DOI: 10.22122/jrrs.v15i2.3449

Published by Vesnu Publications

Design and Validation of a Dual-Tasks Package based on Kinect Sensor in Virtual Reality Environment to Assess Cognitive Disorders in Elderly People

Amir Hasan Torabi[1], Nasibeh Sarrami-Foroushani[2], Javad Rasti[3] Amir Mohammad Ghiasi[4], Reza Soleimani[4]

Original Article

Abstract

Introduction: Studies report that mobility changes could be present in early stages of Alzheimer's disease (AD) or even in previous stages, such as mild cognitive impairment (MCI). The use of motor tests, involving dual task, could facilitate screening and differentiation between the elderly with AD and MCI. The goal of this study is to design and validate dual-tasks based on Kinect sensor in a virtual reality environment to evaluate cognitive disorders in the elderly.

Materials and Methods: This was a validating study with the statistical society including the psychologists who were expert in the field of AD treatment, cognitive disorders, and the educational technologies, among whom 10 people were purposefully selected. A package of dual tasks based on Kinect sensor in a virtual reality environment was developed and evaluated for assessing cognitive disorders in geriatrics. The tools used in this study included a three dimensional game made by Unity, a Kinect sensor, and a virtual reality headset. To determine the content validity of the software, a questionnaire was prepared by the technical team concerning the software content, and then was filled by the psychologists. The software validity was determined using the Kappa coefficient.

Results: Applying the revisions based on the comments received, the experts' opinions were analyzed and resulted in the Kappa coefficient of 93.4%.

Conclusion: The software developed seems to have the acceptable content validity. Dual tasks based on the Kinect sensor may be used to accurately evaluate the cognitive function in the elderly.

Keywords: Dual-task, Kinect, Virtual reality, Cognitive disorder, Elderly

Citation: Torabi AH, Sarrami-Foroushani N, Ghiasi AM, Soleimani R, Rasti J. **Design and Validation of a Dual-Tasks Package based on Kinect Sensor in Virtual Reality Environment to Assess Cognitive Disorders in Elderly People.** J Res Rehabil Sci 2019; 15(2): 86-93.

Received: 02.04.2019 Accepted: 26.05.2019 Published: 05.06.2019

Introduction

Alzheimer's disease (AD) is a progressive disease consisting of three stages: asymptomatic, pre-symptomatic, and complete dementia. It is very difficult for doctors to diagnose the course of these stages and to classify the normal elderly and elderly with early-onset AD. Mild cognitive impairment (MCI) is defined as an intermediate state between the normal cognitive impairment due to aging and severe cognitive impairment due to dementia (1,2). These cognitive disorders are observed in various areas such as episodic memory, executive functions, attention, language, and visual skills (3). MCI disorder appears to be the precursor to dementia, in which subtle cognitive impairments are observed in addition to mild structural changes similar to those occur in AD (4). The most common cognitive impairment is associated with the episodic memory, however subjects with MCI do not show a decline in performance, which may lead to the development of AD among them (5,6). Over the years,

1- Department of Psychiatry, School of Literature, Humanities and Social Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran
2- PhD Student, Department of Psychiatry, School of Human Sciences, University of Science and Arts of Yazd, Yazd, Iran
3- Assistant Professor, Department of Biomedical Engineering, School of Engineering, University of Isfahan, Isfahan, Iran
4- Student, Department of Biomedical Engineering, School of Engineering, University of Isfahan, Isfahan, Iran
Corresponding Author: Javad Rasti; Assistant Professor, Department of Biomedical Engineering, School of Engineering, University of Isfahan, Isfahan, Iran; Email: rasti@eng.ui.ac.ir

various methods have been applied to diagnose symptoms before dementia, none of which have had a definite result (7,8).

In addition to cognitive and functional changes, motor disorders are also observed in patients with AD (9). Walking disorders, including reduced speed and length/width of steps, have been observed in the early stages of dementia or in the preclinical stages of AD (10,11). Moreover, about 60% of older people with MCI are twice as likely as normal older people to be at risk for falls (12). Such movement disorders can cause loss of independence and a decrease in the quality of life (QOL) (13), which in turn accelerates cognitive impairment. Walking in the elderly is considered as an automatic motor activity.

