Journal of Education and Human Development
September 2016, Vol. 5, No. 3, pp. 68-79
ISSN: 2334-296X (Print), 2334-2978 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/jehd.v5n3a8
URL: https://doi.org/10.15640/jehd.v5n3a8

Effects of Different Functions of Attention on School Grades in Primary School Children

Panayiota Metallidou[1], Amaryllis-Chryssi Malegiannaki[2], Konstantinopoulou Eleni[3], & Grigoris Kiosseoglou[4]

Abstract

The present study aimed at exploring the effects of distinct attention functions on school grades in primary school children. The sample consisted of 208 Greek primary school children (2nd up to 6th grade) of both genders. The participants were examined individually with the Test of Attentional Performance for Children (KITAP). KITAP is a non-verbal computerized test battery designed to assess a variety of attention functions in children (e.g., selective, divided, sustained attention, flexibility). Performance in Language, Mathematics and Average mean performance was rated by the teachers. Vocabulary and working memory measures from WISC were used as control variables. The hierarchical regression analyses results provide empirical evidence for the a unique contribution of distractibility, alertness, sustained attention, divided attention, and inhibitory control scores to school grades after controlling for the effect of gender and verbal intelligence scores. Attention errors, omissions of critical stimuli, and variability scores were found to be the most sensitive indices for predicting school grades. Educational implications are discussed.

Key Words: Attention functions, primary school children, KITAP, school grades.

1. Introduction

The role of attention in academic achievement has been attracted recently a growing research interest, given that attention is considered as the key underlying system for the initiation and successful application of basic cognitive processes that are strongly associated to academic achievement, such as memory, learning and self-regulation of emotion and behavior (Posner and Rothbart 2005). The role of attention in academic achievement has been studied, mainly within the executive functions (EF) tradition (e.g., Best et al. 2011; Bull and Scerif 2001; Checa and Rueda 2011; Fuhs et al. 2014; Lan et al. 2011; Müller et al. 2008; Visu-Petra et al. 2011), or the attention problems and deficits/hyperactivity disorders (ADHD) tradition (e.g., Birchwood and Daley 2012; Barry et al. 2002; DuPaul et al. 2004, for a review see Polderman et al. 2010). In most of these studies, however, attention was examined either as a unitary skill (e.g., inhibition control or flexibility), which was part of a more broad category of EF skills, or as symptoms of hyperactivity and inattentiveness, based on parents', teachers' and clinicians' behavioral checklists and questionnaires.

According to contemporary neuropsychological models attention is not a unitary construct but constitutes a rather complex and multidimensional system consisting of several functions or components or processes (see Cohen 1993; Mirsky et al. 1991; Riccio et al. 2001).

[1] School of Psychology, Aristotle University of Thessaloniki
[2] School of Psychology, Aristotle University of Thessaloniki
[3] School of Psychology, Aristotle University of Thessaloniki
[4] School of Psychology, Aristotle University of Thessaloniki

Most of these models support the subdivision of the attention system into three major distinct processes or functions, which are selective attention (i.e., to select the task-relevant stimuli and suppress distractors), sustained attention (i.e., to maintain the focus of attention over an extended period of time) and shifting and divided attention (i.e., attention control, redirect the focus of attention and respond to more than one task at the same time) (see Kelly 2000; Riccio et al. 2001). A different conceptualization of attention has been proposed by van Zomeren and Brouwer (1994), who support the distinction between selectivity (i.e., focused and divided attention) and intensity (i.e., alertness and sustained attention) aspects of attention as well as a supervisory attentional control system. Despite the use of various names and conceptualizations of attention, distinct attention neurofunctional networks are evident even from childhood (see Rueda et al. 2004). Though, the empirical evidence for the association of different functions or components of attention with academic achievement is very limited. Research in healthy school age population which examines the impact of various functions or components of attention on academic achievement and domain-specific cognitive abilities is a relatively new research area (e.g., Commodari and Di Blasi 2014; Steele et al. 2012). Within this framework, the present study aimed at providing empirical evidence for the contribution of distinct attention functions on primary school children's school grades. It is focused on primary school children as this period is characterized by rapid changes in attention functions according to literature and, thus, the role of attention in academic learning and achievement may be critical (e.g., Rueda et al. 2004; Vakil et al. 2009).

1.1. Attention and Academic Performance

Research evidence within the EF tradition has consistently shown that individual differences in aspects of executive attention skills are significantly related to academic performance. Most of these studies were conducted in preschool children. Specifically, there is longitudinal evidence from preschool children for strong bidirectional associations among various EF skills and achievement in mathematics (Fuhs et al. 2014). Further, evidence from preschool and early primary school children indicated the unique contribution of inhibition to the emerging academic skills (math abilities and lexical access) controlling for the effect of chronological age and language skills (Roebers et al. 2011). There is cross-cultural evidence as well for the predictive value of inhibition and attention control for achievement. Namely, attention control was found to predict most aspects of achievement in mathematics and reading tasks, while inhibition predicted aspects of mathematics (e.g., counting) in Chinese and American preschoolers (Lan et al. 2011). Inhibition was found to consistently predict achievement in reading and mathematics in primary school children (e.g., Bull and Scerif 2001; St. Clair-Thompson and Gathercole 2006) with inhibition and shifting to predict school performance in primary and junior high school children (Visu-Petra et al. 2011). Further, effortful control and executive attention (measured as selection of the appropriate response and suppress of interfering incongruent responses) were found to predict average school grades and math grades in early adolescence (Checa and Rueda 2011).

