Prediction of Reading Performance Using the MAPS (Mental Attributes Profiling System) Multimodal Interactive ICT Application

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Abstract: Current literature has put special attention to the issue of reading difficulties. Poor reading performance can suggest possible problems such as dyslexia and other learning disabilities. It is thus important to ensure the early identification of the problem when this exists and provide early intervention to children when needed. The authors of this paper have developed a battery of Internet based applications which collectively operate as a screening test of cognitive abilities capable not only to predict children at risk (e.g., possible dyslexics), but moreover to equip the teacher with a profile of mental abilities relevant for choosing and designing personalized remediation programs. A further constrain that was put was that the system should be language independent, i.e., rely on cognitive rather than language-based measures. This study evaluated the capability of the new computerized cognitive battery of tests to predict reading performance. The MAPS (Mental Attributes Profiling System) battery addressed eight major domains of language-independent tests that have been frequently linked to reading development and/or disability: (1) short-term visual memory, (2) short-term auditory memory, (3) auditory discrimination, (4) visual discrimination, (5) lateral awareness, (6) categorization, (7) sequential processing, and (8) navigational ability. A set of Rapid Naming of pictures and letters and word reading tests (Word Identification and Word Attack) of students attending Grade 2, 4 and 6 was used as the dependent variable of MAPS in predicting reading performance. The analysis of the results suggested five predictors as the strongest, for predicting reading performance; these were lateralization, auditory memory, categorization, sequencing and auditory discrimination. The results suggest these five predictors can be used for early identification of children at risk in order to avoid potential problems in their later learning development.

Keywords: reading performance, profiling system, auditory discrimination, lateralization, categorization, sequencing.

1. Introduction

In the last decades much emphasis has been given to the issue of reading difficulties. Researchers have tried to develop screening tests that will enable them to assess whether a child is facing a reading difficulty. Predicting reading abilities or disabilities in very young children however, is one area that still lacks investigation. Past literature on reading difficulties has focused mainly on screening children with language-based tests. The problem however lies in that language dependent tests do not adequately show whether there is a problem in very young children that might need further investigation. At these very early ages one can only speculate about possible problems in

reading, and intervention is almost always postponed until further examination is conducted in later ages. Reading performance has been found to correlate with several cognitive abilities such as phonological awareness, proccessing and word identification, lateral awareness and auditory/visual perception processes. The following sections will describe the current literature in the area of reading performance, present the materials used in the present study and last sections will deal with the presentation and discussions of results.

2. Phonological Awareness, Phonological Processing & Word Identification in Predicting Reading Performance

Most researchers have been using phonological awareness (Caravolas, Violin, & Hulme, 2005; Frost, Madsbjerg, Neidersoe, Olofsson, & Sorenson, 2005; Lonigan et al., 2000; Muter, Hulme, Snowling, & Stevenson, 2004; Olofsson & Niedersoe, 1999; Wagner et al., 1997), phonological processing such as rapid automatic naming (RAN) and word identification to identify reading difficulties. In 1972, Ingling coined the term categorization as a mechanism for rapid information processing. He hypothesized that participants would encode stimuli into categories, without first making a complete identification (Ingling, 1972). Categorization is a cognitive process in which ideas and objects are recognized, differentiated and understood. Categorization implies that objects are grouped into categories based on prototypes, usually for some specific purpose. Later on, in a series of empirical studies, Gopnik and Nazzi (2003) have shown that children do categorize and name objects on the basis of their causal powers, from early as 30 months of age. This ability seems to be highly correlated with the acquisition of names and particularly with a naming spurt. In a study with an object-sorting task, learning-disabled children categorized significantly less than middle-class children (Auerbach and Melamed-Cohen, 1978). Tests on phonological awareness, phonological processing and word identification have been shown to significantly correlate with later reading performance (Clarke, Hulme, & Snowling, 2005; Compton, Fuchs, Fuchs, & Bryant, 2006; Compton, 2003; Neuhaus & Swank, 2002).

