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The relationship of Inhibitory Processes and Working Memory to Intelligence and Reading Skills in Children with Mild Intellectual Disabilities and Borderline Intelligence

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Abstract

Research on intellectual functioning suggests that intelligence weaknesses could involve deficits in Executive functions. In addition, research on the reading skills of students with Intellectual Disabilities, due to unspecified etiology, is sparse. Thus, the purpose of our study was to investigate inhibitory processes and working memory as well as their relationship to different degrees of intellectual disability and reading attainment. It was conducted on a randomized sample including 20 school children in the age of 6-8, whose intelligence was evaluated with the Wechsler Intelligence Scale for Children. A modified version of a go/no go task was used to assess inhibition. Working Memory Rating Scale (WMRS) was administered for the assessment of the working memory and the "Test of Reading Difficulties in kindergarten and 1st-2nd Elementary School" for the assessment of their reading performance. Results are analyzed in terms of deficits and strengths in children with mild intellectual disabilities and borderline intelligence. The predictive role of the working memory in both groups is also discussed.

Keywords: mild intellectual disabilities, borderline intelligence, inhibition, working memory, reading skills.

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Introduction

Whether EFs are impaired in children with Mild Intellectual Disabilities (MID) and Borderline Intelligence (BI) is not totally clear. Findings suggest developmental delays in the Efs of children with MID and BI (Van der Molen et al., 2007). Differences for inhibition performance and processing speed were also found, but less consistent across the tasks used to measure these aspects of Efs in children with MID and BI (Schuiringa et al., 2017).

Regarding reaction time and its relationship to IQ, studies have mainly reported conflicting results (Khodadadi et al., 2014). In particular, studies on individuals with ID have shown either a meaningful and negative correlation between reaction time and intelligence (Nissan et al., 2013) or no meaningful relationship (Bates & Stough, 1998). Thus, it is concluded that the relationship between reaction time and IQ is too complicated and a significant correlation depends on various variables (Khodadadi et al., 2014).

Concerning working memory (the ability to hold and manipulate information with the aim of recalling it) in children with MID, research shows a developmental lag in this construct of the Efs, which is in line with their general intellectual ability (Schuchardt et al., 2010). Therefore, their performance in working memory components is roughly at the level of younger children matched on mental age (Schuchardt et al., 2010; Van der Molen et al., 2009). It should be noted that children with MID or BI show heterogeneous domain-specific effects on performance with working memory tasks (Van der Molen et al., 2007), which might as well be related to specific “structural” impairments affecting storage of verbal, visual, or spatial information (Jarrold & Towse, 2006).

While students with ID, due to unspecified etiology, demonstrate skills in the field of literacy and a central aim of their education is the acquisition of reading and writing, research on their reading skills is sparse (Channell et al., 2013), which may be due to the heterogeneity of the group of children with ID, since their intelligence and language ranges from borderline to severe cases (Ratz & Lenhard, 2013). Findings suggest that the combination of poor phonological representation and poor phonological output assembly makes decoding difficult for children with ID (Connors et al., 2001). Most of the studies conducted with children, adolescents or adults with ID with mixed or unspecified etiology found that phonological awareness was significantly related to word identification or non-word reading (Soltani & Roslan, 2013; Wise et al., 2010).

This deficit of individuals with ID in the phonological store can be attributed to their working memory capacity and not to the accuracy of processing (Maehler &

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Schuchardt, 2011). Nevertheless, previous research has shown that working memory performance of students with MID can be improved (Danielsson et al., 2015), as well as computerized cognitive training in children with MID leads to improved performance on non-trained tasks (Ottersen & Grill, 2015). However, the evidence is weak for these positive outcomes generalizing to other cognitive skills, such as transfer to nonverbal or verbal ability, word decoding, reading comprehension or arithmetic.

Thus, our goal in the present study, which was conducted from September 2018 until November 2018, was to investigate intelligence and its relationship to inhibition, working memory as well as reading skills in children with MID and BI. The basic objectives of the study were: a) to investigate the correlation (if any) of the reaction time and working memory with the factors as assessed by the subtests of the Wechsler Intelligence Scale for Children battery (WISC-III) in both groups, b) to investigate the correlation (if any) of the reaction time and working memory with the WISC-III Intelligence Quotient (IQ), Verbal Intelligence (VI) and Performance Intelligence (PI) c) to investigate the correlation (if any) of the reaction time as well as working memory with the reading decoding, reading comprehension, phonological awareness and short - term memory as assessed by the subtests of the “Test of Reading Difficulties in kindergarten and 1st-2nd Elementary School” (Porpodas, 2007) and d) to investigate whether the IQ, reaction time and working memory variables (if any) can predict the reading variables.

