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Attention and Academic Performance: The Moderator Role of Weight Status and Diet Quality

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The scientific literature suggests that following a healthy diet and maintaining a healthy weight status are associated with multiple health benefits. However, the cognitive and academic implications of these behaviours in schoolchildren require further study. The aim of this study is to determine the predictive value of attention on academic performance in primary school children observing the moderating role of weight status and diet quality in this relationship. In this quantitative study of 118 schoolchildren from Spain (M ± SD: 10.84 ± 1.20 years), the Perception of Similarities and Differences test (attention) and the KIDMED questionnaire (diet quality) were used. For its part, academic performance was calculated through the grade obtained in the subjects of the primary curriculum and nutritional status was assessed through the Body Mass Index (kg/m2) adjusted for sex and age. The linear regression test showed that higher values in attention correlated with higher values in academic performance in core subjects ($p < .05$) and specific subjects ($p < .05$) with the exception of Physical Education ($p = .112$). This relationship became stronger after the model was adjusted for Normal Weight/Optimal DQ and Overweight/Optimal DQ ($p < .05$). However, after the model was adjusted to Normal Weight/improvable DQ and overweight/improvable DQ, this relationship between attention and academic performance disappeared ($p > .05$). Based on these results, it is concluded that there is a positive relationship between attention and academic performance, with the exception of physical education, which is enhanced when diet quality is optimal, regardless of weight status. The present study contributes to the scientific literature investigating the moderating role of healthy lifestyle habits, such as diet quality or weight status, between cognitive processes (attention) and learning outcomes (academic performance).

Keywords: mediterranean diet, obesity, academic performance, cognition, schoolchildren

INTRODUCTION

Over the last decade, the term executive function has become a buzzword in the field of education, as it is a fundamental term for understanding goal-directed behaviour,

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thoughts and emotions (Bureekhampun et al., 2021; Herrera et al., 2020). These cognitive processes are especially important in novel or demanding situations, as they require rapid and flexible adjustment of behaviour to the changing demands of the environment. The development of executive function relies on the maturation of associated brain regions, as well as stimulation in the schoolchild's social contexts, especially at home and school (Huizinga et al., 2018).

Recent research highlights the importance of executive functions in improving academic performance, understood as a profile of the skills, knowledge, attitudes and values that students develop in the teaching and learning process (Agustin et al., 2021; Golub et al., 2016; Lai et al., 2019).

For example, in a longitudinal study using latent growth curve models with structured residuals created to test associations between two dimensions of executive function (working memory and cognitive flexibility) and two domains of academic performance (mathematics and reading) (Willoughby et al., 2019); they found significant relationships (φ = 0.55- 0.91; β = -0.10 - 0.25) and reflected the need to improve these skills as a means of facilitating school outcomes. Similarly, an intervention study with primary school children (aged 7-12 years) found that higher memory performance without distractors was associated with higher academic scores in literacy (reading and writing), mathematics and science for schoolchildren aged 7-9 years, while these academic scores for schoolchildren aged 10-12 years were associated with memory performance with visual distractors (Tsubomi & Watanabe, 2017).

On the other hand, a systematic review analysing the effect of executive functions on academic performance concluded that they are a good component to take into account in the school curriculum given their proven relationship with academic performance; therefore, it is suggested that they should be strengthened across all subjects (Montes-Miranda et al., 2020). Likewise, in a meta-analysis which analysed the relationship between executive functions and academic performance (in the subjects of Language and Mathematics) in primary schoolchildren (6-12 years) considering 21 studies (n = 7947), they demonstrated, for the subjects of Language and Mathematics, a moderately significant weighted effect size (r = 0.350; r= 0.365, respectively), thus supporting the theory that executive functions have a greater influence on mathematical performance, especially in aspects such as encoding, organising and immediate retrieval of information. This meta-analysis also demonstrated the moderating effect of variables such as physical fitness and motor skills on these relationships (Cortés-Pascual et al., 2019).

In this regard, Polverino et al., (2021) after conducting a literature review point out that in the current research environment in the context of health, other lifestyle factors such as diet quality or weight status may be intertwined in cognition and learning processes, as brain functioning depends both on genes and their interactions with environmental factors. In other words, the close link between genetics and environmental factors leads to structural and functional brain changes early in life. Therefore, understanding the weight of environmental factors in modulating neuroplasticity phenomena and cognitive

functioning is relevant for possible educational interventions. Among these, nutrition plays a key role.

However, Jirout et al., (2019) point out that there is little scientific literature that provides important knowledge to increase the effectiveness of learning-focused interventions. This review notes that, in a climate where childcare and school feeding policies are continually discussed, this review aims to add impetus to the debate and call for more holistic approaches to supporting school development. In turn, this study points out that the learning process is a complex construct that can be described as a series of compromises in information/memory processing and storage systems that ultimately result in knowledge. In this sense, they underline the importance of attention, as it is the first cognitive capacity that allows us to capture information from the outside, being a posteriori, and the working memory that helps the brain to make sense of it (See Figure 1).

