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A review of methods to detect divided attention impairments in Alzheimer's disease.

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Abstract

Identification of Alzheimer's disease is predominantly done through the factor of memory, but with attention being identified as a principal factor, methods are being used based on the attention factor to identify Alzheimer's. Divided attention is the most significant type, out of attentional types to affect Alzheimer's the most. Therefore, this review provides insights into few such methods, which use divided attention to detect Alzheimer's. The PRISMA method was employed, and four methods were reviewed. The review evaluated the methods; Dual tasks, Useful Field of View Test (UFOVT), Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) in terms of their effectivity, efficiency, usability, and limitation. The analysis further investigated each of these method's application in practice to identify the most suitable method for each scenario. Additionally, the review provided evidence for a rising demand in mobile, personal computer-based solutions using dual task methods. With increasing development in the mobile based health informatics, Alzheimer's detection is trackable and becomes predictable making these solutions more desirable. This review will help in choosing the ideal method for detection through divided attention.

Keywords: Alzheimer's; Divided Attention; Mild cognitive impairment; Dementia

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1. Introduction

Alzheimer's disease is a type of dementia that mostly affects older people. According to the World health Organization, 50 million people have dementia & is the 5th leading cause of death[1]. One of the effects of Alzheimer's is the impairment of attention. Attention can be categorized as selective, divided & sustained. Studies have shown that divided attention is most affected by Alzheimer's disease [2], [3]. Also, divided attention impairment is most likely to present in early stages of Alzheimer's [2]. Due to that, works as a good predictor of the progress of the disease as well. Divided attention is the ability to perform more than one task at a time. Also known as multi-tasking or dual tasking[4]. Impairment to divided attention affects motor ability, cortical responses & performance in divided attention tasks[2]. The early symptoms of attention deficit make it an important factor while identifying Alzheimer Dementia and has been used in numerous examinations such as mini mental status examination. This paper's objective is to analyze and review the specialized methods used for detecting of divided attention impairments. Detecting Alzheimer's in early stages is very critical as it returns economical as well as social benefits. Early identification can reduce direct medical, social care costs which in 2020 were $308 billion in the world. Death rate was recorded 122,019 [5] .

Divided attention can be assessed using highly technical medical examinations such as MRI & PET scans. MRIs will scan the frontal lobe of the brain to identify the activities in the cortex [6]While PET scan focuses on primary visual cortex & adjacent cortical regions of the brain [7]. Both providing accurate results for divided attention. However, there are commonly used, low risk examinations used by professionals as well. Dual tasks tests such as: TUG (Time up & go), walking & talking, the dual task game, Use of field view test are significant examinations [2], [6], [7] which are non-invasive. Since the objective of this review is to provide an evaluation of the existing methods for detecting divided attention. When selecting methods, we first considered the types of testing done in terms of the usability of the test. The analysis showed that there can be high technical medical tests that would provide an accurate result as well as cognitive task related tests. For medical tests, we selected the most accurate tests to evaluate. As a result, out of the highly technical tests, MRI & PET scan were chosen. For the cognitive tests, we chose the tests which are most usable in terms of their usability. Out of the cognitive related tests, Dual task tests, UFOVT test were chosen. UFOVT is the most reliable, however, the dual tasks test represents the future of the mobile informatics tests which provides a great value to this research.

We aim to evaluate the above methods of measuring divided attention affected by Alzheimer's disease. The review is conducted under few criteria to evaluate the tests such as effectivity, efficiency, methodology & usability of each test. Also, each criterion will be explored in terms of their importance in conducting a test that would provide successful results. Further analysis will provide the limitations of each test methods & provide evidence to recommend the best methods in applying them in different scenarios. The criteria identified will deliver insight into each method. Effectivity criteria will assess the accuracy of each test. Efficiency will evaluate the ease, or the time taken to complete the test. Methodology will elaborate on how the test is applied & used. Finally, usability will assess the user's experience in facing the testing. Usability is a very important factor in the recent events amidst Covid-19, making conventional methods of testing harder.

