World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(REVIEW ARTICLE)

Check for updates

The role of plant-based foods in brain aging and the role of digital technologies in healthy aging training

Anna Chrysoula Vasileiadou *, Anastasia Loukeri and Anna Maria Driga

Department of Greek Philology, Democritus University of Thrace, Greece.

World Journal of Biology Pharmacy and Health Sciences, 2024, 17(01), 091–100

Publication history: Received on 02 December 2023; revised on 17 January 2024; accepted on 19 January 2024

Article DOI: https://doi.org/10.30574/wjbphs.2024.17.1.0529

Abstract

This literature review surveys the correlation between the aging of the human brain and the effect of plant-based diets. The search, study and analysis of relevant published research papers revealed that while some cognitive functions remain stable or even improve with advancing age (e.g., crystalline intelligence and judgment abilities), most healthy adults experience age-related declines in a variety of cognitive functions, including spatial orientation, episodic memory, processing speed, language, decision-making abilities, judgment, and abstract thinking. These damaging cognitive changes are amplified and accelerated by common age-related progressive neurodegenerative diseases such as depression and dementia. However, it has become clear that foods and diverse nutrients are biologically interactive, acting in coordination rather than as single physiological agents, hence the true benefit of adherence to the dietary pattern is likely to be due to a complex environment of beneficial effects rather than the contribution of individual components. The current research data suggests that following a healthy dietary programme, such as the Mediterranean diet with the addition of foods rich in fiber, vitamin complexes, minerals and trace elements (strawberries, blueberries, grape juice, etc.) are key factors in increasing the likelihood of healthy brain aging.

Keywords: Human brain; Brain aging; nutrition; Plant-based foods; Mediterranean diet

1. Introduction

In recent years, due to a rising concern, multiple studies have been conducted to examine and identify the role of nutrition in the aging of the individual. Meanwhile, the question of whether and to what extent the abundance of certain nutrients can affect both cognitive processes and emotions has been raised.

For thousands of years, nutrition has been deemed essential for the development of the human brain (Gómez-Pinilla, 2008; Puri et al., 2023). During the progress of brain aging, changes in cognitive ability occur, as well as injuries, diseases and mood disorders. While we may not have the ability to intervene in every situation, our lifestyle can play a significant role in preventing some of them (Puri et al., 2023). In recent times, the scientific community has come to recognize that diet and specific nutrients play a significant role in reducing the likelihood of developing neurodegenerative diseases (Gómez-Pinilla, 2008; Puri et al., 2023). A concept that establishes the foundations for new approaches to preventive and therapeutic measures.

2. Aging: A general reference

Aging is an inevitable process for every living organism. Specifically, aging refers to a variety of biological changes; namely, a decline in physical action that contributes to a reduction in the ability to integrate and convert physiological stimuli into muscular action, as well as changes in cognitive function (Coelho-Junior et al., 2022). Furthermore, an

* Corresponding author: Anna Chrysoula Vasileiadou

expression of the brain activity through which thought interacts with external stimuli is also included. All of the above elements are particularly important. In addition, aging affects physical performance involving several activities such as standing, sitting and walking. Consequently, the main criterion of an aging process based on a healthy context is the development of the ability of older people to remain socially active and to perform simple daily activities (Coelho-Junior et al., 2021).

2.1. Aging of the brain

Research results highlight the interaction and correlation between the overall functioning of the body and the Central Nervous System (CNS); hence the aging of the brain is not examined separately. For instance, through scientific research it is known that cardiovascular disease affects cognitive decline; thus, reducing the load of the various factors that lead to arteriosclerosis can contribute to maintaining a functional brain in senior years (Bjelland et al., 2003).

Consequently, aging of the human brain is typically characterized by tissue, biochemical and molecular changes (Reuter-Lorenz & Lustig, 2005). Furthermore, Reuter-Lorenz and Lustig (2005) report a study in which cerebellum and cortical DNA-related changes were observed that were highly dependent on the age of the individual.

Oxidative stress has a huge influence on brain function (Bishop et al., 2010). Butterworth (2006, as referred to Rink & Khanna, 2011), Fekete et al. (2022), Ganong (1987, as referred to Rink & Khanna, 2011) and Klabunde (2005, as referred to Rink & Khanna, 2011), indicate that the human brain processes about 20% of the main oxygen consumption although it accounts for less than 2% of the total body weight. An important role of the cell is to prevent oxidative damage by developing major defense mechanisms to counteract oxidative stress and oxidative damage (Bishop et al., 2010). However, several diseases associated with cognitive loss, such as Parkinson's disease, have a direct link to the aging of the brain (Goodall et al., 2018). Moreover, age-related motor decline results in a decrease in autonomy (Seidler et al., 2010).

Although the exact causes of brain aging are not yet clarified, it is well known that normal brain aging is related to the premature decline of cognitive functions and more specifically to changes in memory (Murman, 2015). Although the type of dementia most commonly encountered is Alzheimer's disease, accounting for 62% of cases (Prince et al., 2014), the identified indications related to cognitive decline do not fully correspond to the essential criteria for the diagnosis of dementia (Winblad et al., 2004).

2.2. Aging of the brain: Depression and dementia

During the progression of brain aging, diseases involving neuronal degeneration as well as depressive disorders are identified (Ali et al., 2016), with depression and dementia being the main brain disorders of concern to the scientific community (National Institute for Health and Care Excellence, 2017).

Ali et al. (2016) highlight the role of specific neurological screenings designed to assess daily responses to mainly cognitive activities as well as to identify mental health disorders. The National Institute for Health and Care Excellence, (2017) identifies the main factors associated with the diagnosis of dementia and highlights the need to evaluate attention, concentration, language, orientation, executive function as well as long-term and short-term memory.

