Original Research

The relationship between mathematical abilities and phonological awareness skills in Greek students: a cross-sectional study in 1st graders

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ABSTRACT

Background: Available literature and research indicates that phonological awareness is correlated to mathematical abilities. There are, however, little evidence concerning Greek language.

Purpose: The purpose of this study is to identify whether there is a relationship between phonological awareness (PA) and mathematical skills in monolingual Greek 1st Graders. Although Greek language differs from English in morphology and phoneme-grapheme correspondence, similar findings are expected as in international literature.

Method: The present study assessed 45 children, students of 1st Grade in non-verbal IQ, reading, Rapid Automatized Naming (RAN), Phonological Awareness (PA) and mathematical skills.

Results and conclusions: Correlation analysis showed that there is a significant correlation between mathematical abilities and PA and RAN. In addition, mathematical skills were correlated to reading abilities and age of the participant. Regression analysis also revealed a correlation between mathematical abilities and PA and RAN.

Keywords: *Cognitive Psychology, Mathematical Abilities, Phonological Abilities*

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Introduction

Mathematical skills develop from an early age [1]. On the other hand, phonological awareness (PA) skills begin to develop at the age of 4, when children begin to be able to identify words that rhyme, and become more sophisticated as children mature [2]. In a similar vein, Greek children develop PA skills in pre-school age, albeit rhyme awareness is not so widely used, as Greek language differs significantly from English language on how words are formed [3].

This study aims to examine the relationship between PA skills and mathematical skills in Greek 1st Graders.

Over the years, numerous studies have indicated that PA is a key factor for developing literacy skills in both shallow and deep orthographies –including Greek [3, 4]. Furthermore, several studies have shown the link between PA skills and numeracy skills [5-7]. Although in several languages, and mainly in English, there is a plethora of research that focuses on the relationship between phonological skills and mathematical abilities [7, 8], and although there are numerous studies examining the link between PA and literacy development in Greek language [3, 9], there is limited research investigating how phonological skills in Greek impact on mathematics. The researcher found only 5 relevant studies (with only two of them examining specifically the association between PA and mathematical skills). The oldest study in Greek, by Porpodas, and Palaiotheodorou[3], investigated whether the training of PA has positive results only in specific domains (i.e. reading and spelling acquisition) or in general student competencies (such as math acquisition). The conclusions suggest that there is no correlation between phonological training and improvement in mathematical competencies.

Furthermore, Manolitsis, Georgiou, & Tziraki [12] found a relationship between early mathematical skills development with home literacy environment. Georgiou, Tziraki, Manolitsis, and Fella [13] examined whether rapid automatized naming is related to both reading and mathematical skill for the same reason (the results of this study underline that, unlikely literacy skills, numeracy skills are not related to a specific component of RAN).

In order to examine the correlation between Mathematical skills and PA skills as well as the existence of an underline mechanism that connects tthese two abilities 45 monolingual 1st Graders were recruited and assessed by the researcher in Mathematical skills, PA skills, reading fluency, non-verbal IQ and RAN. Age was also examined.

The primary purpose of the present study was to examine the contribution of PA in mathematical skills, and furthermore, to examine what other factors (age, RAN, reading fluency non-verbal IQ) may contribute to mathematical achievement. The researcher chose to assess 1st Graders, since this is the class in Greece that formal teaching starts (same curriculum, detailed aims and objectives for each subject and for each lesson and the same books nationwide), which would provide a homogenous sample. Furthermore, the consensus suggests that PA correlates with simple arithmetic skills, as those in younger children, pre-schoolers or students of 1st Grade [7, 14], but not with more complex mathematical abilities, as those obtained by elder students [7, 15]. Thus 1st Grade is an appropriate age to assess children.

Relying on the previous studies the researcher hypothesizes that there will be a strong correlation among mathematical abilities, PA and RAN. Moderate correlation between mathematics and reading skills is expected, since reading is mostly correlated to advanced mathematical skills, and not simple computations, such those of the math measure of the current study. Furthermore, moderate correlation between mathematics and non-verbal IQ is expected, since previous studies has shown that there is a relationship between those two in 1st Graders [16, 17].

