Neuropsychological Alterations of Memory, Attention and Language in Mild Post-Traumatic Cranial Syndrome

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Introduction. *Mild traumatic brain injury (TBI) affects a large percentage of children population; it is an etiologic factor of damage, which is considered without major repercussion in neuropsychological functioning of memory, attention and, language. Sometimes, when children who have suffered TBI are medically stable, they are discharged; however, as it is presented in this research, children would not recover 100% of their premorbid skills.* ***Method****. For this study, it was worked with a longitudinal design of repeated measures in a sample of 30 children between 6 and 10 years of age (Mage = 8.53, SD = 1.45), who had suffered a TBI and were assisted in a pediatric hospital from Quito-Ecuador. Neuropsi battery, WISC-IV, and, TAR were used as neuropsychological assessments to obtain measures for memory, attention, and language, plus three clinical assessment scales that were designed as part of this study.* ***Results****. Statistically significant differences were found in indicators that assessed memory, attention, and language in different moments of measurement.* ***Conclusions.*** *These data suggest that children improved in some of the neuropsychological areas, however, according to clinical referential criteria, in many of them it was not successfully completed. On the other hand, deferred observation scales suggest that parents perceive their children did not achieve a complete recovery after the TBI. Finally, we reflect on the need to provide adequate neuropsychological monitoring, in order to help children suffering from this type of TBI to recover to the highest possible level.*

Key words. *Mild traumatic brain injury, Memory, Attention, Language, Neuropsychological Rehabilitation.*

INTRODUCTION

Traumatic brain injury (TBI) is considered the leading cause of death, disability, neurological injuries, neuropsychological, cognitive, emotional and behavioral alterations in childhood. It constitutes an important factor of vulnerability at this stage of development[1].

TBI is produced by an impact that the brain receives from an external element, which could alter tone and wakefulness, and, as a result, trigger deterioration in physical and cognitive abilities[2]. A TBI can originate from several causes in childhood, the main ones being: falls (39% of the cases), urban and traffic accidents (11%), child abuse (4%), and unknown causes (5%)[3].

The classification of TBI has been established

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according to the Glasgow coma scale that explain the severity of the trauma[4]: (a) mild TBI is characterized by the fact that the patient may briefly lose their alertness; however, at the time of examination, he/she is alert, oriented and does not present cognitive deficit (Glasgow 14-15); (b) moderate TBI, in which the person experiences a decrease in alertness and cognitive level but can perform basic tasks requested (Glasgow from 9-13; (c) in severe TBI the subject is disoriented , with minimal or no alertness and their neuropsychological functions are clearly affected (Glasgow less than 9); finally, (d) in severe TBI, the person cannot show any brain function, which is defined as brain death[5-6].

The neuropsychological functions most sensitive to TBI in childhood, and which are the central interest in this study, are memory, attention, and language. Memory is the function in charge of recording, consolidating, retaining, storing, retrieving, and recalling stored information 1. Attention is a complex functional process that is composed of, and interacts with other, systems, allowing the child to focus, select, sustain, alternate, and divide their alertness to different external and internal stimuli[7]. Finally, language makes communication between individuals possible through the encoding of multimodal signs organized according to a linguistic structure[1].

As for the possible conditions that a TBI may trigger, there are behavioral changes and diffuse cognitive defects. The consequent alterations depend to a great extent on the severity of the TBI. In attention, the child shows a loss of the patient's ability to maintain focus on an activity and control the distraction of the constant irrelevant stimuli, which reduces their proactivity in different activities. Meanwhile, language is affected at the level of communication, which generates deficits in social skills in which the patient must interact. On the other hand, memory is the neuropsychological function most prone to suffer alterations after a TBI, and its disorders usually last and are present for a long time, which causes serious limitations in the patient[8].