As regards the evidence from the attention deficits/hyperactivity disorders (ADHD) tradition, academic underachievement has been consistently associated with attention problems and attention deficits/hyperactivity disorders (for a review see Polderman et al. 2010). ADHD symptoms were found to be as significant predictors of adolescents' school grades as motivation and cognitive abilities (Birchwood and Daley 2012). Further, the more severe the reported by parents' ADHD symptoms the stronger their predictive value was found for academic underachievement in reading, writing and mathematics controlling for intellectual abilities (Barry et al. 2002).

Attention skills, as measured by teachers' and parents' ratings as well as by behavioral observations, were found to explain part of the variance of academic performance (see Muris 2006) and were among the strongest predictors of later academic achievement (Duncan et al. 2007). In Duncan et al. (2007) meta-analysis of six longitudinal data sets has shown that the strongest predictors of later achievement are school entry in math, reading and attention skills and the pattern of the associations was similar in both genders and in children from various socioeconomic backgrounds. The predictive role of attention skills was significant even after controlling for other significant predictors (see also Fergusson et al. 1997). Further, the role of attention skills was found even more important in the academic performance of aggressive/rejected children who are at risk for school problems (Wilson et al. 2011). Recently, Steele et al. (2012) provided empirical evidence for the differential impact of various functions of attention on concurrent and longitudinal abilities related to literacy and numeracy in 3 to 6 years old.

They measured children's sustained attention (using a Continuous Performance Task), selective attention (Visual Search task), and executive attention (Spatial Conflict Task). They also had teacher ratings for children's inattention and hyperactivity. The results have shown the differential contribution of the above functions of attention to children's abilities. Namely, the executive attention factor predicted significantly early literacy and numeracy abilities, while the sustained-selective attention factor predicted basic numeracy one year later. Commodari and Di Blasi (2014) examine in a cross-sectional study the role of different components/functions of attention on calculation skill in primary school years, using standardized measurements for assessing various components of attention and calculation skills. The results have shown an increasing role of attention on calculation competence during primary school years. In fifth grade attention predicted all the components of calculation skill. Specifically, attentive activity rate, that is response time in attention tasks, was the attention component that predicted significantly all aspects of calculation skill.

1.2. The present study

Given the limited research evidence for the contribution of distinct attention functions to children's academic performance, the present study aimed at providing such empirical evidence from primary school children. Attention was examined with KITAP (Test of Attentional Performance for Children; Zimmermann et al. 2002), a computerized test battery designed to assess a variety of attention functions in children based on van Zomeren and Brower's (1994) conceptualization of attention. The main advantage of the test is that it consists of non-verbal subtests that assess children's performance in diverse functions of attention and it is presented in a child-friendly way (see Method). Moreover, the test offers information about speed of processing and possible attenuations as well as about lapses of attention and attention errors, and more important it allows the registration of even the minimal variation in reaction time and variability, permitting, thus, a precise measurement of actual behavior.

KITAP has been proved a valid tool to discriminate clinical populations experiencing attention deficits, e.g. children with ADHD (Kaufmann et al. 2010), children exposed to lead (Nicolescu et al. 2010), and children who received a liver transplant (Kaller et al. 2010). However, research in healthy participants is limited. To our knowledge, only two developmental cross-cultural studies exist comparing the attention performance of Syrian and German pre-school and school-aged children (Sobeh and Spijkers 2012, 2013). Both studies confirmed its sensitivity in detecting age-related changes. Also, there is one study that examined the relationship between the performance of 61 German primary school children (6–10 years) in KITAP and school grades in German Language and Mathematics (Trautmannn and Zepf 2012). Only lapses of attention have shown significant correlations with children's grades in German language. Given the small number of participants in the above study, the sensitivity of each score provided by KITAP in predicting school grades variations is still an open issue.

Teachers' ratings were used for school performance in Language, Mathematics and average performance, as a more ecologically valid measure of children's academic performance. Also, Vocabulary and Digit Span subtests from the standardized WISC-III for Greek population (Georgas et al. 1997) were administered, as control variables. The Vocabulary subtest was chosen due to its high correlation with the general IQ score (Jensen 2001). The inclusion of Digit Span was due to its possible involvement in the KITAP tasks that require counting and working memory. It was hypothesized that performance on various attention functions would have a unique significant contribution to school performance variations, even after controlling for other significant contributors, namely intelligence-related measures and gender (for a meta-analysis of gender differences in academic performance see Voyer and Voyer 2014). Age-related differences in school performance were not expected. Given the lack of previous evidence, it is still an open question which specific functions of attention would have the greatest impact on school grades, as well as which kind of the attention measures provided by the KITAP (i.e., median scores, standard deviation, errors or omissions) would be the most sensitive indices for predicting school grades.

2. Method

2.1. Participants

The sample consisted of 208 primary school children from second (N = 60, Mean age in months = 92.15, SD = 4.26), third (N = 58, M = 103.34, SD = 3.67), fourth (N = 56, M = 115.79, SD = 4.46), fifth (N = 19, M = 125.95, SD = 3.69) and six grade (N = 15, M = 138.47, SD = 3.52).

