Avicenna J Neuro Psych Physio. 2014 November; 1(2): e24208. DOI: 10.17795/ajnpp-24208

Published online 2014 November 16. **Research Article**

Neurocognitive Profile of Children With Reading Disability in Kannada

Surendranath P. Nishanimut [1]; Prakash Padakannaya [2,*]

[1]Samveda Training and Research Centre, Davangere, India
[2]Department of Psychology, University of Mysore, Mysore, India

*Corresponding author: Prakash Padakannaya, Department of Psychology, University of Mysore, P. O. Box: 570006, Mysore, Karnataka, India. Tel: +91-8212419743, E-mail: prakashp99@gmail.com

Received: September 30, 2014; **Revised:** November 2, 2014; **Accepted:** November 6, 2014

Background: The present study was based on the Planning, Attention, Simultaneous, and Successive processes (PASS) theory.
Objectives: We hypothesized that there would be significant differences between children with and without reading disability (RD) on PASS components. Furthermore, we predicted that deficits in children with RD would not be uniform across PASS components.
Patients and Methods: Children with RD who participated in the study were two grades below the expected reading level for their age but were otherwise normal with respect to intellectual functioning, opportunities, and instructions. The comparison group consisted of age-matched children.
Results: Independent-samples t tests (two-tailed) showed significant difference between the groups on all the PASS component subtests. The PASS scores of children with RD were scattered unevenly around the average to well below the average range.
Conclusions: Kannada children with RD were particularly poor on simultaneous and successive processing. Our results support the heterogeneity view of RD.

*Keywords:*Cognitive; Dyslexia; Neuropsychology

1. Background

The main aim of the present study was to elucidate the neuropsychological profiles of children with reading disability (RD) in Kannada, based on the Planning, Attention, Successive, and Simultaneous (PASS) theory propounded by Das et al. (1). The PASS model has three basic units. The first functional unit is responsible for regulating cortical tone and maintenance of attention; the second receives, processes, and stores information using simultaneous and successive information and coding while the third program regulates and directs mental activities (2). The first functional unit explains how the attention and arousal are interrelated. Arousal refers to a state of alertness. When arousal is disturbed, attention cannot be engaged. The inadequate functioning of this unit results in difficulty in information coding and planning (2). The third functional unit is planning, which is the part of the brain that is responsible for the programming, regulation, and verification of human activity. It responds to incoming information; man creates intentions, forms plans and programs of action, inspects their performance, and then regulates his behavior so that it conforms to these plans and programs (3).

The second functional unit of the PASS model comprises activities in the occipital, temporal, and parietal areas of the brain, which perform simultaneous and successive processing. Simultaneous processing and successive processing are two modes of coding information. Simultaneous processing is quasi-spatial in nature in that all parts of it are viewable at any given point of time. Simultaneous synthesis involves the organization of information into a meaningful gestalt. On the other hand, successive processing is temporal in nature and therefore, could be surveyed in only a linear way (4). Successive processing is a mental function where stimuli follow a specific serial order that forms a chain-like progression, whereas simultaneous processing is a mental function that allows a person to integrate separate stimuli into a single whole (5). The second functional unit explains how external stimuli are encoded, which could be either successive or simultaneous in nature. Three coding aspects have been described: level of coding, the code content, and the type of coding (2). The level of coding refers to the complexity of the presented materials and involves the level of abstraction and required inference. Code content refers to the verbal or spatial nature of the content. The type of coding refers to its successive or simultaneous nature. Word reading is related to the dominant interaction between the simultaneous (top-down) and successive (bottom-up) processes. Simultaneous processing is dominant in visual coding whereas successive processing plays a major role in phonological coding (2). In successive processing, the units of information are connected by temporal-order links whereas in simultaneous processing, the units are related in other more abstract or quasi-spatial ways.

Simultaneous processing involves the ability to integrate separate stimuli into a cohesive interrelated whole (6). Children use this mental process to relate separate pieces of information into a group and to see how these parts might be related in a whole.

In order to obtain meaning, simultaneous processing allows integration of words and their inflections through the logical-grammatical processes. Therefore, the individual words make up the meaning of a sentence and individual sentences make up the meaning of a paragraph or a narrative. In other words, pattern recognition and perception of individual components of a whole is perceived through simultaneous processing. If a reader gets the broader picture of the read matter and is able to decode the hidden meaning, it can be assumed that simultaneous processing is functioning at the optimum level. The nonverbal-spatial and verbal-grammatical activities are processed through simultaneous functioning. The simultaneous processing subtests in the cognitive assessment system (CAS) reformulate the perception of parts into a single gestalt, conduct understanding of logical-grammatical relationships, and synthesize parts into integrated groups, which are produced either through examinations of the stimuli during the activity or through recall of the stimuli (7).

