Age-Related Cognitive Decline

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Diets that are high in added sugars and saturated fat have an impact on cognitive functioning, especially on memory. Cognitive task performance worsens with age. However, the frequency of consuming different types of foods (healthy versus unhealthy dietary patterns) moderates the effects of age on cognitive functioning. Different indices of dietary patterns (both positive and negative) seem to be strong predictors of cognitive performance in the older adult group.

Keywords: Western diet ; healthy diet ; food consumption ; cognitive functioning ; cognitive aging ; memory ; arithmetic abilities ; the SynWin multitasking task ; Fatigue Assessment Scale (FAS)

1. Introduction

Age-related cognitive decline is associated with the deterioration of many cognitive dimensions, including memory, cognitive control, attention, and working memory [1][2][3]. Diet is an important factor that may counteract age-related cognitive decline [4]. Further, research has shown that the hippocampus, a brain structure associated with a wide range of cognitive functions, may be influenced directly by diet or by diseases related to diet and eating habits, such as obesity or diabetes [5][6].

Diet is an integral part of preventing civilization diseases (e.g., obesity, diabetes, cardiovascular diseases) and medical treatment [7][8], and an important factor for mental health and cognitive performance [9][10][11]. The Mediterranean diet (MD) is considered to be one of the best dietary models for healthy aging and has been shown to decrease risk factors for cardiovascular diseases and dementia, for example [11]. The MD is a dietary pattern rich in antioxidants and, as such, has been suggested to have a protective effect on cognitive decline and dementia risk [11][12]. Fish is one of the key components of the MD and fatty fish is a good source of omega-3 polyunsaturated fatty acids (PUFAs), which are neuroprotective. Indeed, a recent large observational study reported that adherence to the MD was associated with a decreased risk of cognitive impairment and higher fish consumption was also associated with slower cognitive decline within the context of the MD [13]. Omega-3 PUFAs may also benefit memory performance by improving functional hippocampal connectivity [14].

In contrast, diets high in saturated fat, sugar, and animal protein and low in fiber, known as the Western diet (WS diet), have negative effects on health [4][15]. The WS diet lacks important polyphenols and anti-oxidant, may contain too little beneficial omega-3 PUFAs [5][8], and may cause mood and cognitive functioning decline [16] through hippocampus-dependent memory and learning deterioration [6][17][18]. It also leads to higher consumption of high-energy foods (especially high in saturated fat) and worsens hippocampus functioning, which may result in weight gain through behavioral changes [19][20].

Moreover, hippocampal-dependent memory deteriorates throughout the lifespan [21][22]. Attuquayefio et al. (2016) reported that being on a WS diet for only four days was sufficient to cause higher blood glucose levels, which resulted in worse memory task performance [23]. Glucose in circulating blood can facilitate cognitive functioning, especially by enhancing memory performance [24], but the quality and quantity of consumed products that are converted into glucose in the body are an important factor [25]. Lastly, the WS diet may cause blood–brain–barrier disruption and hippocampal-dependent memory deterioration [6][26].

Lipids are crucial for the development of the central nervous system [27] and PUFA is an important factor for maintaining brain functioning, e.g., synaptic plasticity or regulation of neurotransmission [28]. Horman et al. (2020) showed that the consumption of diets high in omega-6 PUFA, but with lower omega-3 PUFA, and conversely, changed the PUFA composition in brain structures, such as the hypothalamus, hippocampus, and prefrontal cortex [29]. Another study showed that even a short-term high-fat diet may increase the levels of corticosterone in the hippocampus and impair memory

consolidation in rats [30]. The hippocampus is a structure responsible not only for memory and learning but also for controlling digestive functioning through hunger and satiety regulation [17]. The WS diet impairs hippocampal functioning and leads to a deficit in memory performance [31][32], resulting in weakened inhibitory control that leads to greater consumption of high-fat foods, further impairment, and weight gain [20][33].

The aim of the present research was to evaluate whether the type of food products and the frequency of their consumption are associated with cognitive functioning and whether they can moderate age-related changes in cognition. Age is an important factor in the deterioration process of a wide range of cognitive functions, and changes in the brain can alter cognitive functioning as early as just after the age of 35 [34]. We recruited participants in a wide age range to study the relation between diet and cognitive performance in various age groups.