Both genders (N = 104 boys) and different socioeconomic statuses (SES), based on father's educational level and profession, were represented in the sample (Low SES: 11.4%, Medium: 48.6%, High: 37% and 3% missing data). Children with referrals for attention or specific learning difficulties or needs for special education were excluded from the present study.

Children were recruited from different public primary schools, which were randomly selected from various areas in the Prefecture of Thessaloniki in Northern Greece, in order to collect data from different educational environments and geographical areas (West, East and Center areas of Municipality of Thessaloniki, provinces, and villages). The present study was approved by the Greek Ministry of Education and Lifelong Learning and all parents signed informed consent.

2.2. Measures

Attention functions. The participants were examined individually with KITAP (Test of Attentional Performance for Children; Zimmermann et al. 2002). KITAP is a German computerized test battery designed to assess a variety of attention functions in children presented in a child-friendly way (an enchanted castle is presented and the child is required to respond to various tasks with the instruction to be as accurate and quick as possible). It consists of non-verbal subtests assessing children's performance in 8 attention functions: Alertness, Distractibility, Divided Attention, Flexibility, Go/NoGo-Inhibition control, Sustained attention, Vigilance and Visual Scanning. Performance on these tasks can be interpreted by the following parameters: (a) reaction time in medians, which provides information about speed of processing and possible attenuations, (b) standard deviation of reaction times, which provides information about the stability or instability in the level of performance and high instability may be interpreted as lapses of attention, (c) errors (incorrect responses to critical stimuli), and (d) omissions (missed responses to critical stimuli). In the present study, participants were not examined with the Vigilance sub-test due to its long duration (15 minutes). Instead, the administration of the Sustained Attention subtest was assumed as a sufficient measurement of one's ability to maintain attention for a prolonged period of time (10 minutes). Placing further demands on children's ability to sustain attention would not contribute to the goals of this study. Permission was obtained from Psytest© for both the translation of KITAP instructions into Greek and administration of the software for research purposes.

Specifically, in the present study were used the following 7 subtests of KITAP (for a detailed presentation see Zimmermann et al. 2002):

1. *Alertness* (The witch): Is a simple reaction time task that assesses general arousal. On each trial the child had to chase a witch as quickly as possible by pressing an external key (1.5 minutes).
2. *Distractibility* (The Sad and the Happy Ghost): A visual attention task in which the centrally presented target stimulus (cheerful or happy ghost) was surrounded by other distracting stimuli, which had to be ignored. In half of the tasks the distracting stimulus appears shortly before the central stimulus. The child was asked to press as quickly as possible the key only when a sad ghost appears. The presence of the distracting stimulus results in omissions of the critical stimulus or in false alarms (3 minutes).
3. *Divided Attention* (The Owls): A visual-acoustic dual-task in which the child was required to simultaneously respond to critical visual stimuli (the owl closes its eyes) or acoustic stimuli (two successively high or low presented hoots appeared) by pressing the key (4.5 minutes).
4. *Flexibility* (The Dragon's House): the task assesses the ability to redirect or to switch the focus of attention when the target stimuli alternate. The child had to alternate successively attention between two dragons of different color (green and blue), which appeared on the left and right side of a center gate. In the beginning the child had to start by pressing the key on the side at which the green dragon appears. On the next trial the critical stimulus was the blue dragon. In cases of false response, an acoustic feedback was provided to the child and in the subsequent trial the correct stimulus was shown (1 up to 2 minutes).
5. *Go/No-Go* (The Bat): It examined inhibitory control based on the go/no-go paradigm in which the child was required to press the key as quickly as possible every time a 'go' stimulus appeared (the bat) and avoid to press the key every time a 'no-go' stimulus appeared (the cat) (4.5 minutes).
6. *Sustained Attention* (The Ghosts' Ball): An effortful task of maintaining attention for an extended period of time in which ghosts of different colors appeared consecutively at different windows of a castle ruin.

Children were asked to press the key as quickly as possible they detected two ghosts with the same color appearing consecutively (10 minutes).

7. *Visual Scanning* (The Witches' Parade): A selective attention task in which the child was required to scan on each trial a group of witches flying on their brooms in one direction as quickly as possible and to mention by a key press whether there is a witch flying in the opposite direction (10 to 12 minutes).

School Performance. Performance on Language, Mathematics and Average mean performance were rated by the teachers of each class on a 10-point scale from 1 (very low performance) to 10 (excellent performance) for each child. The 10-point scale corresponded to the Greek primary school grading system (10 is the highest school grade).

2.3. Procedure

Students participated voluntarily after being informed about the purpose of the study and assured that it was an anonymous research and that none, except the researchers, would had access to their performance. In order to assure their anonymity, they did not report their name and gave information only about their gender, age, parental educational level and profession. Also, students reported the number of their alphabetical order in the class, enabling the researchers to match students' in-lab performance with their teachers' in-class performance ratings. Teachers assigned ratings for each student using a code number corresponding to the student's alphabetical order in the classroom. After all parents signed an informed consent, the students were assessed individually in a quiet room in their schools with the 7 subtests of KITAP and the Vocabulary and Digit span subtests from the WISC-III by experienced psychologists, trained in test administration and scoring. Latin square was used in order to present each subtest in a random order to avoid sequencing effects. Data collection started in February and lasted for about four months, until the end of the school year.