Successive processing is a mental process by which the individual integrates stimuli into a specific serial order, forming a chain-like progression (8). This involves the ability to integrate stimuli into a sequential order. An example of this process is the sequencing of letters and words in reading and writing. It is suggested that successive processing is needed when things "follow each other in a strictly defined order" (6). Syntactic rules are learned through successive processing. All serial arrangements of movements, perception of stimuli, and the sequential order of arrangement follow successive processing. The series of speech sounds and their synthesis is done through successive processing.

In successive processing, incoming information is organized in sequential order so that the only connections are the links of one part to the next. Those who are adept at successive processing would recall information like sounds and movements in sequential order. For this reason, successive processing is concerned with the blending of sounds to form words as well as the syntax of language. Successive processing subtests in CAS require perception and reproduction of the serial nature of stimuli, an understanding of sentences based on syntactic relationships, and the articulation of separate sounds in a consecutive series.

Simultaneous tasks as set forth in the CAS include nonverbal matrices, verbal-spatial relations, and figure memory. Measures of successive processing reflect the ability of the test tasks to recognize the serial fashion of the stimuli. The tasks range in difficulty and "require the individual to either produce a particular sequence of events or answer questions that require correct interpretations of the linearity of events" (2). Successive processing tasks include word series, sentence repetition and sentence questions or speech rate.

While phonemic awareness, vocabulary, fluency, and comprehension are the essential components of reading, vital cognitive functions such as attention, working memory, visual and auditory perception, and integration also occur during reading. Children with reading difficulties have shown deficits in simultaneous and successive processing, which might underlie difficulties in phonologic and visual coding (9). Studies based on PASS model of cognitive processing (10) have clearly shown dysfunction in successive processing in disabled readers. The relationship of reading to simultaneous and successive processing skills varies in early and later stages of reading acquisition. Though successive processing might have a greater role in the early stages of reading, simultaneous synthesis would be more important at higher grades (4). Several important studies have validated PASS theory and its link to cognition, intelligence, and reading (11-15). Studies on nonalphabetic orthographies such as Kana (16) and Chinese (17, 18) have also demonstrated the efficacy of successive and simultaneous processing skills in predicting reading. They concluded that successive processing predicted reading through the effects of phonologic awareness and simultaneous processing predicted reading through the effects of orthographic knowledge. This premise supports that PASS theory applies reading acquisition across languages. Further, many studies (19) have elicited that reading involves planning, attention, and simultaneous as well as successive processing. They have documented the importance of the coding processes, i.e. successive and simultaneous processing in reading.

The present study was performed on Kannada speaking children in India. Kannada is a Dravidian language used by more than 50 million people in the state of Karnataka and in neighboring south Indian states. It is an alphasyllabary, in which alphabetic segments are combined to form spatially delimited syllabic units called akshara. They vary in their complexity levels as akshara may stand for v, vv, cv, cvv, ccv, ccv ccv cccv and cccvv (v = vowel; vv = long vowel, c = consonant) in Kannada. The orthography is very shallow but the visual complexity and large number of symbol sets might be a challenge to learners, especially to children with reading or language disabilities. A detailed description of Kannada orthography might be seen in several reported studies (20-22).

2. Objectives

The present study hypothesized that there would be a significant difference in the cognitive profiles related to planning, attention, and successive as well as simultaneous processes between children with and without RD in Kannada. We further expected that children with RD would be heterogeneous with respect to cognitive skills.

3. Patients and Methods

3.1. Participants

Children aging eight to ten years with average or above average intellectual abilities who were studying in grade III through V in Kannada-medium schools were recruited. Their first language was Kannada and they belonged to middle-socioeconomic-status family. They had no problem in their vision and hearing. They had regular attendance and received uniform instructions from trained teachers. Their behavioral/emotional disturbance levels were within the normal limits. Children with intellectual disabilities, mental illness (psychotic in nature), major neurological/medical conditions such as cerebral palsy, epilepsy, meningitis, severe febrile convulsions, and head injury were not included in the study.

The participants who met the eligibility criteria were included in the study. Children who scored two or more grades below the level for their expected age in oral reading test in Kannada were designated as RD group. On the same test, children who scored at their grade level or high were designated as non-RD group (NRD). The NRD group comprised 168 children (85 males and 83 females) with mean age of 120.1 ± 10.26 months. Among them, the reading performance of 115 children (mean age, 126 ± 4.45) was grade appropriate at grade V and the reading performance of 53 children (mean age, 107.4 ± 7.6) was over their grade level at grade III. The RD group comprised 104 children (54 males and 50 females) with the mean age of 122.75 ± 4.8 months and all of them were studying in grade V.