In this research, the main objective is to analyze the clinical context of mild TBI, since in most cases, this type of trauma does not generate an identifiable organic injury or loss of consciousness of the patient or any deficit that is evident. However in the clinical observation made to these cases on a day-to-day basis, it is perceived that the patient who suffers from this problem presents cognitive and behavioral changes[9]. For this reason, this study seeks evidence in this regard to improve the processes of care, evaluation, rehabilitation, and neuropsychological monitoring of children affected by this type of trauma.

METHOD

Participants

Before starting the research, the size of the sample necessary to carry out the study was calculated. This procedure was performed in the GPower program[10], considering as indicators a comparison of two longitudinal measurements in the same group, a medium effect size d = .50, an error probability alpha of α = .05 and statistical power of 1-ß = .80, which made it possible to identify a necessary sample of 27 participants. However, the parents of 30 children consented to participate in this study voluntarily; therefore, it can be ascertained that the sample size is adequate for the purposes of this research.

The sample consisted of eleven females (36.70%) and nineteen males (63.30%) between six and ten years of age(Mage = 8.53, SD = 1.45) treated in a paediatric hospital in Quito-Ecuador. Based on the income of the participants' family, their socioeconomic level was medium and low. Regarding height and weight, the participants fluctuated between 18 and 45 kilograms (M = 29.87, SD = 7.15), while height varied between 1.09 and 1.41 meters (M = 1.27, SD = 0.07). All the participants were attending the educational system normally. Regarding the intake of previous medication, twenty-nine patients (96.7%) did not take additional medication and one patient (3.3%) regularly took methylphenidate. Regarding comorbidity, it was determined that twenty-eight participants (93.3%) did not present concomitant diseases, one participant (3.3%) had a diagnosis of a mild intellectual development disorder, and one participant (3.3%) had a mild language disability. However, it should be

mentioned that the aforementioned conditions presented a low percentage of disability in the participants and, when analyzing with non-parametric statistical methods, no statistically significant relationships were found between the sociodemographic variables and the results in the neuropsychological indicators.

Inclusion criteria

The criteria applied: (a) boys and girls between six and ten years of age who have suffered a mild head trauma, (b) are in school, (c) have been hospitalized to assess their recovery, (d) are medically stable, and (e) have skills preserved cognitive factors to perform neuropsychological tests.

Exclusion criteria

The criteria were applied: (a) have a history of severe or profound psychiatric disorders, (b) have a low tone and wakefulness level (which would prevent them from performing the neuropsychological evaluation), (c) have a moderate or severe TBI, and (d) the parents did not sign the informed consent of voluntary participation or the children did not consent to their voluntary participation.

Research design

We worked with a quantitative methodology; the research design was based on the comparison and monitoring of a group through neuropsychological measurements at various times. Temporality is longitudinal since the evolution of neuropsychological performance was followed for one month after the participants suffered TBI.

Instruments

To assess memory and attention, sub-tasks of the Neuropsi neuropsychological assessment battery were used: orientation, rolling digit hold, visual detection, digit detection, successive series, Stroop, spontaneous memory curve, faces, verbal memory, regressing digit hold, face memory, verbal fluency[11]. To assess language, the subtests of the WISC-IV vocabulary and information test were used[12], and the ART articulation of repetition test was applied[13].

In order to have a clinical appreciation of the state of memory, attention and language, three scales of clinical observation were constructed, where, by means of behavioral statements of the three neuropsychological functions, the state of the three skills before the TBI, days after the TBI, and one month after the TBI (these scales, which were completed by the parents of the minors, can be assessed in Annex 1). Finally, a questionnaire was applied to obtain the sociodemographic information of the participants.

Procedure

This research is a reflection and product of the observations of the care received by the child population affected by mild TBI, since in most times it is considered that this condition does not generate any neuropsychological affectation. Therefore, the ethical approval of the research began in the hospital where the study was conducted and in the university affiliated with the authors of the study. Subsequently, the participants were invited to collaborate in the research, their parents signed a voluntary participation consent form and, in a format adapted for children, the participants signed their consent for voluntary participation. It is important to highlight that at all times the authors ensured compliance with the Helsinki ethical standards of research in human beings. The tests were applied in a distraction-free place, individually after the TBI and after one month of evolution. Once the instruments were completed, the data was analyzed and presented in this research report. Additionally, the research participants received a report of their neuropsychological assessment.

