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A Test-Based Confirmatory Study of the Existence of an Underlying Relationship between Linguistic and Mathematical Skills

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Abstract

The present study intended to explore the relationship of second language (L2) skills with first language (L1) skills, and mathematics skills. Language skills and mathematical skills share the same sub-skills, the same regions in the brain for their processing, and similar psychological development (Purpura & Ganley, 2014). Language skills and mathematics skills are shown to be monitored and operated from the same regions of the brain, therefore there is a strong possibility that these skills would be concurrent predictors of one another and could correlate significantly with one another. To test this hypothesis, scores of one hundred girls (of 11 years of age in the subjects of English, Urdu, and mathematics in the grade 5 examination conducted under Punjab Education Commission) were taken as participants. Their statistical analyses confirmed the existence of a strong correlation among L1, L2, and mathematical skills.

Keywords: A Predictor of L2 Skills; L1 Skills; Language Teaching; Linguistic and Mathematical Skills; SLA

Introduction

The relationship between language skills and mathematics skills can be explained on a biological, and psychological basis, as well as based on similar sub-skills involved within these two skills. Children's early mathematics skills develop collectively with the basic skills serving as a base for the learning of later skills. Though, non-mathematical aspects, such as working memory and language skills are also associated with the development of mathematical skills at a more advanced level. Unluckily, little research is present to establish the fine relations of these two non-mathematical factors to the individual skills of early mathematics to the individual skills of mathematics at an earlier stage (Purpura & Ganley, 2014).

Moreover, skills of reading and doing math get processed in the regions of the brain that are more or less common to both of these skills, and on the other hand mathematical skills to are dependent upon verbal skills showing that skills are mutually inter-related. Most of the literature we find to establish the relationship (between linguistic and mathematics skills) comes from the research on the language deficits (e.g. dyslexia) and mathematics deficits (e.g. dyscalculia) which unveiled the underlying processes involved in both.

Dorsal Stream/Visuospatial Deficits

The involvement of the dorsal stream in the process of reading can be attested from the results of various research studies. Converging evidence (coming from studies that employ techniques of neuroimaging and neuropsychology) reflects that separate neural systems are involved in processing the information related to the visual features of objects and information related to their spatial locations (e.g. Haxby et. al., 1991). Of the said specialized neural systems, the system called ventral processing stream deals with the object feature and the system called dorsal stream deals with location information (Mishkin, Ungerleider & Macko, 1983; Ungerleider & Mishkin, 1982).

Disturbance of mathematical skills can also be caused by these visuospatial skills possibly via various channels, for instance, deficits occurring in the basic skills like in the mental number line

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development; deficits occurring in mathematical procedures like digits alignment; deficits occurring inside arithmetic calculation skills like in the acquisition of borrowing and carrying concepts (Venneri, Cornoldi & Garuti, 2003).

Gray Matter Volume in Temporal Lobes

While studying dyslexics' reading process, many studies on brain imaging, came across aberrant patterns of activation in the temporoparietal, and occipitotemporal regions of Broca'sarea (Brumswick, McCroy, Price, Frith & Frith, 1999; Rumse et al., 1997).

Another research work conducted by Vinckenbosch, Robichon, and Eliez (2005) on dyslexic individuals, for measuring the volumes of gray and white matter inside their temporal lobes, a change was observed in the volume of gray matter inside both the lobes, in the form of significant reduction of density in gray matter inside both the middle and the inferior temporal gyri. Besides it, they also found the existence of a positive correlation between the performance on the tasks of rhyme judgment and the density of gray matter in the middle temporal gyri and the middle inferior frontal gyri bilaterally.

Working Memory

Working memory skills have the competence to predict, without any outside support, about the attainments of children in reading, and also in mathematics but to a lesser degree, in addition to the contribution of working memory being common to both ability domains (Gathercole, Alloway, Willis & Adams, 2006).

Working memory serves as a resource to the learner for allowing him to integrate with the current inputs the information that s/he retrieves from long-term memory and thereby, with the help of it, the severity of impairments in the spheres of reading and mathematics can be made (Swanson & Sáez, 2003; Swanson & Beebe-Franken Berger, 2004). Based on all of this discussion, prediction can be made that the processing of math and reading share numerous regions and physiological features inside an individuals' brain.