3.2. Measures

Raven's Colour Progressive Matrices (RCPM) were used to assess the nonverbal intellectual functioning of all children (23). As children with RD do not do well on verbal intelligence tests, RCPM are always used to test the g factor of the intelligence. The socioeconomic scale (24) was used to classify participants according to their socioeconomic status. This scale is the newer version of the National Institute of Mental Health's socioeconomic scale. Behavioral and emotional disturbance levels of the children were determined by Rutter's proforma "A" and "B" (25). The respective class teacher, who knew the child very well, completed these forms. The selected students were given the Kannada oral reading test (26), an old Kannada word reading test, which is popular even today due to its well-developed structure and high validity and reliability.

Finally, 272 participants were tested under the Cognitive Assessment System (CAS) (7) to examine the cognitive profiles with respect to PASS model of cognitive processing. It has been suggested that the PASS model provides a new approach in the assessment of cognitive processes (9). Some components of CAS were translated into Kannada and all instructions were given in Kannada so that the students could understand the tests. Scores on the translated components showed high correlation with the original counterpart. The standard battery of CAS is organized into four scales with three subtests in each one. It yields an overall measure of cognitive functioning called the full-scale score. It is based on equally weighted components of planning, attention, simultaneous processing, and successive processing subtests. The CAS full scale and PASS scales all yield standard scores set at a mean of 100 and standard deviation (SD) of 15. It provides an index of the overall level of an individual's cognitive functioning. The planning scale includes three subtests: matching numbers, planned codes, and planned connections. The attention scale includes three subtests: expressive attention, number detection, and receptive attention. The simultaneous scale includes three subtests: nonverbal matrices, verbal-spatial relations, and figure memory. The successive processing scale includes three subtests: word series, sentence repetition, and sentence question (9).

3.3. Procedure

The study was conducted in Kannada medium primary schools after obtaining official permission from concerned authorities. First, a Kannada oral reading test was administered to 409 children of grades III and V in 19 schools in the Davangere and Chikmagalure districts, Karnataka state. After considering all the above mentioned eligibility criteria, 280 students were shortlisted. They were given the RCPM. Participants ranked as average or above the average (50th percentile and above) were included in the study. Finally, 158 children were selected for the NRD group and 104 children were selected for the RD group. The study was conducted between June 2012 and February 2013.

4. Results

Table 1 shows the mean ± SD, t, and P values of all the scores on four PASS components of CAS and of its subsequent subtests of all the participants. Independent-samples t-test was performed to analyze whether there was significant difference between NRD and RD groups. The NRD Children obtained higher mean scores (90.37 ± 12.4) in comparison to RD children (73.92 ± 8.2) in Full Scale, which showed a significant difference between these two groups ($t = 11.91$ and $P < 0.0001$). This significant difference was also seen in the individual PASS components, where ten planning (mean, 90 ± 12.9), simultaneous (mean 93.1 ± 13.9), attention (mean, 88.4 ± 12.7), and successive (mean, 99.83 ± 11.43) scores of the NRD children were higher than corresponding scores of RD children (see Table 1). Almost all the 12 subtests showed significant difference between the two groups.

Figure 1 shows that the performance of children in RD group (n = 104) on PASS scale standard scores was wide-

ly distributed. On the planning component, the maximum participants were in the low average category (n = 57) and the rest were consecutively in the average (n = 21), well below average (n = 13), below average (n = 12), and high average (n = 1) categories. In case of simultaneous processing, the highest concentration was seen in the well below average category (n = 46), which was followed consecutively by below average (n = 31), low average (n = 13), average (n = 10), and high average (n = 4) categories. Attention subscale had the maximum number of participants in the low average category (n = 57), which was followed consecutively by average (n = 24), well below average (n = 13), below average (n = 9), and high average (n = 1) categories. With respect to the successive subscale, the maximum participants fell in the below average category (n = 31), followed consecutively by the low average (n = 28), average (n = 24), well below average (n = 19), and high average (n = 2) categories. The full-scale distribution shows the maximum concentration of participants in the below average category (n = 57), followed consecutively by well below average (n = 27), low average (n = 14), and average (n = 6) categories.