Data analysis

Descriptive statistical techniques of central tendency and dispersion were applied. Additionally, inferential techniques of mean comparison were applied, where the Student tand Wilcoxon Z analyses were used depending on the normality tests. In addition, given the ordinal measurement of the scales, its reliability was calculated using the McDonald's Omega procedure. All analyses were performed in the SPSS program, version 25.

RESULTS

It began by analyzing compliance with the normality criteria using the Shapiro Wilk test, which allowed to identify the variables to be processed with the parametric and non-parametric statistical methods. Table 1 and 2 show the comparison of neuropsychological

Table 1. Comparison of neuropsychological variables with parametric test

		M	DE	t	gl	p
ADV	PT	11.13	4.39	-2.68	29	.01
	PTT	13.23	4.08			
ACME	PT	13.03	4.83	-4.54	29	< .001
	PTT	16.00	5.86			
AMVE	PT	5.10	2.31	-3.75	29	.001
	PTT	6.53	2.70			
AMVC	PT	5.70	2.54	-2.09	29	.045
	PTT	6.53	2.73			
EMVR	PT	2.87	2.05	.68	29	.504
	PTT	2.63	2.025			
TAMV	PT	20.67	5.66	-3.17	29	.004
	PTT	23.33	6.31			
TEMV	PT	5.53	3.32	1.58	29	.125
	PTT	4.80	3.52			
AFVS	PT	11.73	3.78	-2.39	29	.023
	PTT	12.93	4.28			
AFVF	PT	5.57	3.34	-.51	29	.61
	PTT	5.73	3.15			
VC	PT	15.53	7.98	-4.23	29	< .001
	PTT	18.67	6.23			
VM	PT	10.23	5.26	-.23	29	.817
	PTT	10.40	4.61			

PT: pre-test, PTT: post-test, ADV: hits in visual detection, ACME: hits in spontaneous memory curve, AMVE: hits in spontaneous verbal memory, AMVC: hits in verbal memory by keys, EMVR: errors in verbal memory by recognition, TAMV: total hits in verbal memory, TEMV: total errors in verbal memory, AFVS: hits in semantic verbal fluency, AFVF: hits in phonological verbal fluency, VC: vocabulary, CM: comprehension, M: mean, DE: standard deviation, df: degrees of freedom, p: bilateral statistical significance.

In the reliability analysis of the clinical observation scales, based on the ordinal characterization of the valuation of each item, an exploratory factor analysis was applied and based on the factor loadings of each item on its respective scale. The coefficient was calculated McDonald's Omega Reliability Chart. Adequate reliability was found in the measurements made: memory before TBI $\omega = .83$, memory days after TBI $\omega = .76$, memory a month after TBI $\omega = .87$, attention before TBI$\omega = .80$, attention days after TBI $\omega = .81$, attention a month after TBI $\omega = .83$, language before TBI $\omega = .86$, language days after TBI $\omega = .89$, and language a month after TBI $\omega = .84$.

Subsequently, the normality of the variables evaluated with the deferred observation scale was calculated using the Shapiro-Wilk statistic,

