirty autistic subjects were selected using convenient sampling and four different games were given for three alternate days for 12 weeks, lasting 40 minutes per session. Hand grip strength, visuo-spatial working memory and dexterity were measured by a dynamometer, Corsi-Block Tapping Test and the Jebsen-Taylor Hand Function (JTHF) test. Subjects from 11 to 16 years were considered. Statistical analysis was done using a paired t-test, with a significance level set at p-value<0.05.

Results: After 12 weeks of intervention and 16 weeks of follow-up, significant difference (p-value<0.05) was noticed in all three variables. Hand grip strength for the right hand was measured at post-test (21.48±8.08) and follow-up (21.40±8.11), while for the left hand, it was post-test (13.26±3.75) and follow-up (13.15±3.76). Visuospatial Working Memory (VSWM) showed a backward span post-test (4.86±0.77) and follow-up (4.46±0.73) and forward span post-test (5.36±0.71) and follow-up (5.20±0.76). Dexterity for the non dominant hand was post-test (148.4±5.11) and follow-up (148.8±5.07), while for the dominant hand, it was post-test (138.8±7.86) and follow-up (139.0±7.86).

Conclusion: Gaming technology has shown beneficial effects in improving hand grip strength, dexterity and working memory.

Keywords: E-corsi, Gaming technology, Hand functions, Leap motion controller, Virtual reality

INTRODUCTION

Autism is a heterogeneous and intricate neurodevelopmental disorder with many complexities [1]. The term ‘autism’ is extracted from the Greek term ‘autos,’ which means ‘self,’ indicating a focus on oneself [2]. According to the WHO, around 1 in 100 individuals are identified with autism worldwide, with a higher prevalence in males. There has been a significant increase in the prevalence of autism, rising from 1 in 150 in 2000 to 1 in 36 in 2020 [3,4]. Autism is mainly characterised by a lack of socialisation and restricted, stereotypical activities, that can vary along the continuum of severity according to Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria and International Classification of Diseases 11th Revision (ICD-11) (WHO, 2020) [5]. The primary motor anomaly associated with autism is a deficit in sensorimotor integration, found in both gross and fine motor dexterity tasks [6]. Key indicators of autism are decreased or abnormal vision, decreased orientation, loss in social skills, absence of gestures by 12 months, odd or intensely focused interests and no or limited use of gestures in communication [7]. Although the cause of autism is not confined to a single factor, it may occur due to genetic factors, gene mutations, prenatal and postnatal factors, environmental toxicants, exposure to drugs during pregnancy, maternal infections, etc., which is likely said to alter the structures of the brain at birth [8].

Autistic populations experience feebleness of muscles and atypical changes in the tone of muscles, which is vital in limiting their reach and grasp activity [9]. Autistic subjects also suffer from “sensory hyperreactivity,” such as Decreased Sound Tolerance (DST), which is represented by hyperacusis, misophonia and phonophobia [10]. Deficits in VSWM appear to be familial in autism, as these populations face difficulty in performing tasks that require spatial awareness and memory capacities [11]. This anomaly might be due to hypoconnectivity within cortico-cerebellar tracks and the delay in the maturation process of these structures [12]. Intensive behavioural treatment protocols, such as the Early Start Denver Model, have effectively improved language, play and social communication in children aged five years or younger [13]. Intense upper limb training is among the priorities in rehabilitating the autistic population. Recent breakthroughs in virtual reality technology have become a valid tools in the neurorehabilitation of autistic population [14]. In this context, the Leap Motion Controller is a compact digital sensor appliance that allows for hand tracking through touch-free control gesture movements [15]. The main characteristic of this device is that it has a precise optical tracking program, which forms a digital image of a hands on screen as a result of accurate integration of hands into the field of view of 150°, with a tracking speed of 200 frames per second [16]. Yildirim Y et al., concluded that Leap Motion-based gaming therapy improved gross grip strength and hand functions in individuals with cerebral palsy [17]. Zhang A, stated that subjects with spinal injuries improved upper extremity muscle strength and fine motor skills after immersive virtual reality training using a Leap Motion system [18]. As there is a paucity of literature on the effects of video-based gesture gaming and its long-term effects on hand functions, there is a need for this study in the autistic population. This novel method of virtual reality in rehabilitation has emerged in recent years.