According to Luppa et al. (2012), the symptoms of depression reported by older people differ from those experienced by younger adults, with seniors' physical and psychological symptoms being more frequent and accompanied by sleep disturbances, fatigue, loss of appetite and feelings of hopelessness about the future. An additional difference identified within depression in the elderly, as indicated by Polyakova et al. (2014), is that it is more common in women.

Although the scientific community proposes a range of costly pharmacological interventions, they have low response rates in depression (Ilyas & Moncrieff, 2012). Concurrently, research denotes that dementia-related medications do not lead to a cure (Ilyas & Moncrieff, 2012). Consequently, a stronger emphasis tends to be placed on prevention aimed at brain function and general health of the brain rather than on the treatment of related brain disorders (Macready et al., 2010).

3. Aging and nutrition: A general reference

Diet has an essential role in the prevention of aging-associated diseases, as it contributes to healthy ageing (Kang et al., 2005). Studies suggest that increasing the intake of fruits and vegetables (Kang et al., 2005), such as spinach, strawberries and non-alcoholic red wine (Lampe, 1999), has a beneficial effect on body function (Kang et al, 2005), specifically on biological markers relating to cholesterol levels, blood pressure and immune cell activation (Lampe,

1999), as well as on brain function (Kang et al., 2005) and possibly on brain aging (Lampe, 1999). Lampe (1999) reinforces this insight by pointing out the positive benefits of fruits and vegetables on older people's well-being, highlighting the distinct role they play for women in particular.

Although the role of nutrition in cognitive function and mental health has not been sufficiently examined, particularly in older adults, several studies show a significant association between the two (Goodwin et al., 1983). Research indicates a positive association between increased dietary protein intake with non-verbal learning and reduced incidence of dementia (Roberts et al., 2012) in contrast to reduced protein intake being associated with lower verbal memory in the elderly (Goodwin et al., 1983). Regarding carbohydrates, although the available data is insufficient, it has been found that increasing carbohydrate and sugar consumption results in a decrease in cortical thickness, which is associated with a high risk of mild cognitive impairment and dementia in older individuals (Staubo et al., 2017).

3.1. The effects of nutrients on brain function.

The scientific community is interested in investigating the benefits of nutrients and, in particular, vitamins in terms of brain processes (Benzie, 2003; Fekete et al., 2022). Namely, fruits and vegetables compound a wide range of chemicals that are responsible for the basic functions of plant development. Equally, these chemical compounds have a protective effect on human health through their anti-inflammatory and antioxidant actions. Indeed, the intense color of certain fruits and vegetables, for instance, Concord grape juice and blackberry or strawberry extract, indicates these chemicals, which help to reduce age-related motor and cognitive deficits. (Benzie, 2003).

3.2. Effect of plant-based food on brain aging

Researchers and scientists concentrate on the treatment and, where possible, the prevention of the decline in cognitive functions that characterize old age. Notably, they are interested in the key role of nutrition and, in particular, plant-based diets (Benzie, 2003). According to Stoll et al. (1996), the consumption of plant food some of which are legumes, fruits (strawberry, raspberry), vegetables (leafy greens like spinach), nuts, spices (such as garlic), as well as extracts like green tea, is associated with a reduction in brain aging-related factors along with the degeneration of cognitive functions (Schindowski et al., 2001).

These findings are confirmed by the Nurses' Health Study (Lee et al., 2009), which was conducted among over 15,000 women aged sixty and over. According to this study, the women were divided into two groups. In the first group, the women consumed a small amount of fruits, vegetables and spices as opposed to the women in the second group who had a normal intake. The first group showed negative effects on cognitive brain function (Lee et al., 2001) confirming that overall vegetable consumption, specifically the intake and consumption of green leafy vegetables such as lettuce and cruciferous vegetables such as broccoli and cauliflower, is associated with less cognitive decline (Kang et al., 2005).

In addition, Zeghichi et al. (2003) acknowledge the important role of the Mediterranean diet and, notably, the traditional Cretan diet, which is characterized by an increased intake of greens, in brain health. Another important observation made by Zeghichi et al. (2003) is that, since a large proportion of the vegetables used are semi-cultivated, their high polyphenol content gives them a strong antioxidant effect.

3.2.1. The Mediterranean diet

The Mediterranean diet refers to the eating habits of people living in the periphery of the Mediterranean Basin, which have been passed down through the generations due to the cultural changes that have taken place (Bach-Faig et al., 2011). It is characterized by a high intake of plant foods such as fruits and legumes, a moderate consumption of dairy products, eggs, fish and seafood and a very low consumption of red meat with olive oil being a very good source of fat and a moderate consumption of red wine during main meals being recommended (Bach-Faig et al., 2011).

Bach-Faig et al. (2011), conducted a study in which they found that people who followed the Mediterranean diet for long periods observed positive effects on their physical health by reducing the incidence of chronic diseases and cardiovascular diseases. Concurrently, the Mediterranean diet, through its potent antioxidant and anti-inflammatory nutritional components, exerts positive effects on metabolism (Bach-Faig et al., 2011). Moreover, there has been a significant improvement in the physical performance of adults (Valls-Pedret et al., 2015) and a significant decrease in physical dysfunction in older individuals (Bach-Faig et al., 2011).