Table 2. Comparison of neuropsychological variables with nonparametric test

		M	DE	Z	P
TP	PT	2.90	1.16	-2.56	.010
	PTT	3.37	.81		
ES	PT	1.73	.45	-1.13	.257
	PTT	1.83	.46		
OR	PT	5.67	1.49	-2.56	.010
	PTT	6.20	1.06		
RD	PT	4.87	.82	-2.14	.032
	PTT	5.20	.89		
EDV	PT	.83	1.98	-.36	.717
	PTT	.60	1.91		
ADD	PT	7.90	1.61	-2.49	.013
	PTT	8.67	1.56		
EDD	PT	3.53	2.06	-3.51	< .001
	PTT	2.07	1.78		
ASS	PT	12.67	2.66	-1.49	.136
	PTT	13.27	2.02		
ESS	PT	1.33	2.66	-1.49	1.36
	PTT	.73	2.02		
AST	PT	106.70	1.82	-3.33	.001
	PTT	107.57	1.14		
EST	PT	1.30	1.82	-3.33	.001
	PTT	.43	1.14		
ECME	PT	3.07	2.56	-1.37	.170
	PTT	2.33	1.77		
CC	PT	1.97	1.25	-2.73	.006
	PTT	2.43	1.04		
EMVE	PT	.97	1.00	-2.18	.029
	PTT	.67	.96		
AMVCL	PT	5.70	2.54	-4.30	< .001
	PTT	6.53	2.73		
EMVPC	PT	1.70	2.04	-2.87	.004
	PTT	1.50	2.15		
TEMV	PT	5.53	3.32	-1.53	.127
	PTT	4.80	3.52		
DGR	PT	3.27	1.02	-.95	.342
	PTT	3.50	.86		
EFVS	PT	1.27	1.31	-.54	.587
	PTT	1.13	1.07		
EFVF	PT	.47	.78	-.78	.436
	PTT	5.73	3.15		
ART	PT	61.00	2.27	-3.15	.002
	PTT	62.30	1.02		

with which the use of the general linear model of repeated measures procedure was determined.

In the measurements of repeated metrics, it was found that in the three evaluations of the clinical observation scale, there were statistically significant differences in (a) before the TBI, (b) two days after the TBI and (c) one month after the TBI, for memory $F(1, 29)= 1984.60$, $p = <.001$; attention $F(1, 29)= 1315.24$, $p = <.001$ y language $F(1, 29)= 1728.32$, $p = <.001$. Figures 1, 2 and 3 present descriptive values of the data obtained from the clinical observation scales.

