Impact of nutritious diet on cognition, emotion and neuronal network of brain

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Abstract: Cognitive neuroscience, the study of brain-behavior relationships, has long attempted to map the brain. The discipline is flourishing, with an increasing number of functional neuroimaging studies appearing in the scientific literature daily. Newly described influences of dietary factors on neuronal function and synaptic plasticity have revealed some of the vital mechanisms that are responsible for the action of diet on brain health and mental function. This review focuses on the relation of cognitive science and nutritional aspects. We have highlighted various studies which examined various types of food in form of carbohydrates, proteins, amino acids, folic acid etc. and their effect on functioning of brain. The current review has also summarized the consumption of processed food daily leading to various neurological disorders. Based on these data, the need for food industries to focus on research and development of nutritional strategies that are most appropriate to support our cognitive and emotional health.

Index terms: **cognitive**, ***dietary factors, food, neurological***

I. Introduction

The brain is composed of millions of cells called neurons. Thoughts, memories, actions etc. depends on the interactions between one cell and the others. The transmissions between cells occur by chemicals called neurotransmitters.[1] Neurotransmitters can be divided into two groups: inhibitory and excitatory. As they are produced from exogenous substances, nutrition is essential for the correct function of the brain.[2] Neurotransmitters are composed of aminoacids which are found in food leading to a strong correlation between nutrition and mood also.[3]

Nutrients can affect multiple brain development processes by regulating neurotransmitter pathways, synaptic transmission, signal-transduction pathways, and synaptic plasticity. Subsequent studies showed that the best nutritional support for healthy nervous system development arrives from a balance of the protein and energy nutrients with other essential micronutrients.[4] According to Dr. Richard Wurtman at MIT, who is involved in numerous studies on nutrition and the brain, the nutrients in foods are precursors to neurotransmitters, and depending on the amount of precursors present in the food you eat, the more or less of a certain neurotransmitter is produced. Although this process may seem fairly straightforward, it is complicated by the fact that foods most often are made up of more than one nutrient, and how those different nutrients interact will also impact the production and release of neurotransmitters.

Protein foods are broken down into their amino acid building blocks during digestion. One amino acid, called tyrosine, will increase the production of dopamine, nor epinephrine and epinephrine. These neurotransmitters are known for their ability to increase the levels of alertness and energy. No one eats pure tyrosine, but eating foods high in protein will give a slight mental boost. Many milk products are high in phenylalanine. Cheese and milk, in particular, contain over 500 mg/100g. Cream and cream cheese, which are higher in fat and lower in protein, contain less amounts, but still in excess of 100 mg. An egg contains over 500 mg of phenylalanine. Even most of the nuts are high in protein, which a significant amount is derived from phenylalanine. Five walnuts contains 540 mg, 10 almonds contains 980 mg, and 30 roasted peanuts contains

1400 mg. Peanut butter contains over 3500 mg/100 g. Beans, chickpeas and lentils contain the most phenylalanine, roughly 100 mg/100 g. Soy products, including soy protein isolate, soybean flour and tofu, are also good sources.[3]

Although food has classically been perceived as a means to provide energy and building material to the body, its ability to prevent and protect against diseases is starting to get recognized. In particular, research over the past 5 years has provided exciting evidence for the influence of dietary factors on specific molecular systems and mechanisms that maintain mental function. For example, a diet that is rich in omega-3 fatty acids is garnering appreciation for supporting cognitive processes in humans and upregulating genes that are important for maintaining synaptic function and plasticity in rodents.

In turn, diets that are high in saturated fat are becoming notorious for reducing molecular substrates that support cognitive processing and increasing the risk of neurological dysfunction in both humans and animals. Although these studies emphasize an important effect of food on the brain, further work is necessary to determine the mechanisms of action and the conditions for therapeutic applications in humans. Recent studies confirmed a relationship between food and mental disorders. A World Health Organization study of 14 countries reported occurrence of mental disorders between 4.3 % and 26.4 % has increased in developed countries in correlation with the deterioration of the Western diet. Folic acid deficiencies have been linked to depression in clinical studies. Folic acid deficiency causes serotonin levels in the brain to decrease. Psychiatric patients with depression have much higher rates of folic acid deficiency than the general public.