The hypothesis of the study is as follows:

Null Hypothesis (H0): There will be no significant effect of video-based gesture gaming on hand functions in autistic subjects.

Alternate Hypothesis (H1): There will be significant effect of video-based gesture gaming on hand functions in autistic subjects.

The aim of the study was to determine the effect of video-based gesture gaming on hand grip strength, dexterity and visuo-spatial working memory in autistic population. The primary objective was to evaluate the effect of video-based gesture gaming on hand grip strength, dexterity and working memory. The secondary objective of the study was to evaluate the long-term effects of video-based gesture gaming on all three parameters mentioned above.

MATERIALS AND METHODS

A quasi-experimental study was conducted at an autism centre in Bengaluru, Karnataka, India. The duration of the study was one year, started from June 2022 and ended in June 2023. Approval from the Institutional Ethical Committee (IEC) (EC-MPT/2022/PHY/016) was obtained before the commencement of the study. Participants and their parents or guardians were informed about the research purpose and the methodology. Informed consent was obtained from the subjects (parents or guardians) before participation in the study. The study was carried out using convenience sampling. Thirty subjects participated in the study based on the predetermined criteria.

Inclusion criteria: Children aged 11 to 16 years, irrespective of their Body Mass Index (BMI), diagnosed with autism based on DSM-5 criteria, with a Childhood Autism Rating Scale score of 30-36.5 (mild to moderate) [19], a Movement Assessment Battery for Children-2 score below the 5th percentile [20] and an IQ of 80 or below. Both males and females were included in the study.

Exclusion criteria: Children with orthopaedic impairment of the upper extremity, visual and hearing impairment, history of previous surgeries of the upper extremity that restricts hand movements, history of psychotic disorder and having previous experience playing video games were excluded from the study. Thirty subjects participated in the study based on the predetermined criteria.

Sample size estimation:

$SS_{UKP}=z^2\ p\ (1\text{-}p)\div e^2$

z=1.28

p=(0.9) e=0.05

$SS_{UKP}=(1.28)2\times0.9\times0.1\div(0.05)^2$

=1.476 (0.1)÷0.0025=59

$$SS_{KP}=\frac{SS_{UKP}}{1+SS_{UKP}\div N}=\frac{59}{1+1.476\ (0.1)\div0.1475}=\frac{59}{1+1.00067}=\frac{59}{2}=29.5$$

N=30

p-Probability value [21]

SS_{UKP}-Sample size of unknown/infinite population

SS_{KP}-Sample size of known/finite population

Study Procedure

Every subject was assessed for hand grip strength, visuo-spatial working memory and dexterity using an electronic hand dynamometer (Biotronix Digital Hand Dynamometer, manufactured by Biotronix Forever Solutions), a digital Corsi-block tapping test and JTHF test before the intervention, at 12 weeks postintervention and at the 16-week follow-up.

An electronic dynamometer was used to measure the hand grip strength. The patient was seated with shoulder adducted, elbow flexed to 90° angle and the forearm in semipronation, lying on the armrest. The subject was asked to squeeze the dynamometer three times [22]. Sixty seconds of break was given to interrupt fatigue. A digital Corsi-block tapping test was used to measure VSWM. The subject was shown sequences on the screen, starting with an initial sequence length of two blocks and increasing to a maximum length limit of nine blocks. The subject was advised to memorise the sequence being played and to repeat it once it was finished [23]. The squares must be tapped in the same order as they were indicated, allowing for repetition of the sequence in both forward and backward conditions. The sequence length was increased as the subject correctly tackled previous sequences. The JTHF was used to measure the upper limb dexterity, consisting of seven subtests [24]. The subjects were asked to perform each subtest and the time taken was measured in seconds using a stopwatch. A longer the time indicated a greater the impairment of dexterity.

The subjects were given video-based gesture gaming using a Leap Motion controller. Each participant was given two minutes of pregame practice and was instructed to play four different games for eight minutes each, with two-minutes rest intervals were given between each game. The participants were made to sit in a chair in front of an LED (32") SCREEN at a distance of 1 meter. The device was placed on a table in front of the participant and they were advised to place their hands above the device so that it could detect their hand and finger movements. After connecting the device, the game will begin once the configuration is done. A virtual hand was presented on the screen once the game started. Four different games were selected in the sequence.