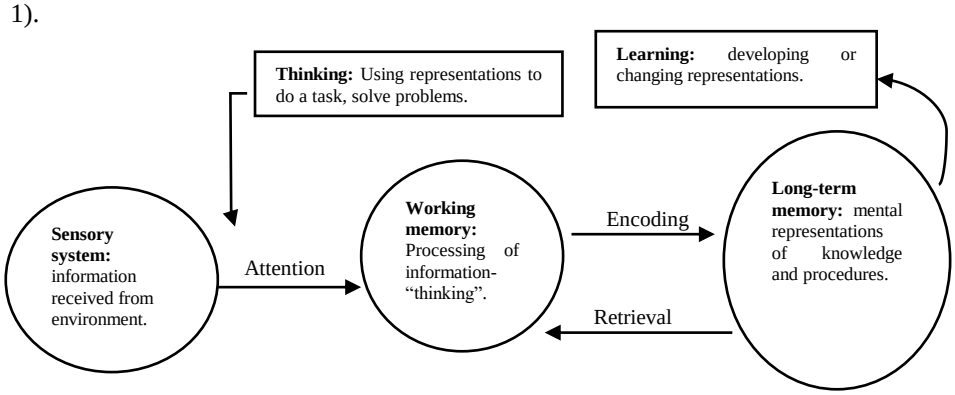

Figure 1
Information processing model. Source: Jirout et al., (2019).

In this sense, it is clear from the scientific literature that attention is the first basic and indispensable psychological process for the processing of information of any modality (images, words, sounds, smells, etc.), defined as the ability to generate, direct and maintain an adequate state of activation for the correct processing of information (Thurstone & Yela (2019), which is linked to academic performance. However, it is necessary to extend this relationship from predictive models considering performance in all primary school subjects and observing the moderating role of such important factors in primary school as diet quality and weight status, since primary school is a transcendental stage where the acquisition of active life habits that last in later stages of life begins.

Based on these precedents, the aim of this study is to determine the predictive value of attention on academic performance in core subjects (Spanish Language and Literature, Mathematics, Natural Sciences, Social Sciences and First Foreign Language (English)) and specific subjects (Art Education, Physical Education, Religion/Values and Second Foreign Language (French)) of the last cycle of Primary Education (Royal Decree

126/2014, 28 February), observing the moderating role of weight status and diet quality in this relationship.

METHOD

Type of study and participants

Prior to conducting this research, the sample size was calculated in order to ensure robust results (Quispe et al., 2020). After jointly estimating the u (in reference to the number of variables) and f^2 (effect size in linear regression models) statistics, it was obtained that the minimum sample had to be a total of 98 subjects to be able to carry out the linear regression technique, something that is fulfilled since we have a total sample of 118 students.

In this respect, a total of 118 schoolchildren (62 boys and 56 girls) belonging to the Autonomous Community of the Canary Islands (South of Tenerife), aged between 10 and 12 years (M ± SD: 10.84 ± 1.20 years) participated in this empirical descriptive and cross-sectional ex post facto study. Sampling was non-probabilistic, non-random and convenience sampling (access to the sample). A public school in the district of Adeje was selected. This school has a medium-high socio-economic level. In previous meetings held with the headmistress of the school and legal guardians of the schoolchildren, they were informed of the study protocol and informed consent was requested so that the schoolchildren could participate. Inclusion criteria were considered to be between 10-12 years of age and regular school attendance (90% of classes during the months of the current academic year). In addition, the following exclusion criteria were considered: 1) Failure to provide informed consent to participate in the research.

Procedure

The work was carried out during the months of March and April of the 2020/2021 academic year, and the head of the school and the representatives of the parents' associations were informed of the purpose and protocol of the research at a meeting. The working team consisted of a principal researcher and two collaborating colleagues (teachers specialising in Primary Education and Physical Education). A theoretical session was held prior to the completion of the questionnaires with each study group in order to ensure that all participants understood the questionnaires in this study. The research team administered the test in the natural groups of the PE class. All questionnaires were administered during the first school session in order to avoid the possible fatigue of the school day and to interrupt the school dynamics as little as possible.

The research was carried out in accordance with the deontological standards recognised by the Declaration of Helsinki (2013 revision), following the recommendations of Good Clinical Practice of the EEC (document 111/3976/88 of July 1990) and the current Spanish legal regulations governing clinical research on humans (Royal Decree 561/1993 on clinical trials).

Instruments

Academic performance was considered as the dependent variable in this study. This was assessed by means of the grade obtained by fifth and sixth grade students in the first and second assessment carried out in the subjects of the Primary Education curriculum: Natural Sciences, Social Sciences, Spanish Language and Literature, Mathematics, First Foreign Language: English, Physical Education, Religion/Values and Second Foreign Language: French (Royal Decree 126/2014, of 28 February, establishing the basic curriculum of Primary Education and Decree 89/2014, of 1 August, establishing the organisation and curriculum of Primary Education in the Autonomous Community of the Canary Islands). The values of all variables ranged from one to ten points. The score obtained in each subject derives from the total assessment of the learning established in the assessment criteria described in the Resolution of 13 May 2015 establishing the rubrics of the assessment criteria in Primary Education in the Autonomous Community of the Canary Islands, which emanate directly from Royal Decree 126/2014, of 28 February. These criteria are the fundamental reference for the assessment and marking of pupils throughout Spain.