Furthermore, the Mediterranean diet is strongly associated with cognitive function in adults generally (Valls-Pedret et al., 2015) and in older adults in particular (Bach-Faig et al., 2011). This dietary pattern has a direct correlation with the reduction of cognitive impairment and with improved cognitive function in adults (Valls-Pedret et al., 2015) as well as

with the deceleration of cognitive decline and hence the development of mild cognitive impairment and dementia in the elderly (Bach-Faig et al., 2011).

The Mediterranean diet's beneficial effect on brain aging has also been established through the findings of magnetic resonance imaging (MRI), which demonstrated greater thickness of the cerebral cortex associated with a reduced risk of cognitive decline (Staubo et al., 2017). At the same time, the international scientific community highlights the fundamental role of the Mediterranean diet in preventing depression in older people (Psaltopoulou et al., 2013). Psaltopoulou et al. (2013) underline the need for more targeted research on the influence of this diet on the overall health of the human brain.

3.2.2. Concord grapes: Their effects on human memory

As the global human population ages rapidly (Fekete et al., 2022), nutrition is a crucial factor in creating specific strategies to enhance healthy brain aging (Krikorian et al., 2008). An important nutrition component that has been shown to have a positive influence on brain function is the consumption of grape juice, specifically Concord, Niagara or Generic White grape juice (Krikorian et al., 2018). In a study conducted by Krikorian et al. (2008) between two groups, one receiving regular juice and the other receiving placebo juice, they found significant improvement in cognitive ability in those who received Concord and Niagara compared with those who received placebo juice.

Furthermore, these researchers examined the relationship between the consumption of grape juice by older people and their cognitive brain functions. The results showed that these elderly people, who suffered from impaired memory rather than dementia, had significantly benefited in terms of their cognitive function (Krikorian et al., 2008). In this study, two groups participated, one of which received a placebo juice. In the elderly who received Concord grape juice, an improvement in learning processes was observed, which supports the hypothesis that Concord grape juice may have an effective and beneficial effect in maintaining memory function and reversing behavioral deficits (Krikorian et al., 2008).

3.2.3. Blackberries - berries and strawberries: Two powerful allies against brain aging

The high metabolic load of the human brain makes it very vulnerable to oxidative damage (Ganguli et al., 2000). Antioxidants derived from plant foods that have a strong antioxidant effect on brain function (Benzie, 2003) have led to the creation of very popular "antioxidant diets" that are recommended by the international scientific community for their positive effects on neural brain function (Martín-Aragón et al., 1997).

Fruits are a source of anti-inflammatory compounds that have a beneficial effect on the body (Fekete et al., 2022; Galimberti & Scarpini, 2011), reducing the damage caused by oxidative stress, which is considered an important mechanism of cognitive decline (Mecocci, 2004). Plant foods rich in antioxidants, in particular polyphenols and flavonoids, the largest subclass of polyphenols, are found in high concentrations in berries and strawberries (Duffy et al, 2008), both of which were found to significantly reduce inflammation in neurons and work in reverse cognitive decline (Joseph et al., 2009). Moreover, research shows that berry and strawberry extracts, due to their ability to maintain metabolic homeostasis, have a protective effect on lipid peroxidation within membranes, while affecting synaptic plasticity (Andres-Lacueva et al., 2005), exerting a positive effect on learning and memory processes (Duffy et al., 2008). Other micronutrients with antioxidant activity are the anthocyanins in berries (Andres-Lacueva et al., 2005; Fekete et al., 2022), which, through the blood-brain barrier, are located in the hippocampus where memory and learning reside (Andres-Lacueva et al., 2005).

Andres-Lacueva et al. (2005) highlight four specific factors whereby these types of foods benefit brain function, namely, free radicals, inhibition of stress signals, activation of protective signals and protein pathways activation. Finally, Devore et al. (2012) found that flavonoids, through increased consumption of strawberries and blueberries, have a direct correlation with delaying cognitive decline in older adults.

4. Other diet-related factors contributing in brain aging

An interesting detail highlighted by Gómez-Pinilla, (2008) is that, besides diet, other aspects of daily living, such as exercise, have had an essential role in determining the process of brain evolution and cognitive capacity. Physical exercise, coupled with the consumption of certain nutrients, such as those included in antioxidant foods, has a profound impact on brain health by affecting molecular systems or cellular processes; vital elements for the maintenance of cognitive function (Vaynman & Gómez-Pinilla, 2006).

Moreover, Molteni et al. (2002) place emphasis on the consumption of high fat diets that portray today's lifestyle in industrialized societies. The impact of these diets is detrimental for both the body and the brain (Molteni et al., 2002). Vaynman et al. (2006), using the example of Brain-derived neurotrophic factor (BDNF), illustrate the way in which the energy transferred from foods to neurons is vital to brain function control. By consuming high fat diets, BDNF, which is connected with cognitive and metabolic regulation (Nawa et al., 1995), decreases in the hippocampus resulting in deterioration of learning and memory (Molteni et al., 2002).

Fekete et al. (2022) and Gómez-Pinilla (2008) focus their attention on the positive impact a caloric restriction may have on cognitive function. In line with this finding, Logroscino et al. (1996) and Luchsinger et al. (2002) ascertain that a low-caloric diet is positively associated with lower risk of contracting neurodegenerative diseases, like Alzheimer's and Parkinson's disease. In parallel, special attention should be given to the nutritional load of a low-caloric diet to prevent malnutrition (Gómez-Pinilla, 2008).