Improving executive performance and minimizing interventions in dual tasks can be clinically effective in preventing the elderly people with MCI from falling (14). Executive performance is defined as the set of cognitive skills required to plan, monitor, and execute a sequence of complex purposeful actions (15). Functional disorders, such as inattention and selective attention, have been reported in the elderly with MCI more frequently than in the control group (16,17). Executive performance can moderate the interference between attention-related tasks and integrate with the spatial and temporal characteristics of dual task gait (18,19). For example, in the study by Doi et al., a significant relationship was observed between executive performance and gait speed dual tasks in 389 elderly individuals with MCI disorder (20). As a result, subjects with poor executive performance suffer from low gait speed, more possibility to fall, and inability to perform daily functions (21,22). Both cognitive and physical exercises have been shown to positively affect MCI in the elderly through interventions that are effective in enhancing cognitive functions (23-25). Therefore, many studies have addressed the combined effects of physical and cognitive exercises (26-29). Investigations indicate that older people with MCI exhibit a better outcome and more progress with combination therapy compared to separate cognitive or physical therapies (30,31). Few studies have been conducted on the effect of combined physical and cognitive exercises on the performance of dual task gait in the elderly with MCI disorder. In a study, Tay et al. concluded that combined physical and cognitive performance exercises improved dual task walking tasks (30).

Virtual reality (VR) is a computer technology that allows interaction between the user and virtual environments. Benefits of VR interventions include increasing access and affordability, creating a comprehensive experience, and providing immediate feedback based on the individual's performance. The results of some studies have reported positive effects of VR interventions on attention, visual and verbal memory, and executive function in the elderly with MCI disorder (31,32). Due to the benefits of VR, the integration of physical and cognitive exercises in VR environment is a good intervention method, but most studies emphasize on one of the two (32) and there is a lack of studies on the effectiveness of combining both physical and cognitive exercises in the VR environment. Besides, the use of the Kinect sensor and the simulation of body movements along with VR have not been used simultaneously in any studies. Therefore, the present study is carried out aiming to design and validate a dual task software package based on the Kinect sensor in the VR environment to assess cognitive impairment in the elderly.

Materials and Methods

This study was a design and validation study that was performed to examine the content validity of the software designed for dual tasks based on the Kinect sensor in a VR environment aiming to evaluate cognitive impairment in the elderly. The statistical population of the study consisted of all psychologists specializing in the treatment of AD, cognitive psychology, VR, and educational technology in Isfahan, Iran, in 2019. Among the statistical population, 10 experts in psychology and educational technology were selected by targeted sampling method and interviewed at the Entertainment Industry Innovation Center, University of Isfahan. The sample size was determined based on Krejcie and Morgan tables (33).

The study tools included a set of physical-cognitive games designed using the Unity engine used to develop games, a VR display (a combination of a VR headset along with a smartphone with a gyroscope sensor), a Kinect sensor, and a validation questionnaire. The Kinect sensor is an important innovation in detecting body movements and image depth, and can be used to control the game by performing various body movements (Figure 1).

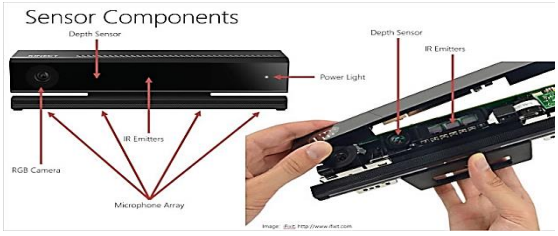

Figure 1. View of the Kinect sensor

In the present study, using the Unity game development engine and the Kinect sensor, a two-part game was designed with body movements and dual tasks.

The body movements were recorded using the Kinect Studio® software and then each movement was defined as an action in the game (Figure 2). This software has been developed by Microsoft Corporation for various versions of Windows operating systems and allows developers to produce software detecting body motion and sound.