2. Method

This review has been performed using Meta-Analysis (PRISMA) method. Resources searched by database references of PubMed, Science Direct, Elsevier, Google Scholar, and IEEE. Keywords such as divided attention, Alzheimer's, divided attention, mild cognitive impairments, detection methods for attention were used to formulate to search the words in above mentioned databases. Studies were eliminated if they focused on inaccurate, inefficient methods, complex methods, and duplicate records in the initial phase. Four methods have been identified to measure

divided attention at the end of the initial phase. Remaining studies were coming to the screening phase and 27 studies were removed due to being out of scope. At the end of the screening phase records were eliminated from each method separately according to the given reasons in the flow diagram fig 1. Then, 6 records were eliminated from Dual tasks test resources due to being high complex, expensive and resource draining. 5 records were eliminated from UFOV test sources due to complex methods to adapt and being out of scope, 9 were removed from MRI test sources due to vagueness of data & scope mismatch reasons, 8 records were eliminated from PET scan sources due to broad scope and irrelevant content, and 3 more records were eliminated due to non-provable content across all test sources. A total of 49 studies were accepted for the complete review. Most of the included studies were focused on older adults since Alzheimer's are being detecting for elderly. Finally, 47 studies were analyzed to investigate the detection methods of divided attention of older adults.

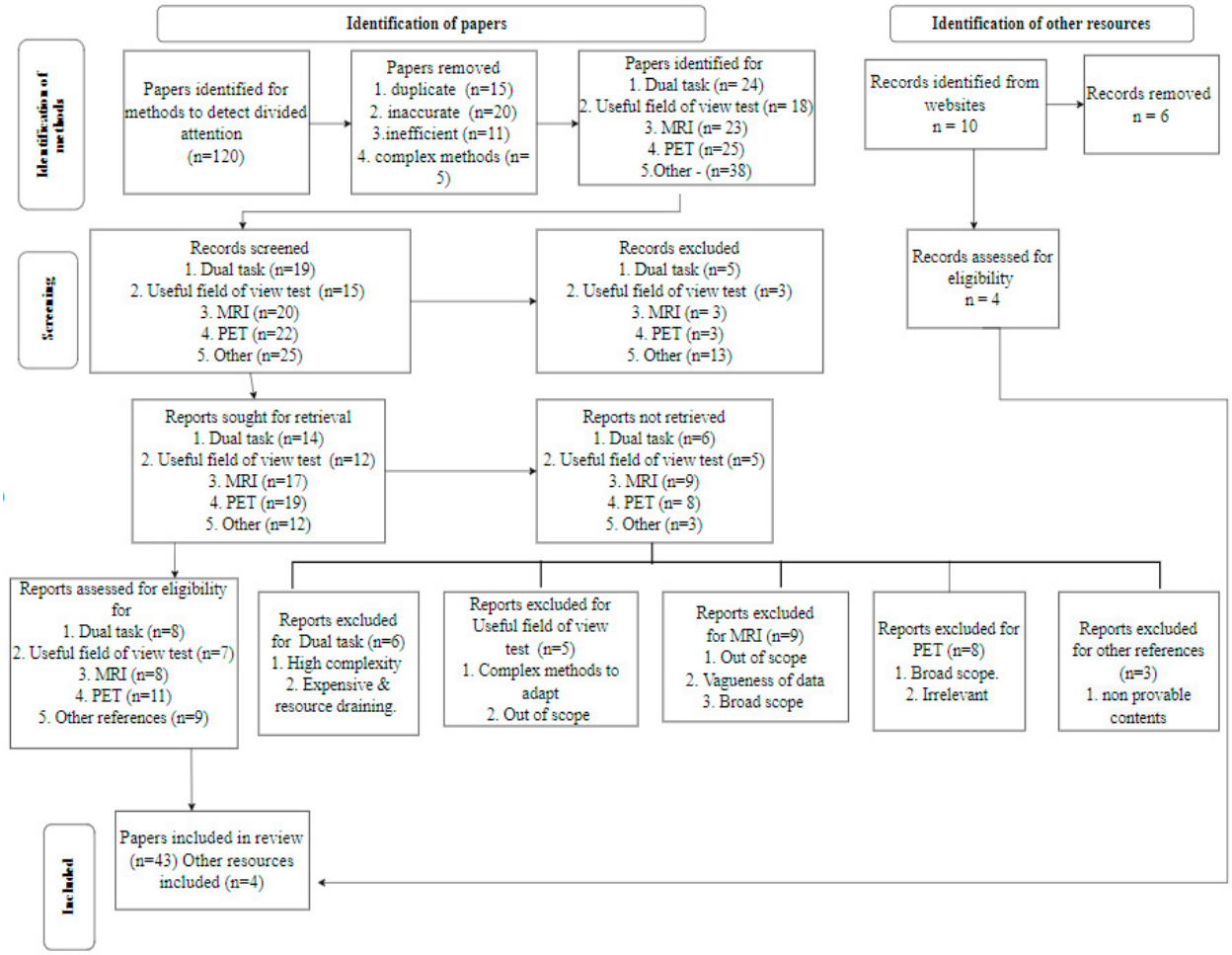

Fig. 1 PRIZMA Process flow

3. Test Methods

3.1. Dual tasks

Dual tasks test is designed to measure the dual tasks performance of an individual. The theory behind this is that two tasks performed together challenges attentional capacity[8], [9]. Attention being an early impairment of Alzheimer's, dual tasks tests are used to do testing at the initial stages. Dual tasks were introduced as solution alternation for conventional methods of detecting dementia. Methods such as blood tests, X-ray, Positron emission tomography, Magnetic Resonance Imaging require far many resources [9], [7], [6]. Alzheimer's and other Dementia diseases are progressive diseases, therefore regular measurements of the cognitive status of patients are particularly important. Dual tasks can be cheap and easy to implement. Therefore, can collect continuous data to get the progressive rates regularly unlike the conventional methods. The typical method of testing attention using dual tasks is the involvement of motor and cognitive skills. The procedure is simple. First it requires the participants to engage in a primary task, either motor or cognitive. Secondary task is used to create a competition between the two tasks to share the same attentional resources. While the secondary task is taken over, there should be a decrease in performance of the