It is also clear that there is a relation of interdependency between them concerning their sub-skills and each of the two performs a compensatory function for the other. Exact arithmetic stresses representations that are language-specific and it is dependent on the left inferior frontal circuit that is used also for establishing associations between words (Dehaene, Spelke, Pinel, Stanescu & Tsikin, 1999). We have a range of studies on the long term interdependent predictive relationship between reading and mathematics. The age before entering school and the age during kindergarten reflect a very critical point in the academic development of a child. Research (e.g. Purpura, Hume, Sims & Lonigan, 2011) confirms it that a child's academic achievement, at the beginning of his/her academic career, is strongly associated to his/her success achieved in academics at a later stage (Butler, Marsh, Sheppard & Sheppard, 1985; Krajewski & Schneider, 2009). Reading and mathematics enjoy core position in the initial achievement of a child in his/her academics, which are significant not only for the child in his/her capacity but also in his/her acquiring of knowledge inside other domains (Anders, 1986; Brown & Murray, 2005; Snow, Burns & Griffin, 1998). Apart from it, mathematics and reading help in each other's development. These domains show signs of inter-relatedness right from a very early age (McClelland et al., 2007; Welsh, Nix, Blair, Bierman & Nelson, 2010) and can make long-term predictions about each other (Duncan et al., 2007; Juel, 1988), though the peculiar identity of the mentioned relation remains cloudy, especially during the age of entry to school (as discussed in Purpura et al., 2011).

The average of correlations between the scores of reading and mathematics is approximately 0.60 in the age of adolescence and during elementary school (Fuchs et al., 2006; Lee, Ng & Ng, 2009) and is possibly higher in degree during the pre-school stage (McClelland et al., 2007; Welsh et al., 2010). Apart from it, skills of mathematics and reading at an early age can predict each other as much as up to the middle and high school levels (Hooper Roberts, Sideris, Burchinal & Zeisel, 2010). Between domains, such as reading and mathematics, a significant relationship exists that can be shown by potential explanations like cognitive, genetic and environmental links (Farrington-Flint, Vanuxem-Cotterill & Stiller, 2009; Gathercole, Pickering, Knight & Stegmann, 2004; Hart, Petrill, Thompson & Plomin, 2009; Rohde & Thompson, 2007).

However, the single reason explored lesser regarding this correlation is that the development of skills of one domain is reciprocally affected by the skills of the other domain. A unique role of some peculiar initial literacy skills is evident in the mathematical abilities development of a later stage. The feature worth-noting is that children suffering from difficulties of reading and children suffering from difficulties of mathematics, both seem to form specific mathematical skills at a comparatively slower pace than children suffering from difficulties of mathematics alone. From amongst the literacy skills, the skill that is most profoundly bound and intimately connected to the skills of mathematics is phonological know-how (Fuchs et al., 2006, 2010; Krajewski & Schneider, 2009).

Many theories propound the existence of a direct or indirect relationship between mathematical skills and phonological consciousness (e.g. Purpura et al., 2011; Simmons & Singleton, 2008). Most notably, the hypothesis of isolated number words indicates that the relationship between mathematics and reading focuses on applying principles of phonological awareness over number words learning. Krajewski along with his colleagues (2008) observed that skills of phonological awareness produce in children the competence of differentiating as well as manipulating individual words in the number sequence. However, in addition to this, the research conducted by them refers to the existence of such relationship mainly at the number word learning level of mathematical skills, which is the base level; it also indicates that there is the only indirect relationship of awareness in phonology to the skills of mathematics of the later stage via the skills of mathematics of the earlier stage. Even though, as compared to phonological awareness, language skills stand less studied, still, a relation has been found to exist between skills of language and concurrent mathematical performance, and language skills have been found to predict about later mathematical performance (Hooper et al., 2010; Romano, Babchishin, Pagani & Kohen, 2010).

Objective of the Study

This study aims at confirming the relationship of (language L2 skills with L1 skills, and mathematics skills. As we have reviewed the literature about the relationship of language (generally) and mathematics, now we can have a view of the research focusing on the relationship between L2 and L1.