The independent variables are:

I) attention assessed by means of the thirteenth version of Thurstone & Yela's (2019) Test of Perception of Similarities and Differences (Faces-R). This test measures the ability to perceive, with the highest processing speed, similarities, differences and partially ordered stimulus patterns. It is used for subjects aged six to 18 years. It consists of 60 graphic items, each consisting of three schematic drawings of faces with the mouth, eyebrows and hair represented with elementary strokes. In each set of three faces, two are the same, and the task is to determine which is different and cross it out. This test has been widely used in education to assess perceptual and attentional aspects in schoolchildren with and without attention deficit hyperactivity disorder (Soldatova & Teslavskaia, 2017). When performing the test, the strategies adopted to discriminate between the different items are inhibited. When the subject finds the different face, he/she must cross it out and continue with the rest of the sets. There is no order in which to complete the test. The subject has a total time of three minutes. The score is obtained directly from the total number of correct answers, the maximum score being 60 points. Test-retest reliability studies conducted by Thurstone & Yela (2019) with individuals aged six years and older showed a test-retest reliability coefficient of 0.95. Based on the CARAS-R test enneotype classification criteria (Thurstone & Yela, 2019), the variable attention was created.

II) The diet quality quantified using the *KIDMED* questionnaire (Serra et al., 2004). This instrument is composed of 16 items that represent standards of the traditional Mediterranean diet. Four of them are assessed with a negative score (-1 point) if answered positively (items 6, 12, 14 and 16), while the remaining twelve items are assessed with a positive score (+ 1) if answered positively. After summation, an overall score between -4 and 12 is obtained, which describes a better or worse quality of the diet. The value of the KIDMED index is: score ≤ 3 indicating a very low quality diet; score between 4 and 7 indicating the need to improve the dietary pattern to conform to

the Mediterranean model; and finally, score ≥ 8, showing an optimal Mediterranean diet. Participants were categorised into two groups: improvable DQ (≤ 7) and optimal DQ (≥ 8).

III) Weight and height were determined using an electronic scale (TANITA TBF 300A, USA) and measuring rod (SECAA800, USA) with an accuracy of 100 g and 1 mm respectively, following the protocol of the International Society for the Advancement of Kynanthropometry (ISAK) with level I certified personnel. From these anthropometric variables, the body mass index (kg/m^2) was calculated. From this index, age- and sex-adjusted nutritional status was diagnosed (Cole & Lobstein, 2012). Participants were categorised into two groups: normal weight and overweight (*overweight + obesity*).

IV) Based on weight status and diet quality, a new combined weight status/diet quality variable was created resulting in four groups (Normal Weight/Optimal DQ, Normal Weight/Improvable DQ, Overweight/Optimal DQ, and Overweight/Improvable DQ), as has been done previously (Carrillo & Prieto, 2020).

Statistical analysis

The normality and homogeneity of variances were obtained through the Kolmogorov Smirnov and Levene statistics, respectively. On observing a normal distribution of the values recorded, a parametric analysis was chosen. The linear regression technique was then carried out using the stepwise method in each of the subjects. A total of five predictive models were estimated. Before interpreting the coefficients, goodness-of-fit and model assumptions were assessed. To analyse the goodness-of-fit, the F-test was used, which indicates whether the linear relationship being analysed is statistically significant. It should be noted that in all models this statistic was significant, thus confirming the relevance of the linear regression technique (Martínez et al., 2020). With respect to the assumptions, as indicated by Pardo & San Martín (2010), the assumption of non-collinearity, linearity, independence of the errors and the Breusch-Pagan test to check the homogeneity of the residuals were checked, as well as the Breusch-Pagan test to check the homogeneity of the residuals. These assumptions are met in all models. The influence of outliers was also tested using Cook's distance. As the value obtained was less than 1, it was concluded that there was no influential case. In turn, since it is essential to determine the individual contribution of each predictor when conducting a linear regression model, the R^2 statistic averaged according to the order in which the predictors are entered into the model was used (Raschka & Mirjalili, 2019). R software version 4.1.2 (R Core Team, 2020) was used for the analysis of all data, specifically the pwr package (Champely et al., 2018) was used to calculate the sample size, with the significance level set at 5% ($p \leq .05$).

FINDINGS

Table 1 shows the scores obtained in the different variables of the study according to sex. It should be noted that no significant differences were obtained for any variable according to sex ($p > .05$). However, a trend towards statistical significance was obtained for the variable BMI ($p \leq .05$).

Table 1
Scores obtained in the different variables of the study according to sex

	Males M ± SD (n = 63)	Females M ± SD (n = 54)	F	*p*	*d*
Natural Sciences (1-10)[a]	5.69 ± 6.88	1.70 ± 1.40	4.132	*.094*	0.15
Social Sciences (1-10) [a]	6.07 ± 1.50	7.05 ± 1.57	1.050	*.823*	0.07
Spanish Language and Literature (1-10) [a]	5.76 ± 1.85	6.79 ± 1.69	1.793	*.183*	0.11
Mathematics (1-10) [a]	5.73 ± 1.99	6.48 ± 1.72	1.457	*.230*	0.10
English (1-10) [a]	5.61 ± 1.52	6.79 ± 1.45	1.591	*.443*	0.09
Art Education (1-10) [a]	5.87 ± 1.18	6.74 ± .97	1.928	*.168*	0.10
Physical Education (1-10) [a]	6.85 ± 1.30	7.09 ± 1.20	1.289	*.592*	0.07
Religion/ Values (1-10) [a]	6.30 ± 1.49	6.77 ± 1.57	1.041	*.947*	0.05
French (1-10) [a]	5.79 ± 1.28	6.90 ± 1.05	4.481	*.064*	0.15
Attention (1-9)[b]	5.88 ± 1.10	5.41 ± 1.55	1.322	.443	0.11
Age (years)	10.44 ± 0.71	10.29 ± 0.84	1.619	.365	0.10
Height (cm)	154.01 ± 8.41	153.51 ± 8.28	1.570	.758	0.09
Weight (kg)	52.19 ± 13.25	48.11 ± 12.53	1.036	.218	0.12
BMI (kg/m^2) [c]	21.84 ± 4.22	22.28 ± 4.09	1.968	.054	0.16
QD [d]	7.53 ± 2.07	7.84 ± 2.62	2.935	.877	0.07

M ± SD = mean ± standard deviation. [a]Mean score obtained in the subject. [b]Global Attention Index calculated from the enneatypes score. [c]BMI = Body Mass Index. [d] Quality diet expressed from the mean score of the *KIDMED* scale.