Methods

Participants

The present study involved two groups of participants: 10 primary school children at the mean age of 7.2 years old, with BI (mean IQ=76.70, s.d. = 4.373) and 10 primary school children at the mean age of 7.4 years old, with BDI (mean IQ=60.10, s.d. = 4.725). The sex ratio in that group was approximately 1:1 (male: female). The children were evaluated by the Public Centre for Diagnosis and Support for Children with Special Educational Needs and Disability (Hellenic Ministry of Education, Research and Religious Affairs) in Kozani, Greece. None of the children had psychopathology or autism spectrum disorders. All attended inclusive settings.

Measures

a) A Greek version of the WISC-III (Georgas et al., 1997). It was administered by a licensed psychologist.

b) “Test of Reading Difficulties in kindergarten and 1st-2nd Elementary School” (Porpodas, 2007). It consists of nine subtests that evaluate four key areas of cognitive-language functions related to the reading process:

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- Reading decoding is divided into two sub-categories: a) reading syllables and reading pseudo-words
 - Reading comprehension consists of: a) Reading sentences and selecting pictures and b) Reading and completing incomplete sentences.
 - Phonological awareness consists of: a) Distinction of phonemes b) Segmentation of Pseudowords in phonemes and c) Deletion of phonemes
 - Short-term memory consists of: a) Memory of sequential numbers and b) Pseudowords repetition
- c) A Greek version of the Working Memory Rating Scale-WMRS (Alloway & Gathercole, 2008). It is a behavioral rating scale developed for teachers to facilitate easy identification of children with working memory deficits. The WMRS consists of 22 items and provides a quick and efficient way for early identification of working memory problems that will impair learning.
- d) Computerized version of a go/no go task

In order to assess simple reaction time, which refers to the time when the individual only reacts to a specific stimulus, such as when subjects must press a button on hearing a voice or seeing a visual stimulus, Psytoolkit platform (Stoet, 2017) was used to create a computerized version of a go/no go task. The go signal was an apple and the no-go signal was an orange. The student was instructed to press the space bar with the index finger of the preferred hand as fast as possible, when a Go signal would appear on-screen. When a No-Go signal appeared on-screen, the student had to inhibit response. Each signal appeared for 2000ms. A valid response window was set to 0–2000 ms post stimulus onset. During the task, 8 trials and 20 go/no go signals were presented in a random order. GNG Inhibition was the mean simple reaction time difference between the congruent and incongruent trials.

Procedure

All participants were tested individually at their school in two 60 min sessions. The sessions took place in a quiet room. Potential ethical dilemmas were dealt with the official permission of the Principals of the schools that participated in the study, the informative cover letter and the consent form signed by the parents of the students.

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Results

The hypothesis of Normality was tested for all variables. In order to test whether there is a statistically significant difference between the two groups' performance, a one-way Analysis of Variance was used for those that follow a Normal distribution, whereas the non-parametric Mann-Whitney test was used for the remaining.

The results depicted (using a 0.05 significance level) statistically significant differences between the two groups' performance in the following subtests of the "Test of Reading Difficulties in kindergarten and 1st-2nd Elementary School" (Porpodas, 2007) in favor of the BI group: Reading Syllables ($Z = -2,365$, $p = 0,019 \leq 0.05$), Reading Pseudowords ($Z = -2,825$, $p = 0,004 \leq 0.05$), Reading and Completing Sentences ($Z = -3,480$, $p = 0,000 \leq 0.05$), Segmentation of Pseudowords into Phonemes ($Z = -2,180$, $p = 0,029 \leq 0.05$) and Pseudowords Repetition ($Z = -2,037$, $p = 0,043 \leq 0.05$). There was no statistically significant difference between the two groups in Mean Reaction Time [$F(1,18) = 0,579$, $p = 0,456$], Error Rate ($Z = -2,010$, $p = 0,063$) and Working Memory ($Z = -0,926$, $p = 0,393$). It should be noted that both groups had low scores in Working Memory performance (in BI group: mean = 73,50, s.d. = 1,515 and in MID group: mean = 75,40, s.d. = 0,618) as it was assessed by the WMRS, with higher scores than the average standardized mean score 50 indicating deficits in working memory.

