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Chapter 12

COMPARISON OF CHILDREN WITH READING COMPREHENSION DIFFICULTY AND CONTROLS USING NEUROPSYCHOLOGICAL TASKS

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ABSTRACT
Objective: This study compared a group of children with reading comprehension difficulty and a group of competent readers using eight neuropsychological measures to find out which are related to performance in reading comprehension. *Design:* Quasi-experimental design. Methods: Participants: Seventy-seven Brazilian children in 4th to 6th grade, 19 with reading comprehension difficulty (high performance in word reading, but low performance in reading comprehension) and 58 good readers (high performance in word reading and reading comprehension). *Materials and measures:* Questionnaire about socioeconomic data, health and educational history, Conners Abbreviated Teacher Rating Scale, Raven matrices, word reading measures, reading comprehension measures (retelling and comprehension questions), Child Brief Neuropsychological Assessment Battery tapping eight neuropsychological functions in 26 tasks. Analysis: Linear regression. *Findings:* After adjusting values for grade and type of school, the tasks that showed a significant association with the variable group (poor comprehenders or good readers) were visuospatial working memory and verbal fluency. *Conclusions:* The impact of working memory and executive functions on reading comprehension suggests the importance of introducing these neuropsychological measures both in assessment and interventions with students who struggle with reading comprehension in the initial years of elementary education.

Keywords: reading comprehension difficulties, neuropsychological assessment, working memory, executive functions.

1. INTRODUCTION

The learning disabilities field recognizes reading comprehension [RC] difficulty as a specific learning disability where, despite intact word recognition, comprehension is not achieved (Fletcher, 2009; Fletcher, Lyons, Fuchs, & Barnes, 2007). Considering the importance of the ability for successful learning, RC difficulty affects school achievement (Meneghetti, Carretti, & De Beni, 2006). There are no epidemiological studies regarding this difficulty, but studies point to a high prevalence - between 5 to 10%, depending on the exclusion criteria and cutoff points used (Fletcher et al., 2007). The current knowledge base on RC is still limited, and the investigation of individual differences is one of the research priorities (Johnston, Barnes, & Desrochers, 2008).

1.1. Identification of specific learning disabilities: Psychometric Perspective *versus* Cognitive and Neuropsychological Approach

The psychometric perspective that has traditionally prevailed in addressing learning disabilities in general, and reading difficulties, in particular, has been gradually replaced by or complemented with a more cognitive approach. More and more studies converge to show that intelligence measures explain a small proportion of variance in reading ability (e.g., Jiménez, Siegel, O'Shanahan, & Ford, 2009). Whereas IQ might not be enough to understand or relevant to understanding what has gone wrong when a child has a learning disability, assessment of cognitive functions can be more informative and can make a real contribution to intervention planning (Fiorello et al., 2007; Fletcher et al., 2002; Francis et al, 2005). Pennington (2009) presents a hybrid model to describe learning and learning disorders, which includes both psychometric and cognitive neuroscience constructs. Both sets of constructs are considered

important for understanding developmental and cognitive differences. An evaluation of children with learning problems must consider measures of working memory, attention, and executive function (Semrud-Clikeman, 2005).

1.2. Neuropsychological aspects of RC difficulty and neuropsychological assessment in children

There is evidence of the relationship between RC on one hand, and language, working memory and executive functions on the other hand. Most studies, however, addresses the relationship of RC with the neuropsychological functions taken in isolation. Neuropsychological batteries may provide a broader evaluation, as they investigate several functions together, which is especially important in children, because of the overlapping of dysfunctions often found in childhood (Argollo et al., 2009).

2. BACKGROUND

In both theoretical models and empirical research, RC has been recognized as a complex activity that relies on a combination of perceptual, cognitive and linguistic processes (Kintsch & Rawson, 2005; Oakhill & Cain, 2006). Text processing begins with word recognition, from visual input (Perfetti, Landi, & Oakhill, 2005). From this initial, bottom-up, processing word meanings are activated, propositions are formed, and inferences and elaborations are produced. Simultaneously, top-down processes guide reading (Kintsch, 1988). In the context of this activity a network of meanings is built and integrated into a coherent overall structure. Thus, the mental representation of the text always results from the interplay of these two kinds of processes, which is established from the most basic linguistic level to the level of knowledge integration (Wharton & Kintsch, 1991).

It is easy to conclude that problems in decoding the word may impair, as a consequence RC, but not all children who have difficulties with understanding have problems with decoding. When decoding difficulties are excluded, the causes of problems in text comprehension may be many and diverse (Perfetti, 1994). It is only possible to consider the presence of a specific RC difficulty when the ability to recognize words is preserved, but, despite that, access to the meaning of the text read is not achieved. In research, one can only define a sample of this population after the word recognition has been formally evaluated and is in the normal range. (Fletcher et al., 2007).