Cognitive neuroscience, the study of brain-behavior relationships, has long attempted to map the brain. The discipline is flourishing, with an increasing number of functional neuroimaging studies appearing in the scientific literature daily. Unlike biology and even psychology, the cognitive neurosciences have only recently begun to apply evolutionary meta-theory and methodological guidance. Newly described influences of dietary factors on neuronal function and synaptic plasticity have revealed some of the vital mechanisms that are responsible for the action of diet on brain health and mental function. Several gut hormones that can enter the brain, or that are produced in the brain itself, influence cognitive ability. Previous research and studies focused only on some neurological disorders.[5] The current review discuss about the effect of various food and diet on the functioning, balancing and mood of brain and also correlation of diet derived signaling molecules with neuroscience. In this review we highlight the effect of processed foods, malnutrients etc. on the health, emotions, disorders and mental behaviour of the individual.

II. General

2.1. Cognitive Science and study of food brain behaviour relationship

Proper nutrition and health are closely interrelated throughout life, but probably the highest importance is the first years of life. Inadequate nutrition causes lower cognitive development, reduced attention and concentration and reduces performance in later life. Also, foetal programming in uterus should not be neglected, for its proven influence on the later development of a child. The memory system and part of the brain is showed in figure 1.

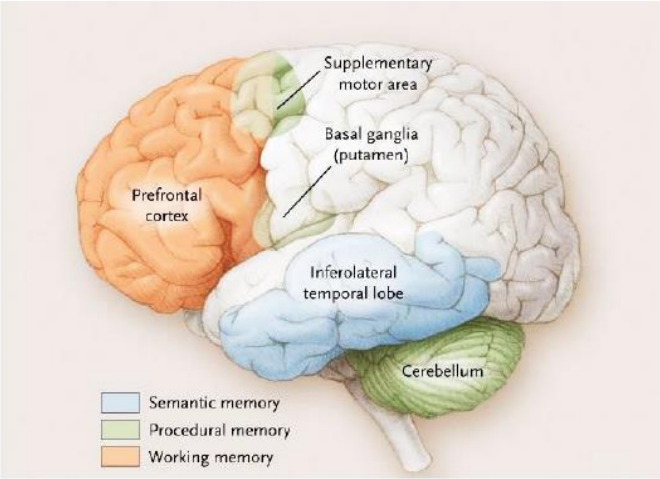

Figure 1: Memory system & part of the brain

Toree[6] in their studies showed that the exact factors and underlying mechanisms precipitating the emotional dysfunction disorders have not yet been elucidated. Next to our genetic makeup, the interplay between specific environmental challenges occurring during well-defined developmental periods seems to play an important role. Interestingly, such brain dysfunction most often co-occurs with metabolic disorders or poor dietary habits; obesity and poor diet can lead to negative health implications including cognitive and mood dysfunctions, suggesting a strong interaction between these elements as described in figure 2.

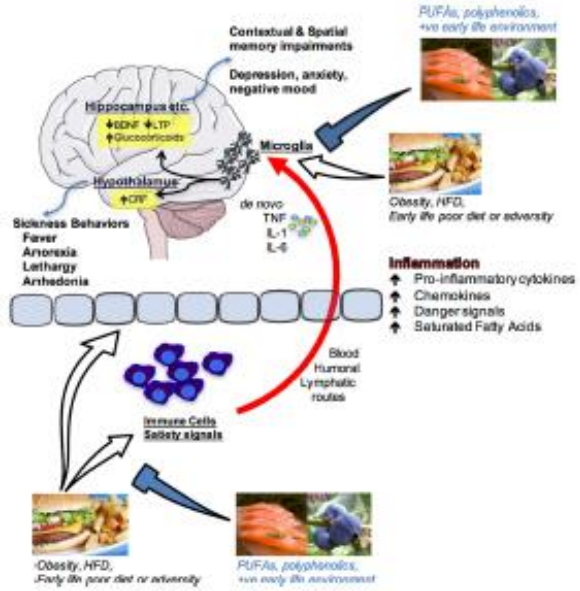

Figure 2: Schematic diagram of how nutrition influences cognition and emotion

2.2. Diet derived signaling molecule (DSM) that supports brain function

The impact of food on brain development and function has been extensively reviewed, although these reviews are often more descriptive than mechanistic in nature (references). In a recent article by Rodriguez et al. (2017), they have shown that a list of dietary factors as shown in Table 1.