tasks due to the resource sharing [10], [11]. The differences of a normal performance decline and patient with Alzheimer's is quite significant because divided attention impairment in Alzheimer's occurs in initial stages [2], [4]. This concept is adopted in many methods such as TUG, Walking and Talking, and Dual tasks test. The effectivity and the accuracy of the dual task test will differentiate on the type of dual tasks that they chose to use and the context it is used. The most important aspect to consider in these tests are the efficiency since divided attention impairment can be caused by several reasons such as Mild cognitive impairment and Subjective cognitive impairment. The test should be able to differentiate these to be effective. TUG test has a few versions where it uses different cognitive functions to isolate another function to measure the exact function they need. Depending on the requirement it can be a verbal or a mobility function. One version is the TUG task along with verbal tasks. This is a test that can differentiate between Alzheimer's and healthy controls. However, this test fails in not being able to differentiate between Alzheimer's and MCI (Mild Cognitive Impairment). This is when the other version, the TUG dual tasks test plays a more significant role. This test can differentiate between Alzheimer's disorder and other cognitive impairment such as SCI (Subjective cognitive impairment), MCI, and with healthy controls [8]. The specificity and sensitivity of the method is 87%.Walking and talking dual tasks are a popular method of measuring divided attention where the walking cognitive function is taken as the function to be observed [4], [9], [2]. In terms of efficiency, it can discriminate between Alzheimer's, MCI, and healthy controls. Further this test scored a 0.88 in the test-retest reliability indicating a high reliable rate [4].To be more precise, a method exists, which is based on the dual task concept known as the Dual Task Game. This method is implemented using an automated system utilizing Kinect device. The device is very precise in measuring gait variables of individuals. This method is using machine learning algorithms to deliver a specificity of 0.799 in mental scores. However, this method fails short in scalability and usability [9] . The TUG test and the Walking and talking tests are currently adopted as manual cognitive methods. The tests are conducted by the help of personal resources. Compared to the dual task game test, it is less complex, time consuming, less resource draining [8], [4]. The Dual Task Game test requires the Kinect device, which is a highly technical automated system. Precise as it may be, the usability, and the practicality of the test is not successful [9]. Conventional methods of detecting attentional deficits require highly specialized equipment, trained personals, and an environment to carry out the test. Instead, dual tasks such as walking and talking, TUG dual task games are much easier to perform [2], [9].

