A Brief Review on the Nutrient Effects on the Brain and Implications

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Abstract Nutrients affect overall human health in various ways and their importance has been well-documented in numerous scientific articles. Recently, new evidence has suggested that diet plays a role in altering brain functions. Such findings have evoked speculation as to how diet can influence brain morphology and impact cognitive functions. Data from mice with modified diets and interpolated results from human studies with specific ingredients suggest that nutrients may act as a signaling molecule when broken down by cells to directly affect the brain itself. From well-controlled single diets to varying supplemental diets, new information has been found of how different diets influence brain functions and aging of the brain.

Introduction The human brain is a collective structure consisting of a myriad of neurons constantly firing signals to create, store, and recall memories. The major functional anatomy of the human brain is divided into four key parts: the parietal, frontal, occipital and temporal lobes (Hoffman, 2017). Each part comes with distinct functions. Although each part can be separated into its respective functions, it is important to note that brain structure as a whole is highly interactive. Therefore, the interactions of inner connections are not trivial and many questions about the function and architecture of the brain remain unanswered. Even with contrast to the remarkable complexity of the brain, scientists have used a relatively simple approach to determine the influence of nutrients on brain morphology and its function. Brain function and mental illnesses have often been associated with factors like mental stress and emotionality. In fact, in one study, researchers suggested that chronic stress leads to changes in brain structure and function (Chetty et al., 2014). However, at a molecular level brain functions can also be affected by tangible, physical factors such as nutrients. After all, the cellular make-up of the brain results from the fundamental building blocks received from foods in general. Hence, it is not surprising that food itself can affect the mental and cognitive functions of the brain. In one study, researchers have verified that tweaking the diet of mice models altered brain cell density, count, weight, and tissue morphology of the brain, leading to the belief that cognitive function and emotionality can be an influence as well (Lemon et al., 2016). It is believed that gut hormones affected by various foods can enter in and out of the brain, interacting with various receptors on the brain itself.

Nutrients affect Aging of the Brain Aging of the brain is commonly associated with a variety of negative changes including cognitive decline, sensory function loss, and neurodegeneration at the cellular level. Among the many symptoms of an aging brain, common characteristics include chronic oxidative stress, resistance to insulin, mitochondrial dysfunction, muscle, and neural atrophy, and increased levels of inflammatory processes; actual mechanisms behind these processes are complex and are the topic of another discussion in themselves. In general, mitochondrial dysfunction and oxidative metabolism are the two main sources of oxidative stress in the brain contributing directly to cognitive, motor and sensory damage (Antier et al., 2004; Wang and Michaelis, 2010; Yin et al., 2014). Neurons in the brain require a great deal of energy which is supplied by the ATP consumption occurring in membrane ionic pumps, synaptic transmission, and channel activity. As a result of such demand, this can lead to increased free radicals which may inhibit the enzyme NADH dehydrogenase and cause a defect in mitochondria. Impaired production of ATP from dysfunctional mitochondria increases reactive oxygen species in the brain which contribute to the commonly observed aging process (Shigenaga et al., 1994, Lenaz, 1998; Sastre et al., 2003). A recent study according to Lemon et al. (2016) has revealed the ways to prevent neural decline through the use of multi-ingredient dietary supplements (MDS). To explore these options, researchers from the study carefully chose key ingredients that have been proven to slow down or completely eradicate each of the five processes associated with aging. The supplements in the study were prepared in a liquid form and a 0.4 ml volume was soaked in a 1 cm x 1.5 cm x 1 cm piece of bagel and allowed to dry. Each mouse was given exactly one piece of the bagel with or without multi-dietary supplements every day. Each piece was eaten within 20 minutes to ensure that the mice received the equivalent and full dosage required for the study. Transgenic growth hormone (TGM) mice were used to model older specimens because the overexpressed growth hormone allows TGM to mature and age faster (Lemon et al., 2016). This allows researchers to study the effects of aging in a shorter period. Results of the experiment demonstrated that various improvements in brain function are due to the MDS treatment in the TGM mice. However, simple somatosensory tests, which included (a) landing response, (b) visual placing, (c) negative geotaxis, and (d) pinch reflex, did not show significant improvement compared to normal, untreated mice. This shows how further improvement from supplementation alone did not occur. However, there are other areas that have been improved to a certain extent. MDS treated TGM brain cells showed significantly greater density as opposed to the brain cells of 12-month-old untreated TGM mice, implying that MDS indeed slowed down the deteriorating effects of aging on the brain (Lemon et al., 2016). In terms of tissue morphology, supplemental mice had a 16% increase in the molecular layer (ML) and 18% increase in the granular layer (GL) of the brain (Lemon et al., 2016). The Mitrial cell layer also showed an increase of up to 29% in treated mice. Loss of mitral cells in aging rodents has been documented and the increase in these cells in the MDS suggests that treatment potentially prevented these neurons from age-related atrophy. In terms of behavioral influence on mice, the effect on the supplemented mice was significantly different from dim light to bright light. This suggests that supplemented mice demonstrated improved contextual discrimination which implies that aging MDS treated mice had stronger cognitive function than their counterparts. In motor coordination, the untreated 12-month TGM mice showed severely hindered coordination compared to same age untreated normal mice, but MDS supplement mice showed significant progress in terms of motor coordination (Lemon et al., 2016). This implies that nutrients play a critical role in the aging of the brain in various areas.

