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LEARNING AND MEMORY: THE EFFECT OF NUTRITION ON BRAIN DEVELOPMENT

Afnan Safiyyah Amru Iskandar[1], Aida Insyirah Amiyamin[2], Nur Aina Qistina Mohd Maznan[3], Nur Daniah Mohammad Azrai[4], Madiha Amani Shukri[5], Che Mohd Nasril Che Mohd Nassir[6], Mohamed Ayaaz Ahmed[7], Huriyyah Hamiemah Md Tajudin[8], Usman Jaffer[9*]

[1] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: afnan.amru@live.iium.edu.my
[2] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: aida.amiyamin@live.iium.edu.my
[3] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: ainaqistina.m@live.iium.edu.my
[4] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: n.daniahazrai@live.iium.edu.my
[5] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: madiha.shukri@live.iium.edu.my
[6] Department of Anatomy and Physiology, School of Basic Medical Sciences, Faculty of Medicine, Universiti Sultan Zainal Abidin (UniSZA), 20400 Kuala Terengganu, Terengganu, Malaysia
Email: nasrilnassir@unisza.edu.my
[7] Southern Ambition 473 CC, 7764, Cape Town, South Africa
Email: ayaaz@reamz.co.za
[8] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: huriyyahamiemah02@gmail.com
[9] AbdulHamid AbuSulayman Kulliyyah of Islamic Revealed Knowledge and Human Sciences, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia
Email: jafferu@iium.edu.my
* Corresponding Author

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Abstract:

A remarkable increase in issues related to learning and memory is found and observed in many schoolchildren and also the elderly. The root of these problems might vary but nutritional intake could be one of the contributing factors. This paper aims to explore the effect of nutritional intake on brain development on learning and memory by reviewing literature within the past five years. We focused on literature related to cognitive function, learning, memory, and brain development. In relation to the current issue, research shows that fast food consumption is significantly related to neurocognitive processes, such as negatively affecting attention span for learning and memory retention which might also affect student's academic achievement. Therefore, future research can elaborate this issue by initiating longitudinal studies on Malaysian students and investigate this issue in a deeper context. Also, research should initiate a study that can assess and include other factors as well instead of just focusing on examining how people are affected by eating habits when it comes to fast food. Lastly, studies can be improved by mentioning interventions that can enhance attention span and memory ability impacted by fast food consumption. In addition, this paper has incorporated this topic and related it with the Islamic perspective.

Keywords:

Nutritional Intake, Cognitive Function, Brain Development, Neuropsychology, Literature Review

Introduction

Many schoolchildren globally are facing learning deficiency without proper interventions (Philips et al., 2020). If not identified and solved quickly, this problem will cause more severe issues for the students and the teachers in the future. One way to solve this problem is to identify the root problem for the issue, which might vary from one student to another. One of the most prevalent causes of learning deficiency among schoolchildren is insufficient nutritional intake (Ozen, 2021), which we will discuss more in detail further in this paper. Another issue that we are interested in studying concerning insufficient nutritional intake is how it affects memory. Memory-related complaints are most prevalent among the elderly despite some school teachers reporting on memory issues among their students. For example, through a survey that was conducted by interviewing homeroom teachers from grade one to six classes, the teachers reported that students, especially in grade five have difficulties in memorizing the lessons such as remembering the mathematical formulas (Parrales et al., 2020).

The current paper aims to study how nutritional intake affects brain development in learning and memory by reviewing past articles related to cognitive functions, brain development, learning and memory from the past five years. In searching for literature, we found out that studies discussing the impact of nutrients on cognitive function specifically on learning are still scarce despite the increasing learning deficiency issues related to poor diet and malnutrition. There are more studies discussing the impact of nutrients on memory, but they mostly focus on the type of nutrients needed to preserve memory and not the physiological process that explains how the nutrients affect the brain areas related to memory. We analyze past literature to provide evidence that this problem is alarmingly significant in today's world, as well as to understand the physiological explanation behind the issue, and lastly to formulate practical suggestions to eradicate or lessen the severity of the issue.