Figure 1. Measurements made on the Memory scale

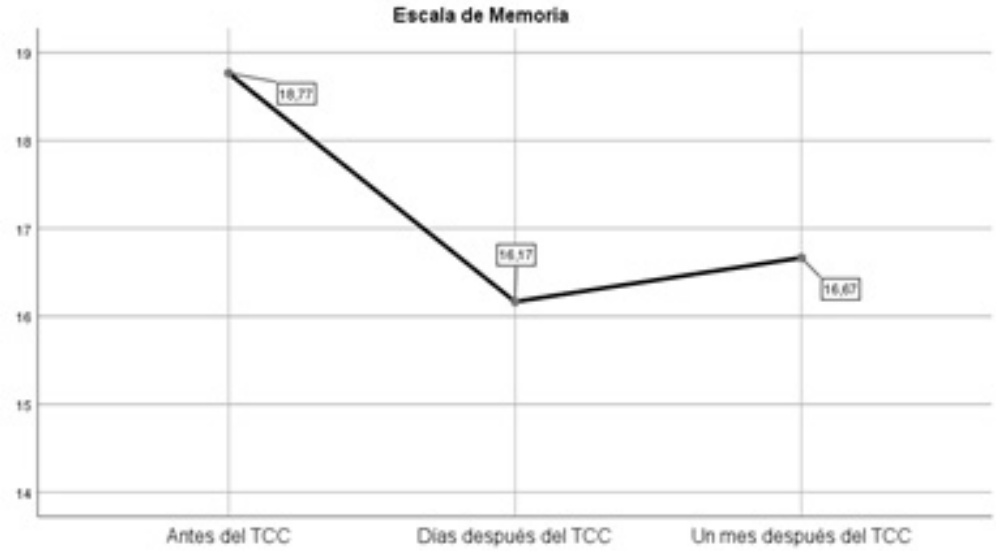


Figure 2. Measurements made on the Attention scale

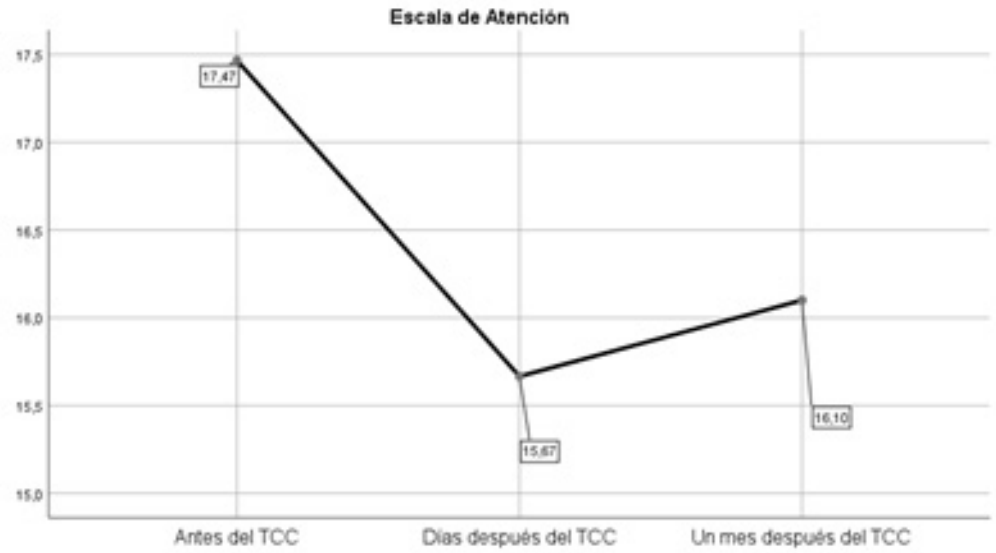
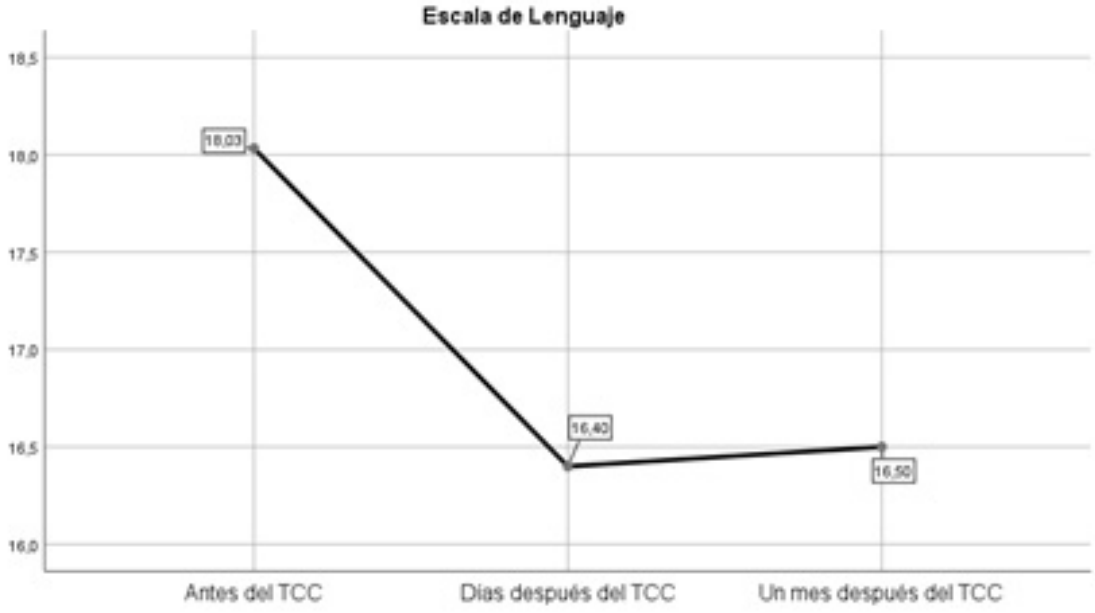


Figure 3. Measurements made on the Language scale



functions days after and one month after the evolution of the TBI.