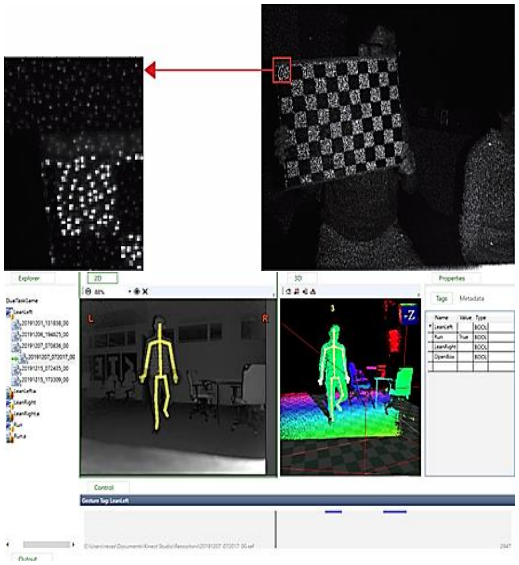

Figure 2. Conversion of body movements using Kinect Studio software

In the Kinect Studio software, raising hands leads to the animation motion towards right and left in the game. The game was created using the Unity engine, which is a multi-platform engine applied to develop games on various operating systems, including Windows, Android, iOS, various game consoles, etc. This engine gives gamers the ability to create 2D, 3D, VR, and augmented reality (AR) games.

Both parts of the game were designed with the same character, but with different cognitive tasks, and the elderly had to do the game strategy correctly in order to earn points. To guide the character, the person had to start running in place in front of the sensor, and as long as the running continued, the game character also continued moving. In the first stage, the game was played in a forest environment using dual tasks such as voice recognition, color recognition, and reversed spelling of the word. To detect sound, there were three boxes in the game environment. The person had to find the relevant boxes through the sound played inside each game box three-dimensionally (stereo) and through the wireless headphones provided for him. Then, in order to recognize color, the person had to direct the game character to the desired color cubes. In the next step, which was the second type of color recognition, the person was supposed to express the colors shown at the bottom of the screen while running, which changed at intervals of 5 seconds. In the next step, some words were expressed for the individual and in a certain period of time, he had to spell them inversely.

The second part of the game took place in a beach environment. The two tasks that a person was supposed to perform in these steps were to count down the numbers from 100 with certain coefficients and to reverse the words that were given to him with different spellings in 5 seconds. In this part of the game, all the desired roles had to be performed correctly so that the person could get the points related to that role (Figure 3).

Figure 3. Excerpts from the game stages

The tasks given to the participants in this game were constantly changing to prevent habituation in the elderly. Before starting each stage, the instructions of that stage were read by the therapist and the subjects were asked to continue the game until they failed and if they failed, to start the game from the beginning.

VR Headset: One of the innovations of the present study was to display a computer game on a smartphone and view it using a VR headset. In the present study, the Dream Vision Plus virtual reality

headset (New Magic, China) was utilized. This headset allows the user to watch common or three-dimensional videos, as well as comprehensive and 360-degree games, and has its own headphones that connect to the smartphone with a 3.5 mm interface. This VR headset weighs about 381 g and is suitable for smartphones of 3.5 to 6 inches, which are in the range of 82 to 154 mm. The smartphone holder opens and closes as a slider. In addition, the part that is placed on the face is soft so that it does not cause discomfort to the user in the long run, and it is well fixed on the head and face by the straps embedded. This headset also allows the user to adjust the lenses to achieve the best image resolution, and the side grooves on it allow air circulation so that no vapor is created on the lenses. This headset is suitable for users of iOS and Android operating systems (Figure 4).

Figure 4. Virtual reality (VR) headset

Questionnaire: To validate the software prepared, a special questionnaire was designed with 6 different items, graded on a Likert scale with options as "agree to strongly disagree". The software was developed and a video of the software development process and its pilot study, along with the Kinect sensor and VR headset, were presented to the psychologists and educational technology experts individually and they observed the video of the software development process and the sample test of execution of the software. Then, in order to verify and observe the software effect using the VR headset, they executed it and then completed the relevant questionnaire. Some of the experts commented on the improvement of the software and after applying the changes, all experts implemented the software and completed the questionnaire again. The data were analyzed using SPSS software (version 22, IBM Corporation, Armonk, NY, USA). Since this study was of the validation type, the evaluation contingency coefficient was calculated using the Kappa coefficient.