An interesting fact emphasized by Gómez-Pinilla (2008) is the comparison between Western countries with middle- and low- income countries, like India, in relation to the amount of food they consume. As stated previously, a diet based on caloric restriction may have beneficial effects for the overall health. Excessive food consumption in Western countries leads to an increase in obesity rates, which is equally damaging as limited access to food. Middle- and low-income countries, such as India, although they have limited resources, they present a reduced prevalence of diet- and age-related neurological diseases like Alzheimer's disease (Gómez-Pinilla, 2008). However, a report conducted in the states of India, covering the period from 1990 to 2019 about age-related neurological diseases, indicated a more than double increase in the cases (India State-Level Disease Burden Initiative Neurological Disorders Collaborators, 2021). Although this finding needs further investigation, changes in dietary patterns (processed foods replace fiber-rich foods) and modification of their lifestyle, with a decrease in exercise, might be a leading cause (Nitika et al., 2014).

5. The Role of digital technologies

Finally, we stress the significance of all digital technologies in the field of health education and in healthy aging training, which is highly effective and productive and facilitates and improves assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [52-54], various ICT applications that are the main supporters of education [55-66], and AI, STEM, Games and ROBOTICS that elevate educational procedures to new performance levers [67-72]. Additionally, [73-88] the development and blending of ICTs with theories and models of metacognition, mindfulness, meditation, and emotional intelligence cultivation, as well as with environmental factors and nutrition, accelerates and improves more than educational practices and results, particularly in healthy aging domain training and its practices like assessment and intervention.

6. Conclusion

The purpose of this literature review is to highlight the positive connection between a plant-based diet and the process of healthy brain aging. As brain aging progresses, tissue, biochemical and molecular changes occur resulting in the development of several neurodegenerative diseases, namely, Alzheimer's and Parkinson's disease as well as depression and dementia. The scientific community is emphasizing a healthy lifestyle approach and a plant-based diet as means of prevention given the high cost and low response rates of pharmacological interventions. Adopting a diet model based on the Mediterranean diet, along with the consumption of foods rich in antioxidants, may result in a delayed decline in cognitive function. The prevalence of age-related neurological diseases between the West and middle- and low-income countries was brought to attention at the same time, exploring the potential impact of Western lifestyle adaptation on these countries. In line with these findings, further investigation regarding dietary interventions for brain aging, as well as the influence of the Western culture on the brain and overall health, is proposed.

Compliance with ethical standards

Acknowledgments

The Authors would like to thank University of Aegean Team for their support.

Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

References

[1] Ali, G. C., Ryan, G., & De Silva, M. J. (2016). Validated Screening Tools for Common Mental Disorders in Low and Middle Income Countries: A Systematic Review. PloS one, 11(6), e0156939. https://doi.org/10.1371/journal.pone.0156939

[2] Andres-Lacueva, C., Shukitt-Hale, B., Galli, R. L., Jauregui, O., Lamuela-Raventos, R. M., & Joseph, J. A. (2005). Anthocyanins in aged blueberry-fed rats are found centrally and may enhance memory. Nutritional neuroscience, 8(2), 111–120. https://doi.org/10.1080/10284150500078117

[3] Bach-Faig, A., Berry, E. M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., Medina, F. X., Battino, M., Belahsen, R., Miranda, G., Serra-Majem, L., & Mediterranean Diet Foundation Expert Group (2011). Mediterranean diet pyramid today. Science and cultural updates. Public health nutrition, 14(12A), 2274–2284. https://doi.org/10.1017/S1368980011002515

[4] Benzie I. F. (2003). Evolution of dietary antioxidants. Comparative biochemistry and physiology. Part A, Molecular & integrative physiology, 136(1), 113–126. https://doi.org/10.1016/s1095-6433(02)00368-9

[5] Bishop, N. A., Lu, T., & Yankner, B. A. (2010). Neural mechanisms of ageing and cognitive decline. Nature, 464(7288), 529–535. https://doi.org/10.1038/nature08983

[6] Bjelland, I., Tell, G. S., Vollset, S. E., Refsum, H., & Ueland, P. M. (2003). Folate, vitamin B12, homocysteine, and the MTHFR 677C->T polymorphism in anxiety and depression: the Hordaland Homocysteine Study. Archives of general psychiatry, 60(6), 618–626. https://doi.org/10.1001/archpsyc.60.6.618

[7] Coelho-Junior, H., Marzetti, E., Calvani, R., Picca, A., Arai, H., & Uchida, M. (2022). Resistance training improves cognitive function in older adults with different cognitive status: a systematic review and Meta-analysis. Aging & mental health, 26(2), 213–224. https://doi.org/10.1080/13607863.2020.1857691

[8] Coelho-Júnior, H. J., Uchida, M. C., Picca, A., Bernabei, R., Landi, F., Calvani, R., Cesari, M., & Marzetti, E. (2021). Evidence-based recommendations for resistance and power training to prevent frailty in community-dwellers. Aging clinical and experimental research, 33(8), 2069–2086. https://doi.org/10.1007/s40520-021-01802-5

[9] Devore, E. E., Kang, J. H., Breteler, M. M., & Grodstein, F. (2012). Dietary intakes of berries and flavonoids in relation to cognitive decline. Annals of neurology, 72(1), 135–143. https://doi.org/10.1002/ana.23594

[10] Duffy, K. B., Spangler, E. L., Devan, B. D., Guo, Z., Bowker, J. L., Janas, A. M., Hagepanos, A., Minor, R. K., DeCabo, R., Mouton, P. R., Shukitt-Hale, B., Joseph, J. A., & Ingram, D. K. (2008). A blueberry-enriched diet provides cellular protection against oxidative stress and reduces a kainate-induced learning impairment in rats. Neurobiology of aging, 29(11), 1680–1689. https://doi.org/10.1016/j.neurobiolaging.2007.04.002

