DO CHILDREN WITH LANGUAGE DYSFUNCTION HAVE VISUAL-MOTOR PROCESSING DIFFICULTIES?: A CROSS-SECTIONAL STUDY OF TYPICALLY AND ATYPICALLY DEVELOPED ARGENTINIAN CHILDREN

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Abstract

Objective: Visual-motor coordination is of great importance for its influence in language development and processing. Thus, the aim of this work is to describe the variability in visual-motor abilities in children with typical and atypical language development.

Method: In this cross-sectional study, six-, seven- and eight-year-old children (n=28) were evaluated with the Illinois Test of Psycholinguistic Abilities. Statistical analysis included Student's t-test in order to find differences.

Results: It was found that the six- and eight-year-old samples with atypical development presented a lower performance in visual-motor sequential memory ($p<0.05$). In addition, in atypically developed six-year-old children, a lower performance was observed in the manual expression subtest ($p<0.01$).

Conclusions: An alteration in the development of language was associated with a deficiency in manipulative and visual resolution, in which could underlie an impaired working memory, cerebellar dysfunction, among other mechanism.

Key words: atypical language, developmental disability, language impairment, memory, neuropediatric, visual-motor abilities

Declaration of interest: all of the authors declare that they have no conflict of interest

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Introduction

Multiple complex processes intervene during language acquisition, which depends on the development of the neurosensory and motor systems, as well as on cognitive, social and affective factors (Miranda et al. 2017). Disorders in psycholinguistic abilities represent one of the most frequent reasons for consultation in pediatric professional practice. Epidemiological researches have shown that the prevalence rate of atypical language development is high (Geoff and Strand 2016) and there is an age effect (Fresneda and Mendoza 2005). It has been reported that ten percent of children under six years old present alterations in language development (Valdivia Álvarez et al. 2013). Children with atypical language development are a heterogenous group not only in terms of the specific linguistic domains altered, but also the causes involved (Geoff and Strand 2016), since it may occur in isolation or in the context of another pathology (McLaughlin 2011, Massana-Molera 2005). Several studies have investigated problems linked to language difficulties, including cognitive disorders (Yang and Gray 2017), cerebral palsy (Mei et al. 2016), behavioral difficulties (Pickles et al. 2016), hearing impairments (De Hoog et al. 2016), among others.

In light of all this, the evaluation of psycholinguistic skills is very useful as it helps to detect those children with developmental deviations (Nelson et al. 2006). Over the last few decades, multiple batteries have been designed for the diagnosis and therapeutic monitoring of alterations in psycholinguistic development, such as the Illinois Test of Psycholinguistic Abilities (ITPA). This battery assesses spoken and written language

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abilities of children aged 5-12 (Shaver and Floyd 2003) and consists of twelve subtests, five of which measure visual-motor abilities (Kirk et al. 2004). The ITPA has demonstrated good psychometric properties (internal consistency, stability, reliability and validity) (Guarnera et al. 2013).

Processing visual information is essential to generate proper motor responses to stimuli, a chief ability for many human interactions (Wang et al. 2015). It is known that the visual-motor abilities play a significant role in the acquisition and execution of the communicative activity (Fu et al. 2015). In dyslexic individuals, a prevalence of motor deficits has been estimated at 30-50% in dyslexic individuals (Ramus 2003), and it has been reported that 90% of children with language disabilities present motor deficit (Hill 2001). These limitations have an impact on social and learning skills (Geoff and Strand 2016, White-Schwoch et al. 2015). Brumbach and Goffman (2014) compared the motor skills of eleven children with specific language impairment and 12 age-matched peers (4–6 years) and concluded that children with language disorder showed co-occurring speech motor and generalized motor deficits. Furthermore, Iannuzzi et al. (2016) studied the relationship between neurofibromatosis type 1 and atypical language development. Researchers found that the deterioration of the fine motor abilities would depends on the existence of comorbidity with language disorders.

There is vast evidence on the relationship between deficits in auditory-vocal abilities and language development pathologies (Rocha-Muniz et al. 2015). However, there is a lack of research focussing on visual-motor skills in children with atypical language development (White et al. 2006), being the majority of works developed in populations with pathologies with great motor commitment (Heiz and Barisnikov 2016, Wuang and Tsai 2016).

The literature suggests that subjects with dyslexia demonstrate deficits in several visual tasks, mainly in search and visual location, as well as in temporal processing. Although the underlying mechanisms are still under debate (Galaburda and Cestnick 2003), various theories have been postulated to understand the processes involved in these language pathologies (**table 1**).

Psycholinguistics is interested in the acquisition and development of the ability to understand and produce language (Miranda et al. 2017), that is, as a child comes to understand and produce language or to perfect this ability (Fonseca Oliveira et al. 2007). On this basis, the hypothesis of the present study is that children with language disorders have lower visual motor skills than those with normal language. To test the hypothesis, this study aims to describe the variability of ITPA visual-motor skills in children aged 6 to 8 with typical and atypical language development from Cordoba (Argentina, years 2015-2016).