Review of the Related Literature

L2 learning depends on L1 learning skill, and thus syntactic, semantic, and phonological skills of L1 determine L2 achievements. Resultantly, according to Farukh and Vulchanova (2015), one’s above-mentioned skills in L1 contribute largely to one’s successful learning of L2. It is observed that L1 and L2 follow the same fundamental process of learning, and, therefore, any shortcomings in the skills of L1 reflect and refer back to the weakness in the system of L2 (Farukh & Vulchanova, 2015; Ganschow, Spark & Javorsky, 1998).

The very neural procedures undergone by L1 in its acquisition are followed by L2 also, in its acquisition, is attested by evidence; however, some resources, including exposure to the target language, age, and degree of mastery are required additionally by L2 learning (Farukh & Vulchanova, 2015; Perani & Abutalebi, 2005).

Different languages follow the same activation patterns of the brain, even though these patterns get regulated by several factors (Farukh & Vulchanova, 2015; Perani & Abutalebi, 2005). According to Ganschow, Sparks, and Javorsky (1998), the dependence of L1 and L2 is proved to be on the same inherited generic systems, due to which deficiency in a skill, like that of phonology or orthography of L1, affects the systems of L2.

Hypothesis

Language and mathematical skills share the same sub-skills, same regions in the brain for their processing, and similar psychological development (Purpura & Ganley, 2014), therefore these skills would be concurrent predictors of one another and can correlate significantly with one another.

Methodology

Data Collection

To test the hypothesis the scores of one hundred, 11 years girls on the grade 5 examination, were taken for all three subjects i.e. English, Urdu, and mathematics from the Punjab Education Commission examination. The students’ scores were selected based on availability/convenience from the results of the 2019 annual examinations.

The girls were studying at a public sector school for girls in an underdeveloped rural area of South Punjab (Pakistan). The children were from similar social backgrounds i.e. lower. Punjabi is L1 of most of the students. Some students have Siraiki as their L1. Urdu is the national and the second L1 for the children.

Description of Tests

All of the 3 tests were of 2 hours and 45 minutes each. Maths test consisted of 100 marks. Half of the weightage was given to the objective part and the other half to the subjective part. The objective part consisted of 25 MCQs. Every question in this portion carried 2 marks each. Questions were all about addition, subtraction, multiplication, division, statements of daily algorithmic questions, LCM, HCF, geometry, an average of numbers and graphs. The subjective portion had 5 long questions each carrying 10 marks. The asked questions were about algorithms (+,-, ×, ÷), LCM / HCF, ratio/proportion, geometry (area/drawing square, etc.), and statistics/graphs, respectively. The areas mentioned above also covered 50 marks of the subjective portion.

Urdu test for grade 5 consisted of 100 marks. Half of the weightage was given to the objective part and the other half to the subjective part. The objective part consisted of 25 MCQs. Every question in this portion carried 2 marks each. All questions were about Urdu grammar (noun, pronoun, verb, and adverb), comprehension questions were from poetry stanza and prose paragraphs. The subjective portion had 5 long questions each carrying 10 marks. The asked questions were to write an application, letter, and explanation of poetry in simple sentences, story writing by using the given hints, and an essay of at least ten sentences on a given topic. The skills mentioned above also covered the 50 marks of the subjective portion.

English test for grade 5 consisted of 100 marks. Half of the weightage was given to the objective part and the other half to the subjective part. The objective part consisted of 25 MCQs. Every question in this portion carried 2 marks each. Questions were all about English grammar (noun, pronoun, verb, adverb, and adjective), rhyming words, simple tense, singular/plural words, and comprehension paragraph questions. The subjective portion had 5 long questions each carrying 10 marks. The asked questions were to write a paragraph about a certain given picture or topic, to write a letter by delivering demanded keywords, story writing by using the given pictorial hints, comprehension paragraph, making sentences from given words, and fill in the blanks by proper given words. The skills mentioned above also covered the 50 marks of the subjective portion.