[11] Fekete, M., Szarvas, Z., Fazekas-Pongor, V., Feher, A., Csipo, T., Forrai, J., Dosa, N., Peterfi, A., Lehoczki, A., Tarantini, S., & Varga, J. T. (2022). Nutrition Strategies Promoting Healthy Aging: From Improvement of Cardiovascular and Brain Health to Prevention of Age-Associated Diseases. Nutrients, 15(1), 47. https://doi.org/10.3390/nu15010047

[12] Galimberti, D., & Scarpini, E. (2011). Inflammation and oxidative damage in Alzheimer's disease: friend or foe?. Frontiers in bioscience (Scholar edition), 3(1), 252–266. https://doi.org/10.2741/s149

[13] Ganguli, M., Chandra, V., Kamboh, M. I., Johnston, J. M., Dodge, H. H., Thelma, B. K., Juyal, R. C., Pandav, R., Belle, S. H., & DeKosky, S. T. (2000). Apolipoprotein E polymorphism and Alzheimer disease: The Indo-US Cross-National Dementia Study. Archives of neurology, 57(6), 824–830. https://doi.org/10.1001/archneur.57.6.824

[14] Gómez-Pinilla F. (2008). Brain foods: the effects of nutrients on brain function. Nature reviews. Neuroscience, 9(7), 568–578. https://doi.org/10.1038/nrn2421

[15] Goodall, E. F., Wang, C., Simpson, J. E., Baker, D. J., Drew, D. R., Heath, P. R., Saffrey, M. J., Romero, I. A., & Wharton, S. B. (2018). Age-associated changes in the blood-brain barrier: comparative studies in human and mouse. Neuropathology and applied neurobiology, 44(3), 328–340. https://doi.org/10.1111/nan.12408

[16] Goodwin, J. S., Goodwin, J. M., & Garry, P. J. (1983). Association between nutritional status and cognitive functioning in a healthy elderly population. JAMA, 249(21), 2917–2921. doi:10.1001/jama.1983.03330450047024

[17] India State-Level Disease Burden Initiative Neurological Disorders Collaborators (2021). The burden of neurological disorders across the states of India: the Global Burden of Disease Study 1990-2019. The Lancet. Global health, 9(8), e1129–e1144. https://doi.org/10.1016/S2214-109X(21)00164-9

[18] Ilyas, S., & Moncrieff, J. (2012). Trends in prescriptions and costs of drugs for mental disorders in England, 1998-2010. The British journal of psychiatry : the journal of mental science, 200(5), 393–398. https://doi.org/10.1192/bjp.bp.111.104257

[19] Joseph, J. A., Shukitt-Hale, B., & Willis, L. M. (2009). Grape juice, berries, and walnuts affect brain aging and behavior. The Journal of nutrition, 139(9), 1813S–7S. https://doi.org/10.3945/jn.109.108266

[20] Kang, J. H., Ascherio, A., & Grodstein, F. (2005). Fruit and vegetable consumption and cognitive decline in aging women. Annals of neurology, 57(5), 713–720. https://doi.org/10.1002/ana.20476

[21] Krikorian, R., Nash, T. A., Shidler, M. D., Shukitt-Hale, B., Joseph, J. A. (2008). Concord grape juice supplementation improves memory function in older adults. American Aging Association Annual Meeting; June 1,. Boulder (CO): American Aging Association.

[22] Lampe J. W. (1999). Health effects of vegetables and fruit: assessing mechanisms of action in human experimental studies. The American journal of clinical nutrition, 70(3 Suppl), 475S–490S. https://doi.org/10.1093/ajcn/70.3.475s

[23] Lee, J. E., Männistö, S., Spiegelman, D., Hunter, D. J., Bernstein, L., van den Brandt, P. A., Buring, J. E., Cho, E., English, D. R., Flood, A., Freudenheim, J. L., Giles, G. G., Giovannucci, E., Håkansson, N., Horn-Ross, P. L., Jacobs, E. J., Leitzmann, M. F., Marshall, J. R., McCullough, M. L., Miller, A. B., … Smith-Warner, S. A. (2009). Intakes of fruit, vegetables, and carotenoids and renal cell cancer risk: a pooled analysis of 13 prospective studies. Cancer epidemiology, biomarkers & prevention : a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology, 18(6), 1730–1739. https://doi.org/10.1158/1055-9965.EPI-09-0045

[24] Lee, L., Kang, S. A., Lee, H. O., Lee, B. H., Park, J. S., Kim, J. H., Jung, I. K., Park, Y. J., & Lee, J. E. (2001). Relationships between dietary intake and cognitive function level in Korean elderly people. Public health, 115(2), 133–138. https://doi.org/10.1038/sj/ph/1900729

[25] Logroscino, G., Marder, K., Cote, L., Tang, M. X., Shea, S., & Mayeux, R. (1996). Dietary lipids and antioxidants in Parkinson's disease: a population-based, case-control study. Annals of neurology, 39(1), 89–94. https://doi.org/10.1002/ana.410390113

[26] Luchsinger, J. A., Tang, M. X., Shea, S., & Mayeux, R. (2002). Caloric intake and the risk of Alzheimer disease. Archives of neurology, 59(8), 1258–1263. https://doi.org/10.1001/archneur.59.8.1258

[27] Luppa, M., Sikorski, C., Luck, T., Ehreke, L., Konnopka, A., Wiese, B., Weyerer, S., König, H. H., & Riedel-Heller, S. G. (2012). Age- and gender-specific prevalence of depression in latest-life--systematic review and meta-analysis. Journal of affective disorders, 136(3), 212–221. https://doi.org/10.1016/j.jad.2010.11.033

