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Author note

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Abstract

Consumption of breakfast, fish or caffeine are each separately often investigated in relation to learning performance in traditional education, but not in distance education (DE). The objective of this study was to investigate whether the relations between the consumption of breakfast, fish and/or caffeine on the one hand and learning performance on the other are also found in DE students. This population is different from traditional students and characterized by a different profile in terms of age, personal and work responsibilities as well as other demographics. In an observational longitudinal study, the consumption of breakfast, fish and caffeine of 1157 DE students (18-76 years old) was used to predict learning performance using multiple regression analysis. In an online digital survey, students provided information about their consumption of these nutritional measures and on important covariates. Learning performance, measured as study progress (i.e., the number of successfully completed modules) was evaluated objectively after 14 months. Results showed that adding the consumption of breakfast, fish and caffeine to the covariate model did not fit the data better, $\chi 2$ (3, N = 1155) = 3.287, p = .35. This means that neither the consumption of breakfast nor fish nor caffeine predicted study progress in adults participating in DE. This study is important as it is the first to report on these relations in this specific age group and educational setting, which is increasingly important due to the increased preference for this type of education.

Keywords: The ALOUD study; Nutrition; Distance learning; Online learning; Learning performance; Omega-3 fatty acids

Introduction

Recent research on nutrition has shown what is consumed is related to learning performance in children and adolescents participating in traditional education [1]. However, there has been no research dealing with the relation between nutrition and learning performance in distance education (DE), which is primarily followed by adults. This specific group is important as the population of most countries is aging because of increased life expectancies. As older adults are the largest growing age group in the Netherlands [2] and worldwide [3], people are working longer. Combined with the demands of our knowledge-based society [4], this has led to increased participation in continuing formal education. Adults often choose for DE because of family and/or work responsibilities as DE offers students the liberty to study anytime, anywhere and often at their own self-determined pace. Proper nutrition could lead to better brain health and thus to better learning performance. As nutrition is a large field of research, the nutritional measures that were recorded in this study were limited to the consumption of caffeine, breakfast and fish. The rationale for this selection will be discussed per measure. Breakfast is an often skipped meal [5] and is mostly considered as having direct effects on cognitive performance as it gives the body energy after a night of fasting. Direct mechanisms of action are increased availability of glucose and other nutrients from which several cognitive and memory processes benefit. Indirectly, regular breakfast consumption could lead to an increased whole-diet adequacy of nutrient intake, which could translate into better cognitive and/or learning performance [6]. This makes the consumption of breakfast possibly an important determinant for learning. In traditional education, breakfast consumption is related to academic performance in children and adolescents [7]. Important to note, is that traditional education is characterized by face-to-face education with fixed schedules. This means that a breakfast directly contributes to the cognitive status in the beginning of the school day. In DE, however, students can determine their own schedule, as they study at their own location of choice and at their own time of choice. Taking into account that most students in DE have work and family (i.e., partner and children) responsibilities, this means that most students often study in the evening, at night or during weekends. The question arises whether these students will benefit from the direct effects of having breakfast. Considering the possible long-term benefits of consuming breakfast, as noted earlier, research shows that a more adequate whole-diet nutrient intake is especially important when deficiencies are apparent [6]. However, in the Netherlands – where the current study is executed – and in Europe in general, people are at a low risk for nutrient deficiencies, especially normal-aged adults [8]. Concluding, it is unlikely to expect a relation between breakfast consumption and learning performance. On the other hand, research shows breakfast skipping to be related with overweight in adolescents [9] and adults [10]. Breakfast skipping is associated with other unhealthy behaviors and obesity [10] and could thus be associated with learning performance. Still, as the students investigated here have a high socioeconomic status, no relation is expected since breakfast skipping is especially apparent in people with a lower socioeconomic status [10].