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In psychology, learning refers to a permanent change in behavior as a result of experience, while memory is "the faculty of encoding, storing and retrieving information" (Squire, 2009 as cited by Zlotnik & Vansintjan, 2019, p.2). Both learning and memory formation happen mainly in the brain and involve certain physiological processes such as the firing of neurons, synaptic processes, changes in the structure of the brain and many more. These processes in brain development are modifiable depending on the nutritional intake of individuals (Mou et al., 2023). Learning is essential for individuals' mental health, cognitive development, and functional independence throughout their lives (Wu et al., 2021), and memory is also a very important part of cognitive function which enables individuals to have a sense of identity and to interact effectively with their social environment. These two processes are key elements that enable humans to grow and develop themselves, making it very significant to explore further the ways to enhance them towards their optimal level.

Methodology

The papers reviewed in this study were gathered using a comprehensive search strategy through academic search engines. The main search engine used was Google Scholar as well as Frontier, PubMed and PsycINFO, targeting papers published from 2019 to 2024 to ensure current and relevant information. The keyword used for the search consisted of a few related terms for food intake and its association with learning and memory, such as, "dietary intake," "nutritional intake," "nutrient," "academic learning," "cognitive function," and "memory functions." Boolean operators (AND, OR) were used to specify related collections of literature.

Inclusion and Exclusion Criteria

The papers of interest were systematic reviews and original research papers with research subjects consisting of both human participants and mice. Additionally, the papers that were included covered the topic of associations between dietary intake and cognitive functions, either measured through learning and memory abilities or neurological markers in the brain. Papers discussing other cognitive functions, unpublished papers and dissertations were not included to maintain the scope of the review.

Data Extraction

The data was extracted after a thorough scrutiny using a standardized format specifically made for this review. The main elements extracted were the research background and objectives, the methodology and the findings as well as the direction for future studies. From there, the relevant information was compiled into several subthemes.

Findings

Various academic studies have been conducted to understand the impact of nutritional intake on brain development. This study of nutrients and brain development is crucial because the brain is the most active organ in the body and its growth and function rely heavily on proper nutrition. Hence why this area of research is essential. The following literature reviews involve the theme of nutrition and brain cognitive development, nutrient and memory and nutrient and learning.

Nutrient And Brain Cognitive Development

Nutrient and brain cognitive development refer to the relationship between the necessity of nutrients and the growth of the brain particularly in relation to cognitive functions. Nutrient intake heavily influences cognitive development across one's lifespan (Nieto, 2024). Several

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studies have shown evidence of the effects of nutrient intake that can give effect to brain cognitive functions. In the upcoming years, it is predicted that approximately 131 million of 2 billion people of 60 years old and above, will be affected by dementia (Moore et al., 2018). Therefore, diet plays a vital role in reducing the risk of onset dementia and cognitive impairment (Bruins et al., 2019). Many studies have suggested that good nutrition intake is associated with high cognitive performance while not enough nutrition can delay cognitive growth (Sussane et al., 2010).

A study by Tao et al. (2019) aimed to explore the effects of nutrients on cognitive function among middle-aged and elderly people. A total of 1,385 middle-aged and elderly people were involved in the study. The study was a longitudinal study where participants were recruited from the hospital. The result shows that the intake of riboflavin, which is also known as Vitamin B and unsaturated fat (USFA), can improve cognitive function in middle-age and elderly populations. Riboflavin can be found in a variety of animal and plant-based foods. Food like meat, dairy products, eggs and green vegetables are some of the foods that are rich with riboflavin. The study suggests that regulation of USFA plays an important role in Alzheimer's disease. It can be found in foods like fish and marine products that are rich with omega-3 fatty acids. It is important for the development of brain tissue and functions (Hashimoto et al., 2017). The findings from past studies are also consistent with this study. This study found that riboflavin and USFA had better effects on cognitive function between female populations. However, more research is needed to completely understand the root cause process of how gender affects nutrition. The research also found that age and BMI are some factors that could threaten cognitive functioning. Physical activities have also been found to help in maintaining cognitive health throughout the human lifespan. Thus, it would be impactful to recommend a further study on physical activity. The study was conducted as a longitudinal study, and the sample size was large and can be considered as the strength of this study.

Additionally, another study by Mou et al. (2023) was aimed to examine dietary patterns towards brain morphology and mediate the relationship with cognition. A total of 1888 and 2326 children with dietary data at age one and eight years and structural neuroimaging at 10 years were collected. Children with higher compliance to the dietary pattern labelled as ‘snack, processed foods, and sugar’ showed smaller cerebral white matter volume at age 10. Conversely, another group of children labelled as ‘whole grains, soft fats, and dairy’ was associated with larger brains and larger grey matter at age 10. In a nutshell, dietary patterns in childhood are associated with differences in brain morphology which explain the relationship between dietary patterns and neurodevelopment in children.