1. Basketball: This game targeted hand grip strength and VSWM. The subject was advised to grab the ball with both hands and throw it into the targeted basket by visualising it [25]. The duration was set to eight minutes.
2. Pin bowling: This game targeted dexterity, grip strength and VSWM. The ball had three holes; the participant was advised to pick it up, hold it using these holes and roll the ball over the five pins [26]. Once a set of pins is cleared, a new set replaces them. The duration was set to eight minutes, with four minutes allocated for each hand.
3. Fizyosoft leap ball game: This game targeted dexterity and VSWM. The game aimed to pick and put the ball in a similar colour mold. The duration was set to eight minutes and four minutes was set for each hand [27].
4. Super mario: This game targeted dexterity and VSWM. The game aimed to tackle the hurdles by hand movements, collect the coins by bringing fingers together and reach the destination. The game's difficulty increased once the participant cleared the previous level [28]. The duration was set to eight minutes and four minutes was set for each hand.

STATISTICAL ANALYSIS

Statistical analysis was done using a paired t-test for within-group analysis, using Statistical Package for the Social Sciences (SPSS) version 29.0 in Windows. A 95% confidence level and 5% error were used to check for significant improvement. Microsoft Excel was used to generate the tables.

RESULTS

The mean age of the study participants was 14.3±1.23 years. A paired t-test was used for pretest, post-test and follow-up within the group analysis to analyse the effect of 16-week intervention and follow-up in the autistic population, as shown in [Table/Fig-1-3]. After analysing the data results, it was observed that significant improvement was seen in the experimental group on the measures of hand grip strength, dexterity and VSWM.

[Table/Fig-1] shows the comparison of Hand Grip Strength (HGS) within the group. For right-hand grip strength, the pretest mean was 17.4±7.71, the post-test mean was 21.48±8.08 and the follow-up mean was 21.40±8.11. For left-hand grip strength, the pretest mean was 11.19±4.13, post-test mean was 13.26±3.75 and the follow-up mean was 13.15±3.76. A significant difference was observed in these parameters.

The comparison of VSWM within the group is shown in [Table/Fig-2]. For the backward span pretest mean was 0.40±0.49, post-test

Test	Mean±SD	Difference Mean±SD	T	p-value	Inference
HGS-R-pre-	17.4±7.71	-4.01±1.98	11.05	<0.05	Significant
HGS-R-post-12W	21.48±8.08				
HGS-R-pre-	17.4±7.71	-3.93±2.00	-10.7	<0.05	Significant
HGS-R-FU-16W	21.40±8.11				
HGS-R-post-12W	21.48±8.08	0.07±0.07	5.76	<0.05	Significant
HGS-R-FU-16W	21.40±8.11				
HGS-L-pre	11.19±4.13	-2.07±1.41	-8.02	<0.05	Significant
HGS-L-post-12W	13.26±3.75				
HGS-L-pre	11.19±4.13	-1.96±1.41	-7.57	<0.05	Significant
HGS-L-FU-16W	13.15±3.76				
HGS-L-post-12W	13.26±3.75	0.11±0.08	7.57	<0.05	Significant
HGS-L-FU-16W	13.15±3.76				

[Table/Fig-1]: Comparison of Hand Grip Strength (HGS) within the group.
p-value (p<0.05) was obtained using paired t-test
SD: Standard deviation; HGS: Hand grip strength; Pre: Pretest; Post: Post-test; FU-Follow-up

Test	Mean	SD	Difference Mean	Difference SD	T	p-value	Inference
VSWM BS-pre	0.40±0.49		-4.46±0.57		-42.8	<0.05	Significant
VSWM-BS-post-12W	4.86±0.77						
VSWM-BS-pre	0.40±0.49		-4.06±0.52		-42.7	<0.05	Significant
VSWM-BS-FU-16W	4.46±0.73						
VSWM-BS-post-12W	4.86±0.77		0.40±0.56		3.89	0.001	Significant
VSWM-BS-FU-16W	4.46±0.73						
VSWM-FS-pre	0.73±0.52		-4.63±0.71		-35.3	<0.05	Significant
VSWM-FS-post-12W	5.36±0.71						
VSWM-FS-pre	0.73±0.52		-4.46±0.73		-33.5	<0.05	Significant
VSWM-FS-FU-16W	5.20±0.76						
VSWM-FS-post-12W	5.36±0.71		0.16±0.37		2.40	0.023	Significant
VSWM-FS-FU-16W	5.20±0.76						