The omega-3 long-chain polyunsaturated fatty acids (n-3 LCPUFAs) – found in fish – are important building blocks for cell membranes, providing the proper permeability and fluidity, which is important for signal transduction in neurons [11]. In addition, they also directly impact the levels of brain-derived neurotropic factor, a neurotrophin responsible for proliferation, synaptic plasticity, survival and growth of neurons [12], improving brain plasticity and possibly influencing cognitive and learning processes [13]. Thus, n-3 LCPUFAs could be a predictor for learning performance. Although research shows n-3 LCPUFAs – found in fish – are important for normal development, it is disputable whether n-3 LCPUFAs are beneficial for cognition in adults [14] as research is limited in young and middle-aged adults. Most research focuses on children and adolescents, and older adults [15], often with developmental disorders or cognitive deterioration, respectively [16]. Research in children, young adults and older adults shows that cognitive processes are enhanced following supplementation of omega-3, a LCPUFA [1,14,17]. However, several strict review studies in children [18] as well as (older) adults [19–21] point out that evidence for enhanced cognition, decreased cognitive decline or dementia onset is lacking. Recent reviews show that findings so far are not conclusive [22] and that randomized controlled trials did not improve cognitive performance [14] in young and middle-aged adults. Concluding, evidence for a relation between n-3 LCPUFAs intake from fish and learning performance is lacking, as findings in young and middle-aged adults are inconclusive. In addition, taking into account the findings in traditional education to derive a hypothesis for adult DE seems incorrect as children and adolescents are still in their development toward adulthood.

Caffeine is the most widely used neurostimulant and prevents binding of the endogenous neurotransmitter adenosine to its receptors by antagonizing them [23]. Adenosine accumulates in the synapse over continued wakefulness and induces drowsiness, which is prevented by caffeine and thus maintains or restores alertness. There are more mechanisms of action reported for caffeine in the brain [23], but the antagonism of adenosine is most likely the mechanism of importance as the effects of caffeine on learning are likely to result from the effects of caffeine on alertness and sleep processes. Caffeine seems to boost a variety of cognitive functions. Research shows that habitual caffeine intake is related to better long-term memory [24], alertness [25], reaction time and short term recall [26]. These findings indicate the caffeine consumption could aid learning performance. However, despite all these cognitive effects and possible resulting effects on measures of learning performance, no persistent effect of caffeine is expected as the effects are purely the result of the reversal of the withdrawal state. The *withdrawal reversal* hypothesis states that caffeine withdrawal (e.g., overnight) leads to lower cognitive performance and alertness and that this is restored by the consumption of caffeine, but that cognitive performance does not exceed ‘higher than normal’ levels [27]. Much research regarding this hypothesis has been executed with inconsistent findings, some were in favor [28] and others against [29]. This scientific dispute has been recently reviewed and evidence seems to generally be in favor for the *withdrawal reversal* hypothesis [30]. Next to direct effects of caffeine on cognitive and memory processes, caffeine also influences sleep processes. Despite the fact that research shows caffeine can actually enhance cognitive performance and alertness after sleep deprivation [31], research in adolescents shows the use of caffeine later at night could disrupt subsequent sleep processes, which in turn could impair cognitive performance [32]. Further research in traditional education shows that learning performance is in fact negatively influenced by caffeine via sleep processes as a possible mediator [33]. Concluding, it is unlikely that the consumption of caffeine will provide benefits to learning performance in healthy adults. On the contrary, sleep processes could be impaired following caffeine consumption [34], leading to lower learning performance. However, this is not expected as fewer portions of caffeine are consumed later in the day [35].

This study was executed among students of the Open University of the Netherlands (OUNL), an institute providing formal university-level DE to adults. The goal was to provide insight in the relation between the consumption of breakfast, fish, and caffeine on the one hand and learning performance on the other. Based on the current knowledge, it was expected that the consumption of: (1) breakfast was unrelated to study progress; (2) fish was unrelated to study progress; and (3) caffeine was unrelated to study progress.

Method

Design

Data from this observational study originated from the Adult Learning Open University Determinants (ALOUD) study, an investigation of different psychological and biological factors possibly affecting learning performance in DE students [36]. Breakfast, fish and caffeine consumption were reported via an online digital survey, which was conducted after registration at the university. Learning performance was measured objectively as study progress using data from the exam registration office.

Participants

During 1 year (Sept. 2012 – Aug. 2013), all new students of the OUNL who signed up for one or more regular bachelor or master course(s) were invited to participate. At the OUNL, students can register and start throughout the year as the education is modular and self-paced, open to everyone (with an age of at least 18 years old), and the curriculum is not fixed. The OUNL mainly delivers online education. The approached population size was 4945, 57.5% (N=2842) of whom responded and 41.3% (N=2040) of whom fully participated. Included in the analyses were all participants who fully completed the survey, attempted an exam (see below), participated within 9 weeks (see Procedures). These participants are similar to the general population of students who normally study at the OUNL [37].