Our main hypothesis was that high consumption of WS diet food products would result in a decrease in the performance on cognitive tasks, especially in the memory aspect. However, as cognitive functioning worsens with age we have also assumed that there are interaction effects of age and food patterns, with healthy foods diminishing the negative influence of age and unhealthy foods magnifying it.

2. Development and Findings

The aim of this study was to determine whether higher consumption of specific food products might affect cognitive functioning depending on age. Our results showed that the frequency of different food consumption might moderate the effects of age on cognitive functioning in both positive and negative directions. We found a negative effect of meat and animal fat consumption on memory, especially in people of older age. Interestingly, also in the older-aged group, higher consumption of white meat and fish was related to better performance in our memory task.

Aging is associated with an increase of inflammation, which has a negative impact on synaptic plasticity and neurogenesis [35][36][37]. Saturated fat, which occurs in red meat or high-fat dairy products [38], may increase inflammation in response to hormonal changes [39]. Alternatively, omega-3 PUFA, which occurs in fish meat [40], could prevent neuroinflammation changes in the hippocampus [28].

In our study, age groups did not differ according to the means of pro-healthy and non-healthy diet indexes (**Table 1**). The maximum values of pro-healthy and non-healthy diet indexes were 47 and 50 respectively, which means that our respondents' dietary patterns were neither healthy nor unhealthy. This allowed us to focus on the frequency of consumption of specific products within the same diet. In addition, 172 participants declared an omnivore diet and only 9 participants were vegetarian, but as they consumed animal protein and animal fat from food products such as eggs or cheese, we decided to include them in further analyses. However, the differences in extracted consumption pattern indexes were related to a different aspect of cognitive functioning among the age groups.

Table 1. Participant characteristics, descriptive statistics, and test differences for: I. all participants, II. each age group.

Characteristics	I. All (*n* = 181) Number/Mean (SD)	II. Age Group ≤ 35 (*n* = 102) Number/Mean (SD)	II. Age Group ≥ 36 (*n* = 79) Number/Mean (SD)	II. Test Differences for Age Groups
Sex	♂ 92; ♀ 89	♂ 46; ♀ 56	♂ 46; ♀ 33	X^2: 3.071
Age	35.5 (9.2)	28.7 (4.3)	44.2 (5.8)	t: −20.061 ***
Employment	83.50%	82.4%	84.8%	X^2: 0.194
Education				X^2: 0.858
secondary	38.1%	35.3%	41.8%	
vocational	1.1%	1%	1.3%	
higher	60.8%	63.7%	57%	
Health	7.2 (1.7)	7.5 (1.6)	6.9 (1.7)	t: 2.235 *
BMI	24.7 (4.9)	23.1 (4.0)	26.9 (5.2)	t: −5.534 ***
FAS score	22.83 (7.3)	23.1 (7.3)	22.4 (7.2)	t: 0.638
Dietary knowledge	12.4 (4.5)	11.9 (4.4)	13.0 (4.5)	t: −1.660

Characteristics	I. All (n = 181) Number/Mean (SD)	II. Age Group ≤ 35 (n = 102) Number/Mean (SD)	II. Age Group ≥ 36 (n = 79) Number/Mean (SD)	II. Test Differences for Age Groups
Pro-Healthy Diet Index	**20.1 (10.0)**	**20.0 (10.5)**	**20.2 (9.4)**	**t: −0.140**
Non-Healthy Diet Index	**16.3 (8.2)**	**16.9 (8.7)**	**15.6 (7.5)**	**t: 1.08**
Smoking	**22.7%**	**19.6%**	**26.6%**	**X^2: 1.236**
Sleeping quality (weeks):				**X^2: 5.919 ***
7–8 h	**61.9%**	**69.6%**	**51.9%**	
<7 h or >8 h	**38.1%**	**30.4%**	**48.1%**	
Sleep quality (weekends):				**X^2: 0.297**
7–8 h	**63.0%**	**64.7%**	**60.8%**	
<7 h or >8 h	**37.0%**	**35.3%**	**39.2%**	
Physical activity				**X^2:2.792**
sedentary or light	**59.1%**	**63.7%**	**53.2%**	
medium active	**37.6%**	**32.4%**	**44.3%**	
vigorously active	**3.3%**	**3.9%**	**2.5%**	
Diet type				**X^2: 0.002**
omnivore	**95%**	**95.1%**	**94.9%**	
vegan	**5%**	**4.9%**	**5.1%**	

SD = standard deviation; BMI = Body Mass Index; FAS = Fatigue Assessment Scale; * p value < 0.05, *** p value < 0.001.