Table 1. *Main explanatory theories for sensorimotor deficits in language alterations*

Temporary processing deficit	People with language impairment present difficulties in the temporal processing of sequence of stimuli, both visual and auditory, with short intervals (Klein 2002, Tallal 2004). Children with atypical language process and solve linguistic and non-linguistic activities at a lower speed than children with normal language (Idiazábal-Aletxa and Saperas-Rodríguez 2008).
Magnocellular theory	Anatomical and physiological alterations in the lateral geniculate nucleus produce a deficit in the visual processing of short stimuli. The magnocellular system would be responsible for the processing of short stimuli, the movement and stimulation of low contrast and low spatial frequency (Ramus 2003).
Double-deficit theory	In children with atypical language development there is a difficulty to process brief and rapid sensory stimuli accompanied by short-term memory disorders and working memory. Consequently, these children fail to learn from the preceding sensory experience (Preilowski and Matute 2011).
Deficit in automation or cerebellar deficit	The presence of cerebellar alterations has been described in patients with dyslexia to explain visuospatial disorders. Problems in balance, motor skills, and phonoarticulation have an impact on reading and writing skills, working memory and spelling. In addition, there are faults in the networks connecting brain and cerebellum, which generates problems in the automation of skills and knowledge (Nicolson and Fawcett 2004).

Material and Methods

Participants

In this cross-sectional study, a group of 6-, 7- and 8- year-old children with typical (n=10, 8 males) and atypical (n=18, 15 males) language development were evaluated to compare the difference in the distribution of the selected variables. Requirements for inclusion in this case study were:

- *Typical language sample*: 6-, 7-, and 8-year-old children, both sexes, no speech language pathologies and good performance in formal aspects of learning.
- *Atypical language sample*: 6-, 7-, and 8-year-old children, both sexes, impairment in language development, and who have been referred to the DSRET Raquel Maurette department for their diagnosis and treatment.

Exclusion criteria were: antecedents of absences, inappropriate behavioural attitudes, those who interact in an inadequate way and/or are isolated from the social group, those requiring periodic controls due to hearing difficulties, equipped with hearing aids or with auditory implants, children who require a support teacher, those who presented disability certificate. This work was approved by the Ethics Committee of the DSRET Raquel Maurette (Faculty of Medical Sciences, National University of Cordoba), and was carried out according to the Declaration of Helsinki. Informed consent was obtained from parents.

Psycholinguistic Assessment

For the evaluation of psycholinguistic abilities, the Spanish version of the Illinois Test of Psycholinguistic Abilities–Third Edition (ITPA-3) was used (Kirk et al. 2004). The ITPA-3 model was developed using a language learning model proposed by Kirk, consisting of two primary communication channels (auditory and visual), two primary output channels (verbal and motor), three psycholinguistic processes (reception, association and expression) and two levels of organization (Automatic and representative) (Rossi et al. 2012). This test evaluates cognitive and linguistic functions involved in communication, and can be used to analyze intraindividual and interindividual differences (Miranda et al. 2017). In this study we present the psycholinguistic scores (scalar scores) obtained in the visual-motor subtests: Visual Reception; Visual Association; Manual Expression; Visual Sequential Memory; Visual Closure. What is more, this research analyses the organization levels of the named subtests (**Table 2**).

Statistical Analysis

Data were expressed as mean ± standard deviation (SD). Given the normal distribution of the variables after analysing Asymmetry, Kurtosis, and studying normality with the Shapiro-Wilk test, the Student's t-test was applied in order to evaluate the difference between the data obtained in typical and atypical language groups (n=28). Probabilities below p=0.05 were regarded as significant.

Results

Table 3 presents the comparisons of mean values of ITPA-3 visual-motor subtest between age groups of

Table 2. *Description of the ITPA visual-motor subtests*

Representational level	Reception	Visual Reception	Obtain meaning from visually presented pictures
	Association	Visual Association	Relate visually received stimuli meaningfully by matching
	Expression	Manual Expression	Capacity to express actions using gestures
Automatic level	Sequential	Visual Sequential Memory	Reproduce a sequence meaningless pictures from memory
	Automatic	Visual Closure	Identify objects from an incomplete visual presentation.