Attrition rates in this population are high, as more than 50% of the full responders in the investigated population did not complete any course after 14 months. Many students simply reported not having started studying. The goal is to predict study progress, thus including these students could confound possible relations. However, excluding those without progress is not desirable as they may have studied, but without successfully finishing a course. To make a more valid data selection, an official examination attempt was used as a proxy of having studied. This way, the high number of students that had bought a course but never attempted to officially finish it or who did not intend to attain course credits (i.e., buying the course purely out of interest) could be excluded. The information on exam attempts was provided by the exam registration office.

Procedures

Participants were invited automatically via the e-mail system of the university 14-21 days after successful registration. The seven days range is because a bulk mailing was sent weekly. Students received a reminder two weeks after the initial invitation and one week later a last reminder by e-mail. Four weeks after the initial invitation, a phone call was made (it was tried to reach participants in the three subsequent weeks) in which potential participants were asked whether they were still interested in participating. If so, they received the original invitation once more when needed and a reminder 6.5 weeks after the initial invitation, which was around 1.5 weeks after the phone call. In case the phone call was made in week 6, the reminder was sent one week later. Participants only received reminders or a telephone call if no full response was recorded.

The survey was administered online using LimeSurvey®, version 1.92+ [38]. Full participation took 45 to 60 minutes on average and it was possible to stop and continue later, allowing participants more freedom in their participation by spreading the time burden. Participants who fully participated could win (5% chance) a gift voucher of €20. The ALOUD study was ethically approved by the local ethical committee of the OUNL. Each participant signed a digital informed consent form, explicating the use of the personal data gathered, voluntary participation, possibility to withdraw at any time and finally giving their permission to use the data for the described goals. Participants had to click a check-box to agree with the terms mentioned; a mandatory action to start the survey.

Materials

Dependent and independent measures

The dependent measure was the participants' objective study progress, operationalized as the number of successfully completed study modules in 14 months (i.e., the standard subscription period when registering for a course). A course at the OUNL consists of one or multiple modules. One module is equal to 4.3 European Credits (EC) in the European Credit Transfer System (ECTS). The nominal study load for one module is approximately 120 hours. The information from which the number of modules was derived came directly from the exam registration system of the OUNL. The independent measures were extracted from various questionnaires. For these measures, all questions involved usual behavior meaning no clear duration of reference was provided. *Breakfast consumption* was measured as a number of days per week that the participants reported to have consumed breakfast. There is no clear definition for breakfast in the literature [5] making it difficult to choose a definition. Breakfast was therefore not further defined in the research, as done in previous research [39]. *Fish consumption* was measured with a questionnaire validated against omega-3 LCPUFAs plasma phospholipid levels [40]. The frequency of consumption of three fish types – classified according to their DHA content – was reported. A 5-point scale and a scoring system were used (see Table 1). The range for overall score was from 0 to 48, which was validated against eicosapentaenoic acid (EPA) and docosapentaenoic acid (DHA) plasma phospholipid concentrations [40]. *Caffeine consumption* was measured as average daily caffeine consumption, in milligram, calculated from the reported consumption of coffee, tea (i.e., only caffeinated tea such as black and green tea) and caffeine-containing energy drinks following standards reported in the literature [26] (see Table 2). Accumulation of the partial score resulted in the overall score ranging from 0 to 1150 mg. of caffeine a day.

Table 1. Scoring for the validated measurement of fish consumption.

Score on scale	Low DHA	Intermediate DHA	High DHA
1	0	0	0
2	1	2	3
3	2	4	6
4	4	8	12
5	8	16	24

Note: DHA means docosapentaenoic acid. The scoring was done on a 5-point scale, with the following choices: never (1), once per month (2), two to three times per month (3), once per week (4), more often than once per week (5). Numbers in columns do not possess a measurement unit. The total scale score was validated against omega-3 LCPUFAs plasma phospholipid levels [40]. The fish types were classified according to their DHA content: low (fish fingers, prawns, pickled herring, cod, mussels, plaice, tuna and tilapia); intermediate (trout, raw herring, smoked eel, smoked salmon, canned salmon); high (smoked herring, herring in tomato sauce, mackerel, canned sardines, salmon).

Table 2. Scoring for the measurement of caffeine.