The relationship between the variables of WISC-III and the variables of the Test of Reading Difficulties as well as Mean Reaction Time, Error Rate and Working Memory was investigated in both groups, using Pearson correlation coefficient for those that follow a Normal distribution, whereas Spearman's rho was used for the remaining.

Regarding students with BI, the results indicated positive correlations between Picture Arrangement and Reading Pseudowords [$r(10) = 0,730$, $p = 0,017 \leq 0,05$] as well as Working Memory and Reading Pseudowords [$r(10) = 0,738$, $p = 0,015 \leq 0,05$]. Reading and Completing Incomplete sentences correlated with Verbal IQ [$r(10) = 0,653$, $p = 0,041 \leq 0,05$], Performance IQ [$r(10) = 0,770$, $p = 0,009 \leq 0,05$], Full Scale IQ [$r(10) = 0,846$, $p = 0,002 \leq 0,05$] and Working Memory [$r(10) = 0,634$, $p = 0,049 \leq 0,05$]. A strong correlation was revealed between Working Memory and Segmentation of Pseudowords into Phonemes [$r(10) = 0,859$, $p = 0,001 \leq 0,05$]. In addition, Mean Reaction Time positively correlated with Working Memory [$r(10) = 0,852$, $p = 0,002 \leq 0,05$], but negatively correlated with Arithmetic [$r(10) = -0,693$, $p = 0,026 \leq 0,05$]. Reading Syllables correlated with Picture Arrangement [$r(10) = 0,828$, $p = 0,003 \leq 0,05$] and Object Assembly [$r(10) = 0,709$, $p = 0,022 \leq 0,05$]. Moreover, Deletion of Phonemes correlated with Picture Arrangement [$r(10) = 0,797$, $p = 0,006 \leq 0,05$], Object Assembly [$r(10) = 0,652$, $p = 0,041 \leq 0,05$] and Digit Span [$r(10) = 0,740$, $p = 0,014 \leq 0,05$]. Finally, Arithmetic correlated with Error Rate [$r(10) = 0,751$, $p = 0,012 \leq 0,05$].

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In respect of the students with MID, the results indicated positive correlations between Reading Sentences and Selecting Pictures and Verbal IQ [$r(10) = 0,633, p = 0,049 \leq 0,05$], as well as Full Scale IQ [$r(10) = 0,632, p = 0,050 \leq 0,05$]. Moreover, Error Rate correlated with Arithmetic [$r(10) = 0,634, p = 0,049 \leq 0,05$], as well as with Digit Span [$r(10) = 0,797, p = 0,006 \leq 0,05$].

In order to examine a causal effect relationship between the variables of the “Test of Reading Difficulties in kindergarten and 1st-2nd Elementary School” (Porpodas, 2007) and Verbal IQ, Performance IQ, Full scale IQ, Mean Reaction time, Error Rate and Working Memory, General Linear Models (GLMs) were applied (Taylor, 2011), having as a factor the variable intelligence and as covariates the Verbal IQ, Performance IQ, Full scale IQ, Mean Reaction time, Error rate and Working Memory.

The model was tested in terms of homoscedasticity of the independent variables. Levene’s tests were computed in order to examine the assumption of equal variances, since our data came from a non-normal distribution. It was found that null hypothesis of homoscedasticity cannot be rejected [$F(1,18) = 0,168, p = 0,687 \geq 0,05$] for Reading Pseudowords and Segmentation of Pseudowords into Phonemes [$F(1,18) = 0,168, p = 0,686 \geq 0,05$] respectively.

Table 1.1 shows the means and standard deviations of the students’ performance on Reading Pseudowords.

The results of the tests of between-subjects effects (Tables 1.2, 1.3) revealed (at a significance level of 10%) that Working Memory can be a statistically important predictor for Reading Pseudowords [$F(1,12) = 3,99, p = 0,069$]. Adjusted R Squared (0,482) shows the percentage of variability of the dependent variable Reading Pseudowords explained by the specific model.

