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ORIGINAL ARTICLE

Studies on the influence of breakfast on the mental performance of school children and adolescents

Aileen Zipp[1] · Günter Eissing[1]

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Abstract

Aim The study determines the influences of breakfast in school on the cognitive abilities of pupils including the factors age, breakfast at home and SES.

Subjects and methods One thousand one hundred eighty-one children and adolescents aged 8 to 18 years (9 primary and 4 secondary schools in Germany) participated in a crossover design. Seven different foods were examined according to the German diet. The test measures used were cognitive domain information processing, memory (KAI: General intelligence) and concentration (KT 3-4 R).

Results The comprehensive evaluation of all assigned test foods shows a significant improvement in the mental performance for all test parameters. The measured improvement of mental performance increases with the age of the subjects. This is based on the decreasing percentage of children having breakfast at home. Breakfasting at home proves generally more effective compared with breakfast at school. The test food consumed suggests an important difference in the increase of mental performance as a function of their composition.

Conclusion Based on the results obtained, it is highly recommended to offer breakfast at school, particularly at the secondary school level.

Keywords Breakfast · Mental performance · Concentration ability · School

Introduction

Breakfast is important for the fluid intelligence (Pivik et al. 2012). In particular, children have fasted a long time during their sleep. Energy and nutrient supplies are therefore necessary. Increasingly as young people get older they skip breakfast (Alexy et al. 2010; Zubrägel and Settertobulte 2003). If breakfast improves mental performance, a change in nutritional behaviour is necessary. Different reviews (Adolphus et al. 2013, 2016; Terschlüsen et al. 2010; Rampersaud et al. 2005) support the evidence to this effect. Many investigations have been carried out in the USA and England. In Germany, only a few empirical studies exist (Eissing 2011; Widenhorn-Muller et al. 2008; Genz 2007; Wagner et al. 2011). The results show that the quality of breakfast described by the GI (glycemic index) greatly influences cognition.

Age is an important measured variable as nutrition habits change as children get older. However, most investigations refer to children in primary school. Few studies exist including an age range and using a uniform methodology (Adolphus et al. 2016). Therefore, this study focuses on the effect of age (9 to 18 years) on diet and mental performance by using the same experimental design. As SES (socioeconomic status) influences diet, this covariable was included, too. The studies were performed as experiments in both schools and the laboratory. Laboratory tests can precisely control conditions such as the previous evening's food consumption or duration of sleep. A clinical study (Iovino et al. 2016) investigated the effect of breakfast and found no significant differences according to breakfast consumption. However, laboratory tests have a strong effect on habits, especially for children, so distortions are to be expected. However, school experiments allow maintaining the normal living style and nourishing habits, and more test subjects can be included (Adolphus

✉ Günter Eissing
guenter.eissing@tu-dortmund.de

[1] Technical University of Dortmund, Professorship for Health Promotion and Consumer Education, Emil-Figge-Str. 50, D 44227 Dortmund, Germany

et al. 2017). Therefore, this investigation approach allows better generalisation and ecologically valid evidence.

The objective of this field study was to investigate the influence of breakfast on the mental performance of school children and adolescents, varying the factors age, SES and food composition, to enable a differentiated analysis.

Methods

Schools and pupils

Table 1 summarises the schools in the investigations. Both primary and secondary level schools were included. The different school levels of the secondary schools and ages of the pupils are important influencing factors. The selection of the schools in Dortmund was made with respect to the SES of the families. The city of Dortmund has classied the town area into five SES types. The schools were selected from SES types 1 (highest SES), 3 and 5 (lowest SES). This investigation includes 1181 pupils.

Food

Altogether seven different foods from the German diet were examined. Table 2 indicates the allocation of food to the schools and the number of pupils included. The investigators prepared test food of standardised quality and quantity. The pupils consumed the complete portion in the first break.

Tests

The used test measured the cognitive domains information processing, memory and concentration. Nutrition influences these elements of cognition (Adolphus et al. 2016).