Score on scale	Coffee	Tea	Energy drinks
1	33	16	38
2	66	33	77
3	132	66	154
4	198	99	231
5	264	132	308
6	330	165	385

Note: The scoring was done on a 6-point scale, with the following choices: less than one (1), one (2), two (3), three (4), four (5), five or more (6). Numbers in columns coffee, tea and energy drinks are milligrams of caffeine. Energy drinks are only those which contain caffeine. Regarding coffee and tea, a standard cup was depicted with the amount of 125 ml. written in the description. Regarding energy drinks, a can was depicted with the amount of 240 ml. written alongside. The literature [26] reports on caffeine: 100 mg. per 190 ml. for coffee; 50 mg. per 190 ml. for tea; and 80 mg. per 250 ml. for energy drinks. Calculating this to the content used in this study led to the values noted in the table.

Covariates

The covariates included in this study were:

- age, as memory performance declines with increasing age [41], possibly hampering learning efficiency;
- sex, as there are profound sex differences in intelligence (e.g., on the domains of memory, reasoning and science) which could influence learning performance. There are intellectual domains where males excel females (e.g., spatial reasoning) and vice versa (e.g., verbal fluency) [42];
- number of working hours per week, as common sense and literature [43] suggests that more working hours lead to less learning performance, as less study time is remaining. However, it has been found that workers with less than 20 work hours per week perform worse than their counterparts working more [44], making it important to correct for working hours separately;
- expected average number of study hours per week to be invested (as reported by the students), as more time invested is likely to lead to better results [45];
- nationality, as non-Dutch nationals could experience difficulties since most courses are in the Dutch language;

- native language, as non-Dutch speakers could have more difficulties with the language.
- body mass index (computed from weight and height), as it is negatively associated with learning performance [46];
- level of education (ordinal variable with eight levels), as previous level of education has been found to be a significant predictor of academic success for DE students [45];
- computer abilities (measured via a self-developed questionnaire mapping attitude, confidence, and skills towards the use of a computer), as students use an electronic learning environment, which could be a disadvantage when being not very ‘computer-adjusted’. The questionnaire used questions such as ‘I’m able to solve problems when I encounter them during computer use’, ‘I feel confident when using new computer programs’, ‘Computers give me an uneasy and confused feeling’ for the subscales skills, confidence, and attitude, respectively;
- study motive (personal or professional), as intrinsic motivation is a better motivator for learning than external triggers [47]. Students could choose one study motive out of seven options (i.e.: ‘I want to better fulfill my current function’, ‘I want to enhance my chances for a (new) job’, ‘I think studying is a good form of recreational activity’, ‘I want to develop my (intellectual) capacities’, ‘I want to operate better on a societal or managerial level’, ‘I want to know more about the issue or phenomenon addressed in this course’, ‘I want to move forward in the relevant scientific field’) or could fill in their study motive themselves. Option 1, 2, and 5 were rescored as a personal motive while option 3, 4, 6, and 7 were rescored as a professional motive. All manually entered motives were individually inspected and rescored;
- study goal (expected number of completed modules after 6 months), provides a clear estimation of the expectation and hence the intention of the learning performance to be made;
- alcohol consumption, as it has been found to influence learning performance [48];
- life satisfaction, investigated using the satisfaction with life questionnaire [49], as more satisfaction is synergistic with better learning [50]. A version of the original article in which the questionnaire is published along with validity and reliability measures is publicly available (http://internal.psychology.illinois.edu/~ediener/SWLS.html).

Statistical analyses

As expected, the data on the dependent measure (i.e., study progress) revealed a negative binomial distribution. Because the current study concerns part-time DE, it was expected that most students would attain an average of 2 to 3 modules per year (i.e., based on data from internal year reports). Students either completed no course at all, or, had completed one, two, three or four courses. The distribution of the dependent variable was highly skewed and resembled a negative binomial distribution.

Therefore, a negative binomial generalized linear regression was conducted (i.e., using the GENLIN command in SPSS). A *P*-value below .05 was considered to be significant. A covariate model was built including all covariates, after which non-significant predictors were excluded following a backward stepwise method, yielding model A. Then, model B was tested by adding the nutritional measures (i.e., breakfast, fish, and caffeine consumption) to model A. All analyses were performed with SPSS (version 20; SPSS Inc., Chicago, IL, USA).