Methods and Materials

Ethical Approval

This project was approved on ethics ground by the University of Sheffield, Department of Human Communication Sciences, in 12/2/2018.

Participants

For the purpose of the current study typically developing children were sought. A total of 45 monolingual Greek participants (21 males and 24 females, age in months: between 76 and 87 months, mean = 82.33, SD = 3.35) were recruited. All participants were recruited from urban and semi-urban areas –Lefkada, Palairos and Agrinion and all children came from middle socioeconomic backgrounds (based on their place of the residence). The recruitment was done through a local after-school club (Agrinion) or through individuals (Lefkada, Palairos and Agrinion). Consent from the after-school club manager (where necessary) and parental contents were obtained prior to testing.

Design and Materials

Nonverbal IQ

Wechsler Abbreviated Scale of Intelligence - Second Edition (WASI-II), Matrix Reasoning subtest (2011) [18] was administrated to assess nonverbal IQ. In this subtest the examinee views a matrix or series that needs to be completed with one of the given options [19]. Since WASI-II is a culturally based test and it has not been standardized in Greek population, row scores were used to indicate whether a participant is considered to have typical IQ or not.

Reading

Detection Test of Reading Difficulties, Syllables subtest and Non-word subtest [20] were used to assess the reading. The Syllables subtest includes 24 syllables in form of CV, VC, CCV, CCCV, CCCVC (C=consonant, V=vowel) in escalating difficulty order, whilst the Non-word subtest includes 24 two-threesyllable or multi-syllable non-words in escalating difficulty order, as well. The children were asked to decode the syllables or the non-words and the test was discontinued after three consecutive false answers.

Rapid Automatized Naming

Children were administered the two subtests taken from [21] "Rapid Automatized Naming (RAN) Test". Each measure included two tasks (an easy one and a more difficult one), RAN Colors (RAN-C) and RAN Digits (RAN-D). In each task, participants were asked to name 20 stimuli as quickly as possible. Originally, participants' score was the ratio of the total number of items named correctly divided by the total time taken, for each pair of tasks individually (averaged across the two cards) [22]. In this research however, a total score of the 42 subtasks (2 RAN-C and 2-RAN-D) will be used as it would be more effective in terms of administration.

Phonological Awareness (PA)

PA was assessed through the "Phoneme Elision Test" [23]. Phoneme Elision Test is part of a larger battery of tests. It is an adaption of Wagner's et al. (1993) respective test. In this test children are asked to repeat a word after deleting a specific phoneme (vowel or consonant) The remaining phonemes form a real word [24, 25]. The test consists of 15 items.

Math Abilities

A simple math tasks battery was used. The tasks included: Addition1(single digit addition, subtraction, group math task, speeded number writing, Addition2 (single and 2-digit number addition with results higher than 10), Addition3 (single and 2-digit number addition with regrouping).

Procedure

Children were assessed in 1 session, either at school or at home. WASI-II, Reading Test, RAN and PA Test were administered to each participant individually. Math Test was administered either in small groups (3-4 children) or individually.

Each session lasted approximately 25 minutes. Children were told they were going to participate in game. All tests were paper-based.

Results

Descriptive statistics for all individual measures are reported below:

The age of the participants was between 76 and 87 months (mean = 82.33, SD = 3.35), WASI-II score was between 1 and 14 (mean = 6.42, SD = 3.18). Reading Test score was between 0 and 48 (mean = 38.40, SD = 10.70). RAN Score was between 0.55 and 1.73 (mean = 1.15, SD = .26). Phoneme Elision Test score was between 0 and 15 (mean = 8.36, SD = 5.04). Math Score was between 31 and 107 (mean = 59.31, SD = 15.60). In Reading Test 48 was the maximum possible score. In Phoneme Elision Test 15 was the maximum possible score.

Correlational analysis

Correlation analysis was carried out in order to investigate the relationship between PA skills and

RAN skills.