3.2. Useful field of view test

Useful Field of View Test (UFOVT) is designed to measure visual attention of individuals. The test is developed around the driving task and hence being used to predict the driving capability of older adults [12]. This test considers the processing speed, divided attention to determine cognitive impairment [13] [14]. Though the UFOV roots back

to the 1970s, it is now implemented as a digitalized test using computers and personal devices. This digitalization allowed the testing of visual acuity and visual fields. Measurements such as the speed of visual processing for rapid detection and localization of targets are measured under conditions of divided attention [15]. Early literature provides evidence to the fact that UFOVT was ideal and most effective to measure divided attention [13]. However, with time as new methods came and the UFOVT's scope was changed [12] to focus on more specific functionality, addition to divided attention, the UFOVT test in measuring divided attention became less common recently. Despite that, the method outstands as it is more adoptable in the digital era as computer applications [15]. Therefore, the UFOVT carries a unique importance in its method of application in modern technologies. The currently used commercialized version of the UFOV test contains 3 sub tasks to measure each needed measurement. The first task is the central task followed by the divided attention task and sustained attention task [12]. The current methodology, UFOV® (visual awareness research group Florida, USA) is implemented using a computer with responses captured from a touch screen or mouse [15]. This test is woven around the functionality of driving to interpret it to the user to be a daily activity [14] [15] [13]. Since the digitalization of the UFOV test, it has been recorded as a high reliable and valid test marking test-retest reliability 0.884 for mouse and 0.735 for touch. The performance of PC version with the standard version has a considerable correlation as well (correlation 0.916) [14]. In addition, with technology being improved, it only makes the current test more reliable with time. Therefore, the test was a practical and sensible one to use in clinical practice as well. However, the test may measure the divided attention capability of individuals, it has narrowed its focus to detection of driving capability, which incrementally excludes the test from being a test for cognitive impairment and Alzheimer's detection [12] [13] [16]. The output of this test can be used as a predictive of early-stage Alzheimer's, but not as a test that could stand sole to detect Alzheimer's. Moving away from a manual process to an automated model, the test became more feasible and practical to be used in clinical practices. It reduced the inputs needed as the test method became more reliable. The test is installed in a personal computer to be used and administered in the same as well. Therefore, time spent for the testing was reduced and will be reduced with the advancement of technologies used due to reduction of processing speed, increase of internet speed, and overall speed of the computer. The UFOV test takes about 20-30 minutes to complete [14]. The UFOVT test is a user-friendly test method as it is woven around the daily activities of people. In this case, driving. In other custom versions of the UFOVT test, daily activities such as mobility, visual search are implemented and administered in an equivalent manner [17]. The application uses mouse inputs or touchscreen interaction based on the version available.

3.3. MRI

Magnetic Resonance Imaging (MRI) uses the demonstration of visual and auditory modality tasks to invoke divided attention in the human brain. While the tasks are carried out to engage the brain in a divided attention activity, the MRI focuses the cortical regions, frontal regions of the brain to capture measurements to measure the cognitive declines [6] [18]. The divided attention is activated using dual-tasking concepts. The concept being, when engaged in dual tasks, cognitive performance in tasks decline in contrast to the single task[10]. These declines are detected in the frontal and parietal cortices, which are known to control the attention functions [19]. MRIs can differentiate among age related cognitive impairment, mild cognitive impairment, and Alzheimer's impairment of divided attention. This affects directly to MRIs being a reliable measurement method in Alzheimer's. Further in identification, MRIs can detect initial stages of Alzheimer's, the amnesia stage as well [18], which has a 10-15% conversion rate to Alzheimer's [18]. Most importantly MRIs can predict the conversion from mild cognitive impairment to Alzheimer's disease with an accuracy rate of 0.70-0.79 [20]. It should be noted that conversion rates from mild cognitive impairment to Alzheimer's within 30 months are 48.7% [20], which is a remarkably high rate. Thus, explains the importance of MRI as a detection tool. This ability to predict the conversion is among the highly useful aspects in Alzheimer's screening as Alzheimer's is an incremental disease. To detect Alzheimer's, MRIs use several different methodologies. All built to demonstrate the stimulus of brain during dual tasking to capture the activation of prefrontal cortex. These methods can come in forms of modality tasks such as divided attention paradigm, visual and auditory processing paradigms,

and stimuli presentation [18]. It has been proven that the best results can be derived from using a methodology that can show high activity in the medial SMA and MFG [6]. For this, nonsense speech and nonsense text can be used as distractors to increase activity. While the brain engages in high activity, brain imaging will capture the cortical regions and the frontal regions of the brain. The key features in using MRIs for Alzheimer's testing are that it can predict conversion to Alzheimer's. This can determine whether the condition of a person is progressive or not with a high reliability rate. This is achieved by brain volumetric using MRI [20]. Magnetic Resonance Imaging is one of the standard methods in detecting Alzheimer's through brain imaging [21]. However, it can be expensive for detecting cognitive impairment. According to the times magazine, an average cost of an MRI is $2611 [22] and can vary based on factors such as the facility network, radiologist, and other healthcare economics of the location. A brain MRI takes 30-60 minutes to conduct. Additionally, takes more time to prepare and availability can be another concern depending on each country's resources. MRI results needs to be reviewed by a doctor to arrive at conclusion [23].