Table 3. *Performance of typically and atypically developed groups in ITPA-3 visual-motor subtests. Data are expressed as means ± standard deviation (SD). p<0.05*, <0.01***

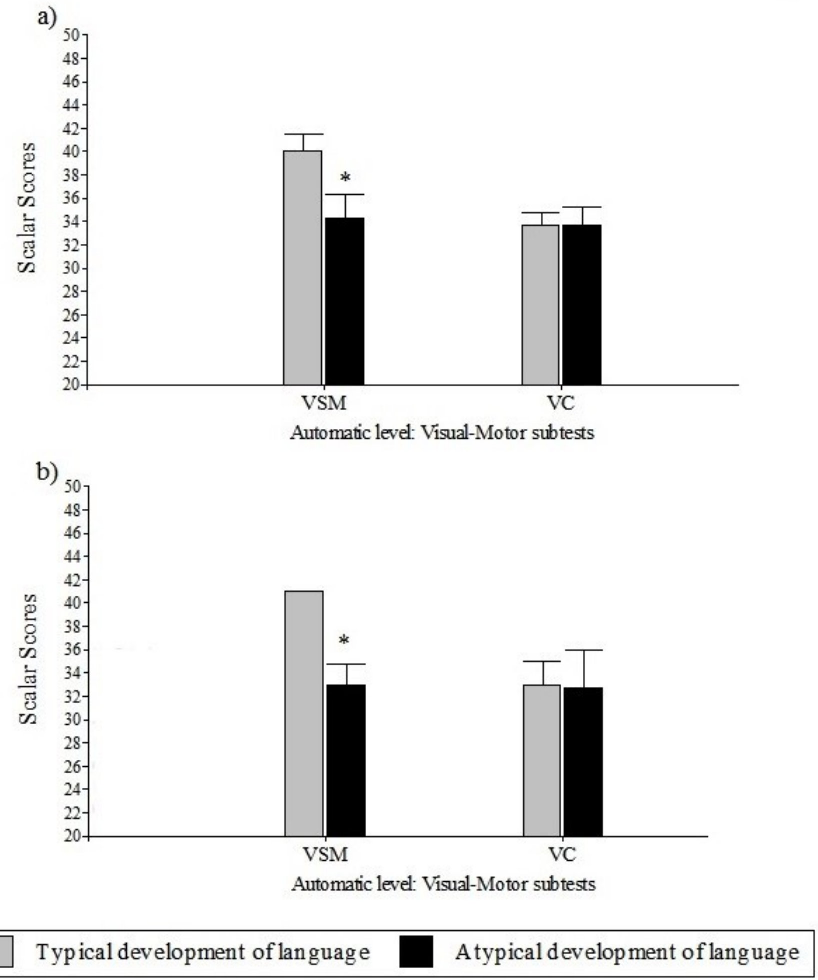
ITPA visual-motor subtests	Sample	Typical Language		Atypical Language	
		Mean	*SD*	*Mean*	*SD*
Visual Reception	6-year-old	35.00	3.35	34.13	2.53
	7-year-old	42.50	3.54	36.17	5.91
	8-year-old	33.50	0.71	31.00	4.24
Visual Association	6-year-old	37.50	2.74	33.88	6.94
	7-year-old	35.00	2.83	39.33	6.89
	8-year-old	33.50	3.54	36.25	2.63
Manual Expression	6-year-old	47.17**	5.34	38.63**	6.16
	7-year-old	42.50	7.78	42.17	7.57
	8-year-old	42.00	3.54	43.00	7.12
Visual Sequential Memory	6-year-old	40.17*	3.06	34.38*	5.55
	7-year-old	39.50	4.95	34.83	4.22
	8-year-old	41.00*	0.00	33.00*	3.56
Visual Closure	6-year-old	33.67	2.66	33.63	4.60
	7-year-old	31.50	2.12	33.33	5.79
	8-year-old	33.00	0.00	32.75	6.45

children with typical and atypical language development.

On the one hand, the analysis of automatic level subtest revealed significant differences in children of 6 and 8 years old in the visual-motor sequential memory subtest (p<0.05). The atypical language development group obtained lower scores than the typical language development group, being the results 40.17±3.06 vs. 34.38±5.55 and 41.00±0.00 vs 33.00±3.56, respectively (**figure 1**). Regarding the visual closure subtest, no significant differences were found.

On the other hand, the analysis of representational level subtests revealed significant differences in children of 6 years old in the manual expression subtest (p<0.01). In this sense, the performance of children with atypical language development was poorer than the performance of children with typical language development (47.17±5.34 vs 38.63±6.16) (**figure 2**).