Nutrients And Memory

Kida (2022), mentioned that nutrients play a vital role to brain function, development and cognitive functions including formation of memory. Memory enables us to obtain, retain, and retrieve information which are crucial for human processes such as adaptation, survival and also learning (Battaglia et al., 2024). Sari et al. (2023) conducted a study on fifth grade children in Indonesia to explore the influence of nutritional status on short-term memory. The authors discovered that having a nutritional problem can lead to disturbance in children's cognitive function, particularly in remembering. The findings revealed that malnourished children who were underweight, overweight or obese performed worse in memory tasks and they performed less in their academics compared to their friends with normal nutritional status. The authors suggested that this happened due to the hippocampus not getting enough nutrition to function

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properly. Malnutrition negatively impacts the formation of neurophysiology and neurochemistry elements in the hippocampus, a region that is responsible for capturing and retrieving memories. Malnutrition may disrupt this region by limiting the brain's ability to remember things and form new memories. These findings conclude that better nutritional status leads to better short-term memory, and eventually better academic performance. Meanwhile, poor nutritional status can interfere with the development of the brain, leading to poorer academic performance, interrupted memorization processes and productivity as well as poor academic performance. These findings underscore the importance of monitoring students' nutritional health in schools and educating parents about the critical role of a balanced diet on cognitive development.

Another study by Zhang et al. (2020) added to this theme by exploring how dietary diversity influenced memory in Chinese adults aged 50 and above. Their study found that people who scored higher in dietary diversity score (DDS), where they consumed a variety of nutrient rich foods were associated with better memory status and decreased risk in declination of cognitive function and memory. Among the key nutrients taken by participants who were high in DDS were antioxidants such as vitamin C and vitamin E, and fatty acids like fish. These nutrients play a role in promoting neurogenesis, supporting myelination, slowing down memory loss, decreasing the risk of Alzheimer, dementia and also reducing inflammation and stress in the brain. To illustrate, take for example, neurogenesis, the process of forming new brain cells particularly in the hippocampus which helps improve memory, but when it is disrupted, it could lead to memory loss like Alzheimer (Ferreiro & Fernandes, 2021). Zhang and colleagues' findings demonstrated the importance of consuming foods and having a diet that contains nutrients to maintain and protect the memories as people age. It helps individuals retain information and stay cognitively active. Zhang et al. (2020) also pointed that higher DDS was linked to fewer reports of memory declination, and incorporating these diets could naturally help slow down cognitive aging. It highlights how a balanced diet will support memory retention and improve brain health, especially for those at risk of memory problems as they get older.

While looking at both studies, it can be summarized that good and proper nutrition is needed in every age of life to protect memory functioning. Sari et al. (2023) showed that poor nutrition in childhood can affect the hippocampus and harm memory which is important in learning, leading to poor academic achievement. Meanwhile Zhang et al. (2020) underscored the important needs to take meals that contain nutrients to prevent cognitive declination and memory loss particularly in adults or older people. These highlighted the strength of the studies where both of them provided a valuable insight into understanding how nutrients are important in memory formation in childhood and memory retention during aging age.

However, some limitations can be discovered. These two studies did not delve into other possible factors that may also contribute to memory declination. For example, Sari et al. (2023) mainly focused on the effects of malnutrition on the hippocampus but did not look into other external factors like environment or genetics influences that might influence the cognitive conditions and memory. Similarly, Zhang et al. (2020) lack discoveries on the participant's life events and other circumstances that may cause negative impacts on their memory functioning. Future researchers can overcome these limitations by including external factors like lifestyle or personal experience into their research to get broader understanding.

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Nutrients And Learning

Nutrients are essential for the optimal functioning of the brain, which directly influence learning abilities. Learning is the process of acquiring skills, relying on cognitive functions such as attention, memory and problem solving. Adequate nutrition provides the foundation of these cognitive processes to develop and operate effectively. Specific eating patterns can contribute to enhancing cognitive functions which are later important for learning processes (Novotny et al., 2019).