[Table/Fig-2]: Comparison of Visuo-spatial Working Memory (VSWM) within the group.
p-value (p<0.05) was obtained using paired t-test
VSWM: Visuo-spatial working memory; Pre: Pretest; Post: Post-test; FU: Follow-up; BS: Backward span; FS: Forward span

mean was 4.86±0.77 and the follow-up mean was 4.46±0.73. For the forward span pretest mean was 0.73±0.52, post-test mean was 5.36±0.71 and the follow-up mean was 5.20±0.76. A significant difference was observed in these parameters as well.

The comparison of JTHF within the group was observed in [Table/Fig-3]. Dexterity non-dominant hand pretest mean was 153.71±5.06, post-test mean was 148.4±5.11 and the follow-up mean was 148.8±5.07. For the dominant hand pretest mean was 149.6±6.70, post-test mean was 138.8±7.86 and the follow-up mean was 139.0±7.86. A significant difference was also observed in the above parameters.

Hence, null hypothesis was rejected, as video-based gesture gaming showed significant changes on hand functions and working memory in autistic population.

Test	Mean±SD	Difference Mean±SD	T	p-value	Inference
JTHF-pre-(ND)	153.71±5.06	5.26±1.48	19.45	<0.05	Significant
JTHF-post-12W (ND)	148.4±5.11				
JTHF-pre-(ND)	153.71±5.06	4.88±1.52	17.56	<0.05	Significant
JTHF-FU-16W (ND)	148.8±5.07				
JTHF-post-12W (ND)	148.4±5.11	-.376±0.262	-7.86	<0.05	Significant
JTHF-FU-16W (ND)	148.8±5.07				
JTHF-pre (D)	149.6±6.70	10.79±3.98	14.85	<0.05	Significant
JTHF-POST-12W (D)	138.8±7.86				
JTHF-pre (D)	149.6±6.70	10.68±3.96	14.75	<0.05	Significant
JTHF-FU-16W (D)	139.0±7.86				
JTHF-post-12W (D)	138.8±7.86	-0.113±0.06	-9.10	<0.05	Significant
JTHF-FU-16W (D)	139.0±7.86				

[Table/Fig-3]: Comparison of Jebsen's-Taylor hand function test (JTHF) within the group.
JTHF: Jebsen's-Taylor hand function test; ND: Non dominant; D: Dominant; Pre: Pretest; Post: Post-test; FU: Follow-up

DISCUSSION

Autism is a heterogeneous neurodevelopmental disorder [28]. Motor impairments are the significant symptoms that create barriers to daily activities like reaching and grasping [9]. Dexterous hands are important for most of the functional activities [14]. It is inferred from the result that the mean value of post-test and follow-up scores of grip strength, dexterity and VSWM showed significant improvement with p-value (<0.05). A study done by Tarakci E et al., observed a significant difference in hand grip strength (p-value<0.05) with the use of leap-motion controller-based training for upper extremity rehabilitation in children and adolescents with physical disabilities after eight weeks of intervention [29]. Wagle S et al., intervened with autistic youngsters with game-based training and observed significant improvement in working memory [30]. Autistic children who received leap-motion-based gaming intervention in a study by Cai S et al., showed significant improvement in fine motor abilities [31].

The leap-motion controller was designed for hand tracking in virtual reality [15]. Virtual reality-based training was given as a part of the neurorehabilitation protocol to patients with conditions where recovery was possible via a human mirror system. It is said that virtual reality generates motions similar to the bodily illusions that underlie mirror therapy for persistent pain and limb dysfunction. This is the basic principle behind gaming rehabilitations, in which human mirror systems get activated and thus can be used for training in visuomotor skills [32]. The major elements of motor learning are motivation, task difficulty development, repetition and variety in practice, problem solving and error correction and feedback frequency and quality, all of which are increased by virtual reality. Furthermore, virtual reality offers task-specific exercises, appropriate training intensity and repetition. The main goal of virtual environments is to enhance motor learning [32]. This virtually enriched environment is provided by video gaming, which provides stimulation to the hippocampus. The hippocampus plays a pivotal role in spatial navigation and working memory. A virtually enriched environment enhances hippocampal cognition and neuroplasticity, reducing hippocampal cognitive deficits. This leads to hippocampal neurogenesis, synaptogenesis and neurotrophic factors, thereby improving hippocampal-dependent learning and memory tasks [33].