Figure 1. *Performance of six (a)- and eight (b)-year-old children with typical and atypical development of language (n=28) in automatic level subtests of ITPA-3. VSM: Visual Sequential Memory; VC: Visual Closure. *p<0.05*



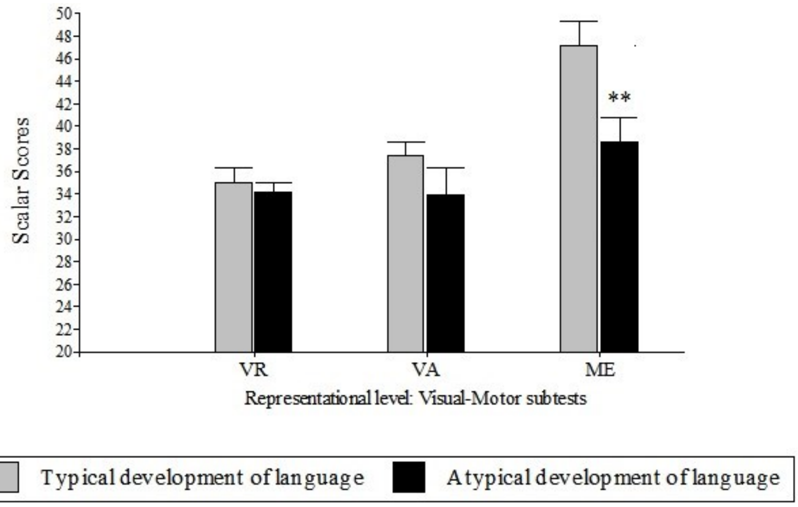
Discussion

Differences between children with typical and atypical language development in visual-motor processing were shown in the present work. These data are preliminary because of the small sample size and the difficulty to differentiate the specific linguistic domains altered. Yet, these findings are consistent with the results of studies conducted in children with language disorders secondary to other pathologies characterized by a greater commitment of psychomotor skills (Heiz and Barisnikov 2016, Wuang and Tsai 2016).

Our results show significant differences in the performance of both groups in visual-motor sequential memory. Memory impairments in samples with atypical development are well documented, although the studies are not homogeneous regarding the experimental procedures used: visual-motor sequences, visual-spatial tasks or procedural learning tasks (Howard et al. 2006, Menghini et al. 2006, Stoodley et al. 2006, Vicari et al. 2005, Vicari et al. 2003). It has been found that people with developmental disorders have dysfunctions in mnesic abilities, especially regarding operational memory. In this sense, they have difficulties to reproduce a sequence of figures presented for a short period of time. Moreover, a significant correlation between visual and auditory memory deficits was found by Shalaby et al. (2017), with temporal processing resolution being the mechanism involved.

In addition, a lower performance in manual expression of 6-year-old children with atypical language development was found in this study, reflecting motor coding compromise. With respect to the association between language deficit and motor skills commitment, a number of potential explanations have been proposed. While some authors relate it to the connection between hemispheres, others argue for cerebellar mediation

Figure 2: *Performance of six-year-old children with typical and atypical development of language (n=28) in representational level subtests of ITPA-3. VR: Visual Reception; VA: Visual Association; ME: Manual Expression. **p<0.01*



mechanisms (Menghini et al. 2006), where an interruption in the control of temporary coupling of signals would be established (Estil et al. 2003). In this sense, motor and cognitive development are related since their processing involves areas of the prefrontal cortex and cerebellum, hence the loss of automaticity is associated with impairment of motor skills (Fusco et al. 2015). By using functional magnetic resonance, Menghini et al. (2006) detected an atypical pattern of cerebellar activation in people with dyslexia. This could explain the encountered difficulties in phonological and extra-phonological processes in dyslexic population. Moreover, these impairment of the cerebellar system in patients with language development disorders was evidenced by others in dyslexic adult sample Stoodley et al. (2006), suggesting that some dyslexic suffer from an implicit motor learning deficit.

Understanding the relationship of visual motor processes and psycholinguistic abilities is of great need when defining pedagogical strategies and designing therapies. In this regard, future researches should investigate the effectiveness of therapeutic approaches based on linguistic games or combinations of motor movements with language (such as clapping for each syllable, going to the rhythm of syllables) (Goswami 2015).

Due to the prevalence of visual and motor deficiencies in the population of children with atypical development language, we suggest to incorporate tools for the evaluation of visual motor skills into the clinical practice. There is even evidence about language and its influence on the evolution of certain chronic pathologies, such as neurofibromatosis, in which language commitment determines a decline in motor skills (Iannuzzi et al 2016). Thus, the purpose of research into developmental psycholinguistic is to improve clinical neuropsychiatry practice.

Conclusion

In conclusion, children with atypical language development present difficulties in skills of visual-motor domain, which may be secondary to atypical temporal resolution and cerebellar functioning. Our results demonstrate that children with disorders in language development present alterations in multiple domains of language processing. Further work is necessary to determine other variables that may interfere in language processing, i.e. cognitive functions and audiocognition. These preliminary findings suggest that more studies needs to be done to assess visuospatial abilities in language deficits. For future recommendations, it is important to determine if visual-motor skills and language development share common mechanisms or are independent comorbidities.

Compliance with Ethical Standards

Ethical approval: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2005.

Informed consent: Informed consent was obtained from all participants included in the study.

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