3. Results

3.1. Correlations

Prior to the examination of the associations between attention and school performance, correlations of attention and school grades with age and verbal intelligence measures were applied. Transformations (*log10* and *SQRT)* of KITAP raw values were applied where necessary, in order to correct for normality requirements according to relevant literature criteria (De Carlo 1997). All the values of Skewness and Kurtosis but one were below 2 after the transformations (more specifically, Skewness ranged from .001 to 1.238 and Kurtosis from -.924 to 2.077). Table 1 presents the respective correlation coefficients. As regards the correlations between age and attention scores in each sub-test, significant negative correlations were found in most of the cases. As expected, the older the participants the less errors and omissions they did and the lower median reaction scores and standard deviations they had. School grades were not found to correlate significantly with age.

In the next step, partial correlations between working memory, vocabulary and attention scores were applied, controlling for the effect of the age. As can be seen in Table 1, above one third of the correlations were not found significant and the rest were significant, although weak in most of cases, indicating the divergent validity of the KITAP as a measure of attention and not of intelligence-related measures. Next, the correlations between school grades and both intelligence scores were found significant in all the cases in the expecting direction.

Given the significant correlations that were found between age and attention scores and between school performance and intelligence scores, Pearson correlations between the attention scores and school performance, controlling for the effect of the age and intelligence measures, were applied. Table 2 presents the respective correlation coefficients and the mean attention performance scores in each task. As can be seen in Table 2, the scores in specific functions of attention were found to correlate significantly with school performance. Specifically, errors, omissions and standard deviations in performance in most of the attention tasks, except of two, significantly correlated with school grades in the expected negative direction. Only performance on Visual Scanning and Flexibility tasks did not correlate significantly with school performance. Also, median reaction times in all the tasks did not correlate significantly with school grades.

Table 1: Correlations coefficients between KITAP scores, school grades (z scores), age (in months), and Vocabulary and Digit Span scaled scores.

		Age	Vocabulary	Digit Span
KITAP scores				
Distractibility	Omissions	-.14	.05	-.09
	Errors	-.21**	-.15*	-.02
	RT	-.17*	-.06	-.15*
	SD	-.18**	-.10	-.08
Alertness	RT	-.25***	-.05	-.21**
	SD	-.18**	-.19**	-.19**
Sustained attention	Omissions	-.12	-.23**	-.17*
	Errors	-.18*	-.22**	-.04
	RT	-.30***	-.07	-.15*
	SD	-.25***	-.16*	-.07
Flexibility	Errors	-.22**	-.16*	-.04
	RT	-.40***	-.17*	-.22**
	SD	-.39***	-.23**	-.23**
Divided attention	Omissions	-.10	-.17**	-.17**
	Errors	-.07	-.31***	-.21**
	RT	-.38***	.02	-.07
	SD	-.05	-.15*	-.10
Go / no Go	Errors	-.17	-.09	.05
	RT	-.26***	-.09	-.19**
	SD	-.15*	-.18*	-.15*
Visual scanning	Omissions	-.11	-.26**	-.16*
	Errors	-.02	-.06	-.03
	RT	-.19**	.18*	.17*
	SD	-.30***	-.17*	-.08
School Grades	Language	-.01	.28***	.30***
	Mathematics	-.09	.36***	.36***
	Average	-.06	.36***	.37***

Notes: Omissions = omissions in performance, Errors = performance errors, RT = reaction time (medians in ms), SD = standard deviation of reaction times. *p* * < .05, ** <.01, *** <.001

Table 2: Partial correlations coefficients between KITAP scores and School grades (z scores) after being controlled for age (in months) and verbal intelligence scaled scores.

		Academic Performance		
KITAP subtests' scores		Language	Mathematics	Average
Distractibility				
Omissions	(3.86)	-.15*	-.09	-.11
Errors	(15.66)	-.12	-.16*	-.10
RT	(463.76)	.08	.08	.05
SD	(325.05)	-.26***	-.16*	-.23***
Alertness				
RT	(333.51)	-.03	-.02	-.05
SD	(81.45)	-.15*	-.12	-.18*
Sustained attention				
Omissions	(7.43)	-.15*	-.14*	-.16*
Errors	(12.13)	-.16*	-.13	-.13
RT	(657.13)	.12	.12	.08
SD	(188.04)	-.02	.01	-.04
Flexibility				
Errors	(2.79)	-.08	-.10	-.09
RT	(1000.33)	-.03	-.04	-.05
SD	(358.64)	-.06	-.04	-.08
Divided attention				
Omissions	(5)	-.17**	-.20**	-.24***
Errors	(10.18)	-.15*	-.20**	-.18**
RT	(744.62)	.05	.02	.01
SD	(261.82)	-.15*	-.20**	-.19**
Go / no Go				
Errors	(3.57)	-.25***	-.16*	-.21**
RT	(466.94)	.10	.08	.06
SD	(117.32)	-.04	-.01	-.03
Visual Scanning				
Omissions	(9.84)	-.06	-.01	-.07
Errors	(3.24)	.06	.01	.05
RT	(8169.17)	-.01	-.08	-.01
SD	(2883.17)	.04	-.00	-.03

Notes: Omissions = omissions in performance, Errors = performance errors, RT = reaction time (medians in ms), SD = standard deviation of reaction times, p * < .05, ** <.01, *** <.001.