In order to determine the predictive power of attention on academic performance in core curriculum subjects by looking at the moderating role of weight status and diet quality, a linear regression test was applied (see Table 2). The crude model showed that higher values in attention correlated with higher values in academic performance for all subjects ($p < .05$). Specifically, the coefficient value indicated that, for each point that students' attention increases, performance in Mathematics will increase by 0.334 points, Language and Literature by 0.232 points, Natural Sciences by 0.288 points and Social Sciences by 0.163 points. These relationships become stronger for all curricular variables after the model is adjusted for Normal Weight/optimal DQ ($p < .05$) and Overweight/optimal DQ ($p < .05$). In relation to the goodness of fit of attention adjusted for the latter dimension, this model explains approximately 28.2% of the score obtained in the area of Spanish Language and Literature or 25.7% of the score obtained in the area of Social Sciences. However, after adjusting the model for Normal Weight/improvable DQ and Overweight/improvable DQ, this relationship between attention and academic performance disappears ($p > .05$).

Table 2
Predictive value of attention on academic performance in core subjects considering weight status and diet quality

	Natural Sciences	Sciences Social	Spanish Language and Literature	Mathematics	English
Model I [a]	*B* = 0.288	*B* = 0.163	*B* = 0.232	*B* = 0.334	*B* = 0.258
	t = 3.749	t = 2.141	t = 2.644	t = 3.830	t = 3.439
	R^2 = .108	R^2 = .038	R^2 = .057	R^2 = .112	R^2 = .093
	p = .001**	*p* = .034*	*p* = .009*	*p* = .001**	*p*= .001**
Model II [b]	*B* = 0.370	*B* = 0.201	*B* = .272	*B* = 0.486	*B* = 0.307
	t = 3.023	t = 1.734	t = 1.177	t = 3.359	t = 2.969
	R^2 = .217	R^2 = .084	R^2 = .087	R^2 = .213	R^2 = .116
	p = .005*	p = .042*	*p* = .045*	*p* = .002*	*p* = .006*
Model III [c]	*B* = 0.023	*B* = .803	*B* = 0.384	*B* = 0.023	*B* = 0.104
	t = .110	t = .203	t = .890	t = .041	t = .456
	R^2 = .001	R^2 = .129	R^2 = .140	R^2 = .001	R^2 = .009
	p = .914	*p* = .085	*p* = .072	*p* = .967	*p* = .653
Model IV [d]	*B* = 0.331	*B* = 0.364	*B* = 0.438	*B* = 0.440	*B* = 0.320
	t = 2.904	t = 3.004	t = 3.195	t = 3.886	t = 2.360
	R^2 = .245	R^2 = .257	R^2 = .282	R^2 = .243	R^2 = .211
	p = .007*	*p* = .006*	*p* = .004*	*p* = .008*	*p* = .026*
Model V [e]	*B* = 0.212	*B* = 0.116	*B* = 0.256	*B* = 0.193	*B* = 0.288
	t = 1.115	t = .658	t = 1.249	t = .884	t = 1.516
	R^2 = .040	R^2 = .015	R^2 = .051	R^2 = .026	R^2 = .007
	p = .281	*p* = .516	*p* = .222	*p* = .384	*p* = .140

Note. [a]Model I in crude; [b]Model II after adjustment to Normal Weight/ Optimal DQ; [c] Model III after adjustment to Normal Weight/ Improvable DQ; [d]Model IV after adjustment to Overweight/ Optimal DQ and e Model V after adjustment to Overweight/ Improvable DQ.

On the other hand, after observing the predictive power of attention on academic performance in the specific subjects of the curriculum by observing the moderating role of weight status and diet quality (see Table 3), significant values were obtained in the crude model for all subjects ($p < .05$) with the exception of Physical Education ($p > .05$). These relationships become more pronounced in Art Education, Religion/Values and French after the model was adjusted to Normal Weight/Optimal DQ ($p < .05$) and Overweight/Optimal DQ ($p < .05$). However, after adjusting the model to Normal Weight /improvable DQ and Overweight/improvable DQ, this relationship between attention and academic performance disappears ($p > .05$).