Table 1. Comparision of Planning, Attention, Simultaneous, and Successive Model Measures Between Those With and Without Reading Disabilities [a]

PASS Components	NRD (N=168) [b]	RD (n = 104) [b]	SE	t (df = 270)	P Value
Planning					
Matching numbers	8.36 ± 3.07	6.45 ± 2.18	0.32	5.51	0.001
Planned Codes	10.55 ± 2.88	9.49 ± 2.27	0.33	3.17	0.001
Planned Connections	6.62 ± 2.38	5.79 ± 2.45	0.31	2.7	0.007
PASS Scale Standard Score	90.1 ± 12.9	82.9 ± 9.7	1.44	5.25	0.001
Simultaneous					
Nonverbal Matrices	8.02 ± 3.02	4.7 ± 2.29	0.35	9.58	0.001
Vision-Spatial Relationship	7.41 ± 3.58	4.14 ± 3.54	0.45	7.28	0.001
MemoryMemory	11.56 ± 2.58	9.58 ± 3.05	0.37	5.37	0.001
PASS Scale Standard Score	93.1 ± 13.9	74.39 ± 14.58	1.79	10.95	0.001
Attention					
Expressive Attention	8.68 ± 2.5	7.66 ± 2.67	0.32	3.14	0.002
Number Detection	8.05 ± 2.39	7.2 ± 2.41	0.31	2.82	0.005
Receptive Attention	7.45 ± 2.39	6.75 ± 2.16	0.29	2.43	0.015
PASS scale Standard Score	88.4 ± 12.7	82.79 ± 10.53	1.51	4.12	0.001
Successive					
Word series	11.46 ± 3.04	7.39 ± 2.69	0.37	11.46	0.001
Sentence repetition	10.44 ± 2.37	7.57 ± 2.58	0.31	6.31	0.001
Sentence question	8.11 ± 2.41	6.58 ± 3.1	0.34	4.48	0.001
PASS scale standard score	99.83 ± 11.43	81.96 ± 13.47	1.53	11.87	0.001
Full scale	106.95 ± 17.7	74.55 ± 8.7			
PASS scale standard score	90.37 ± 12.41	73.92 ± 8.2	1.38	11.91	0.001

[a] Abbreviations: df, degree of freedom; NRD, non-reading disability group; PASS, planning, attention, simultaneous, successive model; RD, reading disability group; SE, standard error.
[b] Data are presented as mean ± SD.

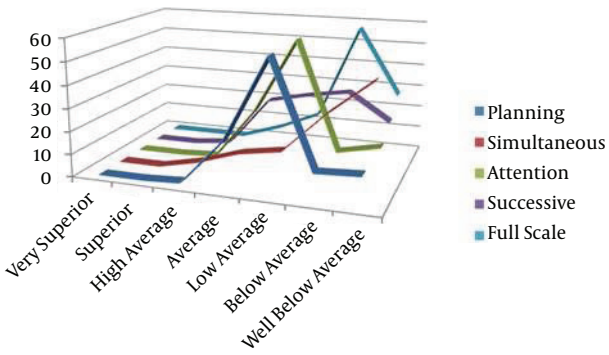

Figure 1. Distribution of Participants With Reading Disability According to Cognitive Assessment System Categories

5. Discussion

The objective of the present study was to compare and contrast the cognitive profiles of children with and without RD in Kannada using CAS. The results showed a significant difference between children with and without RD on all the components of CAS and the full-scale scores. Successive processing was seen as the crucial deficiency in children with RD in English (7). In this study, the results indicated that children with RD were poor in both simultaneous and successive processing skills. We found no significant difference in performance on CAS between the male and female participants of the NRD and RD groups, suggesting that gender did not have any effect on the scores.

The distribution of RD participants across the seven de-

fined categories, based on their performance on all the four PASS components, further elucidated the heterogeneity of their cognitive profiles. There were no participants under the categories "very superior" and "superior" in any of the components. The majority of participants with RD performed at low average level, followed consecutively by below average and well-below average levels. In the planning, simultaneous, attention, and successive components, the majority of participants scored respectively under the low average, well-below average, low average, and below average categories. This supported the hypothesis that children with RD in Kannada were heterogeneous with respect to PASS components. It also established clearly that children with RD in Kannada were in the well below and below average categories in simultaneous and successive processes, respectively. The performance of the NRD group was on par with the norms in the manual (7).

We found significant deficits in cognitive processing skills in children with RD in comparison to NRD group. The results suggested that children with RD in Kannada were poor in both simultaneous and successive processing. This differs from the general notion that deficits in successive processing are the hallmark of children with RD. Children with RD were poor on all the components of PASS but the scores were not evenly distributed across the subtests, reflecting heterogeneity of dyslexia population. Thus, PASS approach might help better understanding the cognitive deficits underlying RD conditions in persons from varied language/orthography backgrounds.

Acknowledgements

We would like to thank all the participant children and their parents for their cooperation.

Authors' Contributions

This study was part of the doctoral work of the first author, who was also responsible for data collection. Both authors were involved equally in planning the study, analysis of results, and preparing the manuscript.

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