KAI: General intelligence

The information-psychological approach describes intelligence by two fundamental values: data processing speed (IVG) and memory span. The IVG shows up in the speed with which we record something as well as look for connections and memory contents. The memory span describes the time interval in which contents such as words or numbers remain directly in our consciousness (Lehrl 2015). The combination of both values forms the work memory capacity (bit) (Wagner et al. 2015; Lehrl et al. 1978, 1991). The KAI ppt version (Lehrl et al. 2016) makes simultaneous testing for an entire class possible. The test has been proven sensitive to changes according to cognition by nutrition (Eissing 2011; Wagner et al. 2015).

Table 1 School forms, classes and pupils in the investigation

School form	Grade	No. of classes	Pupils
1 Primary school	3 + 4	35	765
2 Secondary school	7 + 9	10	265
3 Gymnasium	9	3	78
4 Vocational school	12	3	73
Total		51	1181

KT 3-4 R

The concentration test is a general performance test for the 3rd and 4th grade (Heck-Möhling et al. 1993). The KT 3-4 R is a revised version (Nell et al. 2004). The KT 3-4 R is a crossing-out test. The whole grade can take the test simultaneously. The psychometric test procedure claims the selective attention of the test person (Heubrock and Petermann 2001). The individual concentration ability is measured as it is considered an important condition for school learning.

Study design

The studies were conducted as quasi-experimental field studies in a crossover design on 3 investigation days during instruction in schools. After attaining the agreement of the school administration for participation in the study, information letters were sent to the parents and their written declaration of patient consent was obtained. The teachers informed the secondary school pupils about the upcoming project, and agreement was obtained. All participants were queried about food allergies.

All studies had a standardised operational sequence on the 3 investigation days with a 1-week interval:

Day 1: Introduction;
Day 2: Test procedure with intervention (standardised breakfast meal);
Day 3: Test procedure without intervention (without breakfast meal).

The first date served to introduce the test subjects to the purpose of the study. The investigator described the exact course of the study and familiarised the pupils with the test materials. As background knowledge and for the evaluation of breakfast quality, the breakfast circle (Molderings and Eissing 2006b) was explained. Cognitive tests were carried out for training.

On the 2nd study day, the intervention took place. A randomised half of the classes received a standardised breakfast test meal during the first large break (usually around 9:30 a.m.); the other half received only mineral water and no meal. The test breakfast was consumed in the classroom; the

Table 2 Examined food and included schools and pupils

Food	School form (pupils)	Components	Weight (g)	Energy (kcal)	Carbohydrate (g)
Balanced breakfast	1, 2, 3 ($n = 486$)	Whole-grain bread, cheese or turkey sausage, sandwich spread Fruit and vegetable Milk or chocolate drink (250 ml) Mineral water	450	379–504	60.0
Fruit and vegetable	1 ($n = 99$)	Apple, mini-banana, cherry tomatoes	100	57	12.2
Chocolate drink	1 ($n = 97$)	1.5% Fat portion	250	163	22.5
Milk	2 ($n = 51$)	1.5% Fat portion	250	120	10.2
Nut and raisin mix	1, 2 ($n = 165$)	Peanuts, almonds, cashews, raisins	50	268	18.3
Sweets	2 ($n = 46$)	Gummi bears (Halal certified)	32	104	25.0
Cereal	1, 4 ($n = 237$)	Test cereal with 125 ml milk (1.5%)	200	345	52.0

investigator observed the intake. We used a fixed portion of food (Table 2) to reduce variability in the consumption caused by taste preferences. Those pupils who did not eat breakfast in the break received a balanced breakfast after the test procedure to support compliance motivation.

Following the break, teachers held conventional instruction in the 3rd school hour with the exception of classroom tests. In the 4th school hour, the KAI and KT 3-4 R cognitive tests were taken in all participating classes as a group test. This time was specified as obligatory to guarantee an effective time between the breakfast consumption and 60-min testing. The test procedures lasted 1 school hour. Between the two tests the pupils had a break with exercises according to their age.

The 3rd study day followed the same procedure. The allocation of the classes to the intervention groups was exchanged systematically in the crossover design.

One did not affect the breakfast meal, which the test persons possibly consumed at home. It was measured with the questionnaire 'breakfast circle' as a proven method to quantify the quality of breakfast (Eissing et al. 2009).