The importance of pre-literacy skills and reading performance has been clearly demonstrated by several past authors (Carroll et. al, 2003; Lonigan et al, 2000; Wagner et al., 1997). Smith et al (2008) conducted a longitudinal retrospective study to examine the relationship between pre-reading skills and later reading performance. Their results suggested that phonological awareness is a strong predictor of reading abilities in the pre-literacy period. Yet, despite the wealth of evidence supporting the view that phonological and speed naming skill deficiencies are preeminent causes of reading disability, they alone cannot explain the total variability. There is abundant evidence that poor readers also tend to perform poorly on tests requiring semantic or syntactic processing (e.g., Scarborough, 1990; Vellutino, 1987), lateral awareness and navigation ability that might be interconnected with functions in the occipital-temporal cortex (Ramus, in press), and sequencing ability (Das, Naglieri, & Kirby, 1994; Papadopoulos, 2001).

3. Using lateral awareness to predict reading abilities

Many authors have searched over the years for possible relationships between lateral preferences in hand and eye usage, lateral awareness and reading ability. Harris (1957) and Zangwill (1962) explored the incidence of reading disability in relation to handedness. Rabinovitch et al. (1954) and Belmont and Birch (1963) have shown that spatial discrimination (i.e., lateral awareness), rather than lateral preference was significantly correlated to reading ability. In a systematic study, Belmont and Birch (1963) have found clearly significant correlations between reading ability and both left-right awareness with reference to parts of their own bodies and lateral awareness with reference to their environment. It is known that laterality of own body parts is fully stabilized at the age of 7

(earlier than eye and hand preferences, which stabilize at around 9), this measure might render itself appropriate for early diagnosis.

4. Auditory and Visual Perception Processes in Predicting Reading Performance

Moreover, auditory and visual perception processes have also been found to predict reading performance (Kavale & Forness, 2000). According to Kavale and Forness (2000), four skills were identified for auditory perception in predicting reading abilities: "(a) auditory discrimination (AD): ability to differentiate among auditorally presented stimuli; (b) auditory memory(AM): ability to recall a sequence of auditorally presented stimuli; (c) auditory blending (AB): ability to perceive separate auditory stimuli (phonemes) and to combine them into a whole unit (word); and (d) auditory comprehension (AC): ability to interpret and to understand auditorally presented material" (p.256). Auditory discrimination appears as the most important predictor of reading disabilities. Research on children and adults with developmental disabilities showed that when tested they might pass visual discrimination, but almost always fail to pass auditory discrimination (e.g., Martin & Yu, 2000; Meyerson, 1977).

In their study on auditory and visual perception, Kavale and Forness (2000) separated visual perception into seven skills "(a) visual discrimination (VD): ability to perceive dominant features in visual stimuli; (b) visual memory (VM): ability to recall a sequence of visually presented stimuli or ability to recall a dominant feature of a visual stimulus; (c) visual-motor integration (VMI): ability to integrate visual stimuli with body movements (i.e., eye-hand coordination); (d) visual closure (VC): ability to recognize a complete figure from fragmented visual stimuli; (e) visual association (VA): ability to relate conceptually visually presented stimuli; (f) visual spatial relationship (VS): ability to perceive position of objects in space; and (g) figure-ground discrimination (FG): ability to distinguish an object from irrelevant background visual stimuli" (p.256-257). Here again, visual discrimination comes as the most important predictor of reading performance.

Auditory and visual discrimination seems to be related with developmental disabilities. In their study with children with developmental delays especially in the autistic-spectrum, Ward and Yu (2000) examined the possible significant gap in difficulty level between learning of visual and auditory discriminations in more detail. The goal of their study was to identify additional discrimination skills, which might be prerequisites for learning auditory discriminations. The following two out of four identified component skills that might be prerequisites for speech discrimination are of great value: auditory-visual matching involving object sounds and auditory-visual matching involving speech and object sounds. The performance in visual and auditory discrimination is possibly also an indicator for intellectual disabilities in children. In a study with mildly to profoundly mentally disabled children none of the participants with greater than mild disability successfully completed the discrimination tasks of the AVC Scale, which is a behavioral instrument encompassing non-language tasks (Kerr, 1977).