Hierarchical regressions results

In order to examine the effect of performance in each function of attention on school grades, a series of hierarchical regression analyses were implemented. Separate analyses were applied for each function of attention and for each parameter within each attention sub-test. Namely, for the Distractibility task four separate analyses were applied, one for each parameter of the task (omissions, errors, reaction time and standard deviation). In each analysis gender and intelligence measures (Vocabulary and Digit span) were included as control variables, the score in each KITAP subtest parameter as predictor and grades in Mathematics, Language and Average school performance as dependent variables. Also, separate analyses were applied for school grades in each subject. Gender was introduced as a control variable, since there were found significant gender differences in participants' school grades in Language and Average performance in favour of girls, which is rather common evidence in primary school settings. Teachers' rated higher the performance of girls in Language ($F(1,207) = 12.86$, $p < .001$, $M_{girls} = 9.01$, $SD = 1.03$ and $M_{boys} = 8.35$, $SD = 1.58$) and in Average mean performance ($F(1,207) = 5.90$, $p < .05$, $M_{girls} = 9.08$, $SD = .98$ and $M_{boys} = 8.67$, $SD = 1.38$). Table 3 presents the results of the regressions analyses in cases that attention scores were found to be significant predictors of school grades.

Gender was found to be a significant predictor of grades in Language (R^2 = .059, p < .001) and of Average mean performance (R^2 = .028, p < .05). Both verbal intelligence measures were found to predict a significant part of the variation of school grades in all the school subjects above the effect of gender, as expected. Both intelligence measures had a significant contribution. Namely, vocabulary was a significant predictor of school performance even after controlling for the effect of gender and of working memory (ΔR^2 = .031, p < .01 for Language, ΔR^2 = .056, p < .001 for Mathematics, and ΔR^2 = .052, p < .001 for Average mean performance).

Finally, attention errors, omissions of critical stimuli, and attention standard deviation measures had a unique contribution on school performance after being controlled for gender and intelligence measures, while the effect of median attention scores wasn't found significant. Specifically, attention scores on distractibility, alertness, sustained attention, divided attention, and inhibitory control were found to be significant predictors of grades in all the school subjects. Among the most important predictors of grades in Language were: the standard deviation of reaction times in the task that measures distractibility (ΔR^2 = .048, p < .001), omissions of critical stimuli in the divided attention task (ΔR^2 = .032, p < .01), and errors in the inhibition control task (ΔR^2 = .034, p < .01). As regards performance in Mathematics, the most significant predictor was the performance on the divided attention task (ΔR^2 = .035, p < .01 for errors, ΔR^2 = .034, p < .01 for omissions, and ΔR^2 = .033, p < .01 for standard deviation of reaction times). Finally, the omissions in the divided attention task were the strongest predictor of Average mean performance (ΔR^2 = .030, p < .001). The same attention scores predicted significantly the Average school performance.

Table 3: Results of regression analyses for the prediction school achievement using Gender, Digit Span, Vocabulary and Attention as predictors.

	R^2	ΔR^2	ΔF	β
Language				
Model 1: Gender	.059***			.242
Model 2: Gender + Digit Span	.165	.106	26.034***	.327
Model 3: Gender + Digit Span + Vocabulary	.196	.031	7.888**	.195
Model 4: Gender + Digit Span + Vocabulary +				
+ Distractibility SD	.224	.048	12.886***	-.223
+ Alertness SD	.217	.021	5.423*	-.147
+ Sustain Attention Errors	.215	.019	4.85*	-.141
+ Sustain Attention Omissions	.216	.021	5.324*	-.147
+ Divided Attention Errors	.218	.022	5.843*	-.157
+ Divided Attention Omissions	.228	.032	8.313**	-.180
+ Divided Attention SD	.216	.020	5.146*	-.142
+ Go / No Go Errors	.230	.034	9.099**	-.193
Mathematics				
Model 1: Gender	.009			.094
Model 2: Gender + Digit Span	.142	.133	31.775***	.366
Model 3: Gender + Digit Span + Vocabulary	.197	.056	14.121***	.261
Model 4: Gender + Digit Span + Vocabulary +				
+ Distractibility Errors	.214	.017	4.366*	-.133
+ Distractibility SD	.213	.016	4.007*	-.127
+ Sustain Attention Omissions	.213	.016	4.148*	-.130
+ Divided Attention Errors	.233	.035	9.313**	-.197
+ Divided Attention Omissions	.231	.034	8.934**	-.186
+ Divided Attention SD	.230	.033	8.675**	-.183
Average Performance				
Model 1: Gender	.028*			.167
Model 2: Gender + Digit Span	.174	.146	36.153***	.383
Model 3: Gender + Digit Span + Vocabulary	.226	.052	13.691***	.252
Model 4: Gender + Digit Span + Vocabulary +				
+ Distractibility SD	.260	.034	9.330**	-.188
+ Alertness SD	.248	.023	6.089*	-.153
+ Sustain Attention Omissions	.246	.020	5.428*	-.145
+ Divided Attention Errors	.254	.028	7.683**	-.176
+ Divided Attention Omissions	.276	.050	14.020***	-.227
+ Divided Attention SD	.256	.030	8.191**	-.175
+ Go / No Go Errors	.251	.025	6.835**	-.165

p * < .05, ** <.01, *** <.001.