SPSS V23 was used for the statistical calculations; the significance of differences was calculated with a paired Student t-test and a multivariate ANOVA. As covariates age, breakfast at home und SES were analysed.

Results

Results from the five studies for the seven foods

The first analysis summarises the results of all five studies including all school grades as well as all test foods. Table 3 compares the obtained average values of the two cognitive test procedures, KAI and KT 3-4 R, without breakfast consumption in the first large break (B2) with the consumption of test food (B3). Both the test value of the KAI and the three test characteristic values of the KT 3-4 R show high ($p \leq 0.001$) or very significant ($p \leq 0.01$) improvements.

The 2.25-bit increase of the working memory capacity is highly significant ($p \leq 0.001$). The same is valid for the positive change of the total number of correct answers, which after consumption increases by an average of 2.54 correct answers, as well as of the total number of cubes (working speed). In the consumption condition, the test subjects executed nearly three additional cubes. Both changes are highly significant. The concentration performance rose by 0.68 points. This increase is very significant ($p \leq 0.01$).

The working memory capacity and/or fluid intelligence clearly rise from the 3rd to the 9th grade (Fig. 1). The 4.18-

Table 3 Total results of all experiments in the comparison with (B2) and without (B3) breakfast in the first break (t-test paired samples, all test food, all schools, $n = 845$; KAI test for general intelligence; KT concentration test)

Test	Reference values	Mean	SD	Significance
KAI	Work memory capacity_B2	75.24	27.15	0.001***
	Work memory capacity_B3	77.49	29.06	
KT	Total correct answers_B2	104.75	45.23	0.000***
	Total correct answers _B3	107.29	45.90	
KT	Total number cubes_B2	108.62	45.79	0.000***
	Total number cubes _B3	111.27	46.58	
KT	Concentration performance _B2	31.15	14.34	0.004**
	Concentration performance _B3	31.83	14.52	

n.s., not significant

*$p \leq 0.05$ (significant); **$p \leq 0.01$ (very significant); ***$p \leq 0.001$ (highly significant)

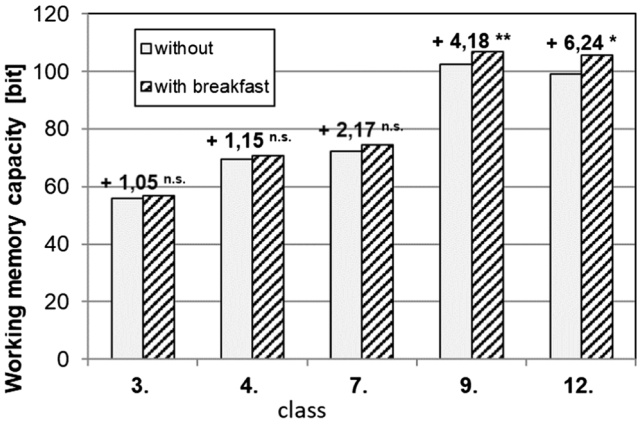

Fig. 1 Change of work memory capacity according to breakfast at school (without, with) for different grades; all test foods, all schools, $n = 843$

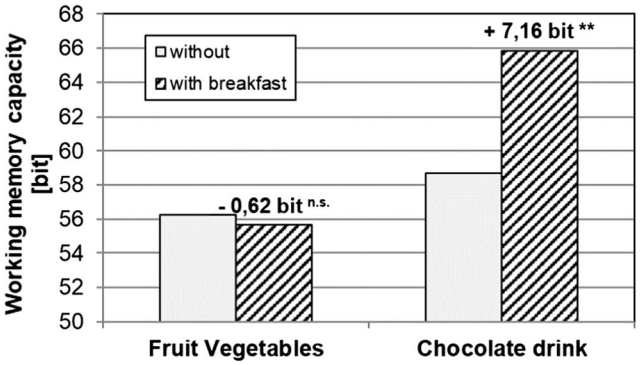

Fig. 3 Work memory capacity comparison without breakfast in the first break with consumption of fruits and vegetables and of chocolate drinks, primary schools, $n = 132$

bit increase of working memory capacity with breakfast in the 9th grade is very significant. The positive influence of previous breakfast consumption is strongest in the 12th grade with 6.24 bits. The same is valid for the results of the KT 3-4 R (Fig. 2).