5. Mental Attributes Profiling System (MAPS)

The MAPS (Mental Attributes Profiling System) test is a battery of computer-based tests that assess the learning abilities of pre-elementary and elementary age school children. It consists of eight language-independent tests that measure various aspects of learning. In addition, it is an attempt for teachers and psychologists to map a profile for each child in order to identify their specific needs and decide on appropriate interventions on their benefit.

5.1 *"Left-Right Game" Lateral awareness Test*: This test provides two types of measures. One, it evaluates the child's ability to make left-right discriminations on his own body. During the first part, the test shows a child "sitting" in the same orientation as the subject (i.e., the subject sees on the screen the back of the child) in front of two objects, one on his/her upper left and the other on his/her upper right visual field. The computer asks the subject to "grab" the left or right object using his/her left or right hand. What is measured is (1) the time taken to select an arm (by clicking at the shoulder), and (2) whether the selected arm was correct or wrong. The same procedure is repeated during the second part of the test, in which the orientation of the child on the screen is reversed, i.e., the child on the screen is facing the subject. The second type of measures are derived from Piaget's (1928) tests to evaluate awareness of right-left relations outside our own body, i.e., in the environment. To evaluate this ability, the test measures (1) the time taken by the subject to decide which object to "grab" and (2) the number of correct/wrong decisions.

5.2 *Categorization:* The test presents an object and invites the subject to "drag" it in one of three "worlds," for which there is a match. The following "categories" were tested: (1) Objects of different color to be placed in one of three possible "colored worlds." (2) One geometrical object, (i.e., triangular, circular, or rectangular), to be placed in its corresponding world. (3) A plant matched as a vegetable, a tree, or a flower. (4) An animal (or fish) to be placed in one of three possible environments: sea, sky, or open fields. (5) Objects usually found in a home environment, to be "placed" in one of three rooms of a house (office, kitchen, or bathroom).

5.3 *Visual memory*: This test is based on the well-known card game called "Memory," in which the subject uncovers two cards at a time. If they have the same picture they remain uncovered and visible, otherwise they are turned back as they were.

5.4 *Auditory memory*: The test was modeled using the digital phone metaphor. The computer instructor invites the subject to "dial" a telephone number. Two sets of two-digit numbers are followed by four sets of three-, four-, five-, and six digit numbers, respectively. The test concludes by presenting a set of two seven-digit numbers. The feedback is positive/neutral giving no clue regarding the correctness of the response. The test is terminated if the subject makes 3 consecutive errors.

5.5 *Auditory discrimination test*: The main screen of the test features two human-like figures, who "speak" a word, one after the other. The subject is asked to decide whether the two words are the same or different by clicking on an "✗" or a "✓" sign. Each word includes consonants, which sound similar and are therefore confused by weak readers and especially by dyslexics in the Greek language. The following letter combinations were tested: (1) φ-β, (2) δ-θ, (3) ζ-σ, (4) χ-γ, (5) τ-ντ, (6) κ-γγ/γκ, (7) π-μπ, (8) τσ-στ, (9) γ-γγ/γκ, (10) ξ-κς. In additional sets, the test also evaluates the ability of the child to differentiate between the same letter combinations when they are embedded in non-sense words.

5.6 *Visual discrimination:* Modeled using the popular "Find the differences" game, this test presents three pictures very similar to one another and one that must be matched. The exercise is repeated four times with four different pictures. The total correct score is used as an index of visual discrimination.

5.7 *Sequencing:* This test was inspired by the "connect the puzzle" games. Different objects or animals appear in two-, three-, four-, or five pieces and the subject is requested to "drag" the pieces and place them in the right order to complete the picture. The second part of the test presents pictures, which represent different stages of a temporal process. The subject is expected to put them in the right order.

5.8 *Navigation:* The test consists of an 8x8 matrix of small pieces of cheese and a mouse. The computer instructs the subject to move in one of eight possible directions and "eat" the corresponding piece of cheese: Up, Right-up, Right, Right-Down, Down, Left-down, Left, and Left-up. The instructions are given both visually (with the aid of a small arrow) and/or orally.