[28] Macready, A. L., Butler, L. T., Kennedy, O. B., Ellis, J. A., Williams, C. M., & Spencer, J. P. (2010). Cognitive tests used in chronic adult human randomised controlled trial micronutrient and phytochemical intervention studies. Nutrition research reviews, 23(2), 200–229. https://doi.org/10.1017/S0954422410000119

[29] Martín-Aragón, S., Benedí, J. M., & Villar, A. M. (1997). Modifications on antioxidant capacity and lipid peroxidation in mice under fraxetin treatment. The Journal of pharmacy and pharmacology, 49(1), 49–52. https://doi.org/10.1111/j.2042-7158.1997.tb06751.x

[30] Mecocci P. (2004). Oxidative stress in mild cognitive impairment and Alzheimer disease: a continuum. Journal of Alzheimer's disease : JAD, 6(2), 159–163. https://doi.org/10.3233/jad-2004-6207

[31] Molteni, R., Barnard, R. J., Ying, Z., Roberts, C. K., & Gómez-Pinilla, F. (2002). A high-fat, refined sugar diet reduces hippocampal brain-derived neurotrophic factor, neuronal plasticity, and learning. Neuroscience, 112(4), 803–814. https://doi.org/10.1016/s0306-4522(02)00123-9

[32] Murman D. L. (2015). The Impact of Age on Cognition. Seminars in hearing, 36(3), 111–121. https://doi.org/10.1055/s-0035-1555115

[33] National Institute for Health and Care Excellence. (2017). Dementia Diagnosis and Assessment. London: National Institute for Health and Care Excellence, Retrieved from https://pathways nice.org.uk/pathways/dementia/dementia-interventions# path=view%3A/pathways/dementia/dementia-diagnosis-andassessment.xml&content=view-index (accessed June 2017).

[34] Nawa, H., Carnahan, J., & Gall, C. (1995). BDNF protein measured by a novel enzyme immunoassay in normal brain and after seizure: partial disagreement with mRNA levels. The European journal of neuroscience, 7(7), 1527–1535. https://doi.org/10.1111/j.1460-9568.1995.tb01148.x

[35] Nitika, Lohiya, A., Nongkynrih, B., & Gupta, S. K. (2014). Migrants to urban India: need for public health action. Indian journal of community medicine : official publication of Indian Association of Preventive & Social Medicine, 39(2), 73–75. https://doi.org/10.4103/0970-0218.132718

[36] Polyakova, M., Sonnabend, N., Sander, C., Mergl, R., Schroeter, M. L., Schroeder, J., & Schönknecht, P. (2014). Prevalence of minor depression in elderly persons with and without mild cognitive impairment: a systematic review. Journal of affective disorders, 152-154, 28–38. https://doi.org/10.1016/j.jad.2013.09.016

[37] Prince, M., Knapp, M., Guerchet, M., McCrone, P., Prina, M., Comas-Herrera, A., Wittenberg, R., Adelaja, B., Hu, B., King, D., Rehill, A., & Salimkumar, D. (2014). *Dementia UK: Second Edition - Overview*. Alzheimer's Society. Retrieved from https://www.researchgate.net/publication/265508409_Dementia_UK_Second_Edition_-_Overview

[38] Psaltopoulou, T., Sergentanis, T. N., Panagiotakos, D. B., Sergentanis, I. N., Kosti, R., & Scarmeas, N. (2013). Mediterranean diet, stroke, cognitive impairment, and depression: A meta-analysis. Annals of neurology, 74(4), 580–591. https://doi.org/10.1002/ana.23944

[39] Puri, S., Shaheen, M., & Grover, B. (2023). Nutrition and cognitive health: A life course approach. Frontiers in public health, 11, 1023907. https://doi.org/10.3389/fpubh.2023.1023907

[40] Reuter-Lorenz, P. A., & Lustig, C. (2005). Brain aging: reorganizing discoveries about the aging mind. Current opinion in neurobiology, 15(2), 245–251. https://doi.org/10.1016/j.conb.2005.03.016

[41] Rink, C., & Khanna, S. (2011). Significance of brain tissue oxygenation and the arachidonic acid cascade in stroke. Antioxidants & redox signaling, 14(10), 1889–1903. https://doi.org/10.1089/ars.2010.3474

[42] Roberts, R. O., Roberts, L. A., Geda, Y. E., Cha, R. H., Pankratz, V. S., O'Connor, H. M., Knopman, D. S., & Petersen, R. C. (2012). Relative intake of macronutrients impacts risk of mild cognitive impairment or dementia. Journal of Alzheimer's disease : JAD, 32(2), 329–339. https://doi.org/10.3233/JAD-2012-120862

[43] Schindowski, K., Leutner, S., Kressmann, S., Eckert, A., & Müller, W. E. (2001). Age-related increase of oxidative stress-induced apoptosis in mice prevention by Ginkgo biloba extract (EGb761). Journal of neural transmission (Vienna, Austria : 1996), 108(8-9), 969–978. https://doi.org/10.1007/s007020170016

[44] Seidler, R. D., Bernard, J. A., Burutolu, T. B., Fling, B. W., Gordon, M. T., Gwin, J. T., Kwak, Y., & Lipps, D. B. (2010). Motor control and aging: links to age-related brain structural, functional, and biochemical effects. Neuroscience and biobehavioral reviews, 34(5), 721–733. https://doi.org/10.1016/j.neubiorev.2009.10.005