Table 1. Diet-derived signaling molecules (DSM) that supports brain function

DSM	Function in the Brain	References
Choline	A macronutrient important for normal brain development, nerve function; a precursor of acetylcholine which promotes cognitive flexibility and adaptive behavior in response to new and unexpected environmental circumstances	55,156
D-Glucose	Biotransformed from more complex sugars and carbohydrates; D-glucose provides the energy needs of the brain in the form of ATP; enhances cognitive function and neuroprotective for AD	78,107
Folate	Required for metabolism of 5-MTHF and homocysteine; deficiency in 5-MTHF is associated treatment-refractory depression while overproduction homocysteine is associated with neuropsychiatric disorders; folate is also a precursor for the methyl-donor, SAM, which is required to epigenetic modification of DNA and chromatin	21,55,131,136–138,149
Omega-3 fatty acids (EPA, DHA, ALA)	Neuroprotective against AD; reduces the levels of AD biomarkers (β-amyloid plaque and neurofibrillary tangles) in cerebral spinal fluid; DHA has been implicated reducing severity of depression and bipolar disorder	56–59,73,147,148, 157,158
Plant polyphenols	Neuroprotective for AD and Parkinson's disease; neurotrophic and associated with enhanced neuronal survival and promotes neuronal differentiation in vitro; helps maintain metabolic homeostasis which has a protective effect on membranes; involved in histone deacetylation	13,43,45,49,54,55
Vitamin A	Antioxidant; prevents cognitive decline; perinatal deficiency correlated with increased risk of schizophrenia; promotes neuronal differentiation of neuronal stem cells	21,55,159
Vitamin B3 (niacin)	Transactivation of a PI3K/Akt signaling cascade to prevent/reduce brain damage from stroke; neuroprotective for Parkinson's disease	156,160
Vitamin B6 (pyridoxine)	Coenzyme for the biosynthesis of neurotransmitters; required for metabolism of homocysteine which is implicated in the development of psychiatric disorders including depression	21,161
Vitamin B12	Essential for brain development, neuronal myelination and cognitive function including mood; methyl-donor for methionine and SAM, the latter serving as the methyl-donor for epigenetic modification of DNA and chromatin	15,131,162
Vitamin C	Neuroprotective against oxidative damage in the brain; higher intake associated with lower AD	21,55,163
Vitamin D	Neuroprotective against oxidative damage; deficiency correlated with greater risk of schizophrenia and multiple sclerosis	55,164
Vitamin E	Antioxidant; prevents membrane oxidation DHA peroxidation; slows cognitive decline and the advancement of AD	55,165

Table 1 lists twelve well-characterized DSMs and their purported and demonstrated impact on neurological function. Not shown are various non-dietary plant compounds (e.g., forskolin, huperzine A, ginko) and minerals (i.e., Ca, Cu, Fe, Se, Zn) known, or thought to be involved in preserving or stimulating cognition in humans and/or laboratory animals. Table adapted from Gomez-Pinilla[4]

Table 1: List of dietary factors

For DSMs to impact various neurological structures and functions in ways that produce neurogenesis, synaptic plasticity and adaptive behaviors, there must be an efficient communication system allowing dietary stimuli to be delivered to the brain from the gut. These connections are provided by the 400–600 million neurons in the human enteric system[7] that creates a virtual information highway through which DSMs can communicate critical chemical information from the environment to the brain.[8] These communication channels allow dietary inputs to be building blocks for the brain, but also a means for delivering important chemical signals from the extracellular environment to the neuron where they are continually integrated into those signaling pathways and neuronal activity needed for metabolic homeostasis, cognition and overall health.[9]

2.3. Role of Sia concentration present in human milk

The Sia-glycoconjugates are present in human breast milk and are species specific and therefore provide a natural source of structurally and biologically complex nutrients that are designed for the human infant. The level of Sia expressed in human breast milk glycoconjugates is influenced by a variety of genetic factors, geographic regions, and dietary intakes of mothers. The concentration of Sia in brain gangliosides significantly correlated with ganglioside ceramide, DHA, and total (n-3) fatty acids in breast-fed, but not in formula-fed, infants. Wang et al.[10] in their studies demonstrated that the cortical tissue from human brain has 2–4 times more Sia than that of 7 other mammals, including our closest relative, the chimpanzee.