Table 3
Predictive value of attention on subject-specific academic performance considering weight status and diet quality

	Art Education	Physical Education	Religion/ Values	French
Model I [a]	*B* = 0.164	*B* = 0.197	*B* = 0.165	*B* = 0.171
	t = 2.980	t = 1.603	t = 2.254	t = 2.801
	R^2 = .071	R^2 = .022	R^2 = .042	R^2 = .055
	p = .004*	*p* = .112	*p* = .026*	*p* = .006*
Model II [b]	*B* = 0.200	*B* = 0.168	*B* = 0.118	*B* = 0.224
	t = 2.244	t = 2.016	t = 1.084	t = 2.284
	R^2 = .132	R^2 = .110	R^2 = .023	R^2 = .156
	p = .032*	*p* = .052	*p* = .038*	*p* = .019*
Model III [c]	*B* = 0.078	*B* = .212	*B* = *0*.234	*B* = 0.198
	t = .556	t = 0.698	t = 1.162	t = 1.328
	R^2 = .014	R^2 = .115	R^2 = .001	R^2 = .074
	p = .584	*p* = .104	*p* = .945	*p* = .198
Model IV [d]	*B* = 0.269	*B* = 0.082	*B* = 0.234	*B* = 0.814
	t = 3.313	t = 2.881	t = 2.162	t = 2.547
	R^2 = .297	R^2 = .029	R^2 = .152	R^2 = .200
	p = .002*	*p* = .385	*p* = .040*	*p* = .017*
Model V [e]	*B* = 0.139	*B* = 0.212	*B* = *0*.202	*B* = *0*.148
	t = .919	t = 1.395	t = 1.022	t = 1.967
	R^2 = .031	R^2 = .065	R^2 = .035	R^2 = .031
	p = .345	*p* = .173	*p* = .245	*p* = .342

Note. [a]Model I in crude; [b]Model II after adjustment to Normal Weight/ Optimal DQ; [c] Model III after adjustment to Normal Weight/ Improvable DQ; [d]Model IV after adjustment to Overweight/ Optimal DQ and e Model V after adjustment to Overweight/ Improvable DQ.

DISCUSSION

The aim of this study was to determine the predictive value of attention on academic performance in core subjects (Spanish Language and Literature, Mathematics, Natural Sciences, Social Sciences and First Foreign Language (English)) and specific subjects (Art Education, Physical Education, Religion/Values and Second Foreign Language (French)) of the last cycle of Primary Education, observing the moderating role of weight status and diet quality in this relationship. The main finding of the study reveals that attention is a powerful predictor of academic performance in upper primary school students in all subjects of the curriculum except Physical Education.

These results are similar to those found in other studies. For example, in 10-12 year-old schoolchildren, they found that an attention intervention improved performance in a musical aptitude test (Martín et al., 2007). Likewise, in 9-year-old (Reyes et al., 2015), 6-12-year-old (Fonseca-Estupiñan et al., 2016), secondary (León, 2008; Zorza et al., 2016; Escolano-Pérez & Bestué, 2021) and high school (Manriquez-López, 2019) schoolchildren, they found a significant relationship between attention and academic

performance in core curriculum subjects. Ison & Korzeniowski, (2016) found that attention modulated performance in word reading and text comprehension in 10-11 year-old schoolchildren. Likewise, Kheirati et al., (2019) point to the effectiveness of self-monitoring of attention on academic reading performance, concluding that primary schools should increase attentional processes to improve students' educational effectiveness. On the other hand, these results differ from those obtained in other studies. For example, the study by Cárdenas et al. (2018) with 9-year-old schoolchildren did not find a statistically significant relationship between attention and academic performance measured globally. Similarly, Díez-Reviriego et al., (2018) found that there is no statistically significant combination between attention and mathematical problem solving in sixth grade schoolchildren. In turn, Coneo et al. (2019) point out that the visual attention process and academic performance classified as high or low in secondary school students do not show a significant relationship.

It is worth highlighting the absence of a relationship between attention and academic performance in the area of Physical Education. This result may be due to the fact that the predominant methodology in the area of Physical Education is motor play and the attention for understanding the game and playing is high in all students (Rosa et al., 2018). In other words, in pedagogical terms, motor play is the means by which schoolchildren express themselves, where work is just as important as it is for adults. In this line of argument, motor play is an essential methodological resource for developing a large part of the learning in the area. Through play, the activation of perception and decision-making mechanisms is made possible, as well as the development of execution capacities; the acquisition of new motor skills is made possible, concepts are contrasted and the motivation of pupils to participate in activities and tasks which have an eminently recreational character, typical of the use of play and the forms played, without losing their priority function of training, is activated. In this sense, it has been described that distraction directly influences the individual's ability to concentrate and correctly grasp external stimuli. Therefore, it has a robust power to predict later academic success (Rosa-Guillamón et al., 2020). Hence, as schoolchildren are not distracted by playing in Physical Education, there may be an absence of a relationship between attention and academic performance in this area.

On the other hand, this research has shown that this relationship between attention and academic performance is intensified when the quality of the diet is optimal, regardless of weight status. In this sense, Chacón-Cuberos et al. (2018) found that a high degree of adherence to the diet quality is positively related to elaboration strategies, organisational strategies, critical thinking, self-regulation, time and study habits, self-regulation of effort, and intrinsically oriented goals. On the other hand, it has been pointed out that thoughts, emotional patterns and psychological dynamics are strongly interrelated with learning. That is, if a person is aware of how they can influence and regulate their situation, they acquire a sense of control and self-awareness, which can be extrapolated to other contexts in their lives, such as academic performance (Ekman, 2021). In this sense, in 10-14 year-old schoolchildren, it was found that eating breakfast just before a cognitive demand, not skipping breakfast regularly and consuming a high quality breakfast is related to higher cognitive performance than those who do not, regardless of

weight status (Peña-Jorquera et al., 2021). Nyaradi, (2013) points out that there is no conclusive evidence regarding the association between obesity and learning as people consume combinations of foods, therefore, they point out that it is necessary to study the quality of the diet.