The aim of the present study is to suggest a new approach of predicting reading abilities or disabilities with the use of non-verbal computer oriented tests. This paper attempts to examine which of the eight MAPS tests will appear as the best predictors of reading performance and to identify possible difficulties that might require intervention. Past literature focused on examining each of the aforementioned separately as predictors of reading performance while using verbally restricted tests. The MAPS test is an attempt to examine all possible predictors together and at the same time provide a language independent screening test that could be used for children at any age in predicting potential problems. A total of 134 children participated in the study. Out of them, 44 participants (25 females & 19 males) were 7-8 years old, 44 participants (22 females & 24 males) were 9-10 years old, and 46 participants (24 females & 22 males) were 11-12 years old. The mean age for the younger group was 7.40 years (SD = 0.45), for the middle group was 9.49 years (SD = 0.47), and for the older group was 11.27 (SD = 0.39). There were no significant differences in age between males and females across groups. The participants came from three age groups: The second, the fourth, and the sixth Grades of elementary school. We aimed at 45 subjects per age group. The parents of the participants had predominantly low levels of education (less than one quarter of the sample had parents, who were college educated). Also, participants came from 16 regular elementary schools, which were equally sampled from urban, suburban, and rural public school districts, in Cyprus.

6. Reading Measures Used for Predicting Reading Performance

The participants' reading ability was assessed through two different tasks involving the reading of real words and pseudo-words. Both reading measures were Greek adaptations of Woodcock's Reading Mastery Test-Revised (1987), and have been used in previous studies (Papadopoulos, 2001; Papadopoulos et al. in press). In both tests, the participants' score was the number of words read correctly within 60 sec.

- Word Identification: This test consisted of 85 words forming a 2 x 2 x 2 factorial design in terms of frequency (high/low), orthographic regularity (regular/exception), and length (bi-syllable/tri-syllable). Due to the absence of standard frequency counts in Greek, half of the words were sampled from the first-to-second grade language books, and the other half taken from third-to-fourth grade language books. The stimulus words were mainly nouns with a few adjectives and verbs.
- Word Attack: This test consisted of 45 pronounceable non-words that were derived from real words after changing two or three letters (either by substituting them or using them backwards). The task started with bi-syllabic words and ended with five-syllabic words.

7. Administration

Letters were sent to all parents, whose children were selected, seeking their permission. No parent withheld permission. All participating children attended two individual testing sessions lasting from 30 to 40 minutes each. All testing took place during school hours in a private room in the

participants' respective schools. All paper-and-pen tests were administered and scored by the participating educators. Also, all M.A.P.S. tests were administered in their presence. The scores were written on the computer automatically by the software. The educators copied those files on disks and delivered them to the authors.

Before launching the experiments, the authors secured special permission by the Ministry of Education authorizing them to contact schools directly. Sixteen regular elementary schools, which were equally sampled from urban, suburban, and rural public school districts, in Cyprus, were chosen for the experiments. Twenty four educators (where possible, preference was given to those employed in participating schools) were identified to serve as administrators of the tests. Almost all of them are qualified and experienced teachers who participated in similar exercises in other occasions. Before the experiments, these twenty four experts received an 8-hour training (spread over two sessions) in how to conduct individual assessment interviews with children and how to administer the paper-and-pen as well as the M.A.P.S. computer-based tests.

8. Results

The results were analyzed using the Statistical Package for Social Sciences. A linear multiple regression was conducted to signify the best predictors of reading performance. The model explains 53.7% of the variance and it appears to be significant ($F=8.725$, $df=20$, $p<.001$). Table 1 shows the strongest predictors of MAPS tests for reading performance. As it can be seen, the strongest predictor appears to be lateralization same orientation ($beta=.264$, $t(113)=3.391$, $p=.001$). This result suggests that reading performance can be predicted from the number of correct responses the participant had when asked to note left and right while the orientation was the same with his/her own body. As table 1 suggests the second strongest predictor appears to be auditory memory ($beta=.988$, $t(113)=2.398$, $p<.05$). This result suggests that the total of correctly typed digits (despite the order on which they were put) shows appears as a good predictor of reading performance. The third good predictor of reading performance as shown from the regression analysis is categorization ($beta=.264$, $t(113)=2.300$, $p<.05$). This suggests that the total time taken to categorize objects can predict reading performance. The fourth best predictor of reading performance as shown in table 1 is sequencing ($beta=-.221$, $t(113)=-2.243$, $p<.05$). The total time taken for a participant to put objects in the correct sequence appears as a good predictor of reading abilities. Last, auditory discrimination is also found to be a predictor of reading performance ($beta=-.184$, $t(113)=-2.095$, $p<.05$).