3.4. PET scan

Positron Emission Tomography (PET) scans are used for measuring divided attention in mild dementia of the Alzheimer's type. The core concept behind using the PET and 2-fluoro-2-D-glucose for Alzheimer's detection is the levels of regional metabolic rates for glucose. Patients with Alzheimer's has reduced rates of glucose [24], [25], [26]. Additionally, it has been stated that with these methods, the pattern of metabolic defects changes as the diseases progresses; therefore, it is a clear indicator of the Alzheimer's level of the patient as well [24]. This method unlike other methods carries a unique feature, where the method does not include in any engagement of the patient for the test, which can eliminate any environmental test errors and can provide independent data. The PET identifies the decreased glucose metabolism in parietal, temporal, and frontal association neocortex. The predictive nature of this methods has proven an effective prediction accuracy of 84% from mild cognitive impairment to Alzheimer's disease [27]. With continuous improvement, the conversion can be predicted with high accuracy with new methods introduced into PET. APOE genotype was such a method, which delivered a 100% efficiency and 90% specificity with an accuracy of 94% [27]. As per the method of glucose measurements, with technologies improving and new detector technology and advanced signal analysis such as high resolution research tomography (HRRT) the accuracy keeps getting high [28]. A PET scan of the brain for glucose rates identification is however needs to be performed by a nuclear medicine technologist under the nuclear medicine department. Further, the participants should not eat 4-6 hours prior to the test since glucose is being tested. Other complexities such as clothing, medications should be considered highly. Therefore, takes much time and resources. The test might take up to 3 hours. However, the result of the test needs to be reviewed by the doctor to derive the results. According to the new choice health web site, average PET scan of brain costs from $2,250 - $10,700 in USA. In India it costs about $450 both are expensive. Selective and divided had non overlapping regions of the brain. PET can work as a predictor as well because the glucose levels in brain decrease as the disease progresses, which is identifiable through PET scans [20], [24]. As stated above, the PET scan tests for detecting Alzheimer's are not simple and straightforward.

4. Discussion

Divided attention is a key factor that would help identify Alzheimer's [2], [26], [27]. The analysis carried out revealed that it is also a good predictor of the conversion from mild cognitive impairment to Alzheimer's with a considerable accuracy of results [28], [20], [24], [25]. This paper has explained a few methods that exist to detect Alzheimer's through divided attention impairment. Each method has been analyzed in terms of their concept, methodology, efficiency, effectivity, and usability. Each of these methodologies has their own advantages and disadvantages.

4.1. Effectivity

Considering the duals tasks, each of the tasks has different accuracies as depending on the environment they operate in. However, each should be effective in identification of the disease. Alzheimer's often carry similar symptoms to SCI (Subjective cognitive impairment) and MCI(Mild Cognitive Impairment). Dual tasks such as TUG can discriminate between Alzheimer's, MCI, SCI, and healthy controls [8] with a specificity of 0.87. However, walking and talking task can discriminate between these conditions with a much higher reliability rate of 0.88 [4]. Out of the dual tasks, the most precise method is the Dual Task Game, which leans towards measuring cognitive functions. However, this method is expensive, complex, and not scalable[9]. The Digitalized UFOV (Useful field of view test) can mark up to a 0.887 test reliability and can improve its accuracy with improvement of gesture technologies [16], [14]. This test can be effective in predicting early-stage Alzheimer's as well. MRIs and PET scans are the non-invasive tools, which can be seen as the most effective and often taken as the confirmation mechanism for Alzheimer's disease. For instance, PET's APOE Geno type exam can reach up to an accuracy of 0.94 [27]. This can be attributed with the fact that certain external environmental factors do not affect these non-invasive test methods.