[45] Staubo, S. C., Aakre, J. A., Vemuri, P., Syrjanen, J. A., Mielke, M. M., Geda, Y. E., Kremers, W. K., Machulda, M. M., Knopman, D. S., Petersen, R. C., Jack, C. R., Jr, & Roberts, R. O. (2017). Mediterranean diet, micronutrients and macronutrients, and MRI measures of cortical thickness. Alzheimer's & dementia : the journal of the Alzheimer's Association, 13(2), 168–177. https://doi.org/10.1016/j.jalz.2016.06.2359

[46] Stoll, S., Scheuer, K., Pohl, O., & Müller, W. E. (1996). Ginkgo biloba extract (EGb 761) independently improves changes in passive avoidance learning and brain membrane fluidity in the aging mouse. Pharmacopsychiatry, 29(4), 144–149. https://doi.org/10.1055/s-2007-979561

[47] Valls-Pedret, C., Sala-Vila, A., Serra-Mir, M., Corella, D., de la Torre, R., Martínez-González, M. Á., Martínez-Lapiscina, E. H., Fitó, M., Pérez-Heras, A., Salas-Salvadó, J., Estruch, R., & Ros, E. (2015). Mediterranean Diet and Age-Related Cognitive Decline: A Randomized Clinical Trial. JAMA internal medicine, 175(7), 1094–1103. https://doi.org/10.1001/jamainternmed.2015.1668

[48] Vaynman, S., & Gomez-Pinilla, F. (2006). Revenge of the "sit": how lifestyle impacts neuronal and cognitive health through molecular systems that interface energy metabolism with neuronal plasticity. Journal of neuroscience research, 84(4), 699–715. https://doi.org/10.1002/jnr.20979

[49] Vaynman, S., Ying, Z., Wu, A., & Gomez-Pinilla, F. (2006). Coupling energy metabolism with a mechanism to support brain-derived neurotrophic factor-mediated synaptic plasticity. Neuroscience, 139(4), 1221–1234. https://doi.org/10.1016/j.neuroscience.2006.01.062

[50] Winblad, B., Palmer, K., Kivipelto, M., Jelic, V., Fratiglioni, L., Wahlund, L. O., Nordberg, A., Bäckman, L., Albert, M., Almkvist, O., Arai, H., Basun, H., Blennow, K., de Leon, M., DeCarli, C., Erkinjuntti, T., Giacobini, E., Graff, C., Hardy, J., Jack, C., … Petersen, R. C. (2004). Mild cognitive impairment--beyond controversies, towards a consensus:

report of the International Working Group on Mild Cognitive Impairment. Journal of internal medicine, 256(3), 240–246. https://doi.org/10.1111/j.1365-2796.2004.01380.x

[51] Zeghichi, S., Kallithraka, S., Simopoulos, A. P., & Kypriotakis, Z. (2003). Nutritional composition of selected wild plants in the diet of Crete. World review of nutrition and dietetics, 91, 22–40. https://doi.org/10.1159/000069928

[52] Stathopoulou A, Karabatzaki Z, Tsiros D, Katsantoni S, Drigas A, 2019 Mobile apps the educational solution for autistic students in secondary education Journal of Interactive Mobile Technologies (IJIM) 13 (2), 89-101https://doi.org/10.3991/ijim.v13i02.9896

[53] Drigas A, DE Dede, S Dedes 2020 Mobile and other applications for mental imagery to improve learning disabilities and mental health International Journal of Computer Science Issues (IJCSI) 17 (4), 18-23 DOI:10.5281/zenodo.3987533

[54] S Politi-Georgousi, A Drigas 2020 Mobile Applications, an Emerging Powerful Tool for Dyslexia Screening and Intervention: A Systematic Literature Review International Association of Online Engineering

[55] Drigas A, Petrova A 2014 ICTs in speech and language therapy International Journal of Engineering Pedagogy (iJEP) 4 (1), 49-54 https://doi.org/10.3991/ijep.v4i1.3280

[56] Bravou V, Drigas A, 2019 A contemporary view on online and web tools for students with sensory & learning disabilities iJOE 15(12) 97 https://doi.org/10.3991/ijoe.v15i12.10833

[57] Xanthopoulou M, Kokalia G, Drigas A, 2019, Applications for Children with Autism in Preschool and Primary Education. Int. J. Recent Contributions Eng. Sci. IT (IJES) 7 (2), 4-16 https://doi.org/10.3991/ijes.v7i2.10335

[58] A Drigas, P Theodorou, 2016 ICTs and music in special learning disabilities International Journal of Recent Contributions from Engineering, Science & IT …

[59] Stathopoulou A, Spinou D, Driga AM, 2023, Burnout Prevalence in Special Education Teachers, and the Positive Role of ICTs, iJOE 19 (08), 19-37

[60] Stathopoulou A, Spinou D, Driga AM, 2023, Working with Students with Special Educational Needs and Predictors of Burnout. The Role of ICTs. iJOE 19 (7), 39-51

[61] Loukeri PI, Stathopoulou A, Driga AM, 2023 Special Education Teachers' Gifted Guidance and the role of Digital Technologies, TECH HUB 6 (1), 16-27

[62] Stathopoulou A, Temekinidou M, Driga AM, Dimitriou 2022 Linguistic performance of Students with Autism Spectrum Disorders, and the role of Digital Technologies Eximia 5 (1), 688-701

[63] Vouglanis T, Driga AM 2023 Factors affecting the education of gifted children and the role of digital technologies. TechHub Journal 6, 28-39

[64] Vouglanis T, Driga AM 2023 The use of ICT for the early detection of dyslexia in education, TechHub Journal 5, 54-67

[65] Drakatos N, Tsompou E, Karabatzaki Z, Driga AM 2023 Virtual reality environments as a tool for teaching Engineering. Educational and Psychological issues, TechHub Journal 4, 59-76