There is also a significant moderate correlation between reading abilities and both PA skills and RAN skills. There is no correlation between non-verbal IQ and either age, reading abilities, PA skills or math skills. There is, nevertheless, a significant moderate correlation between WASI-II score and RAN score.

Regression Analysis

Regression analysis was carried out to investigate the contribution of PA skills (i.e. phoneme elision test), non-verbal IQ (i.e. WASI-II), age, reading abilities (i.e. reading test) and RAN skills (i.e. RAN Overall (ratio) in predicting individual differences in maths ability (Table 2).The model accounted for 36.6% (F = 4.504, p = .002, Regression df = 5, Residual df = 39) of the variance of Math Skills. RAN skills was the only predictor that explained a statistically significant unique variance in Math skills, while PA skills may be a predictor of Math skills. The results, however, need to be explained with cautiousness. No other variable can be a predictor of Math skills.

Table 1
Correlations between Age, Non-verbal IQ, Reading Ability, RAN, Phoneme Elision Ability and Math Ability

	AGE (in months)	WASI-II	Reading Test	RAN Overall (ratio)	Phoneme Elision Test	Math Test Overall
AGE (in months)		.102	.255*	.260*	.243	.292*
WASI-II	.102		-.033	.309*	.134	-.035
Reading Test	.255*	-.033		.370**	.563**	.276*
RAN Overall (ratio)	.260*	.309*	.370**		.539**	.484**
Phoneme Elision Test	.243	.134	.563**	.539**		.486**
Math Test Overall	.292*	-.035	.276*	.484**	.486**	

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

Table 2
Simultaneous regression with age, non-Verbal IQ, Reading, RAN Score, Phoneme Elision Test Score and Math (N=45)

Variable	R^2	Math			
		B	SE B	β	t
	.366				
AGE (in months)		.753	.626	.162	1.203
WASI-II		-1.035	.669	-.211	-1.548
Reading Test		.137	.232	-.094	-.591
RAN Overall (ratio)		21.801	9.642	.363	2.261*
Phoneme Elision Test		1.028	.531	.332	1.937**

Note: F=4.501, p=.002. B, unstandardized coefficients; SE B, standard error for unstandardized coefficients; β, standardized beta coefficients.
* p<.05
** p=.06

Discussion

The current study aimed to elucidate the predictors of mathematical development. The main objective of the study was to investigate if PA is a predictor of mathematical abilities in Greek-speaking children and if that is true, to examine which other factors contribute to this relationship. Despite the plethora of studies in several languages that confirm the correlation between mathematical abilities and PA [7, 26] and the argument that other factors as well, and especially RAN, can be a predictor of mathematical development [6, 8, 27-29], only a few studies have been conducted in Greek-speaking children. Since differences in the syllable structure and the lexical stress of each language affect the phonological awareness of its speakers –e.g., phoneme awareness is more salient in Greek and English, while syllable awareness is more salient in French and Spanish– [30, 31], it is important to conduct research in various languages in order to examine whether the relationship between PA and mathematical ability is cross-linguistic or it differs from language to language. In this case, it is possible that other factors, or underlining mechanisms –such as RAN or working memory- might facilitate the relationship between PA and mathematical abilities. Furthermore, it was examined the contribution of non-verbal IQ, age, and reading abilities in mathematical abilities, based on findings of previous studies [30, 32, 33].

The results of this research were consistent with previous research. In fact, the study generated two main findings. Firstly, the research replicated core findings of previous studies in other languages [5, 7, 26, 33, 34], as well as in Greek-speaking children of the same age [13], suggesting that individual differences in PA are a strong predictor of mathematical abilities. As previous research has indicated, children's early mathematical skills (such as counting) are strongly related to PA, despite the differences in the structure of different languages [29]. Moreover, the findings were congruent with findings in children with poor phonological awareness and/or low performance in mathematics [34-36], suggesting that deficits in phonological awareness lead to poor academic performance not only in reading, but also in maths.