Results

Dataset compilation

The original dataset contained 2842 cases. Participants were excluded if they: (1) did not attempt an exam (1236 cases); (2) did not complete the survey (416 cases); (2) did not participate within 9 weeks (32 cases); or (3) made a remark at the end of the survey that led to exclusion (1 case). After excluding mentioned cases, a total of 1157 people were included in the analyses.

Descriptives

Table 3 provides the descriptives for the variables measured. The assumption of no multicollinearity was met as the correlations between all predictors were low (i.e., below .4). This was also indicated by high tolerances (i.e., above .7) [51]. All predictors (i.e., covariates and independent variables) were included in the evaluation of this assumption.

Table 3. Descriptives of all included variables

Variable (measured at interval level)	*Mean*	*SD*
Study progress (successfully completed modules in 14 months)	2.5	2.6
Total work hours per week	25.8	16.0
Expected study hours per week	13.4	7.6
Age (years)	35.8	11.1
Educational level (ordinal)[1]	5.9	1.4
Body mass index (kg/m^2)	23.8	4.0
Computer abilities (scale score)	42.8	5.8
Expected number of attained modules	2.2	2.3
Total weekly alcohol consumption (standard glasses)	3.5	5.5
Life satisfaction (scale score)	25.3	5.5
Caffeine (mg/day)	201.4	125.4
Fish consumption (scale score, higher means more consumption)	9.7	8.2
Breakfast consumption (days/week)	6.2	1.8
Variable (measured at nominal level)	*Number*	*Percentage*
Sex		
Female	730	63.1
Nationality		
Dutch	1041	90.0
Native language		
Dutch	1096	94.7
Study motive		
Personal	657	56.8

Note: suffix 1: Educational level is measured on an eight-level scale, ranging from low general education to post-higher education.

Multiple regression analyses

Chi square comparisons revealed that model A (i.e., the covariate model) was better than the null model (i.e., an intercept only model). Comparison of model B (i.e., model A with the nutritional measures included) with model A revealed that model B did not fit the data better, $\chi 2$ (3, N = 1155) = 3.287, p = .35. This means that adding the consumption of breakfast, fish, and caffeine to model A did not explain study progress better. Consumption of breakfast, fish, and caffeine were not predictive for study progress, as indicated by the number of successfully completed modules after 14 months (see Table 4).

Table 4. Generalized linear regression (negative binomial) of Model A and Model B

Predictor variable	*β (standardized)*	*Significance (p-value)*
Model A (χ^2=91.530, df=5, *p*<.001)		
Expected study hours	.118	<.001
Expected number of completed modules after 6 months	.153	<.001
Alcohol consumption per week	.054	.041
Life satisfaction	.091	.001
Native language[1]	.569	<.001
Model B (χ^2=94.817, df=8, *p*<.001)		
Expected study hours	.123	<.001
Expected number of completed modules after 6 months	.153	<.001
Alcohol consumption per week	.055	.041
Life satisfaction	.093	<.001
Native language[1]	.550	<.001
Caffeine consumption	.033	.247
Fish consumption	-.036	.208
Breakfast consumption	.019	.501

Note: suffix 1: This dichotomous variable is not standardized.

Discussion

The aim of the study was to investigate the relation between the consumption of breakfast, fish and/or caffeine on the one hand and learning performance on the other in adults participating in DE. Analyses revealed that the consumption of breakfast, fish and, caffeine were not related with learning performance. This means that neither the consumption of breakfast, nor fish nor caffeine predicts the number of successfully completed modules after 14 months of studying. These results are important as the preference for DE is increasing in adults because of the flexibility it offers and because lifelong learning is important nowadays, resulting from the need for knowledge development in society and lengthening of employment age. Research in traditional education focuses on these nutritional measures. However, no research so far was focused on these relations in DE. We discuss the results for each nutritional measure separately.

In line with our hypothesis, breakfast consumption appeared to be unrelated to learning performance. This means that the number of days per week that a student eats breakfast is not predictive for learning performance. DE provides the students with the liberty to study whenever they want. As stated earlier, most students study in the evening during weekdays, likely resulting from work and family responsibilities. As such, direct effects of breakfast consumption will not influence their learning performance. Only the consumption of breakfast was measured in the current study, not the content of breakfast. It could be that, depending on the content, breakfast has a relation with learning performance. However, it is doubtful whether certain breakfasts have a generalizable effect on learning as there seems to be no general recipe for breakfast [52].