A study by Tenzin et al. (2021) aimed to investigate the relationship between academic performance of college students and nutritional diet that they receive from the college cafeteria. A total of 141 students participated in the study with 135 participants going through a survey and six people going through a structured interview. The result revealed that food quality and nutritional diets served by college cafeterias have an impact on students' eating habits and academic learning. Studies have concluded that dietary habits affect brain functions. Children of school age who consumed nutritious, balanced diets have better brain capacity, maximized cognitive functions and can perform well academically (Rausch, 2013). For the brain to work at its best and improve learning ability, proper nutritional support is necessary. According to Wolfe et al. (2000, as cited in Tenzin et al., 2021), students' health, behavior and cognitive abilities are all impacted by diet, which has an effect on their academic performance. Mora et al. (2019) showed a positive relationship between eating habits and academic performance among adolescents. Tenzin and colleagues also explained how nutrients like protein, iron and vitamins influenced brain function. Iron produces a neurotransmitter that regulates focus and memory while iron improves the flow of oxygen, providing more energy to concentrate. This process highlights how nutrition is associated with learning abilities.

The strength that can be demonstrated from this study is it provides a detailed explanation on how nutrition affects academic performance. It highlights how dietary habits and consuming nutritional foods influence cognitive functions like improving memory, focus and problem solving. These findings provide an insight on how nutrition enhances cognitive process and learning. Despite the strength, there are a few limitations that can be addressed including the generalizability aspect. The study of Tenzin et al., (2021) only focused on a single cohort of college students in Bhutan. This limits the generalizability of the results as their cultural, economic and dietary context differ from people across the globe. Another limitation that can be seen is the lack of longitudinal data. The study presents cross-sectional data on nutrition and academic performance caused by learning abilities. This limits the understanding on how long-term nutritional habits may affect academic performance, learning and cognitive development. Future researchers could address this gap by examining how maintaining these dietary habits impacts students over time.

Discussion

Application to Current Issue

As in the literature review, nutrition has been explained in three themes that are interrelated; cognitive development, memory and learning. The extent of a person's ability to memorize and learn new things are related to the development of their brain. From the review, it can be seen that nutrition has an impact in the formation of new brain pathways and the overall physical aspects of the brain. Specifically, the area involved in memory processes, the hippocampus is sensitive to food contents and may be disrupted with the lack of nutrition-dense food. With this

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insufficiency, this part of the brain will be under-developed, leading to impaired memory consolidation, formation and retention which will influence student's ability to perform cognitive tasks related to learning. Consequently, due to impaired cognitive functioning, academic performance will reduce. With this understanding, the current section will try to apply these points to one of the contemporary issues, which is students' fast-food consumption and its effect on academic performance. As fast food is an integral part of students' diet, examining the relevant data can provide a valuable insight to this growing concern.

Currently, the growing number of fast-food branches in Malaysia can be seen as one of the factors that may lead to an unhealthy lifestyle as people increasingly depend on fast food almost every day. Evidence published by Siddharta (2024) on the Statista website mentioned that there will be an increased number of fast-food outlets in Malaysia in 2022, around 7.72 thousand and nearly 7000 restaurants. Besides that, it is expected that it will be increasing by around 9.72 thousand by 2026. The increase in fast-food outlets not only reflects the societal demand for unhealthy food but will increasingly change the way eating out is perceived by people. This is because, with increased availability, people will be more propelled to choose eating fast-food rather than cooking at home. Generally, with increased numbers of outlets, the price of fast-food will be more affordable than healthy-cooked food which will paint a more favorable picture for the fast-food option. As this option becomes easier, cheaper, and more available, the consequence would be dependency on fast-food consumption. One reason for fast food consumption is because of time and energy constraints which translate into busy schedules and increasing need to reduce cooking time as people have less time and energy to spend on preparing home-cooked meals or even grocery shopping (Amin et al., 2023). Other than that, involvement in many social activities with peers is a significant factor that influences students' tendency to consume fast food (Lam et al., 2014, as cited in Chai & Cheah, 2024).