Comparison of fruit/vegetables and chocolate drinks

In the investigation at primary schools, different test foods were used, including 100 g fruits and vegetables (apple slices, mini-bananas, cherry tomatoes; the quantity corresponds to the European Union school fruit program) as well as 250 ml low fat chocolate drinks (Table 2). Figure 3 compares working memory capacity without breakfast in the first break with the consumption of fruits and vegetables as well of the chocolate drinks. Consuming chocolate drinks results in a very significant ($p \leq 0.01$) increase of 7.16 bits. Fruit and vegetable consumption results in a small, non-significant reduction of 0.62 bits after consumption. The essential test characteristic value of the KT 3-4 R shows improvements after consumption of the test food (Fig. 4). For fruits and vegetables, the increase is 0.37 and for the chocolate drinks the significant ($p \leq 0.05$) increase is 1.97. The insignificant influence of fruit and vegetable consumption on the mental performance of pupils is due to the small quantity of 100 g, which does not provide a sufficient carbohydrate supply of approximately 12 g. The carbohydrate amount of 22.5 g provided by the 250 ml chocolate drink is enough to affect cognitive achievements however. The fat in the chocolate drink delays the metabolism, so the increased blood sugar level is sustained over a longer time.

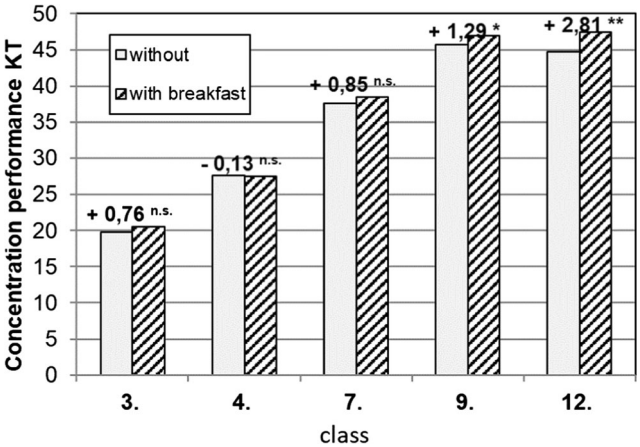

Fig. 2 Change of KT 3-4 R concentration performance according to breakfast at school (without, with) for different grades; all test foods, all schools, $n = 843$

Comparison of the results of different school levels

In the following, the results are represented according to the school levels of primary school, secondary school, gymnasium and vocational school (Table 1). The German educational system has different school levels with different requirements for the secondary level school. The performance requirements increase from secondary and vocational schools to the gymnasium. To obtain an age-fair comparison between the

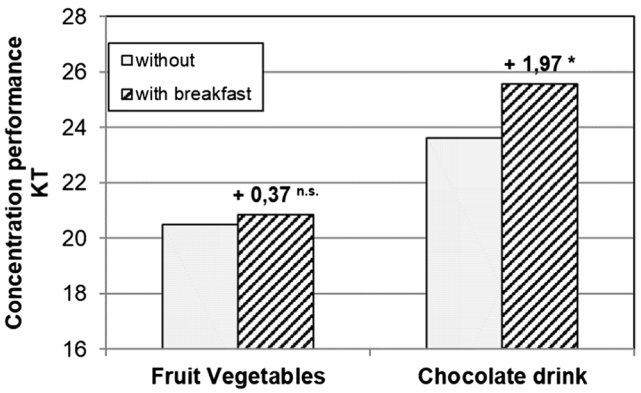

Fig. 4 KT 3-4 R concentration performance comparison without breakfast in the first break with consumption of fruits and vegetables and of chocolate drinks, primary schools, $n = 132$

secondary school and gymnasium, the 7th grade is not considered for the following analysis. For all four school levels, an increase in the working memory capacity results after breakfast consumption (Fig. 5). The 7.76-bit increase is particularly pronounced and highly significant in secondary school. The rise of 6.24 bits is significant in vocational schools.