2.4. Dietary lipids action on brain

Dietary lipids, which were originally thought to affect the brain through their effects on cardiovascular physiology, are garnering recognition for their direct actions on the brain. Omega-3 polyunsaturated fatty acids are normal constituents of cell membranes and are essential for normal brain function. There is a general consensus that a deficiency of omega-3 fatty acids in rodents results in impaired learning and memory. Dietary deficiency of omega-3 fatty acids in humans has been associated with increased risk of several mental disorders, bipolar disorder, depression, dyslexia, dementia and schizophrenia. Docosahexaenoic acid (DHA) is the most abundant omega-3 fatty acid in cell membranes. As the omega-3 fatty acid DHA is a prominent component of neuronal membranes, and as the human body is inefficient in synthesizing DHA, people are reliant on dietary form of DHA.[11]

2.5. Role of antioxidants in food

The brain is highly susceptible to oxidative damage because of its high metabolic load and its abundance of oxidizable material, such as the poly-unsaturated fatty acids that form the plasma membranes of neural cells. Several 'anti-oxidant diets' have become popular for their positive effects on neural function. Berries, for example, have been shown to have strong antioxidant capacity and many components in it have been evaluated quantitatively. Berries especially blackberries, blueberries, strawberries, raspberries are packed with antioxidants that help keep memory sharp according to the age. They are also a great source of fibre and glucose, the main energy source for the brain. Research by Krikorian and his team[12], examined different rat sp. and showed the ability of berry fruit to protect against age-related cognitive decline. Thus, blueberry juice significantly improved word list recall and paired associate learning in older men and women with age related memory decline that consumed it, relative to baseline, with paired associate learning also significantly improved relative to placebo controls. A recent study that measured similar cognitive tasks as those in the rodent studies, showed that freeze dried blueberries (24 g/day, equivalent to one cup of fresh blueberries) for 90 days improved two measures of executive function in older adults (ages 60–75).[13]

Another micronutrient involved with the antioxidant capacity is alpha lipoic acid, which is found in meats such as kidney, heart and liver, and vegetables such as spinach, broccoli and potatoes, is a coenzyme that is important for maintaining energy homeostasis in mitochondria. Quinn and Holmquist et al.[14,15] in two different studies showed that alpha lipoic acid improved memory deficits in animal models of Alzheimer's disease and to reduce cognitive decay in a small group of patients with Alzheimer's disease. A common antioxidant found in India, cucurmin (turmeric) is relatively non-toxic, and it is highly consumed in India, it is possible that it might contribute to the low occurrence of Alzheimer's disease in the country.[16,17]. It also seems to protect the brain from lipid peroxidation and nitric-oxide-based radicals.[18]

2.6. Effect of processed foods

A lot of studies have shown that eating foods high in sugar and fat actually changes the chemical activity of the brain making it more dependent on such foods. A study conducted at the University of Montreal on mice showed that they suffered with withdrawal symptoms after their regular junk food diet was discontinued. In humans, these withdrawal symptoms can lead to the inability to deal with stress, make person feel depressed and eventually would return back to those foods to comfort themselves. Also, by consuming too much fast food that person may lose out on essential nutrients like amino acid tryptophan, the lack of which can increase feelings of depression. An imbalance of fatty acids is another reason why people who consume more junk food are at a higher risk of depression.[19] A recent study showed the relation of eating junk food and its effect on brain behavior as shown in figure 3.