Nevertheless, it is proven that despite providing high energy, fast food contains a lot of trans fat, refined carbs, sugar, and preservatives (Chai & Cheah, 2024; Herlin Widasiwi Setianingrum & Martinus Tukiran, 2024). Trans fats and refined sugars severely impact children's cognitive development because they can disrupt neural signaling and plasticity which leads to a lack of cognitive development, affecting learning processes. Results of a study have shown that diets high in saturated fat may cause consistent damage to hippocampal-dependent forms of cognition, resulting in reduced ability to consolidate and encode episodic memories and slower retrieval of information. (Abbott et al., 2019). Additionally, Kaur (2019) provides evidence for impaired prefrontal-hippocampal trajectory due to excessive glucose consumption, leading to reduced attention span and the ability to control attention. Aligned with this, according to Yeomans et al. (2023), consistent fat and sugar intake may lead to reduced hippocampal memory performance and greater impulsivity. This is because habitual intake can be directed to addiction as glucose disrupts the dopaminergic pathways in the hippocampus, a part of the brain that is located in the temporal lobes which is associated with the reward-related mechanism. It should be noted that most of the studies mentioned are cross-sectional which means the data is limited to only one period of time. This instance limits the understanding of dietary influences across lifespan and the changes that might take place through other developmental changes such as hormonal and physical changes. In regards to this, some studies mentioned also lack objective measures such as biomarkers which may impact the outcome and its interpretation.

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Despite profound discussion on the effect of nutrition on cognitive functioning, the long-term effect of fast-food consumption on student's cognitive ability and their academic performance is not broadly studied. Additionally, studies on the effect of dietary patterns in Malaysia are still scarce as most of the studies have been focusing on western countries. Therefore, future research can elaborate on this by initiating longitudinal studies on Malaysian students over time to investigate this issue in a deeper context, exploring the underlying mechanisms through neuroimaging to monitor hippocampal development over time. Additionally, a longitudinal study assessing dietary influences on blood lipids and hormone biomarkers can be explored to explain the complex integration of nutrition and hormones with brain developments. To understand the issue across cultures, future studies must include different ethnicity in the study samples as well as factoring in the variables such as peer pressure, social and cultural norms, and lifestyle differences (Chai & Cheah, 2024).

Islamic Perspective

The brain is a very complex creation of Allah that He bestowed upon human beings along with other body parts in the best form. As mentioned in the Qur'an (95:4), human creations are the best of creations, thus, nothing created by humans is comparable to the brain, even the most advanced technology of computers or artificial intelligence. This irreplicable design is in place to support higher levels of thinking and contemplation upon His creation to increase our Taqwa. Allah has wisdom in His creation, and in the Quran (2:30), Allah mentions that He created man in this world to be the Khalifah who will govern and administer the earth using the faculty of reasoning bestowed by Him. Therefore, humans are placed on Earth with a mission which is to remind and bring fellow humans towards Allah, the Creator by utilizing the power of reason and guided by the Qur'an and Sunnah.

Compared to the 'Aql which is immaterial, the brain is a material organ in the human body where the cognitive processes take place. Hence, the brain and its ability to perform complex tasks is taken as a responsibility, which means preserving it through a nutrition diet to help it develop and function. In line with this belief, Islam guides in the selection of food through the concept of halalan tayyiban which means permissible and good, prioritizing only the most nutritious and properly prepared meals to be consumed. To support this notion, Allah also mentioned in the Qur'an (2:172), which focuses on utilizing the provided means to choose which food is beneficial to the bodily functions. It is notable to mention that one of the practices of the Prophet was to be mindful in consuming food by avoiding excessive consumption of food. In line with this, the current diet recommendation also supports this notion by limiting glucose and fat intake to ensure a balanced diet. Therefore, this shows support that the teaching of Islam encourages healthy diet to preserve the functions of the brain.

Conclusion

This paper aims to explore the effects of nutritional intake on brain development and cognitive functions mainly the learning and memory abilities. The findings showcase the vast importance of a nutritional diet consisting of vitamins, minerals, fiber, riboflavin, whole grains and unsaturated fat on cognitive development, memory formation, learning efficiency and focus retention. This category of diet has been shown to influence neural signaling and plasticity, supporting neural connections in the brain to facilitate its functions. In contrast, unhealthy food categories, mainly fast-food, showed a relation to neurocognitive decline, disruption of dopaminergic pathways, impaired prefrontal-hippocampal circuit and increased impulsivity. Due to this, dietary health, as emphasized by Islamic and prophetic teachings, can be an

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effective prevention plan to maintain cognitive health. In this regard, the Islamic perspective on the blessings of cognitive functioning and providence of healthy food were explored to emphasize on the relationship between mindful consumption and its benefit. Consequently, this review concludes that research on nutritional health and cognitive functions should be explored further to inform better intervention plans and increase the understanding in cognitive science and brain health.

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