4. Discussion

The aim of the present study was to provide empirical evidence for the contribution of distinct attention functions to primary school children's school grades. Attention skills were examined with KITAP, a non-verbal computerized test battery designed to assess various attention skills in children presented in a child-friendly way. Academic performance in Language, Mathematics and Average mean performance was rated by the teachers of each class on a 10-point scale for each child. Gender, vocabulary and working memory measures from WISC-III were used as control variables. It was hypothesized that scores on the attention subtests would have a unique significant contribution to academic performance variations, even after controlling for verbal intelligence measures and gender. The question, though, to be answered was which specific functions of attention would have the greatest impact on school performance, as well as which kind of the attention scores provided by the KITAP (i.e., median scores, standard deviation, errors or omissions) would be the most sensitive indices for predicting school performance. Starting the discussion from the role of the control variables used in the present study, the initial correlation analyses showed that the vocabulary and working memory scores were correlated significantly with school grades in all the school-subjects in the expected positive direction. Further, the results of the hierarchical regressions have shown that working memory and vocabulary were the most significant predictors of school performance having each of them a unique significant contribution, which is a rather expected evident. Concerning the effect of gender, the initial mean-level differences analyses indicated significant gender differences in performance in Language and Average mean performance in favor of girls, which is again a rather consistent evidence in primary school, especially for Language (for a meta-analysis of gender differences in academic performance see Voyer and Voyer, 2014). Gender differences in grades in mathematics were not found significant. Similar male and female performance in mathematics was also supported by Lindberg et al. (2010) in their meta-analysis of gender and mathematics performance. In the respective regression analyses gender was found to be a significant predictor of performance mainly in Language, while its contribution on Average school performance was smaller as compared to Language, though still significant.

As regards the predictive value of attention skills, the results confirmed at a large extent the main hypothesis of the present study, by providing empirical evidence for the unique contribution of attention scores to school performance, above the significant effect of intelligence measures and gender. More specifically, performance scores in all the attention functions assessed by the KITAP, except flexibility and visual scanning scores, were found to be significant predictors of school grades. In addition, almost the same attention scores predicted performance in all the school subjects. Namely, distractibility, sustained attention, and divided attention scores had a significant unique contribution on performance in Language, Mathematics, and Average performance, while alertness and inhibitory control scores significantly predicted performance in Language and Average mean but not in Mathematics. The above results comply with previous evidence from different research traditions, which indicate the unique predictive value of attention skills for academic performance even after controlling for other significant predictors (e.g., Duncan et al. 2007; Fergusson et al. 1997; Muris 2006; Roebers et al. 2011).

The present results also extend previous evidence by demonstrating that distinct functions of attention are important predictors of school grades. More specifically, both selectivity and intensity aspects of attention were found to predict a unique variance of school performance. The most effortful aspects of attention, that is sustained and mainly divided attention, were found to explain a significant part of variance of both subject-specific and average school grades, while the ability to select the task-relevant stimuli and ignore distracters was found to predict a greater part of performance variation in Language and Average mean as compared to performance in Mathematics. Further, inhibition control was found to predict performance in Language and Average mean performance but not in Mathematics, contrary to previous evidence from primary school children that support its predictive value not only for reading but for mathematics as well (Bull and Scerif 2001; St. Clair-Thompson and Gathercole 2006). The above mentioned studies, however, used achievement tests and not teachers' ratings. Future research could provide further information about this issue. Finally, flexibility and visual scanning scores did not have a significant contribution to school performance, a result that may be due to task-specific characteristics as regards their cognitive load and needs further investigation. It is worth mentioning that the above result is in accordance with recent evidence from a study aimed at assessing the diagnostic utility of the same KITAP attention functions in discriminating primary school children diagnosed with ADHD from typically developing children. The results indicated that the scores on flexibility and visual scanning tasks did not contribute significantly to group discrimination (Kaufmann et al. 2010).

The second contribution of the present results is that they provide evidence for the sensitivity of various attention scores provided by the KITAP (i.e., median scores, standard deviation, errors or omissions) in predicting school performance. One of the most interesting findings was that the effect of median reaction time scores on performance was not found significant. Instead, standard deviation, error and omission measures proved to be the most sensitive indices for predicting school grades. It seems that speed of processing, as represented by reaction time in medians, is not critical for academic performance since it may be in the cost of more errors and omissions. Variation of reaction times, though, which provides information about the stability or instability in the level of performance, seems to be a much more sensitive index for assessing lapses of attention in cases of high instability, which may harm academic performance. The results of the present study partially confirmed Trautmannn and Zepf's (2012) findings with KITAP in German primary school children (6–10 years). They found that only lapses of attention significantly correlated with children's grades in German language and but not in Mathematics. Their results, however, are limited by the small number of the sample. In the present study, the number of errors (incorrect responses to critical stimuli) and omissions (missed responses to critical stimuli) were found to be critical attention scores for academic performance in primary school children and seem to constitute a sensitive measure of inattentiveness.