[66] Drakatos N, Tsompou E, Karabatzaki Z, Driga AM 2023 The contribution of online gaming in Engineering education, Eximia 8, 14-30

[67] Chaidi E, Kefalis C, Papagerasimou Y, Drigas, 2021, Educational robotics in Primary Education. A case in Greece, Research, Society and Development 10 (9), e17110916371-e17110916371 https://doi.org/10.33448/rsd-v10i9.16371

[68] Lytra N, Drigas A 2021 STEAM education-metacognition–Specific Learning Disabilities Scientific Electronic Archives 14 (10) https://doi.org/10.36560/141020211442

[69] Demertzi E, Voukelatos N, Papagerasimou Y, Drigas A, 2018 Online learning facilities to support coding and robotics courses for youth International Journal of Engineering Pedagogy (iJEP) 8 (3), 69-80, https://doi.org/10.3991/ijep.v8i3.8044

[70] Ntaountaki P, et all 2019 Robotics in Autism Intervention. Int. J. Recent Contributions Eng. Sci. IT 7 (4), 4-17, https://doi.org/10.3991/ijes.v7i4.11448

[71] Chaidi I, Drigas A 2022 Digital games & special education Technium Social Sciences Journal 34, 214-236 https://doi.org/10.47577/tssj.v34i1.7054

[72] Bravou V, Oikonomidou D, Drigas A, 2022 Applications of Virtual Reality for Autism Inclusion. A review Retos 45, 779-785 https://doi.org/10.47197/retos.v45i0.92078

[73] Drigas A, Mitsea E, Skianis C 2021 The Role of Clinical Hypnosis & VR in Special Education International Journal of Recent Contributions from Engineering Science & IT (IJES) 9(4), 4-18. https://doi.org/10.3991/ijes.v9i4.26147

[74] V Galitskaya, A Drigas 2021 The importance of working memory in children with Dyscalculia and Ageometria Scientific Electronic Archives 14 (10) https://doi. org/10.36560/141020211449

[75] Chaidi I, Drigas A 2020 Parents' Involvement in the Education of their Children with Autism: Related Research and its Results International Journal Of Emerging Technologies In Learning (IJET) 15 (14), 194-203. https://doi.org/10.3991/ijet.v15i14.12509

[76] Drigas A, Mitsea E, Skianis C. 2022 Virtual Reality and Metacognition Training Techniques for Learning Disabilities SUSTAINABILITY 14(16), 10170, https://doi.org/10.3390/su141610170

[77] Drigas A,. Sideraki A. 2021 Emotional Intelligence in Autism Technium Soc. Sci. J. 26, 80, https://doi.org/10.47577/tssj.v26i1.5178

[78] Bamicha V, Drigas A, 2022 The Evolutionary Course of Theory of Mind - Factors that facilitate or inhibit its operation & the role of ICTs Technium Social Sciences Journal 30, 138-158, DOI:10.47577/tssj.v30i1.6220

[79] Karyotaki M, Bakola L, Drigas A, Skianis C, 2022 Women's Leadership via Digital Technology and Entrepreneurship in business and society Technium Social Sciences Journal. 28(1), 246–252. https://doi.org/10.47577/tssj.v28i1.5907

[80] Drigas A, Papoutsi C, 2021,Nine Layer Pyramid Model Questionnaire for Emotional Intelligence, International Journal of Online & Biomedical Engineering 17 (7), https://doi.org/10.3991/ijoe.v17i07.22765

[81] Drigas A, Papoutsi C, Skianis, 2021, Metacognitive and Metaemotional Training Strategies through the Nine-layer Pyramid Model of Emotional Intelligence, International Journal of Recent Contributions from Engineering, Science & IT (iJES) 9.4 58-76, https://doi.org/10.3991/ijes.v9i4.26189

[82] Drigas A, Mitsea E, Skianis C, 2022 Intermittent Oxygen Fasting and Digital Technologies: from Antistress and Hormones Regulation to Wellbeing, Bliss and Higher Mental States BioChemMed 3 (2), 55-73

[83] Mitsea E, Drigas A,, Skianis C, 2022 Breathing, Attention & Consciousness in Sync: The role of Breathing Training, Metacognition & Virtual Reality Technium Social Sciences Journal 29, 79-97 https://doi.org/10.47577/tssj.v29i1.6145

[84] Drigas A, Mitsea E, Skianis C 2021. The Role of Clinical Hypnosis and VR in Special Education International Journal of Recent Contributions from Engineering Science & IT (IJES) 9(4), 4-17.

[85] E Mitsea, A Drigas, C Skianis 2022 Metacognition in Autism Spectrum Disorder: Digital Technologies in Metacognitive Skills Training Technium Social Sciences Journal, 153-173

[86] Drigas A, Karyotaki M, Skianis C, 2017 Success: A 9 layered-based model of giftedness International Journal of Recent Contributions from Engineering, Science & IT 5(4) 4-18, https://doi.org/10.3991/ijes.v5i4.7725

[87] Mitsea E, Drigas A, Skianis C, 2022 ICTs and Speed Learning in Special Education: High-Consciousness Training Strategies for High-Capacity Learners through Metacognition Lens Technium Soc. Sci. J. 27, 230, https://doi.org/10.47577/tssj.v27i1.5599

[88] Drigas A, Karyotaki M, 2016 Online and Other ICT-based Training Tools for Problem-solving Skills. International Journal of Emerging Technologies in Learning 11 (6) https://doi.org/10.3991/ijet.v11i06.5340