Results

Table 1 presents the demographic information of the participants in the questionnaire validity analysis.

Table 1. Demographic characteristics of the study groups

Field of education	n	Work experience (year)	Age (year)	degree of education
Educational Sciences	3	10 ± 2	40 ± 5	PhD
Counselling	3	15 ± 3	50 ± 5	PhD
Psychology	3	20 ± 5	50 ± 5	PhD
Psychiatry	1	10 ± 3	40 ± 5	Subspecialist

Data were reported as mean ± standard deviation (SD).

The responses given to the questionnaire are presented separately in table 2. Given the data in this table, score 3 was given only to three items by the experts, and in most cases, the designed software was able to attract the positive opinion of more than 80% of the experts. In the present study, the Kappa coefficient was obtained as 93.4%. Therefore, the prepared treatment package was of the required content validity.

Table 2. Questionnaire scores

Items	Agree	Agree to some extent	No idea	Disagree	Totally disagree
Game content is effective in delaying AD and MCI disorders in the elderly.	8 (80)	1 (10)	1 (10)		
Given the treatment protocol of the proposed game, the order of the sessions is appropriate to increase the attention and focus of the elderly.	9 (90)	1 (10)			
Given the treatment protocol of the proposed game, the number of sessions is suitable for increasing cognitive power and preventing MCI and AD disorders.	10 (100)				
The disturbing factors used in the game change the cognitive power of the elderly and affect their performance.	9 (90)		1 (10)		
The presentation time is appropriate for each session.	9 (90)	1 (10)			
The game difficulty level is proportional to the characteristics of the person with MCI and AD disorders.	10 (100)				

Data were reported as number (%).

Discussion

The current study was accomplished with the aim to investigate the possibility of using dual tasks based on the Kinect sensor as a diagnostic tool in the elderly with MCI disorder. Aging affects the nervous system as well as other body systems (34). With aging, individuals suffer from memory loss and learning becomes difficult for them (35), in addition suffering from physical problems. Studies suggest that physical activity is very important in maintaining fitness and intelligence and prevents brain problems to a large degree. Practicing with video games enhances motivation and confidence among the older people, which was the goal of the system proposed in the present study (36).

Montero-Odasso et al. stated that cognitive function plays a key role in regulating gait and balance (37). Dual task-based evaluations, which include physical and cognitive tasks, seem to be a reliable tool for diagnosing the pre-symptomatic dementia; because performing daily activities requires the ability to perform several cognitive and physical actions simultaneously. Therefore, dual tasks play a key role in gait performance, especially for individuals with MCI who are at risk for falls (38). Performing a study, Muir et al. found that older people with MCI show a significant decrease in gait speed and an increase in stepping time. Moreover, when dual tasks change, the variability of stepping time increases (39).

The meta-analyses performed in the area of gait indicators (including speed and length/time of steps) during dual tasks show differences between patients with MCI and healthy patients. Furthermore, the gait performance in dual tasks is associated with the progression of dementia in patients with MCI disorder (40). The VR platform includes a variety of exercises that allow the user to reinforce several aspects such as strength and aerobic or cognitive capacity. Therefore, task design in a VR environment can be more effective than simple tasks.

In the present study, special dual tasks were designed by the researchers for patients at high risk for severe dementia, such as AD. Dual tasks activate the brain and body simultaneously, in addition to improving cognitive function and body strength. An individual with MCI cannot be harmed and at the same time maintain a good balance. It is assumed that these people are not able to perform the dual tasks correctly. Experts believe that using dual tasks based on the Kinect sensor, one can confidently assess cognitive function in the elderly.