Research from a neuropsychological approach has investigated the neuropsychological functions associated with RC, which might explain individual differences that determine difficulties in respect to this capacity. Linking underlying neuropsychological processes associated with different types of readers to the rich body of literature on RC is essential for ultimately understanding underlying neurobiological bases of RC, which may impact evaluation, treatment and prevention of RC difficulties (Cutting, Materek, Cole, Levine, & Mahone, 2009).

Neuropsychological functions relate to performance and difficulties in reading differently, depending on the level involved: word recognition or RC from a text (Salles & Corso, 2011). Specifically regarding RC it is quite evident its relationship with working memory (Nation, 2005). Models of RC assume that processing at the level of sentence, paragraph, and text as a whole must take place in a limited capacity working memory (Kintsch & Rawson, 2005). Evidence for the relationship between working memory and RC comes from numerous studies. While some conclude that what explains this correlation is the specific features of working memory that are specialized for language processing (Seigneuric, Ehrlich, Oakhill & Yuill, 2000), others identify the central executive system of working memory as a factor directly related to RC, specifically the updating and/or inhibition function of working memory (Carretti, Cornoldi, De Beni, & Romano, 2005; De Beni & Palladino, 2000; Swanson & Jerman, 2007). The working memory tasks that are most accurate at distinguishing between good and poor comprehenders are tasks that are demanding in terms of attentional control and that require verbal information processing (Carretti, Borella, Cornoldi, & De Beni, 2009).

Poor RC is often associated with weaknesses in oral language (Nation & Norbury, 2005; Clarke, Snowling, Truelove, & Hulme, 2010). Studies of children with difficulties in RC show that some children with problems in comprehension have poor vocabulary skills (Catts, Adlof, & Weismer, 2006) and syntactic awareness (Johnston et al., 2008). Morphological awareness may explain the variance in RC after controlling for word reading (Kirby et al., 2012). Lipka and Siegle (2012) conclude that a variety of cognitive processes, such as working memory and phonological, syntactic, and morphological awareness are important for RC and compromised in poor comprehenders.

There is increasing evidence in the literature that executive functions contribute to RC. In a study investigating the effects of word fluency, oral language and executive functions on RC performance with three groups (typically developing, general reading disability and specific RC deficits), Cutting et al. (2009) found significantly lower performance on executive function for the latter group. Sesma, Mahone, Levine, Eason, and Cutting (2009) found that executive function – particularly in the areas of working memory and planning skills – was significantly associated with RC skill, but not with single-word-reading accuracy. Executive function proved to be a contributor to comprehension ability after controlling for well-documented predictors of RC (attention, decoding skills, fluency and vocabulary).

There is enough evidence of the relationship between RC on one hand, and language, working memory and executive functions on the other hand. However, differently from prior research, in which the neuropsychological functions were taken in isolation, this study addresses several functions together, through the use of a neuropsychological battery. The joint investigation of various neuropsychological functions in the frames of reading comprehension difficulty has the advantage of offering a neuropsychological profile associated with these cases. Knowing the weaknesses and strengths of a particular clinical population, on the other hand, is important for a better characterization of this learning disability and for the outlining of rehabilitation strategies. Concomitant evaluation of different neuropsychological functions in children is especially important, considering the large modifications due to the child development (Lefèvre, 2004), and considering also that commonly there is overlap of dysfunctions (Argollo et al., 2009).

3. OBJECTIVES

This study compared a group of students with RC difficulties (poor comprehenders: high performance in word reading and low performance in RC; n = 19) and a group of competent readers (good comprehenders: high performance in word reading and RC, n = 58) in terms of performance in a brief instrument of neuropsychological evaluation that assesses eight functions in children: orientation, attention, perception, memory, language, visual constructive ability, arithmetic abilities and executive functions.

Regarding our hypotheses, and due to the previous findings revised above, we expect the group with reading comprehension difficulty to perform in a low way in tasks involving working memory, executive functions and language. However, each one of those neuropsychological functions is evaluated through three or more different tasks, and we don't have hypotheses about which specific tasks will differentiate both groups. In addition, the battery involves other functions besides the three mentioned, and, again, we do not have hypotheses regarding a possible worse performance – on these other functions – among the participants with reading comprehension difficulties.

4. METHOD

4.1. Participants

Seventy-seven children aged 9 to 12 years and studying in the 4th or 6th grade in public (PuS) and private (PrS) schools underwent tests to evaluate word reading and text comprehension. The group of poor comprehenders (n=19) had an average or above average performance in word recognition, but a poor performance in RC simultaneously. The group of good readers (n=58) had an average or above average performance in reading isolated words

along with a very good performance in RC tasks. Inclusion criteria were absence of neurological or psychiatric disorders, absence of uncorrected auditory or visual disabilities and performance equal to or higher than the 25th percentile in the Raven colored progressive matrices test (Angelini, Alves, Custódio, Duarte, & Duarte, 1999). According to the Fisher exact test, there were no significant differences in grade or type of school, nor among good readers, nor among poor comprehenders.