Secondly, there was a clear interrelationship between RAN, PA, and mathematical skills, confirming previous research [13]. This interrelation may be a possible explanation for the first finding, since both mathematical skills and PA correlate directly to RAN (for the relationship between maths and RAN see: Swanson, 2006 [27]; Koponen et al., 2007 [6]; for the relationship between PA and RAN see: Papadopoulos et al., 2009 [25]). RAN seemed to be one of the strongest predictors of both mathematical skills and PA. Indeed, research has shown that there is a significant correlation between RAN and mathematical skills, especially regarding arithmetic calculation and math fluency [37].

These findings are very important since they confirmed the existence of a relationship between PA and RAN, and mathematical skills in Greek language, where little research has been done.

Furthermore, there was a correlation between mathematics and reading skills, which, however, was not as strong as between them and RAN, and PA. In fact, only RAN and PA, accounted as predictors of mathematical skills in the simultaneous regression analysis, accounting for 36.6%. This is in line with previous data [5, 14] that suggest the contribution of reading skills in mathematical skills can be explained due to the common phonological influences on both of them. In fact, as it was excepted, reading skills were associated with PA. Although the association between PA and both reading and mathematical skills is well-documented the interpretation of these relationships remains unclear. Reading skills were also correlated to RAN, confirming the findings of previous research, which have indicated that RAN pause time was a key component of reading skills during 1st Grade, after controlling for general ability and phonological awareness skills [13]. These correlations, as well as the strong correlation between PA and RAN, might indicate that RAN and PA share common mechanisms. Indeed, some researchers have proposed that RAN is, in fact, the measure of phonological retrieval [38]. Georgiou and his colleagues [39] suggest that RAN indicates how quickly can someone access to both phonological and numerical representations in their long-term memory. While Koponen et al meta-analysis [37] indicate that both math and RAN require quick access to and retrieval of phonological representations from long-term memory. Furthermore, different types of RAN are associated to reading skills and mathematical skills- alphanumeric RANs were stronger predictors of reading skills, while number-

specific RANs were stronger predictors of arithmetic fluency [40].

There is a correlation between age and mathematical skills, which, however, does not apply in simultaneous regression analysis. The weak correlation between math and age, as emerges from regression analysis, might be explained because of the fact that math performance is directly associated to formal education, thus, children of typical development of the same class are expected to score similar results in the maths assessment.

There is no correlation between mathematical abilities and non-verbal IQ. This can be attributed to the fact that the test that was used for measuring non-verbal IQ (WASI) is not standardized in Greek population, and possibly cultural differences might have altered the results. Furthermore, the results were congruent with Moll's et al. findings [41] arguing that non-verbal IQ is correlated to neither counting or number knowledge and do not account for significant variation in early number skills.

The results of the current study are important since they contribute in the international literature, adding information about Greek-speaking population. Practically, this research may contribute to the improvement of the present screening and intervention programs for Greek students.

Limitations and Future Directions

The results of the current research should be considered in light of a few limitations. The sample of the study included only 45 participants due to the researcher's difficulty in recruiting more children. Furthermore, the design of the study was simple and only basic contributors of mathematical skills were assessed. Moreover, regarding mathematical skills only counting, addition and subtraction were assessed, neither problem-solving nor patterns were assessed. due to time limitation, which might have led to a rough estimation of how PA and RAN contribute to mathematical skills. Regarding PA, only one phonological processing task was administered (this of phoneme elision). So, to fully understand the relation between PA and mathematics, it is possible that other, more sophisticated phonological tasks (such as phoneme blending) should be administered.

Conclusions

The present study gave experimental support to the relationship between mathematical skills, and PA and RAN. It is one of the few studies that examine this relationship in Greek children. In terms of theory, these findings can give direction for future studies in Greek-speaking children. Practically, researchers and educators can use these findings in order to create more effective intervention programmes for children with poor performance in mathematics.

Although the findings of this study confirm previous research and add valuable information regarding the predictors of mathematical development in Greek children, further research should be conducted. Longitudinal research, larger sample, different age groups, more sophisticated mathematical skills, and other cognitive skills (such as working memory) across languages varying in orthographic consistency are needed for further investigation.

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