At the physiological level, Jirout et al. (2019) provide an example of the learning process and the possible impact of nutrition, based on information processing theory. That is, one of the most basic conditions for a schoolchild to complete academic tasks is to have the necessary energy and no inhibiting discomfort factors (e.g. hunger or fatigue). If the conditions are not optimal, the scholar experiences a lower level of alertness, or caution, and thus a decreased attention to any information in the environment. Therefore, the capacity of working memory will be restricted, limiting the information that is encoded and retained in long-term memory, from which it can be retrieved later.

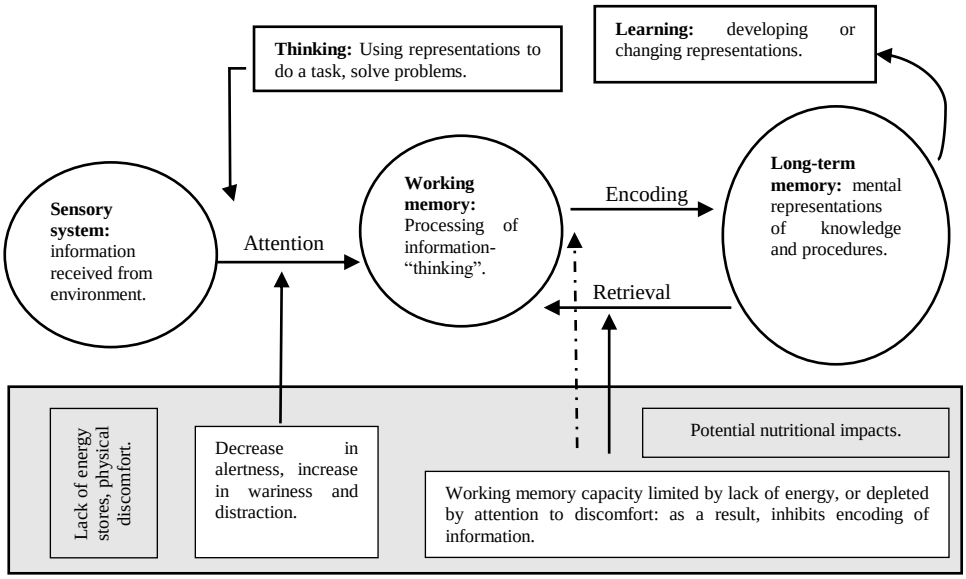

Figure 2
Information processing model. Source: Jirout et al., (2019).

Godos et al. (2020) point out that diet quality is a major contributor to the prevalence of non-communicable diseases, including neurodegenerative disorders. Dietary polyphenols, antioxidant components and anti-inflammatory agents in diets rich in plant-based foods have been shown to modulate neuroinflammation, neurogenesis and brain signalling, all of which are related to cognitive function. In this regard, Gabbianelli & Damiani (2018) suggest that the link between nutrition and learning may derive from the close interconnection between gut microbiota and cognitive mechanisms transiting the gut-brain axis. That is, an unhealthy diet may modify the gut microbiota, leading to altered intestinal permeability, with consequent absorption of toxic substances and release of pro-inflammatory cytokines, which mediate inflammation and

neuroinflammation. In this regard, Ceppa et al., (2019) note that the gut-brain axis is a current area of research linking the food we eat to development and neurophysiological functions. Some gut microorganisms have been shown in laboratory animals to alleviate anxiety and depression, improve cognitive performance and play a role in early brain development. However, further research is needed to investigate how interactions between diet and microbes within the gut may affect the production of neurotransmitters or their downstream biological effects within the nervous system and thus learning.

In this sense, these findings should be interpreted with caution due to the fact that this study was not interventionist, but based on self-reported data, with unknown quality and quantity of food consumed daily by schoolchildren. In addition, the low sample size is undoubtedly another limitation. Similarly, it is difficult to infer a cause and effect relationship between attention and academic performance, since, as we have seen, there are confounding factors that are likely to influence these relationships and have not been considered in this study (such as socio-economic status). Thus, these effects could be related to environmental aspects and deserve to be further investigated in future studies. Furthermore, teachers are also a fundamental factor of quality in the educational process. Therefore, how teachers contribute to the acquisition of healthy lifestyle habits needs to be analysed in more detail (Barattucci et al., 2021; Luján, 2021).

CONCLUSION

The present study contributes to the scientific literature investigating the moderating role of healthy lifestyle habits, such as diet quality or weight status, between cognitive processes (attention) and learning outcomes (academic performance). Based on these results, it is concluded that there is a positive relationship between attention and academic performance, with the exception of physical education, which is enhanced when diet quality is optimal, regardless of weight status. Future studies should shed more light on this association. Mainly, intervention and longitudinal studies are needed that take into account the variables described above and other confounding variables such as socioeconomic status or other lifestyle indicators such as screen time or hours of sleep. It is also recommended to include all executive functions. Meanwhile, health promotion professionals in the school environment should consider the positive role that diet can play in the attention-academic performance association and initiate programmes to promote healthy eating among school children, as the promotion of healthy habits could be a cost-effective strategy in promoting the development of learning, in terms of attention and academic performance.