4.2. Instruments

A questionnaire about socioeconomic, health and educational data was completed by parents, and used to check for inclusion criteria relating to children's medical and schooling history. The Conners abbreviated teacher rating scale - CATRS-10 (Brito, 1987) – a screening instrument for ADHD – was completed by teachers, and used as part of the inclusion criteria. The participants underwent the following tests: The Raven colored progressive matrices test (Angelini et al., 1999); evaluation of oral reading of isolated words and pseudo-words (Salles & Parente, 2007); RC measures based on retelling and questionnaire (Corso, Sperb, & Salles, 2012); Brief Neuropsychological battery for children (Salles et al., 2011) to assess the eight mentioned functions through 25 subtests.

4.3. Data analysis

Regression analysis was used to check which neuropsychological functions were associated with the variable group (poor comprehenders versus good readers), controlling, at the same time, for grade and type of school.

5. RESULTS

Group homogeneity was confirmed for behavior, intelligence (Raven; p=0.122) and isolated word reading (p=0.062), as seen in Table 1.

Table 1. Comparison of groups on age, word reading, RC, CATRS e IQ.

	Good readers (n=58)		Poor Comprehenders (n =19)		*U/t*	*p*
	Median	IQI	Median	IQI		
Age[a]	10,5	1,1	10,9	1,0	-1,488	0,141
Word Reading (percentile)	75	(40;90)	50	(30;70)	706,5	0,062
CQ[b] – Literals	5,0	(5;5)	4,0	(3;5)	227,5	<0,001
CQ[b] - Inferentials	5,0	(4;5)	2,0	(1;3)	0,0	<0,001
Conners scale	1,0	(0;5)	0,0	(0;3)	460,5	0,495
RAVEN (percentile)	90,0	(60;99)	75,0	(50;90)	421,5	0,122

Note: Significance level of 0,05; [a] Values presented as mean and standard deviation, compared by Student's t test; IIQ: Interquartile intervals (percentiles 25 and 75); [b] Comprehension questions.

Table 2 presents both descriptive statistics (mean and standard deviation) of the performance of groups in different tasks /functions, as beta coefficients resulting from the regression analysis that tested the effect of the group variable (poor comprehenders *versus* good readers) upon scores on neuropsychological tasks. Group (poor comprehenders *versus* good readers) was significantly associated with three of the eight neuropsychological functions evaluated: working memory, executive functions and written language. The specific tasks that had a significant beta coefficient were visuospatial working memory ($\beta = 0.311$; $p < 0.01$), verbal ($\beta = 0.270$; $p = 0.01$) and semantic ($\beta = 0.279$; $p = 0.01$) fluency, and written language – writing words and pseudo words ($\beta = 0.246$; $p < 0.05$).

Table 2. Performance of the groups on neuropsychological tasks and beta values.

Neuropsychological Functions /Tasks	Maximum score	Poor Comprehenders (N= 19) Mean (*SD*)	Good Readers (N = 58) Mean (*SD*)	Beta
Orientation	6	5,74 (0,56)	5,83(0,53)	0,07
Attention	59	53,68 (2,84)	54,77(3,83)	0,05
Perception	6	5,74 (0,45)	5,83 (0,42)	0,06
Verbal Episodic Memory	18	9,00 (2,02)	9,14(2,13)	0,01
Working Memory – Phonol. and Central Execut.	48	33,11 (5,13)	35,79(4,54)	0,18
Visuospatial working memory	28	22,63 (4,69)	25,31 (3,28)	0,31**
Semantic Memory	4	3,95 (0,22)	3,97 (0,18)	0,03
Oral Language – Naming	9	8,79 (0,41)	8,91 (0,33)	0,14
Oral Language – Phonological Awareness – Rime	5	3,79 (0,41)	3,86 (0,34)	0,04
Oral Language – Phonological Awareness – Phonemic subtraction	5	5,68 (0,74)	5,90 (0,30)	0,10
Oral Language – Oral Comprehension	5	4,95 (0,22)	4,76 (0,43)	-0,19
Oral Language – Inference Processing	8	6,58 (1,34)	6,66 (1,37)	-0,04
Written Language – Oral Reading	17	16,32 (0,58)	16,43 (0,56)	0,02
Written Language – Writing Comprehension	5	4,89 (0,31)	5,00 (0,00)	0,21
Written Language – Writing Words and Pseudo words	19	17,89 (0,99)	18,52 (0,78)	0,24*
Written Language – Spontaneous Writing	2	1,79 (0,41)	1,95 (0,22)	0,21
Written Language – Copy	2	2,00 (0,00)	1,98(0,13)	-0,05
Visual-Spatial Abilities – Copy from Figures	24	21,42 (1,53)	22,17 (1,45)	0,12
Arithmetic Abilities	25	23,83 (1,29)	24,55 (0,92)	0,20
Executive Function – Verbal Fluency	[a]	22,63 (5,09)	28,38 (5,92)	0,35**
Orthographic Verbal Fluency	[a]	7,74 (3,38)	10,28 (3,42)	0,01**
Semantic Verbal Fluency	[a]	14,89 (4,29)	18,10 (4,15)	0,01**
Executive Function – Go/No-go Task	60	56,89 (4,52)	58,05 (2,40)	0,11