Table 1.1: Means and Standard Deviations of the Students’ Performance on Reading Pseudowords

Descriptive Statistics			
Dependent Variable: READING PSEUDOWORDS			
Grouping2	Mean	Std. Deviation	N
Mild Intellectual disability	3,90	4,202	10
Borderline Intelligence	11,70	5,813	10
Total	7,80	6,354	20

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Table 1.2: Tests of Between-Subjects Effects - Dependent Variable: Reading Pseudowords

Dependent Variable: READING PSEUDOWORDS					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	516,017 ^a	7	73,717	3,522	0,027
Intercept	17,342	1	17,342	0,828	0,381
VERBAL IQ	1,713	1	1,713	0,082	0,780
PERFORMANCE IQ	10,668	1	10,668	0,510	0,489
FULL SCALE IQ	4,882	1	4,882	0,233	0,638
MEAN REACTION TIME	3,017	1	3,017	0,144	0,711
ERROR RATE	16,417	1	16,417	0,784	0,393
WORKING MEMORY	83,520	1	83,520	3,990	0,069
Grouping2	45,326	1	45,326	2,165	0,167
Error	251,183	12	20,932		
Total	1984,000	20			
Corrected Total	767,200	19			

a. R Squared = .673 (Adjusted R Squared = .482)

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Table 1.3: Parameter Estimates - Dependent Variable: Reading Pseudowords

Parameter Estimates						
Dependent Variable: READING PSEUDOWORDS						
Parameter	B	Std. Error	t	Sig.	90% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	56,279	58,594	0,960	0,356	-48,153	160,710
VERBAL IQ	0,704	2,462	0,286	0,780	-3,684	5,093
PERFORMANCE IQ	1,546	2,166	0,714	0,489	-2,314	5,407
FULL SCALE IQ	-2,007	4,156	-0,483	0,638	-9,414	5,400
MEAN REACTION TIME	-0,003	0,008	-0,380	0,711	-0,018	0,012
ERROR RATE	-0,324	0,366	-0,886	0,393	-0,976	0,328
WORKING MEMORY	-0,849	0,425	-1,998	0,069	-1,607	-0,092
[Grouping2=1]	-6,804	4,624	-1,472	0,167	-15,046	1,437
[Grouping2=2]	0 ^a	.	.	.	.	.

Table 2.1 shows the means and standard deviations of the students' performance on Segmentation of Pseudowords into Phonemes. Similarly, Working Memory can be a statistical important predictor for Segmentation of Pseudowords into Phonemes [$F(1,12) = 7,09$, $p = 0,021$]. Adjusted R Squared (0,490) shows the percentage of variability of the dependent variable Segmentation of Pseudowords into Phonemes explained by the specific model (Tables 2.2, 2.3).

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Table 2.1: Means and Standard Deviations of the Students' Performance on Segmentation of Pseudowords into Phonemes

Descriptive Statistics			
Dependent Variable: SEGMENTATION OF PSEUDOWORDS INTO PHONEMES			
Grouping2	Mean	Std. Deviation	N
Mild Intellectual Disability	3,20	3,393	10
Borderline Intelligence	7,90	5,216	10
Total	5,55	4,915	20

Table 2.2: Tests of Between-Subjects Effects - Dependent Variable: Segmentation of Pseudowords into Phonemes

Dependent Variable: SEGMENTATION OF PSEUDOWORDS INTO PHONEMES					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	311,171 ^a	7	44,453	3,610	0,025
Intercept	4,688	1	4,688	0,381	0,549
VERBAL IQ	5,526	1	5,526	0,449	0,516
PERFORMANCE IQ	9,226	1	9,226	0,749	0,404
FULL SCALE IQ	6,094	1	6,094	0,495	0,495
MEAN REACTION TIME	0,277	1	0,277	0,023	0,883
ERROR RATE	0,003	1	0,003	0,000	0,987
WORKING MEMORY	87,423	1	87,423	7,099	0,021
Grouping2	0,951	1	0,951	0,077	0,786
Error	147,779	12	12,315		
Total	1075,000	20			
Corrected Total	458,950	19			

a. R Squared = .678 (Adjusted R Squared = .490)