4.1. Strengths and limitations of the present study

There are a number of strengths and limitations in the present study. One of the strengths is that it utilized a child-friendly behavioral task for assessing distinct functions of attention in a sample of healthy children with no referrals of attention problems. On the one hand, the use of less child-friendly material designed for adults or laboratory-based measurements of attention have raised questions regarding their ecological validity, that is, lack of motivation and interest along with boredom as reactions to the experimental material (see Hughes and Graham 2002). On the other hand, studies that used only teachers' ratings for assessing attention skills and school performance they might be biased since they come from the same informant source. A further strength is that it showed the predictive value of attention skills on school grades after controlling for the impact of other well-established significant contributors, such as gender and cognitive abilities that are strongly related to aspects of intelligence.

One limitation of the present study, apart from of its cross-sectional design, is the use of teacher ratings only for the assessment of academic performance. Future studies should use achievement tests as well. School performance, however, as assessed by teachers in the form of grades (school grades in Greek primary school are rated from 1 to 10) is a measure of high ecological validity, since it is representative of children's cumulative effort for a long period of time, which is indicative of their volition to control cognition, emotion, behavior, and environmental resources in order to achieve not only their personal goals but goals that to a large extend are set by the curriculum. A great deal of attention focus and attention control is needed in order to avoid environmental distracters or irrelevant disturbing thoughts. Future research should assess attention skills by using multiple informant ratings (i.e., parents, teachers, and the child) as well as "objective" behavioral measures (like the one used in the present study) in order to examine the predictive value of each source of information for school performance. A discrepancy between different assessments could be very informative as well, since the same behavior or skill is evaluated from different perspectives and each source has access to unique information. Moreover, multiple informants may use different evaluative standards.

4.2. Conclusion and implications

This work provided empirical evidence for the unique contribution of distinct attention skills to school performance in primary school, a period which is characterized by rapid changes in various attention functions (Rueda et al. 2004; Vakil et al. 2009). Taking into consideration, along with the present results, that academic underachievement has been consistently associated with attention problems and that the attention network is considered as very important for self-regulation of emotion and behavior (Rueda et al. 2005), it is crucial, then, to start "paying more attention" to find ways to foster attention skills from early childhood. Attention training programs, although they limited in number, have already provided promising evidence (see Posner and Rothbart 2005).

Future studies should evaluate attention in children with poor self-regulated learning skills as well as in children at risk for school problems, given the recent research evidence for the important role of attention skills in the academic performance of aggressive/rejected children who are at risk of school problems (Wilson et al. 2011).

Attention can be easily assessed in schools with a computerized non-verbal and child-friendly test, such as KITAP. The present results provided evidence for its sensitivity to explain a significant proportion of variation in school grades in primary school years. They also provide evidence for the predictive value of errors, variability and omissions of critical stimuli scores instead of the reaction time scores in KITAP. The test is also sensitive to age-related effects on attention performance, given the significant correlations found in the present study between age and attention scores (see also Sobeh and Spijkers 2012, 2013). The "objective" measurement of attention skills accompanied with teachers' and parents' ratings might allow teachers and researchers to identify those children who have difficulties in attention that could contribute to the explanation of their low school performance or dysfunctional achievement-related behaviors, such as lack of self-regulatory skills.

Acknowledgement

Part of this work was supported by grants from the Research Committee of the Aristotle University of Thessaloniki to P. Metallidou and from the Alexander S. Onassis Public Benefit Foundation to A. Malegiannaki (predoctoral grant). We would like to thank postgraduate students of the Experimental and Cognitive sector of the School of Psychology, Aristotle University for their contribution to the data collection phase.

References

Barry, T. D., Lyman, R. D., & Klinger, L. G. (2002). Academic underachievement and Attention-Deficit/ Hyperactivity Disorder: The negative impact of symptom severity on school performance. *Journal of School Psychology*, *40*, 259-283.

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large representative national sample. *Learning and Individual Differences*, *21*, 327-336.

Birchwood, J., & Daley, D. (2012). Brief report: The impact of Attention Deficit Hyperactivity Disorder (ADHD) symptoms an academic performance in an adolescent community sample. *Journal of Adolescence*, *35*, 225-231.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematical ability: Inhibition, switching and working memory. *Developmental Neuropsychology*, *19*, 273-293.

Checa, P., & Rueda, R. (2011). Behavioral and brain measures of executive attention and school competence in late childhood. *Developmental Neuropsychology*, *36*, 1018-1032.

Cohen, R. A. (1993). *The neuropsychology of attention.* New York: Plenum Publishing.

Commodari, E., & Di Blasi, M. (2014). The role of the different components of attention on calculation skill. *Learning and Individual Differences*, *32*, 225-232.

De Carlo, L. T. (1997). On the meaning and use of kurtosis. *Psychological Methods*, 2, 292-307.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., et al. (2007). School readiness and later achievement. *Developmental Psychology*, *43*, 1428-1446.

DuPaul, G. J., Volpe, R. J., Jitendra, A. K., Lutz, J. G., Lorah, K. S., & Gruber, R. (2004). Elementary school students with AD/HD: Predictors of academic achievement. *Journal of School Psychology*, *42*, 285-301.

Fergusson, D., M., Lynskey, M. T., & Horwood, L. J. (1997). Attentional difficulties in middle childhood and psychosocial outcomes in young adulthood. *Journal of Child Psychology and Psychiatry*, *38*, 633-644.