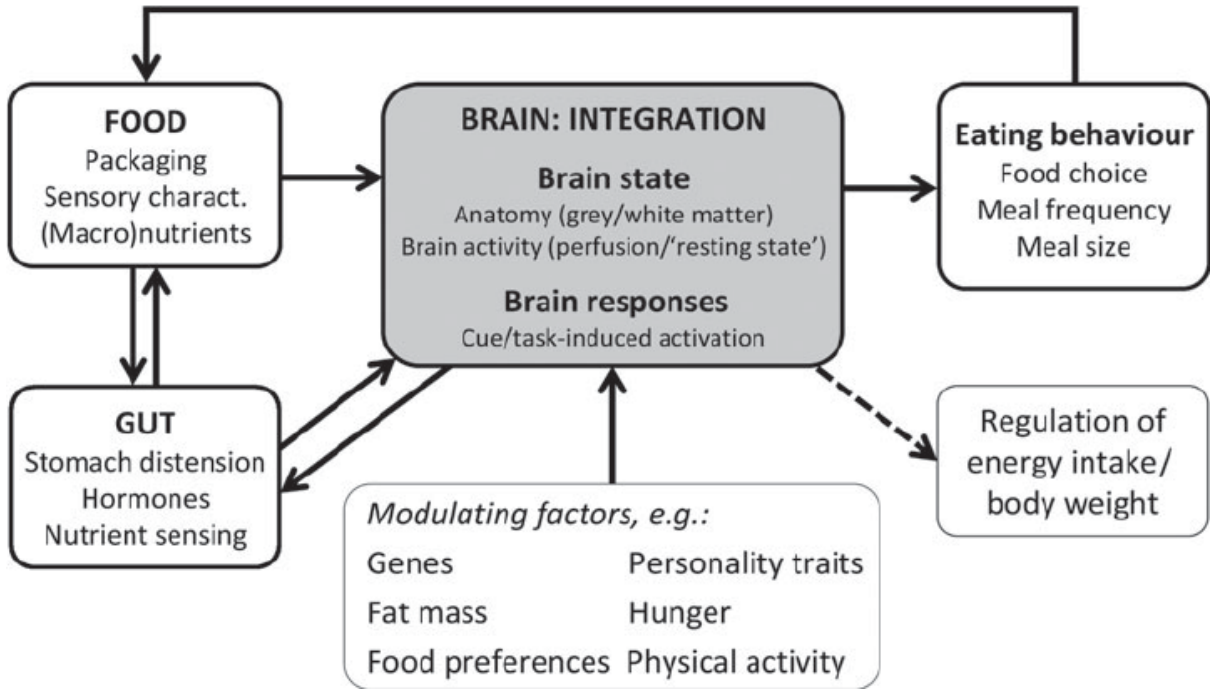

Figure 3: Brain responses and processed food effects

According to Danish study, people who eat a lot of fast food are 51% more likely to be depressed than those who steer clear of it. The more burger, pizza, and fries people ate the greater their risk. More research is needed to see whether a fast food diet causes depression or whether people with depression are simply more likely to dine or fast food. "Higher intakes of fast food may very well increase the risks of depression by causing poor health in general. But depression may also increases fast food intakes. A study in clinical paediatrics revealed that artificial colours and preservatives can creates hyperactive sensation in the brain that we have probably heard of "sugars rush". But its less tied to sugar than to the artificial ingredients. Sodium benzoate can be found in products like diet soda, fruits juices and condiments. The refined carbohydrates can cause blood sugar to fluctuate. Extremely low blood sugars can cause panic attacks, insomnia, and other anxiety symptoms. Yet more research and thorough study is required to fill the gaps in this area.[20,21]

III. Conclusion

Studies have shown that food can promote proper functioning of the brain. In order to improve our mental abilities, concentration, memory and vigilance, proper nutrition is of great importance. Cognitive performance and maintenance of mental health, especially among elderly may be improved with proper diet consisting of complex carbohydrates, polyunsaturated fatty acids, especially omega-3 fatty acids, proteins and specific foods containing specific nutrients, like flavonoids, antioxidants etc. Keeping in mind the risk factors for loss of mental abilities, by proper nutrition we can potentially prevent or delay neurodegenerative changes in the brain including Parkinson's and Alzheimer's disease which have become common.

The conclusion arising from the compiling review elaborated says that in order to improve cognitive performance and maintain brain vitality, diet rich in antioxidants, folic acid, vitamins, omega-3-fatty acid etc. found in natural food products should be taken instead of consuming processed foods. Collectively these data show that attention to dietary composition is important for lasting impact beyond the metabolic and highlight the promising likelihood that we may improve our cognition throughout life and into the aging period with simple dietary interventions. The food industries, dietician, industrialists should concentrate the need for food industries and science, on research and development of nutritional strategies that are most appropriate to support our cognitive and emotional health.

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