Eight factors were extracted from factor analysis, four from pro-healthy food products and four from non-healthy food products. We found three components had moderating effects of age on cognitive functioning: the HCHF food, the meat and animal fat, and the white meat and fish components. The relationships between them were checked with Pearson's correlation (**Table 2**). The HCHF food component was derived from the unhealthy food products frequency consumption data and had the highest loadings of white flour baked products, fried products, lunch meat, butter, and confectionery, which typically have a high caloric content and can cause a heightened insulin response [41][42].

Table 2. Rotated component matrix of pro-healthy food products.

	Fruit and Vegetables	Fermented Dairy, Cottages	Legumes, Whole Grain	White Meat and Fish
whole meal bread	**0.536**	**0.073**	**0.155**	**0.017**
whole grain cereal	**0.163**	**0.373**	**0.623**	**−0.046**
milk	**0.387**	**0.456**	**−0.185**	**0.208**
fermented dairy	**0.091**	**0.845**	**0.02**	**0.005**
fresh stretched curd cheeses	**0.016**	**0.687**	**0.404**	**0.12**
white meat	**0.040**	**0.182**	**−0.130**	**0.837**
fish	**0.072**	**−0.061**	**0.443**	**0.734**
legume vegetables	**0.128**	**−0.038**	**0.854**	**0.099**
fruits	**0.850**	**0.083**	**0.037**	**0.048**
vegetables	**0.815**	**0.052**	**0.095**	**0.025**

Varimax rotation with Kaiser normalization converged in six iterations.

The meat and animal fat component was derived from the unhealthy food products frequency consumption data, but we did not interpret this component as a part of the WS diet, despite the fact that eating fried meat items is often a part of the WS diet. Because the meat and animal fat component was positively correlated with the legume vegetables and whole grain component, we interpreted it as a part of the traditional Polish cuisine. Meat and fish, lunch meat, legume vegetables, and whole grain cereal are common products in Polish cuisine. While Polish cuisine is not unhealthy it is difficult to digest. Overeating and ensuing stomach fullness with stretching of the gastric mucosa cause abnormal hormonal secretion and may worsen cognitive functioning [17][43].

The white meat and fish component was derived from healthy food products frequency consumption data. White meats have relatively low fat levels and are a good source of protein [44], while fish is rich in long-chain PUFA, which has beneficial effects on brain function [4].

Our results show that the components related to meat consumption, the meat and animal fat and the white meat and fish components, may moderate the effects of age on memory. The meat and animal fat component was negatively related to memory search performance as the main effect in the model and with interaction with age. The white meat and fish component was positively related to memory search performance as a main effect and with interaction with age (although only a tendency). After splitting the interaction effects (age × meat and animal fat and age × white meat and fish) on memory search performance into simple effects, we found that in younger individuals the model did not show a significant relation between meat components and memory search performance. However, in the older group, the model showed strong effects for both meat patterns. The meat and animal fat component showed a negative relationship with the memory search task score, with red meat and animal fat increase accompanying worse performance on the memory task. Alternatively, for the white meat and fish component, there is a positive effect of consumption frequency on the memory search task score, with more frequent consumption relating to greater memory search performance.