Limitations

Due to the sanctions imposed on our country and the lack of access to simulation skeletons, the present study was conducted with the simplest form of body skeleton and failed to simulate many aspects of the body movement. Additionally, a complete study of all cognitive and motor dimensions was not conducted within the country and the studies accomplished on other countries in this field were very limited and therefore there were limitations in game design and comparison of results.

Recommendations

Using more advanced software to model body movements can be more effective in displaying the movements more realistically in the game environment and increasing the participant's focus on performing the movements correctly during games. Access to more advanced versions of the body skeleton allows designers to design more accurately with more flexibility and better evaluation for more movement. Based on the results of the present study, it is recommended that in future studies, the effectiveness of this software be evaluated both in terms of assessment and treatment of the elderly. After conducting effective studies and modifying the software, the final version can be provided to counseling centers, nursing homes, and medical centers. Furthermore, different sections can be added to the software in the field of cognitive and physical activities to evaluate or practice different functions in the elderly.

Conclusion

Simulating the body skeleton and performing dual tasks using the Kinect sensor and converting it into a VR environment made them attractive for the elderly. The software designed was able to attract the positive opinion of experts in the field of cognitive impairment and VR and may be recommended as a tool for evaluation and treatment in the elderly with MCI.

Acknowledgments

The present study was one of the articles submitted to the Secretariat of the Fifth International Conference on "Computer Games; Challenges and Opportunities" with a special focus on therapeutic games (February 2020, Isfahan), which was praised by the editorial board of the Journal of Research in Rehabilitation Sciences (JRRS). The authors would like to appreciate the Cyberspace Research Institute, National Cyberspace Center for supporting the

publication of this article. The Entertainment Industry Innovation Center, University of Isfahan, which played an important role in collecting data and accomplishing this project, is also appreciated.

Authors' Contribution

Amir Hasan Torabi: Study design and ideation, supportive, executive, and scientific services of the study, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, specialized manuscript evaluation in terms of scientific concepts, confirmation of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, and responding to the referees' comments; Nasibeh Sarrami-Foroushani: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific services of the study, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, specialized manuscript evaluation in terms of scientific concepts, confirmation of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, and responding to the referees' comments; Amir Mohammad Ghiasi; Study design and ideation, supportive, executive, and scientific services of the study, providing study equipment and samples, manuscript preparation, specialized manuscript evaluation in terms of scientific concepts, confirmation of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, and responding to the referees' comments; Reza Soleimani: Study design and ideation, supportive, executive, and scientific services of the study, providing study equipment and samples, manuscript preparation, specialized manuscript evaluation in terms of scientific concepts, confirmation of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, and responding to the referees' comments; Javad Rasti: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific services of the study, providing study equipment and samples, data collection, analysis and interpretation of results, manuscript preparation, specialized manuscript evaluation in terms of scientific concepts, confirmation of the final manuscript to be submitted to the journal office, responsibility for maintaining the integrity of the study process from the beginning to publication, and responding to the referees' comments.

Funding

The study was funded by the research team. The present study was published in JRRS, with the financial support of the Cyberspace Research Institute of the National Cyberspace Center, the sponsor of "Fifth International Conference on Computer Games with an Approach to Therapeutic Games". This research institute did not contribute to designing, compiling, and reporting this study.

Conflict of Interest

The authors declare no conflicts of interest.