Fuhs, M. W., Nesbitt K. T., Farran, D. K., & Dong, N. (2014). Longitudinal associations between executive functioning and academic skills across content areas. *Developmental Psychology*, *50*, 1698-1709.

Georgas, D. D., Paraskevopoulos, I., Bezevengis, I., & Giannitsas, N. (1997). *Guidelines for the Greek WISC-III.* Athens: Ellinika Grammata.

Hughes, C., & Graham, A. (2002). Measuring executive functions in childhood: Problems and Solutions? *Child and Adolescent Mental Health, 7,* 131-142.

Jensen, A. R. (2001). Vocabulary and general intelligence. *Behavioral and Brain Sciences, 24*, 1109-1110.

Kaller, T., Langguth, N., Ganschow, R. Nashan, B., & Schulz, K-H. (2010). Attention and executive functioning deficits in liver-transplanted children. *Transplantation*, *90*, 1567-1573.

Kaufmann, L., Zieren, N., Zotter, S., Karall, D., Scholl-Bürgi, S. et al. (2010). Predictive validity of attentional functions in differentiating children with and without ADHD: A componential analysis. *Developmental Medicine and Child Neurology*, *52*, 371-378.

Kelly, T. P. (2000). The clinical neuropsychology of attention in school-aged children. *Child Neuropsychology, 6,* 24-36.

Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology*, *108*, 677-692.

Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin*, *136*, 1123-1135.

Mirsky, A. F., Anthony, B. J., Duncan, C. C., Ahearn, M. B., & Kellam, S. G. (1991). Analysis of the elements of attention: A neuropsychological approach. *Neuropsychology Review, 2,* 109-145.

Müller, U., Lieberman, D., Frye, D., & Zelazo, P. D. (2008). Executive function, school readiness, and school achievement. In S. K. Thurman & C. A. Fiorello (Eds.), *Applied Cognitive Research in K-3 classrooms* (pp. 41-84). New York: Routledge.

Muris, P. (2006). Relation of attention control and school performance in normal children. *Perceptual and Motor Skills*, *102*, 78-80.

Nicolescu, R., Pectu, C., Cordeanu, A., Fabritius, K., Schlumpf, M. et al. (2010). Environmental exposure to lead, but not other neurotoxic metals, relates to core elements of ADHD in Romanian children: Performance and questionnaire data. *Environmental Research*, *110*, 476-483.

Polderman, T. J. C., Boomsma, D. I., Bartels, M., Verhulst, F. C., & Huizink, A. C. (2010). A systematic review of prospective studies on attention problems and academic achievement. *Acta Psychiatrica Scandinavica*, *122*, 271-284.

Posner, M. I., & Rothbart, M. K. (2005). Influencing brain networks: Implications for education. *Trends in Cognitive Sciences*, *9*, 99-103.

Riccio, C. A., Reynolds, C. R., & Lowe, P. A. (2001). *Clinical applications of continuous performance tests: Measuring attention and impulsive responding in children and adults.* New York: John Wiley & Sons Inc.

Roebers, C. M., Röthlisberger, M., Cimmeli, P. Michel, E., & Neuenschwander, R. (2011). School enrolment and executive functioning: A longitudinal perspective on developmental changes, the influence of learning context, and the prediction of pre-academic skills. *European Journal of Developmental Psychology*, *8*, 526-540.

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P. et al. (2004). Development of attentional networks in childhood. *Neuropsychologia*, *42*, 1029-1040.

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28*, 573-594.

Sobeh, J., & Spijkers, W. (2012). Development of attention functions in 5- to 11-year-old Arab children as measured by the German Test Battery of Attention Performance (KITAP): A pilot study from Syria. *Child Neuropsychology*, *18*, 144-167.

Sobeh, J., & Spijkers, W. (2013). Development of neuropsychological functions of attention in two cultures: A cross-cultural study of attentional performances of Syrian and German children of pre-school and school age. *European Journal of Developmental Psychology, 10*, 318-336.

St. Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology*, *59*, 745-759.

Steele, A., Karmiloff-Smith, A., Cornish, K., & Scerif, G. (2012). The multiple sub-functions of attention: Differential developmental gateways to literacy and numeracy. *Child Development*, *83*, 2028-2041.

Trautmannn, M., & Zepf, F. D. (2012). Attentional performance, age and scholastic achievement in healthy children. *PLOS ONE*, *7*, e32279.

Vakil, E., Blachstein, H., Sheinman, M., & Greenstein, Y. (2009). Developmental changes in attention test norms: Implications for the structure of attention. *Child Neuropsychology, 15,* 21-39.

van Zomeren, A. H., & Brouwer, W. H. (1994). *Clinical Neuropsychology of Attention.* New York: Oxford University Press.

Visu-Petra, L., Cheie, L., Benga, O., & Miclea, M. (2011). Cognitive control goes to school: The impact of executive functions on academic performance. *Procedia Social and Behavioral Sciences*, *11*, 240-244.

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin, doi: 10.1037/a0036620*.

Wilson, B. J., Petaja, H., & Mancil, L. (2011). The attention skills and academic performance of aggressive/rejected and low aggressive/popular children. *Early Education and Development, 22*, 907-930.

Zimmermann, P., Godan, M., & Fimm, B. (2002). *Testbatterie zur Aufmerksamkeitsprüfung für Kinder (KITAP).* Herzogenrath: Psytest.