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Table 2.3: Parameter Estimates - Dependent Variable: Segmentation of Pseudowords into Phonemes

Dependent Variable: SEGMENTATION OF PSEUDOWORDS INTO PHONEMES						
Parameter	B	Std. Error	t	Sig.	90% Confidence Interval	
					Lower Bound	Lower Bound
Intercept	27,987	44,943	0,623	0,545	-52,115	108,089
VERBAL IQ	1,265	1,889	0,670	0,516	-2,101	4,632
PERFORMANCE IQ	1,438	1,661	0,866	0,404	-1,523	4,399
FULL SCALE IQ	-2,242	3,188	-0,703	0,495	-7,923	3,439
MEAN REACTION TIME	0,001	0,006	0,150	0,883	-0,010	0,012
ERROR RATE	-0,005	0,280	-0,016	0,987	-0,504	0,495
WORKING MEMORY	-0,869	0,326	-2,664	0,021	-1,450	-0,288
[Grouping2=1]	-0,986	3,547	-0,278	0,786	-7,307	5,336
[Grouping2=2]	0 ^a	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Discussion

In the present study, intelligence and its relationship to inhibition, working memory as well as reading skills in children with MID and BI was investigated. Moreover, an effort to determine which of the Efs (if any) can predict the reading factors was attempted.

Students with MID and students with BI were found not to differ statistically significant either in Reaction Time or in Working Memory tasks. In addition, Full scale IQ does not correlate with Mean Reaction time and Working Memory in both groups. Our results are consistent with other previous reports (Bates & Stough, 1998; Jauregi et al., 2007).

In general, the relationship between the Efs and IQ in children with BI and MID is too complicated and revealing a significant correlation depends on various factors, such as developmental delay in working memory, which is in line with their general intellectual ability (Schuchardt et al., 2010). Moreover, specific "structural" impairments affecting storage of verbal, visual, or spatial information (Jarrold & Towse, 2006; Lanfranchi et al., 2004) contribute to the heterogeneity of this population. Besides, it should be noted that both groups received low scores in WMRS,

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which is in accordance with findings from previous reports which have shown that working memory deficits increase in inverse proportion to IQ (Schuchardt et al., 2010; Van der Molen et al., 2009).

The analysis of the data, with respect to the relationship of intelligence with the reading variables as well as Mean Reaction Time, Error Rate and Working Memory revealed significant correlations, which are also in line with those of previous studies. Arithmetic correlated with Error Rate in both groups (Clark et al., 2010). Digit Span positively correlated with Reading Pseudowords and the Deletion of Phonemes in BI group (Mayes et al., 2009). Moreover, Working Memory correlated with Reading Pseudowords, Segmentation of Pseudowords into Phonemes and Mean Reaction Time (Channell et al., 2013).

It is worth mentioning that Object Assembly and Picture Arrangement, both assessing nonlinguistic reasoning ability, were found to correlate with Reading Pseudowords and Reading Syllables in BI group. It seems that when cognitive impairments are apparent, the development of reading skills is affected not only via linguistic skills but also via nonlinguistic reasoning ability, with the latter most likely explained by the fact that it represents general intelligence capacity (van Wingerden et al., 2018).

The key finding in our study is that Working Memory appears to have a predictive power in relation to reading abilities in both groups, more specifically to Phonological Awareness and Reading Decoding. In general, it seems that working memory deficits themselves lie at the heart of some of the learning difficulties experienced by such individuals (see also Jarrold & Brock, 2012).

Conclusion

Considering the aforementioned findings and the results of previous studies showing that there is a developmental lag in working memory as well as “structural” deficiencies affecting storage of verbal, visual, or spatial information, which are in line with their general intellectual ability, we suggest implementing working memory training programmes adapted to students’ abilities with MID and BI, by taking into consideration their neurobiological limitations and reducing the cognitive load. Besides, research has shown that the working memory of children with ID can be improved (Danielsson et al., 2015). With regard to their reading skills, similar approaches should be applied, aiming to reduce the amount of phonological information to be held in working memory, thus leaving cognitive reserve for reading decoding.

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Given the limited number of the target population, the results of the present study cannot be generalized. A larger sample of both BI and MID students should be included in a further study, in order to comparatively investigate the Efs and their relationship with reading skills using a variety of cognitive tools.

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