REFERENCES

Agustin, M., Puspita, R. D., Inten, D. N., & Setiyadi, R. (2021). Early Detection and Stimulation of Multiple Intelligences in Kindergarten. *International Journal of Instruction*, *14*(4). https://doi.org/10.29333/iji.2021.14450a

Barattucci, M., Zakariya, Y. F., & Ramaci, T. (2021). Academic Achievement and Delay: A Study with Italian Post-Graduate Students in Psychology. *International Journal of Instruction*, *14*(4). https://doi.org/10.29333/iji.2021.1441a

Bureekhampun, S., Techakarnjanakij, K., & Supavarasuwat, P. (2021). Thai Seven Year Old Early Learner Creativity Design and Study Activities Promotion. *International Journal of Instruction*, *14*(4). https://doi.org/10.29333/iji.2021.14420a

Cárdenas Ávila, N., López-Fernández, V., & Arias-Castro, C. C. (2018). Análisis de la relación entre creatividad, atención y rendimiento escolar en niños y niñas de más de 9 años en Colombia. *Psicogente*, *21*(39), 75-87. https://doi.org/10.17081/psico.21.39.2823

Carrillo, P. J., & Prieto, F. J. (2020). Niveles de ansiedad según el estado de peso y la calidad de la dieta durante el estado de alarma en escolares de Primaria. *Nutrición Clínica y Dietética Hospitalaria*, *40*(3). https://doi.org/10.13042/Bordón.2021.89626

Ceppa, F., Mancini, A., & Tuohy, K. (2019). Current evidence linking diet to gut microbiota and brain development and function. *International journal of food sciences and nutrition*, *70*(1), 1-19. https://doi.org/10.1080/09637486.2018.1462309

Chacón-Cuberos, R., Zurita-Ortega, F., Martínez-Martínez, A., Olmedo-Moreno, E. M., & Castro-Sánchez, M. (2018). Adherence to the Mediterranean diet is related to healthy habits, learning processes, and academic achievement in adolescents: a cross-sectional study. *Nutrients*, *10*(11), 1566. https://doi.org/10.3390/nu10111566

Champely S, Ekstrom C, Dalgaard P, Gill J, Weibelzahl S, Anandkumar A, et al. (2018). Package 'pwr.' http://cran.r-project.org/package=pwr

Cole, T.J., & Lobstein, T (2012). Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatric Obesity. 7(4), 284-294. https://doi.org/10.1111/j.2047-6310.2012.00064.x

Coneo, E., Martínez, C., & Amed, E. (2019). Atención visual y auditiva y su relación con el rendimiento académico en estudiantes de secundaria. *Espacios*, *40*(19), 29.

Cortés Pascual, A., Moyano Muñoz, N., & Quilez Robres, A. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in psychology*, *10*, 1582. https://doi.org/10.3389/fpsyg.2019.01582

Díez–Reviriego, E., & Bausela–Herreras, E. (2018). Funciones ejecutivas y la competencia para resolver problemas matemáticos en Educación Primaria. *Cuadernos de Neuropsicología*, *12*(1).

Ekman, R., Fletcher, A., Giota, J., Eriksson, A., Thomas, B., & Bååthe, F. (2021). A Flourishing Brain in the 21st Century: A Scoping Review of the Impact of Developing Good Habits for Mind, Brain, Well-Being, and Learning. *Mind, Brain, and Education*. https://doi.org/10.1111/mbe.12305

Escolano-Pérez, E., & Bestué, M. (2021). Academic Achievement in Spanish Secondary School Students: The Inter-Related Role of Executive Functions, Physical Activity and Gender. *International Journal of Environmental Research and Public Health*, *18*(4), 1816. https://doi.org/10.3390/ijerph18041816

Fonseca Estupiñan, G. P., Rodríguez Barreto, L. C., & Parra Pulido, J. H. (2016). Relación entre funciones ejecutivas y rendimiento académico por asignaturas en escolares de 6 a 12 años. *Hacia la promoción de la salud*, *21*(2), 41-58.

Godos, J., Caraci, F., Castellano, S., Currenti, W., Galvano, F., Ferri, R., & Grosso, G. (2020). Association Between dietary flavonoids Intake and cognitive function in an Italian cohort. *Biomolecules*, *10*(9), 1300. https://doi.org/10.3390/biom10091300

Golub, T. L., Rijavec, M., & Olcar, D. (2016). The relationship between executive functions and flow in learning. *Studia psychologica*, *58*(1), 47. https://doi.org/10.21909/sp.2016.01.706

Herrera, E. Y., Álvarez, G. C. P., & Alencastro, A. G. (2020). Desarrollo de las funciones ejecutivas en la infancia. *Revista Cognosis*, *5*(1), 103-114. https://doi.org/10.33936/cognosis.v5i1.1656

Huizinga, M., Baeyens, D., & Burack, J. A. (2018). Executive function and education. *Frontiers in psychology*, *9*, 1357. https://doi.org/10.3389/978-2-88945-572-0

Ison, M. S., & Korzeniowski, C. (2016). El rol de la atención y percepción viso-espacial en el desempeño lector en la mediana infancia. *Psykhe*, 25(1), 1-13. https://doi.org/10.7764/psykhe.25.1.761

Jirout, J., LoCasale-Crouch, J., Turnbull, K., Gu, Y., Cubides, M., Garzione, S., & Kranz, S. (2019). How lifestyle factors affect cognitive and executive function and the ability to learn in children. *Nutrients*, *11*(8), 1953. https://doi.org/10.3390/nu11081953

Kheirati, H., Ghobari Bonab, B., & Beh-Pajooh, A. (2019). The effectiveness of teaching self-monitoring of attention on academic performance and attention in students with reading difficulties. *Journal of Learning Disabilities*, *8*(4), 27-54.