Table 1: Multiple regression in predicting reading performance

Coefficients [a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1. Lateralization same orientation total correct=(lsoc1+lsoc2+...lsoc8)	.307	.091	.264	3.391	.001
2. Categorization total time = (ctt1+ctt2+...ctt5)/5	1.313E-6	.000	.152	2.300	.023
3. Sequencing total time = (stt1+stt2+...stt6)/6	.000	.000	-.221	-2.243	.027
4. Auditory discrimination total time = (adtt1+adtt2+...adtt10)/10	-.003	.001	-.184	-2.095	.038
5. Auditory memory total correct weighted number of correct digits (2x2; 3x3 etc.)	.112	.047	.988	2.398	.018

a. Dependent Variable: reading composite score = zwid+zwat

9. Discussion

The purpose of this paper was to find out which of the eight MAPS tests are the best predictors of reading performance in children. Results suggested that the strongest predictors were those expected by past literature. These are: lateralization, categorization, sequencing, auditory discrimination and auditory memory. First, lateralization that focuses on lateral awareness, the ability of a child to distinguish between left and right. Children with reading difficulties appear to score significantly lower than normal readers in the lateralization tests (Belmont and Birch, 1963). Second strongest predictor appears to be auditory memory. Depending on the type of problem a child is facing (such as dyslexia, ADD/ADHD), auditory memory tests can serve as good predictors of reading performance. The ability of a child to remember and present the spoken message or numbers back involves a complex processing in the brain that in case of problematic readers can become confusing and cause low scores. Consistent with most past studies, categorization has also appeared as a good predictor of reading performance. The ability of a child to categorize objects can reveal whether a child has some kind of learning difficulty. Results from previous studies showed that children with learning difficulties score low on this kind of test (Auerbach and Melamed-Cohen, 1978). Even though no information was found in regards to sequencing and reading performance, the fourth test that appears as a predictor of reading performance is putting objects in the correct order (sequence). The ability to sequence involves a complex processing on the brain and it is likely that children with problems in coding/decoding and processing of information would score low on this test. Last, the auditory discrimination test appears also as a predictor of reading performance. Consistent with past studies results suggest that children with reading difficulties score low on auditory discrimination tests (Kavale & Forness, 2000).

These five cognitive processes have appeared to be the strongest predictors of reading performance. The predictors are important in screening children for reading difficulties in order to provide intervention that could help potential problems in the school environment. Intervening measures can be developed by the teachers for children who are identified with a reading difficulty, in order to help them achieve their highest potential and not feel inferior or stigmatized towards their

classmates. In the past, children who presented learning difficulties but were not identified were considered as lazy or weak students, and most of the times they were leaving the school out of their frustration of not successfully learning school courses. Children like that were most of the times feeling incompetent and stupid and were stigmatized from other students. Thus, prediction of possible difficulties can ensure that a child receives the attention he/she deserves in order to be able to effectively learn and succeed in the school setting.

MAPS is a battery of screening tests that can create a child's profile signifying abilities and problems in learning. What is important however, is that the MAPS is a language independent test which means that it can be used for screening very young children as also children who are bilingual or multilingual. It is widely accepted now that early diagnosis is crucial for dealing with the spectrum of learning difficulties and it is equally important for children who are at risk of later problems to engage in an intervention program that will minimize their risk of failure at school. The MAPS test has been designed to provide this kind of help to instructors and specialists, and to pinpoint where problems may appear in the learning spectrum of a child. Differentiating from past tests, the MAPS test offers an assessment in a broad spectrum of cognitive processes and offers the potential of identifying possible problems not only on reading performance but on learning in general. In addition, the MAPS test is a computerized test that can design a child's profile without the hassle of writing info down and can be accessed for review at any time through its data bank that saves the profiles of the users. Finally, the MAPS tests has been designed to examine the cognitive processes for learning and in the area of reading performance five subtests have been found to correlate significantly in its identification.

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