The primary and vocational schools show very significant improvements in concentration performance after consumption of a breakfast meal (Fig. 6). The 2.49 increase in concentration performance in the secondary school is highly significant. For the gymnasium, no significant influence could be determined by the previous breakfast, since repetition effects of the test procedures arose at this school level.

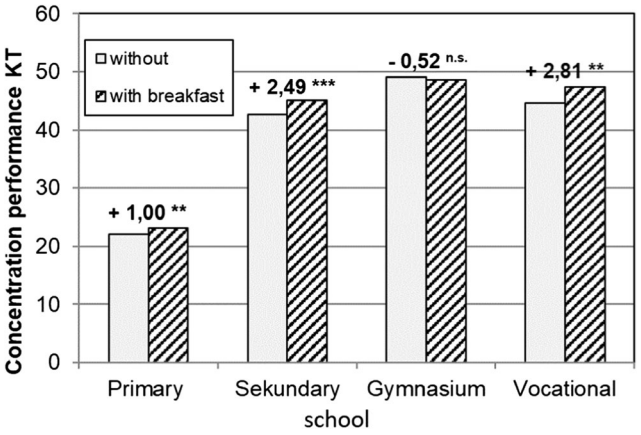

Fig. 6 KT 3-4 R concentration performance: Comparison of school levels (without breakfast in the first break compared with consumption; all test foods; $n = 659$)

Discussion

Influence of methodology

Particularly in the USA many studies exploring the impact of breakfast have been conducted. The results show a predominantly positive influence on the mental performance conferred by previous breakfast consumption. The comparability of the different studies however is low because of the very different food selections in the different countries. Frequently different cereals were used as were wafers with syrup, muffins, small cakes, eggs with bacon, cheese, toast, sandwiches and other bread types. Beverages included fruit juices, milk and milk-like beverages, cocoa or lemonade. Some studies emphasised different nutrient compositions of the breakfasts, including the sugar, fat or carbohydrate content, or compared foods with different glycaemic indexes (Adolphus et al. 2013, 2016; Terschlüsen et al. 2010; Rampersaud et al. 2005; Hoyland et al. 2009). The four existing German studies used a test breakfast consisting primarily of whole-grain bread, fruits and vegetables, milk products and mineral water (Eissing 2011; Widenhorn-Muller et al. 2008; Genz 2007; Wagner et al. 2011). The assigned tests for the measurement of mental performance show large differences as well.

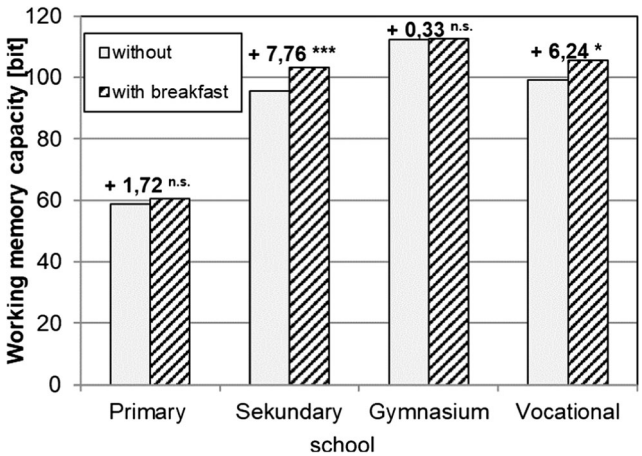

Fig. 5 Work memory capacity: Comparison of school levels (without breakfast in the first break compared with consumption; all test foods; $n = 659$)

The selection of the test subjects is very different and affects the results. The test subjects were predominately adolescents in secondary schools (Adolphus et al. 2013). In the previous studies from Germany, for example, only pupils from secondary schools were included. This study includes a wide range from class 3 to 12 (age 9 to 19 years) using a comparable method.

This study examined the influence of several factors that affect the efficacy of breakfast on mental performance with a uniform investigation design: An important factor is the age, since it has a large influence on nourishing behaviour. Further, this study takes into account the socio-economic status (SES) and different food compositions.