Lai, R. P., Ellefson, M. R., & Hughes, C. (2019). Executive Function and Metacognition Show Independent Associations with Academic Performance During Late Childhood and Early Adolescence. *University of Cambridge*.

León, B. (2008). Atención plena y rendimiento académico en estudiantes de enseñanza secundaria. *European journal of education and psychology*, *1*(3), 17-26. https://doi.org/10.30552/ejep.v1i3.11

Luján, E. L. (2021). The Beliefs of Primary School Teachers: A Comparative Analysis. *International Journal of Instruction*, *14*(3), 223-240. https://doi.org/10.29333/iji.2021.14313a

Manriquez-López, L. (2019). Executive functions and academic achievement in students from a baccalaureate integrated to an orphanage. *RIDE. Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *9*(18), 897-922. https://doi.org/10.23913/ride.v9i18.482

Martín, E., León del Barco, B., & Vicente Castro, F. (2007). Mejora de las aptitudes musicales mediante una intervención en atención auditiva e interior. *Revista galego-portuguesa de Psicoloxía e Educación*, 14, 95–105.

Martínez, M., Sánchez-Villegas, Toledo, E., y Faulín, J. (2020). *Bioestadística amigable*. ELSEVIER

Montes-Miranda, M. M., Flores Builes, R., & Andrés-Roqueta, C. (2020). Revisión sistemática del efecto de las funciones ejecutivas en el rendimiento académico. *Àgora de salut*, 7(2). https://doi.org/10.6035/AgoraSalut.2020.7.21

Nyaradi, A., Li, J., Hickling, S., Foster, J., & Oddy, W. H. (2013). The role of nutrition in children's neurocognitive development, from pregnancy through childhood. *Frontiers in Human Neuroscience, 7*, 97. https://doi.org/10.3389/fnhum.2013.00097

Pardo, A. & San Martín, R, (2010). *Análisis de datos en Ciencias Sociales y de la Salud II*. Editorial Síntesis

Peña-Jorquera, H., Campos-Núñez, V., Sadarangani, K. P., Ferrari, G., Jorquera-Aguilera, C., & Cristi-Montero, C. (2021). Breakfast: A crucial meal for adolescents' cognitive performance according to their nutritional status. the cogni-action project. *Nutrients*, *13*(4), 1320. https://doi.org/10.3390/nu13041320

Polverino, A., Sorrentino, P., Pesoli, M., & Mandolesi, L. (2021). Nutrition and cognition across the lifetime: an overview on epigenetic mechanisms. *AIMS neuroscience*, *8*(4), 448. https://doi.org/10.3934/Neuroscience.2021024

Quispe, A., Pinto, D., Huamán, M., Bueno, G., & Valle-Campos, A. (2020). Metodologías cuantitativas: Cálculo del tamaño de muestra con STATA y R. *Revista Del Cuerpo Médico Hospital Nacional Almanzor Aguinaga Asenjo*, 13(1), 78 - 83. https://doi.org/10.35434/rcmhnaaa.2020.131.627

Raschka, S. & Mirjalili, V. (2019). Python machine learning: machine learning and deep learning with Python, scikit-learn, and TensorFlow. *Marcombo*

Reyes, S., Barreyro, J. P., & Injoque Ricle, I. (2015). El rol de la función ejecutiva en el rendimiento académico en niños de 9 años. *Revista Neuropsicología Latinoamericana*, 7 (82): 42-47.

Rosa, A., Cantó, E., & López, P. J. (2018). La educación física como programa de desarrollo físico y motor. *EmásF: revista digital de educación física*, (52), 105-124.

Rosa-Guillamón, A., López, P. J., Cantó, E., & García, J. E. (2020). La organización y la gestión de la clase de Educación Física. *VIREF Revista de Educación Física*, *9*(4), 81-96.

Serra-Majem, L., Ribas, L., Ngo, J., Ortega, R. M., García, A., Pérez-Rodrigo, C., & Aranceta, J. (2004). Food, youth and the Mediterranean diet in Spain. Development of KIDMED, Mediterranean Diet Quality Index in children and adolescents. *Public Health Nutrition*, *7*(7), 931–935. https://doi.org/10.1079 /PHN2004556

Soldatova, G. U., & Teslavskaia, O. I. (2017). Videogames, academic performance and attention problems: practices and results of foreign empirical studies of children and adolescents. *Journal of Modern Foreign Psychology*, *6*(4), 21-28. https://doi.org/10.17759/jmfp.2017060402

Thurstone, L. L., Gonzalez, M., Granizo, M. Y., Pando, A. C., & Cubero, N. S. (2019). *Test de Percepción de Diferencias (Caras)* (TEA (ed.); TEA).

Tsubomi, H., & Watanabe, K. (2017). Development of visual working memory and distractor resistance in relation to academic performance. *Journal of experimental child psychology*, *154*, 98-112. https://doi.org/10.1016/j.jecp.2016.10.005

Willoughby, M. T., Wylie, A. C., & Little, M. H. (2019). Testing longitudinal associations between executive function and academic achievement. *Developmental psychology*, *55*(4), 767. https://doi.org/10.1037/dev0000664

Zorza, J. P., Marino, J., & Mesas, A. A. (2016). Executive functions as predictors of school performance and social relationships: Primary and secondary school students. *The Spanish journal of psychology*, *19*. https://doi.org/10.1017/sjp.2016.23.