Statistical Analyses

The skewness of data was determined for all 3 variables which remained .13 for English scores, -.06 for Urdu scores, and .72 for mathematics scores.

All of these skewness values were normal, and further analyses were performed.

To assess our hypothesis concerning the concurrent predictors of performance in English, a hierarchical regression analysis was performed. Before the hierarchical regression, we ran a Pearson's correlation analysis (Tables 1).

Table 1. Summary of Inter-correlations for Scores on all Variable

Variables	1	2	3
English		.62**	.59**
Urdu			.64**
Mathematics			

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

Table 1 shows that all the 3 variables are highly correlated with one another. In the hierarchical regression analysis (Table 2), the variables were entered one by one, and the contribution of every variable was calculated by controlling the effect of the other variable as there were only 2 independent variables. English language skills were used as dependent variables, the independent variables i.e. Urdu literacy skills and math skills, were entered in two steps. Urdu literacy skills were entered at the first step, whereas math skills were entered at the second step, after controlling for the effect of Urdu language score effect.

Table 2. Hierarchical Regression Analysis Exploring Predictors of English Proficiency

Step	**Variables**	**$R^2/\Delta R^2$**	**Beta**
1	Urdu	.39***	.62***
2	Mathematic	.45***	.32***

*p<.05. **p<.01. ***p<.001. Beta=standardized coefficients beta.

The regression analysis shows significant beta values indicating that both L1 (Urdu), and Mathematics scores (Table 3) are concurrent predictors of English scores. To further explore the relationship among the variables, a principal component analysis was conducted with varimax rotation. Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) = 0.72, Barlett's test of sphericity $\chi 2$ (3) = 108.31, $p < .001$. All the variables were let to load on factors without specifying the number of factors, resulting in loading on one factor.

Table 3. Summary of factor Loadings with Varimax Rotation of the English, Urdu, and Mathematics Scores

Item	Component
English	**.85**
Urdu	**.88**
Mathematics	**.86**

Extraction Method: Principal Component Analysis
a. 1 component extracted. Note: Factor loadings >.40 are in boldface.
Loading of all variables on one factor with all values above **.4** shows a high association among them.

Discussion

All the statistical tests used to do the analyses show a strong correlation among the variables that means that first language skills and mathematics skills can be strong concurrent predictors of second language skills.

The loading of all 3 skills on one factor also shows that all variables are strongly related.

The strong predictive relationship between L2 skills, L1 skills and mathematics is in line with the previous studies which claim that mathematics and reading (a language skill) help in each other's development, and show signs of inter-relatedness right from a very early age (McClelland et al., 2007; Welsh, Nix, Blair, Bierman & Nelson, 2010). The domains can make long-term predictions about each other (Duncan et al., 2007; Juel, 1988). The relation in its peculiar essence, however, remains unclear (as discussed in Purpura et al., 2011).

The study also supports the previous research which shows a high degree of correlation in adolescence and during elementary school (Fuchs et al., 2006; Lee Ng, & Ng, 2009). Furthermore, skills of mathematics and reading at an early age can be predictors of each other as much as up to the middle and high school levels (Hooper et al., 2010). For the sake of explaining the significant relationship between reading (the language skill) and mathematics, domains like cognitive, genetic, and environmental links are potential explanations (see Farrington-Flint, Vanuxem-Cotterill & Stiller, 2009; Gathercole, Pickering, Knight & Stegmann, 2004; Hart, Petrill, Thompson & Plomin, 2009; Purpura et al., 2011; Rohde & Thompson, 2007).

The results are also in line with the studies which support that language has a broad relation to all mathematics skills evaluated at an early stage (e.g. Purpura & Ganley, 2014).

The study has some limitations like the data is only from girls, and secondly, the children were not controlled for their IQ level.

Conclusion and Pedagogical Implications

The conclusion of the study is that language and mathematics skills are highly correlated, and the pedagogical implication of this, in turn, is that if a child performs well in L1 and/or mathematics skills, s/he would perform well in L2 as well. If s/he does not perform well in L2 then the methodology to teach might be changed to get good results as s/he is using the same underlying systems for L1, and mathematics and producing good results, therefore the problem is not with the child's capability, but with the teaching process.

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