In summary, the results of this study prove that a breakfast in the first large break positively affects the mental performance of children and young people. The effect is present for each age, at primary schools too, and becomes more pronounced with increasing age of the pupils.

The results in Figs. 1 and 2 (comparison of school grades) and Figs. 5 and 6 (comparison of school levels) show the validity of the tests used, KAI and KT 3-4: As the working memory capacity is an indicator of intelligence, the increase follows the school grades and types, as expected. Although it was not the target of this study, this underlines the validity of the results, i.e., the increase of cognition conferred by the school breakfast for each age.

Because of the number of pupils, the validity is higher for younger (primary school) than for older pupils. The requirements of the test were too high for some pupils on certain days so that they could not demonstrate an acceptable test performance. As was obvious, one could exclude these results. All tests were performed as group tests. Therefore, it was not

possible to observe the test performance of all pupils. This results in a higher variation of test performance. The strength of this study is that the same procedure was used for all types of food and ages of pupils, providing high comparability and a high evidence level of the results.

Influence of the studied food

The food selection is important because of the acceptance required to achieve improved mental performance following nutritional recommendations. The study showed this experience when using a mix of nuts and raisins as the test food: Primary school pupils did not eat it, or just some of it (no raisins), because of neophobia. Thus, no performance improvement resulted. The pupils in the 9th grade achieved a performance increase, which was expected because of the laboratory tests (Wagner 2017) for the glycaemic index. The problem of unacceptability also arose when offering cereal to primary school pupils. For countries with different eating cultures and for different age groups, different recommendations can be necessary. Recommendations have to take the eating habits of the respective target group into consideration. Different eating cultures reduce the transferability of the results between different countries.

The nutrient composition of the breakfast greatly influences the effect on mental performance. Not only the quantity of the supplied carbohydrates is important, but also the lasting effect over a longer period of time because of the nutrient composition. Consuming fat as part of the breakfast proved important because it slows down the metabolism. This effect can be seen for example in the comparison of the test breakfasts with fruits and vegetables (12.2 g carbohydrate supply) with the test food milk (10.2 g) or chocolate drinks (22.5 g). Although a breakfast with fruits and vegetables provides 2 g more carbohydrates than milk, it causes no significant improvement of the mental performance. In contrast, milk and, even more strongly, chocolate drinks improve mental performance because of the combination of carbohydrates and the fat components in the milk. Also regarding the nut and raisin mix, the fat portion in the nuts leads to a lasting improvement of the mental performance.

Influence of the first breakfast at home

The quality of the breakfast at home before the start of school was measured. The effects of this breakfast will be analysed for the pupils in the primary school (grades 3 and 4) and the 9th grade of the secondary level school, since over 100 pupils are included in these grades in each case group. Seventy per cent of primary school pupils had breakfast at home and 50% of the older pupils. This finding is consistent with new studies on the breakfast behaviour of German school children. Kesztyüs et al. (2017) and Kuntz et al. (2017) show that eating breakfast at home decreases with age.

Breakfast at home clearly gives the highest test values for mental performance. The mental performance of all tested pupils who had breakfast at home is consistently higher than that of pupils without breakfast at home (Tables 4 and 5). For the condition "no breakfast in the first break (B2)", the difference is more than twice as large as for the condition "with breakfast in the first break (B3)". Breakfast at home has a large effect on mental performance, which was measured in the 4th school hour. If pupils have had no breakfast at home or at school up to this time, the mental performance is clearly reduced.

The improvement of the mental performance conferred by the test breakfast at school is more pronounced in the 9th grade than in the primary school. This is based on the breakfast behaviour of the test subjects: The older they are, the more rarely and irregularly they have breakfast at home before school. Because primary school pupils eat breakfast regularly before school, they are less sensitive to skipping breakfast in the first large break compared with pupils in secondary schools.