Note: [a] Maximum score = number of words evoked; * $p < 0,05$; ** $p < 0,01$

6. CONCLUSION/DISCUSSION

The aim of this study was to compare two groups – the good readers and the poor comprehenders – on their performance on different neuropsychological functions tasks. Thus, we tested the effect of the group variable upon participants' scores on tasks. Furthermore, we controlled for the variables of grade and type of school as prior research has shown that these variables may also affect performance. After adjusting values for grade and type of school, the tasks that showed a significant association with the variable group (poor comprehenders *versus* good readers) were visuospatial working memory, verbal fluency and writing words and pseudo words.

The visuospatial working memory task, of all the working memory tasks evaluated in this study, is the one that most intensely demands the activation of the executive component of the working memory: the participant should reproduce a sequence of cubes indicated by the examiner and invert the series at the same time. Trying to determine which specific component

of working memory explains its relationship to RC gave rise to different studies, some emphasizing the verbal domain of the task (Seigneuric, et al., 2000), others highlighting the presence of the executive component of the task, which involves not only storage, but manipulation of information (Swanson & Jerman, 2007). Our results confirm those that emphasized the presence of executive control in the tasks that differentiate poor and good comprehenders (Swanson & Jerman, 2007; Carretti et al., 2009). In contrast with other studies (Oakhill, Yuill, & Garnham, 2011), however, the verbal domain did not prevail, maybe because the executive component was demanded more intensively in the visuospatial task than in the verbal task used in the study (backward digit span).

Consistent with research findings that verified the involvement of executive functions among participants with specific difficulties in RC (Cutting et al., 2009), this study showed that performance on tasks of executive functions suffers the effect of the group variable (good readers *versus* poor comprehenders). The tasks that in this respect, helped differentiating between the two groups were the verbal fluency, both orthographic fluency (say words beginning with a specific letter in a given time) and semantic fluency (say words related to a particular category, such as animals). Performing tasks of verbal fluency activates several executive processes, such as attention, monitoring and working memory, and that is the reason why they are useful for detecting possible deficits in executive functions (Welsh, Pennington, Ozonoff, Rouse, & McCabe, 1990). From the perspective of Baddeley's (2007) model of working memory, it appears that besides the evident involvement of the executive component, each of the two tasks receive the specific contribution of one subcomponent: the phonological component contributes especially with the orthographic fluency task, while the visuospatial component is especially involved with semantic fluency (Rende, Ramsberger, & Miyake, 2002). Consistent with the verification of singularities that differentiate the two tasks, it is known that each of them activates different neural networks (Birn et al., 2010). The orthographic and semantic verbal fluency tasks involve the executive ability to coordinate attention, working memory, use of strategies and monitoring (McNamara & Scott, 2001; Schelble, Therriault, & Miller, 2012), which may explain lower performances among poor comprehenders.

As to the writing words/pseudo-words task, it is known that impairments in similar cognitive functions may explain the simultaneous presence of problems in reading and writing domains. Berninger, Nielsen, Abbott, Wijsman and Raskind (2008) found an association of inhibition failures and verbal fluency with spelling problems. Specific difficulties in RC are also associated with inhibition (Palladino, Cornoldi, De Beni, & Pazzaglia, 2001) and failure in verbal fluency (Miranda-Casas, Fernández, Robledo, & García-Castellar, 2010).

Taking into account the different cognitive and linguistic aspects present in the ability to understand a text, it is not difficult to understand that, due to various reasons, a difficulty in RC may exist. Investigating different neuropsychological functions together, along with word and text reading, enables the verification of functions that, when impaired, demand special attention in the evaluation of and intervention on these specific learning difficulties. The impact of working memory and executive functions on RC suggests the importance of introducing these neuropsychological measures both in assessment and interventions with students who struggle with RC in the initial years of elementary education.

The group with reading comprehension difficulty showed a low performance in one task, among three working memory tasks, and in one of two EF tasks. Different tasks may activate different components of those complex and multidimensional neuropsychological functions. Thus, a possibility in terms of future research would be exactly to verify the relationship between reading comprehension and the specific components of the neuropsychological functions in consideration, through the use of more tasks that assess both functions.

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