DISCUSSION

In the present study, the impact of mild TBI on the child's neuropsychological status was analyzed days and one month after the event. Next, there will be a discussion about the results obtained from the application of neuropsychological tests and the clinical observation scales.

The results of the evaluation of the neuropsychological tasks one month after the TBI showed a statistically significant increase in the performance of the memory, attention, and language tests. This significant difference can be explained from the theory of Spontaneous Brain Recovery, which, through processes of intervention and operability of neuroplasticity systems, activate the metabolic functions of the areas near the injury to favor a functional restoration. This spontaneous recovery process in children is much richer than in adults, and points to a better restoration of altered neuropsychological functions[8].

Plasticity is a set of modifications that are produced by two elementary factors: the brain's development and maturity, which are strengthened through learning and previous experiences that the child has maintained 8. This brain mechanism would explain the improvements in the neuropsychological functioning of the children, since in no case, after the TBI, did they receive any type of formal neuropsychological treatment - although the interaction with experiences and learning after the TBI could have allowed to generate the plasticity process brain and thus achieve a gradual recovery of memory, attention and language[14].

In this recovery process, the brain uses approaches that involve mechanisms that determine an improvement in neuropsychological alterations. In the brain recovery approaches, the following stand out[15]: a) restoration, which is characterized by training or retraining again the reconstitution work of the altered function; b) replacement or compensation, in which brain circuits in areas surrounding the injury take over the functions performed by the altered areas; and c) the modification according to the environment, meaning that the demands of the injuries presented by the child must be supported in relation to the environment or environment in which it develops[16]. In the case of this research, the restoration process plays a relevant role, since the child's brain, being exposed to constant stimulation activities, seeks to recover and return to the pre-morbid state.

Factors such as the patient's schooling, the parents' academic level, the performance of cognitive activities, an adequate diet, height and weight, among other factors in favor of the child suffering from TBI, are identified as protective factors in the brain recovery; factors whose function is to prevent a further deficit from being generated and make the recovery process viable[8, 17,18]. At a month's mark of evolution, it is hinted that time is an important factor in the restoration process, since the brain had a period of time to reactivate its neural connections through intra-systemic restoration mechanisms[19]. Finally, other factors that influenced the study's results were the motivation, predisposition and attitude that the child had at the time of recovery, which were positive in the group of children and became contributions for the minors' benefit[10,11,20].

Despite the fact that the neuropsychological functions showed an increase in their performance level, there was not a total recovery of the altered neuropsychological functions in all cases. That is, the data suggest that memory, attention, and language did not been improved in their entirety, which was evidenced in neuropsychological tests and clinical observation scales - especially in the latter, since parents of the minors indicated that during the month of evolution, they found alterations and decrease in aspects such as: the efficiency, agility, speed, and abilities that the child possessed when solving tasks related to memory, attention and language. Therefore, the results of the clinical observation scale applied to the parents showed that their children were not the same again after the TBI.

For this reason, from a clinical perception, a referential clinical criterion was established, which was taken into account for the appreciation of the improvement in each neuropsychological test and allowed to interpret if the progress achieved by the children in the evaluation conducted one month later could be admitted as a full neuropsychological recovery. Based on this, the mean score of the test protocol was considered as the minimum expected result to indicate that the higher mental functions in the child were preserved. With this analysis, the data suggest that, in most of the variables they managed to obtain the minimum expected score. However there is a discrepancy between the appreciation of the child's parent who affirms that the patient had a neuropsychological level lower than the one he had before the TBI .