Table 4 Comparison of test results of mental performance of primary school pupils with and without breakfast at home (PS, primary school; B2, no breakfast in the break; B3, breakfast in the break)

		PS without breakfast at home				PS with breakfast at home				
Test parameter	Condition	n	Mean	SD	Sig.	n	Mean	SD	Sig.	Delta with_without breakfast
KAI Work memory capacity (bit)	B2	104	60.1	20.5	ns	238	62.4	20.3	ns	2.3
	B3	104	63.1	20.8		238	63.5	21.8		0.4
KT Total correct answers	B2	104	77.2	28.4	0,009	238	81.1	28.5	0.022	4.0
	B3	104	82.1	28.0		238	84.1	30.4		2.0
KT Total number cubes	B2	104	80.3	29.3	0,006	238	84.5	28.7	0.028	4.3
	B3	104	85.7	28.7		238	87.5	31.0		1.8
KT Concentration performance	B2	104	23.1	9.4	ns	238	24.1	9.6	0.021	1.0
	B3	104	24.1	9.6		238	25.0	10.0		0.9

Table 5 Comparison of test results of the mental performance for secondary level school with and without breakfast at home (Cl., class; B2, no breakfast in the break; B3, breakfast in the break)

Test parameter	Condition	Cl. 9 Without breakfast at home				Cl. 9 With breakfast at home				Delta with_without breakfast
		n	Mean	SD	Sig.	*n*	Mean	SD	Sig.	
KAI Work memory capacity (bit)	B2	92	98.8	24.8	0.024	93	104.3	25.8	ns	5.5
	B3	92	104.3	28.6		93	107.9	26.0		3.6
KT Total correct answers	B2	92	149.3	35.1	0.000	93	159.8	35.2	ns	10.5
	B3	92	158.0	32.6		93	159.5	32.1		1.5
KT Total number cubes	B2	92	154.2	35.3	0.000	93	163.8	35.7	ns	9.6
	B3	92	162.6	33.4		93	163.3	32.6		0.7
KT Concentration performance	B2	92	44.5	11.3	0.001	93	48.1	11.1	ns	3.6
	B3	92	47.3	9.8		93	48.2	9.6		0.9

For both groups (with/without breakfast at home), breakfast in the first break leads to a significant improvement of the mental performance, as has been shown before. Only for 9th grade pupils (Table 5) did the breakfast at school cause no further significant increase of the mental performance in case of eating breakfast at home. In addition, the mental performance of pupils who had breakfast in the morning at home improves with an additional breakfast in the school break compared with the pupils without breakfast at home. These results agree with the investigation of Lozano and Ballesteros (2006), who identified a better final grade at the end of the 7th grade with improved quality of the breakfast at home. On the other hand, Dickie and Bender (1982) could not find improvements of mental performance for pupils in the 7th and 9th grades when they ate breakfast at home and at school.

Further evaluation regards whether the moderator variables influence the effects (statistical procedure: multivariate ANOVA). The influence of SES is proven, for example, on nutrition (Adolphus et al. 2013) and on children being overweight (Eissing and Düsterhaus 2015). The evaluations of this study show that the SES factor significantly affects the absolute height of the working memory capacity and concentration performance. The improvement of mental performance by eating breakfast has however no significant interaction with the SES factor. Also the inclusion of a further factor such as eating breakfast at home as a second influence variable leads to no improvement of the statistical model. In particular, no interaction effect exists between these factors. This means that eating breakfast at school is effective for all SES levels, also for children from high social levels. Furthermore, the interaction effect between the class level and eating breakfast at home factors was examined. No significant interaction effect was determined here. Thus, from the results of this study, the conclusion can be reached that the improvement of mental performance is effective on all class levels.

Conclusions

This study clearly shows that breakfasts, both at home and in school, contribute to an increase of pupils' mental performance in primary and secondary schools. Eating breakfast at home has a greater effect on mental performance than eating it at school. It is difficult to get families to change and eat breakfast using educational measures (Molderings and Eissing 2006a), however. The offer of a school breakfast in the first break leads to a significant improvement in mental performance and can be recommended as a public measure. Due to the poor home breakfast habits of young people in secondary schools, offering a school breakfast is highly recommended as a very effective instrument for improving mental performance.

Compliance with ethical standards

Conflict of interest No conflict of interest.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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