The role of meat, especially red meat, in brain function is still under consideration. Meat is a good source of proteins, vitamins, and minerals that the body and brain need to develop and maintain health [44][45]. For example, red meat is a good source of iron [46] and research has shown that early-life iron deficiency may have a negative impact on hippocampus-dependent memory [47]. Research has also shown that red meat and animal fats may support mental health because avoiding meat consumption was associated with depression, higher anxiety, and lower iron levels [48]. Zupo et al. (2021) also showed that lower consumption of red meat was associated with cognitive impairment and seems to have beneficial effects on cognition [49]. However, other studies showed that animal fat is also a factor contributing to the formation of inflammation in the body [50][51]. While aging is associated with an increase in inflammatory markers, it may also affect mental health [35]. Red meat is high in saturated fat and studies of high-fat diets have shown the negative effect of high saturated fat intake on the hypothalamus and the hippocampus in animals models [30][51]. In humans, higher consumption of red meat worsened attention, concentration, and information processing speed in the elderly, but has not been associated with the rate of cognitive decline [52]. It may also be related to our result, showing that with age, the frequent consumption of red meat and animal fats can decrease cognitive performance. However, there are more factors to consider with meat consumption such as gut microbiota composition and food component digestion [53].

Our results show that the components HCHF food and meat and animal fat negatively affect the performance of a cognitive task in interaction with age. However, after splitting the interaction effects (age × HCHF food and age × meat and animal fat) on cognitive task performance into simple effects, we found that in younger individuals the model did not show a significant relationship between the HCHF food index and cognitive performance. In the older group, the model showed a tendency for higher meat and animal fat consumption and worse performance in the cognitive task, but frequent eating of HCHF food did not relate to task performance as strongly.

The HCHF food component was interpreted as a WS diet-like component, due to the simple carbohydrates and fat occurring together in food products and their mutual negative effects. Consuming simple carbohydrates and fat at the same time leads the organism to higher lipoprotein levels and higher insulin levels than when consuming those organic compounds separately [54][55]. Consequently, there are disruptions in insulin signaling that may cause insulin resistance in the hippocampus and deterioration of hippocampal-dependent cognitive processes [6]. Research presented on humans has shown that one week of the WS diet weakened appetitive control, which was also negatively correlated with memory cognitive task performance [20]. Furthermore, studies on rodents also show that short-term consumption (1–7 days) of food products high in saturated fats or high in added sugar (or both) initiates inflammatory processes in the hippocampus [56]. Overall, those studies suggest that obesity is not necessarily the only problem connected with the WS diet [25], it seems that it could also lead to cognitive impairments due to changes in digestive signaling pathways.

Our results showed that changes in cognitive performance may occur along with changes in the frequency of food products consumption, especially in the case of memory. However, the estimation of cognitive performance was not assessed at baseline, which is the main limitation of the present study. It cannot be confidently stated that those nutritional choices caused changes in the performance of the cognitive task, although independent mean comparison tests based on the two age groups did not show any essential differences between the groups.

The age groups did not differ in the fatigue score or lifestyle factors, such as education, employment, physical activity, or smoking. In addition, they did not differ in knowledge about nutrition and on the main dietary metrics, the pro-healthy diet index and non-healthy diet index. However, the age groups differed in the sleep quality factor on weekdays. Young adults were more likely to sleep irregularly than midlife adults, but on weekends those differences were not observed. The age groups also differed in terms of BMI and health factors, which may also be reflected in cognitive functioning. Younger adults have lower BMI scores and rate their health better than midlife adults. Considering that we examined physically and mentally healthy people, the observed cognitive performance may depend on the frequency of consumption of food products. Research also showed that cognitive performance may be affected by stress [57]. Although FAS includes questions about mental fatigue, which is a symptom of stress [58], the stress was not examined in our study. In future research, a stress questionnaire should be included in the study to eliminate this factor as well.

3. Conclusions

Our results showed that the frequency of different food consumption could be seen as an important factor modifying age-related cognitive decline. One of the more significant findings from this study is that the type of meat consumed, white or red, relates differently to memory performance in the group of older participants. Eating more white meat and fish was related to better memory in the older group and, conversely, consuming more red meat and animal fat was accompanied by lower scores on the memory task. Those findings are especially interesting in light of the recently published paper by Noble et al. (2021) on the impact of an unhealthy diet on rat memory performance and the hippocampus [59]. The results in our research support the idea that diet may be a protective (or worsening) factor in age-related cognitive decline.

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