References

1. Golob EJ, Irimajiri R, Starr A. Auditory cortical activity in amnestic mild cognitive impairment: Relationship to subtype and conversion to dementia. Brain 2007; 130(Pt 3): 740-52.
2. Irimajiri R, Golob EJ, Starr A. Auditory brain-stem, middle- and long-latency evoked potentials in mild cognitive impairment. Clin Neurophysiol 2005; 116(8): 1918-29.
3. Albert MS, DeKosky ST, Dickson D, Dubois B, Feldman HH, Fox NC, et al. The diagnosis of mild cognitive impairment due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. Alzheimers Dement 2011; 7(3): 270-9.
4. Bischkopf J, Busse A, Angermeyer MC. Mild cognitive impairment--a review of prevalence, incidence and outcome according to current approaches. Acta Psychiatr Scand 2002; 106(6): 403-14.
5. Lopez OL, Jagust WJ, DeKosky ST, Becker JT, Fitzpatrick A, Dulberg C, et al. Prevalence and classification of mild cognitive impairment in the Cardiovascular Health Study Cognition Study: part 1. Arch Neurol 2003; 60(10): 1385-9.
6. Petersen RC. Mild cognitive impairment as a diagnostic entity. J Intern Med 2004; 256(3): 183-94.
7. Li H, Li J, Li N, Li B, Wang P, Zhou T. Cognitive intervention for persons with mild cognitive impairment: A meta-analysis. Ageing Res Rev 2011; 10(2): 285-96.
8. Chertkow H, Massoud F, Nasreddine Z, Belleville S, Joanette Y, Bocti C, et al. Diagnosis and treatment of dementia: 3. Mild cognitive impairment and cognitive impairment without dementia. CMAJ 2008; 178(10): 1273-85.