Limitation(s)

This study cannot be generalised to all autism subjects with different severity. Sample size and control group are two confounding factors that affects the reliability of the study. This study was conducted with 30 subjects, so larger samples can be used to generalise these findings. A control group is needed to observe the effectiveness of video-based gesture gaming. Even though the study's follow-up revealed a substantial difference, more research is needed to determine the long-term effects of gesture gaming.

CONCLUSION(S)

Significant improvements were shown in hand grip strength, dexterity and VSWM in autistic population. As there are advancements in physiotherapy protocols and technology, it can be suggested that video-based gesture gaming be incorporated into upper-limb rehabilitation protocols as well as cognitive development protocols for the autistic population.

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REFERENCES

[1] Alpert JS. Autism: A spectrum disorder. Am J Med. 2020;134:13-25.
[2] Golt J, Kana RK. History of autism. The Neuroscience of Autism. 2022;1:1
[3] Zeidan J, Fombonne E, Scorah J, Ibrahim A, Durkin MS, Saxena S, et al. Global prevalence of autism: A systematic review update. Autism Res. 2022;15(5):778-90.
[4] Rabot J, Rødgaard EM, Joober R, Dumas G, Bzdok D, Bernhardt B, et al. Genesis, modelling and methodological remedies to autism heterogeneity. Neurosci Biobehav Rev. 2023;(26):105-201.
[5] Rice CE, Carpenter LA, Morrier MJ, Lord C, DiRienzo M, Boan A, et al. Defining in detail and evaluating reliability of DSM-5 Criteria for Autism Spectrum Disorder (ASD) among children. J Autism Dev Disord. 2022;(4):01-03.
[6] Khoury E, Carment L, Lindberg P, Gaillard R, Krebs MO, Amado I. Sensorimotor aspects and manual dexterity in autism spectrum disorders: A literature review. L'encephale. 2020;46(2):135-45.
[7] Myers SM, Challman TD, Bernier R, Bourgeron T, Chung WK, Constantino JN, et al. Insufficient evidence for "autism-specific" genes. Am J Hum Genet. 2020;106(5):587-95.
[8] Chaste P, Leboyer M. Autism risk factors: Genes, environment, and gene-environment interactions. Dialogues Clin Neurosci. 2022;(14):1.
[9] Panigrahy CN, Dandekar RV. Effect of bimanual activities on hand and proprioception in autism spectrum disorder. Indian J Public Health Res Dev. 2021;12(2):80-83.
[10] Williams ZJ, He JL, Cascio CJ, Woynaroski TG. A review of decreased sound tolerance in autism: Definitions, phenomenology, and potential mechanisms. Neurosci Biobehav Rev. 2021;121:01-07.
[11] Goldfarb MA. Working memory and language associations in children with autism spectrum disorder. University of New Orleans Theses and Dissertations. 2023;3087. Available from: https://scholarworks.uno.edu/td/3087.
[12] Unruh KE, Bartolotti JV, McKinney WS, Schmitt LM, Sweeney JA, Mosconi MW. Functional connectivity of cortical-cerebellar networks in relation to sensorimotor behaviour and clinical features in autism spectrum disorder. Cereb Cortex. 2023:bhad177.
[13] Hirota T, King BH. Autism spectrum disorder: A review. JAMA. 2023;329(2):157-68.
[14] Durkin K. Videogames and young people with developmental disorders. Rev Gen Psychol. 2015;14(2):122-40.
[15] Păvăloiu IB. Edu World 2016- 7th International Conference. Leap motion technology in learning. The European Proceedings of Social & Behavioural Sciences. 2017;1025-32. Available from: https://www.europeanproceedings.com/article/10.15405/epsbs.2017.05.02.126.
[16] Cortés-Pérez I, Zagalaz-Anula N, Montoro-Cárdenas D, Lomas-Vega R, Obrero-Gaitán E, Osuna-Pérez MC. Leap motion controller video game-based therapy for upper extremity motor recovery in patients with central nervous system diseases. A systematic review with meta-analysis. Sensors. 2021;21(6):2065.