Fish consumption proved to be unrelated to learning performance following the analyses, in line with our hypothesis. This means that the consumption of fish – and hereby the resulting levels of n-3 LCPUFAs – is not predictive for learning performance in adults participating in DE. As discussed before, research regarding the relation between fish consumption and learning performance in young and middle-aged adults is scarce, making these results an important addition to the body of knowledge.

As hypothesized, the analyses show that the consumption of caffeine was not related to learning performance. The use of caffeine has been regarded beneficial for cognition [24–26], but detrimental for learning [34,53] most likely resulting from the mediating effects of sleep processes influenced by caffeine [32]. In addition, the benefits of caffeine on cognitive performance are disputed, considering the *withdrawal reversal* hypothesis. This makes the interpretation of the possible benefits or detriments of caffeine difficult. First, the results from the current study could simply mean that caffeine does not impair or support learning performance. Second, since most adults in the current study have work (i.e., often a fulltime job) and family responsibilities (i.e., children and a partner), they are likely to study in the evening (as confirmed by the data; more than 70% will study in the evening on week days). This could mean that a caffeinated drink could boost performance during studying in the evening, but that the disruption of the sleep process in the following night cancels possible benefits. Third, if the *withdrawal reversal* hypothesis was incorrect and cognitive benefits that translate to learning performance were following caffeine use, the caffeine consumers should have outperformed the non-users. However, this is not the case, providing indirect evidence for the *withdrawal reversal* hypothesis.

The current study has multiple strengths. It is the first of its kind evaluating the relation between the consumption of breakfast, fish, and caffeine on the one hand and learning performance on the other in adults participating in DE. The nutritional measures are of interest in traditional education, but have not yet been investigated in another educational setting. A second aspect is that this study used a large sample providing high power and decreased the risk of contracting a type-1 error. Last, multiple possible confounders were controlled for, ruling out possible spurious relations.

Along with these strengths there are limitations to the current study. First, these results must be interpreted with caution as its observational design does not allow for causal inferences. The data collected for the independent variables are self-reported, which carries limitations such as social desirability, faulty reporting due to memory issues, and/or question interpretation. The measurements regarding the consumption of breakfast, fish, and caffeine reflect behavior around the start of the participants' study. Although dietary patterns are relatively stable throughout adulthood [54], it is not possible to rule out changes in dietary behavior over the time period that learning performance was measured. In order to expect beneficial effects in the brain following the consumption of breakfast, fish, and caffeine that translate into learning and the resulting learning performance, consistent and long-term intake is required. Breakfast consumption was solely measured asking participants how often they had breakfast. No definition for breakfast was given and no components were investigated. Fourth, study progress is a fairly large-grained measure, but the best one available to measure learning performance, as grades were not possible to use because a significant number of courses were evaluated with a pass/fail and not with a grade. Furthermore, comparing students based on achieved credits is most reliable considering the non-fixed and modular form of education given at the OUNL. However, it is likely that nutritional factors tend to have small relations with learning performance. Therefore, it could well be that this measurement of learning performance is too crude to register any relation. Last, considering their popularity in traditional education, we investigated these three nutritional measures in this study, though the nutritional palette is much more extensive. As stated earlier, the nutritional palette is much more extensive than just these three measures. Other nutritional measures are also known to possibly influence learning performance (e.g., macronutrient intake [55]). Therefore, it would be interesting to investigate other measures as well.

To evaluate whether the investigated relations are truly not apparent, dietary patterns must be measured repetitively to make sure intake of nutrients are stable. In case that relation would be apparent at that point, it is recommended that research focuses on the causality of the relations by using an experimental design and the evaluation of possible underlying mechanisms (e.g., sleep processes when it comes to caffeine). Last, it would be interesting to see whether other nutritional measures are related to learning performance in DE students.

Conclusion

To summarize, the present study showed that the consumption of breakfast, fish and caffeine did not predict learning performance in adults participating in DE. This study is important as it is the first to report on these relations in this specific age group and educational setting. DE is increasingly important due to the increased preference of students for this type of education because of the flexibility and the need for knowledge development in society and lengthening of employment age, demanding lifelong learning.

The role of each author

This study was mainly executed and written by Jérôme Gijselaers, the first author of this research paper. Renate de Groot and Paul Kirschner were at the time supervisors of Jérôme Gijselaers during his PhD project and guided him through the process of executing this study and helped him writing the research paper.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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