Gut to Brain Connection The Human body consists of complex systems of connections that interact with different parts of the body. For example, the enteric nervous system (ENS) consists of more than 100 million nerve cells lining the gastrointestinal tract from esophagus to rectum. While the brain and gut may appear to be two different tissue systems with little interaction, it is highly probable that events in the gut can trigger reactions in the brain and vice-versa. A piece of great evidence about the gut-to-brain connection can be found in the interaction between insulin and specific signal transduction receptors located in the hippocampus. Insulin has been known to be a gut hormone produced in the pancreas and involved in changes in cognitive processing in the brain. As discussed above, the brain to gut connection plays a significant role in shaping the brain and further verifies the importance of nutrients.

Effects of Specific Nutrients on Cognition There is a belief that a deficiency of omega-3 fatty acids in rodents results in impaired learning and memory. In addition, even in humans, omega-3 deficiencies have been linked with increased risk of mental disorders such as bipolar disorder, schizophrenia, dementia and dyslexia (Peet, Laugharne, Mellor & Ramchand, 1996). According to current data, a diet rich in omega-3 fatty acids can promote brain health. On the other hand, high contents of trans and saturated fats adversely influence brain cognition as described below. In rodent studies, so-called "junk food" with high trans and saturated fat content led to a decline in cognitive performance in rats as well as reduced hippocampal levels of BDNF related synaptic plasticity in only three weeks of such treatment. This once again implies that nutrients have a huge role in brain health (Molten, Barnard, Ying, Roberts, & Gomez-Pinilla, 2002). At a molecular level, broken down foods can become building blocks for signaling molecules to promote neural synaptic plasticity. Antioxidants and micronutrients, in particular, are other great examples known to influence learning capacity and memory performance of the brain. Various micronutrients with an anti-oxidant capacity can influence these functions. However, constituents that make up an "antioxidant" substance are great in number and only a few of them has been extensively evaluated separately. Two tannins (procyanidin and prodelphinidin), anthocyanins, and phenolics are well-known compounds with antioxidant properties commonly found in grapes, tea leaves, and seeds. Researchers evaluated their influence on mice, and polyphenols have been shown to increase hippocampal plasticity to enhance learning and memory performance (Casadesus et al., 2004). For example, alpha lipoic acid, which is found in meats such as the kidney, heart, and liver, and vegetables like spinach, broccoli, and potatoes, is a coenzyme important for energy homeostasis in mitochondria (Liu, 2008). Another example is a curcumin, curry spice, which has been shown to reduce memory deficits in animal models, implying that nutrients indeed have a positive effect on cognitive functions in the brain (Frautschy SA, et al 2001).

High Salt Diet on the Brain It is an accepted fact that the human body requires a sufficient amount of sodium to stay healthy and maintain functioning. However, a high sodium diet is detrimental to cognitive function and seems to have a role in a variety of cardiovascular disorders (Nwanguma and Okorie, 2013). A high salt diet undeniably has a critical role in shaping human health, yet the exact mechanism with which a high salt diet impairs cognitive function and learning remains unknown. However, it is well-documented that excessive salt intake has undesirable physiological effects. Various studies on animals have shown that such cases are true. Increased oxidative stress in cells, as well as the generation of reactive oxygen species which can turn into free radicals, can damage the brain over time. However, according to a study where scientists compared 4-week and 7-week high-salt diets in mice, it was found that the more salt was consumed, the more weight the mice lost. It is also important to note that in the same study, it is mentioned that the mice consumed a gradual increase in food and water (Ge et al., 2017). However, both short-term and long-term memories with mice treated with 7-week long high salt diets were impaired. The high 7-week salt group had disturbances in the hippocampal long-term potentiation (LTP). In addition, the same studied also showed that high salt diets induce oxidative stress and trigger metabolic reprogramming in the hippocampus (Ge et al., 2017). High salt treatment is associated with neurotransmitter release, implying that nutritional diet specification such as a high salt diet can affect brain function.

Conclusion In-depth analyses have shown that by tweaking and controlling diet, even aging of the brain can be slowed down and functions can be restored to normal levels. Further research is necessary to study the exact mechanism behind how specific nutrients can influence brain-cell interactions. Both high and low levels of brain functioning are affected by nutrients as evidence shows, which is why it is crucial to research and modify other experimental diets in order to promote the health of the brain.

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