[17] Yildirim Y, Tarakci MBD, Algun ZC. The effect of video-based games on hand functions and cognitive functions in cerebral palsy. Games for Health Journal. 2021;10(3):180-89. Available from: https://doi.org/10.1089/g4h.2020.0182.
[18] Zhang A. Immersive virtual reality training improved upper extremity function in patients with spinal cord injuries: A case series. (2020). Theses & Dissertations. 460. Available from: https://digitalcommons.unmc.edu/etd/460.
[19] Young RL, Rodi ML. Redefining autism spectrum disorder using DSM-5: The implications of the proposed DSM-5 criteria for autism spectrum disorders. Journal of Autism and Developmental Disorders. 2014;44:758-65.
[20] Valentini NC, Ramalho MH, Oliveira MA. Movement assessment battery for children- 2: Translation, reliability, and validity for Brazilian children. Res Developmental Disabilities. 2014;35(3):733-40.
[21] Charan J, Biswas T. How to calculate sample size for different study designs in medical research. Indian J Psychological Med. 2013;35(2):121-26.
[22] Romero-Franco N, Fernández-Domínguez JC, Montaño-Munuera JA, Romero-Franco J, Jiménez-Reyes P. Validity and reliability of a low-cost dynamometer to assess maximal isometric strength of upper limb: Low-cost dynamometry and isometric strength of upper limb. J Sports Sci. 2019;37(15):1787-93.
[23] Brunetti R, Del Gatto C, Delogu F. eCorsi: Implementation and testing of the Corsiblock- tapping task for digital tablets. Front Psychol. 2014;5(1):939.
[24] Angélico SS, Quintas RH, Blascovi-Assis SM. Evaluation of manual dexterity of teenagers with autistic spectrum disorder: Comparison among validated tests. Int J Innov Educ Res. 2019;7(8):308-18.
[25] Huang MC, Chen S, Wang PC, Su MC, Hung YP, Chang CH, et al. Automate virtual reality rehabilitation evaluation for chronic imbalance and vestibular dysfunction Patients. In: Huang YM, Chao HC, Deng DJ, Park J. (eds) advanced technologies, embedded and multimedia for human-centric computing. lecture notes in electrical engineering. 2014. 260. Springer, Dordrecht. Available from: https://doi.org/10.1007/978-94-007-7262-5_125.
[26] Sui Y, Lin F, Seah HS. VR bowling for muscular rehabilitation. International Forum on Medical Imaging in Asia 2019. 2019;11050:1105002. SPIE. Available from: https://doi.org/10.1117/12.2518579.
[27] Keskin Y, Atçi AG, Ürkmez B, Akgül YS, Özaras N, Aydin T. Efficacy of a video-based physical therapy and rehabilitation system in patients with post-stroke hemiplegia: a randomized, controlled, pilot study. Turkish J Geriatrics/Türk Geriatri Dergisi. 2020;23(1). Doi: 10.31086/tjgeri.2020.145.
[28] El-Seoud SA, Halabi O, Geroimenko V. Assisting individuals with autism and cognitive disorders: An augmented reality-based framework. Int J Online and Biomedical Engineering. 2019;15(4):28-39.
[29] Tarakci E, Arman N, Tarakci D, Kasapcopur O. Leap motion controller–based training for upper extremity rehabilitation in children and adolescents with physical disabilities: A randomized controlled trial. J Hand Ther. 2020;33(2):220-28.
[30] Wagle S, Ghosh A, Karthic P, Ghosh A, Pervaiz T, Kapoor R, et al. Development and testing of a game-based digital intervention for working memory training in autism spectrum disorder. Sci Rep. 2021;5(11):01-04.
[31] Cai S, Zhu G, Wu YT, Liu E, Hu X. A case study of gesture-based games in enhancing the fine motor skills and recognition of children with autism. Interactive Learning Environments. 2018;17;26(8):1039.
[32] Bostanci H, Emir A, Tarakci D, Tarakci E. Video game-based therapy for the non-dominant hand improves manual skills and grip strength. Hand Surg Rehabil. 2020;39(4):265-69.
[33] Clemenson GD, Stark CE. Virtual environmental enrichment through video games improves hippocampal-associated memory. J Neurosci. 2015;35(49):16116-25.

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