9. Kato-Narita EM, Nitrini R, Radanovic M. Assessment of balance in mild and moderate stages of Alzheimer's disease: Implications on falls and functional capacity. Arq Neuropsiquiatr 2011; 69(2A): 202-7.
10. Verghese J, Lipton RB, Hall CB, Kuslansky G, Katz MJ, Buschke H. Abnormality of gait as a predictor of non-Alzheimer's dementia. N Engl J Med 2002; 347(22): 1761-8.
11. Buracchio T, Dodge HH, Howieson D, Wasserman D, Kaye J. The trajectory of gait speed preceding mild cognitive impairment. Arch Neurol 2010; 67(8): 980-6.
12. Liu-Ambrose TY, Ashe MC, Graf P, Beattie BL, Khan KM. Increased risk of falling in older community-dwelling women with mild cognitive impairment. Phys Ther 2008; 88(12): 1482-91.
13. Zidan M, Arcoverde C, Araujo NBd, Vasques P, Rios A, Laks J, et al. Motor and functional changes in different stages of Alzheimer's disease. Arch Clin Psychiatry (Sao Paulo) 2012; 39(5): 161-5.
14. Bahureksa L, Najafi B, Saleh A, Sabbagh M, Coon D, Mohler MJ, et al. The impact of mild cognitive impairment on gait and balance: A systematic review and meta-analysis of studies using instrumented assessment. Gerontology 2017; 63(1): 67-83.
15. Diamond A. Executive functions. Annu Rev Psychol 2013; 64: 135-68.
16. Johns EK, Phillips NA, Belleville S, Goupil D, Babins L, Kelner N, et al. The profile of executive functioning in amnestic mild cognitive impairment: Disproportionate deficits in inhibitory control. J Int Neuropsychol Soc 2012; 18(3): 541-55.
17. Kirova AM, Bays RB, Lagalwar S. Working memory and executive function decline across normal aging, mild cognitive impairment, and Alzheimer's disease. Biomed Res Int 2015; 2015: 748212.
18. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture 2002; 16(1): 1-14.
19. de Bruin ED, Schmidt A. Walking behaviour of healthy elderly: attention should be paid. Behav Brain Funct 2010; 6: 59.
20. Doi T, Shimada H, Makizako H, Tsutsumimoto K, Uemura K, Anan Y, et al. Cognitive function and gait speed under normal and dual-task walking among older adults with mild cognitive impairment. BMC Neurol 2014; 14: 67.
21. Johnson JK, Lui LY, Yaffe K. Executive function, more than global cognition, predicts functional decline and mortality in elderly women. J Gerontol A Biol Sci Med Sci 2007; 62(10): 1134-41.
22. Herman T, Mirelman A, Giladi N, Schweiger A, Hausdorff JM. Executive control deficits as a prodrome to falls in healthy older adults: a prospective study linking thinking, walking, and falling. J Gerontol A Biol Sci Med Sci 2010; 65(10): 1086-92.
23. Simon SS, Yokomizo JE, Bottino CM. Cognitive intervention in amnestic Mild Cognitive Impairment: a systematic review. Neurosci Biobehav Rev 2012; 36(4): 1163-78.
24. Suzuki T, Shimada H, Makizako H, Doi T, Yoshida D, Ito K, et al. A randomized controlled trial of multicomponent exercise in older adults with mild cognitive impairment. PLoS One 2013; 8(4): e61483.
25. Suzuki T, Shimada H, Makizako H, Doi T, Yoshida D, Tsutsumimoto K, et al. Effects of multicomponent exercise on cognitive function in older adults with amnestic mild cognitive impairment: a randomized controlled trial. BMC Neurol 2012; 12: 128.
26. Barnes DE, Santos-Modesitt W, Poelke G, Kramer AF, Castro C, Middleton LE, et al. The Mental Activity and eXercise (MAX) trial: A randomized controlled trial to enhance cognitive function in older adults. JAMA Intern Med 2013; 173(9): 797-804.
27. Anderson-Hanley C, Barcelos NM, Zimmerman EA, Gillen RW, Dunnam M, Cohen BD, et al. The aerobic and cognitive exercise study (aces) for community-dwelling older adults with or at-risk for Mild Cognitive Impairment (MCI): Neuropsychological, neurobiological and neuroimaging outcomes of a randomized clinical trial. Front Aging Neurosci 2018; 10: 76.
28. Damirchi A, Hosseini F, Babaei P. Mental training enhances cognitive function and bdnf more than either physical or combined training in elderly women with MCI: A small-scale study. Am J Alzheimers Dis Other Demen 2018; 33(1): 20-9.
29. Plummer P, Zukowski LA, Giuliani C, Hall AM, Zurakowski D. Effects of physical exercise interventions on gait-related dual-task interference in older adults: A systematic review and meta-analysis. Gerontology 2015; 62(1): 94-117.
30. Tay L, Lim WS, Chan M, Ali N, Chong MS. A combined cognitive stimulation and physical exercise programme (MINDVital) in early dementia: Differential effects on single- and dual-task gait performance. Gerontology 2016; 62(6): 604-10.
31. Mrakic-Sposta S, Di Santo SG, Franchini F, Arlati S, Zangiacomi A, Greci L, et al. Effects of combined physical and cognitive virtual reality-based training on cognitive impairment and oxidative stress in mci patients: A pilot study. Front Aging Neurosci 2018; 10: 282.
32. Coyle H, Traynor V, Solowij N. Computerized and virtual reality cognitive training for individuals at high risk of cognitive decline: Systematic review of the literature. Am J Geriatr Psychiatry 2015; 23(4): 335-59.
33. Krejcie RV, Morgan DW. Determining sample size for research activities. Educ Psychol Meas 1970; 30(3): 607-10.
34. Garcia-Betances RI, Jimenez-Mixco V, Arredondo MT, Cabrera-Umpierrez MF. Using virtual reality for cognitive training of the elderly. Am J Alzheimers Dis Other Demen 2015; 30(1): 49-54.
35. Tseng CN, Gau BS, Lou MF. The effectiveness of exercise on improving cognitive function in older people: A systematic review. J Nurs Res 2011; 19(2): 119-31.
36. Sofi F, Valecchi D, Bacci D, Abbate R, Gensini GF, Casini A, et al. Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. J Intern Med 2011; 269(1): 107-17.

37. Montero-Odasso M, Muir SW, Speechley M. Dual-task complexity affects gait in people with mild cognitive impairment: The interplay between gait variability, dual tasking, and risk of falls. Arch Phys Med Rehabil 2012; 93(2): 293-9.
38. Maillot P, Perrot A, Hartley A. Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. Psychol Aging 2012; 27(3): 589-600.
39. Muir SW, Speechley M, Wells J, Borrie M, Gopaul K, Montero-Odasso M. Gait assessment in mild cognitive impairment and Alzheimer's disease: The effect of dual-task challenges across the cognitive spectrum. Gait Posture 2012; 35(1): 96-100.
40. Springer S, Giladi N, Peretz C, Yogev G, Simon ES, Hausdorff JM. Dual-tasking effects on gait variability: the role of aging, falls, and executive function. Mov Disord 2006; 21(7): 950-7.