4.2. Efficiency

Dual tasks tests can come in many forms. Therefore, its' efficiency depends on the method used to measure divided attention. Exams such as TUG and walking talking are fully manual tests, which requires time, resources, expertise and preparation [2], [4], [8]. However, the dual task game is an automated task, which is efficient to use but needs a highly technical Kinect device to perform [9]. However, with human computer interactions being revolutionized each day, modern technologies facilitate dual tasking applications, and simulators [32], [33], [34]. One of the examples for this scenario is the next methodology that was analyzed, which is the UFOVT. This test is fully automated and can be used via a PC [35] making it fast, accurate, and taking only up to 20-30 minutes of time. Efficiency of the USFOV test increases with processing speed, internet speed, and other computer performances [14], [15], . Therefore, this method is expected to be even more efficient in time to create more realistic simulations [36]. In terms of preparation and resources needed, MRIs and PET scans are not simple. Though an MRI takes only 30-60 minutes to perform, the preparation time, preparation tasks and the results release time make it a less efficient test [23]. However, time may decrease due to improvements in brain MRIs using deep learning [37]. PET scan as a testing mechanism is much more complex than any method described before, even more than an MRI [31], [24], [38], [39]. The preparation alone takes 4-6 hours before the test since glucose levels need to be levelled [40]. Additionally, it needs to suffice a comprehensive checklist that would not compromise the test such as, medications, allergies, medical conditions, claustrophobia making the test dependent on several aspects, which might not be always efficient [41].

4.3. Usability

The analyzed methods produce its own set of challenges while being used. Out of the analyzed test methods, Dual tasks has the ability of being used as fully automated tests that require minimum resources to perform [2], [9]. Out of them, the dual task game is a fully automated test that would be easy to use. However, the tests such as TUG, walking and talking are primarily manual test that are currently being made into automated as computer applications. UFOVT test can be found as fully automated self-examined tests using personal computers [17]. In contrast, the MRI and PET scans are only usable at controlled environments that require highly specialized equipment, expertise, and personals. Compared to Dual tasks and TUG tasks MRI and PET scans are not easily usable [42], [43], [44] .

4.4. Limitations and challenges

Dual tasks present its unique challenges in situations that would make it a less qualified test. The two tasks are verbal and mobility performance, because mobility function is a task that requires physical movement of the body such as walking, it becomes challenging for older, disabled, and movement challenging individuals [4], [9]. To be more specific, each dual task version has their own challenges as well. In the TUG, while performing the test, in the event of an attention loss, the other tasks is to be continued. Therefore, there will be a low score for the test, which derives an inaccurate result [8]. As the name of the task suggests, Walking and talking requires the participant to walk 10m for the test where the targeted audience; older individuals will face challenges [4].
The dual task game is performed using a dual tasks system, which requires a certain number of hardware configurations. The system drains a lot of resources as well. It produces a staggering amount of data that are too complex for interpretation [9]. The UFOV test can impose limitations when it comes to motor abilities of the user [12]–[14]. Patients with Alzheimer's are mostly older people [1] therefore, can lack motor skills enough to perform the test or in fact cause errors to result. MRIs are good in detecting divided attention but presents limitations in being expensive, complex, and time consuming. There are safety risks that can be caused by magnetic fields used in MRIs such as strong static magnetic fields and radio frequency fields [45]. Contradictions such as, burn due to energy depositions, nerve simulations, and auditory loss are possibilities. Complexities can occur for patients with implants, hearing aids, artificial limbs, any metallic implants, and piercing [45]. PET does come with the same complex, expensive, and time-consuming factors of MRIs. Additionally, it is proven that PET scans can expose to significant radiation exposures that may lead to cancer [46], [47].

5. Conclusion

In this review, the researchers have analyzed a key factor in detecting Alzheimer's disease [48], which is divided attention. Literature provides evidence that divided attention factors in to Alzheimer's and dementia the most out of the attention types [2], [49]. While analyzing the four varied methods, by considering efficiency, effectivity, usability, and limitations of each method few conclusions were arrived. Non-invasive methods such as MRI and PET are effective in diagnosis but fails in being a practical detector due to the low benefits compared to high risks and cost. However, TUG test carries the effectivity, but lacks usability and efficiency in use. The efficient and low-cost solutions are the Dual tasks that are being applied into in the past decade into mobile, computer-based solutions. While these solutions carry a low effectivity, with time and technological improvements, the effectivity is increasing at a high pace. Its' ease of use, affordability, and availability provides unique advantages. With mobile based healthcare solutions increasing rapidly in this decade, much improvements have been carried out. While the current cognitive manual tests, and non-invasive high technical solutions exist, there remains a significant lack in mobile, PC based solution to detect Alzheimer's through divided attention using Dual tasks test methods. It is worth noting that the elderly population's usability, adaptability factors into the effectivity in such mobile and PC solutions.

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