These findings invite us to reflect on the urgent need of children who experience a TBI, who should receive a neuropsychological assessment and adequate follow-up. Since these repetitive TBI can generate an alteration in their cognitive level despite not presenting such an obvious alteration that justifies it and notwithstanding if it deteriorates brain function in the future, almost like what happens with athletes who are exposed to micro-traumas that do not generate damage at that time or a loss of consciousness that justifies immediate specialized care but nevertheless damage their neuropsychological performance[12].

Therefore, the most important contribution of this work is to highlight the need for a neuropsychological evaluation, rehabilitation, control, and follow-up system to be implemented in the context of child health, and in this way, establish prevention, treatment, and care plans for the neuropsychological functions that can be seen exposed in TBI.

Finally, it is important to highlight the context in which this research was developed, which is Ecuador, a country that has an economic system based on the United States of America dollar and capitalism. The majority of its population is Catholic, its educational system is private and public with similar characteristics to other countries in the region and at a higher level of development. Therefore, the results of this research can provide insights to understand this same phenomenon in other contexts that share similar characteristics as described.

Annex 1. Clinical observation scale at.me.le

On this scale you will be presented with various questions regarding tasks, skills, or activities that are part of memory, attention, and language. Please answer if your child does the above, scoring per the following scale: 3 points for almost always, 2 points for many times, 1 point for some times or 0 points for never.
On the scale you will find three columns: BTBI (before head injury), DATBI (days after head injury), OMATBI (one month after head injury).

Memory:

Questions:	BTBI	DATBI	OMATBI
Does the child easily solves the tasks of everyday life?			
Does the child recall specific events?			
Can the child narrate a story in chronological order?			
Does the child easily recall things learned?			
Can the child reproduce what has been learned, based on what is known?			
Can the child identify people close to his environment and distinguish them from others?			
Can the child recall and repeat word immediately after hearing them?			

Attention:

Questions	BTBI	DATBI	OMATBI
Is the child able to attend to a task?			
Does the child perform tasks without being easily distracted by irrelevant stimuli?			
Does the child organize his/her activities without difficulties?			
Does the child follow directions in activities at school or home?			
Does the child pay attention to details and avoid making mistakes when performing a task?			
Can the child complete the designated activities?			
Does the child perform any tasks without supervision?			

Language:

Questions	BTBI	DATBI	OMATBI
Can the child articulate all the words?			
Does the child use synonyms for words that are not commonly used? Example: auto instead of car			
Is the child fluent in speaking or expressing him/herself?			
Does the child manage to articulate complete sentences when expressing him/herself?			
Does the child manage to express ideas in a coherent way?			
Is the child able to clearly understand instructions given?			
Can the child point to the meaning of a word or concept?			

BIBLIOGRAPHY

1. Purves, D., Augustine, G., Fitzpatrick, D., Katz, L., LaMantia, A., & McNamara, J. Invitación a la neurociencia. Buenos Aires: Editorial Médica Panamericana S.A., 2001.

2. Portellano, J. A. Introducción a la neuropsicología. Madrid: McGrawHill, 2005.

3. Basso, A. Neurocirugía: aspectos clínicos y quirúrgicos. Rosario: Corpus, 2010.

4. Ortega, J., Jusué, I., López, R., Riqué, I., & Sánchez, R. Traumatismo Craneoencefálico. In A. Verdú, A. García, O. García, G. Arriola, B. Martínez, & P. Castro, Manual de Nneurología Infantil (págs. 627-632). Madrid: Editorial Médica Panamericana, S.A., 2014

5. Perla, D. Traumatismo encefalocraneano en el niño. In P. David, J. Föster, M. Devilat, & M. Díaz, Neurología Pediátrica (págs. 641-646). Madrid: Editorial Médica Panamericana, S.A., 2014.

6. Varela, A., Pardo-Camacho, G., & Pardo-Cardoso, G. Síndrome postraumático: lesión orgánica vs. neurosis de renta. Revista Mexicana de Neurociencia 2007; 8 (4): 367- 371.

7. Fernández, A. (2014). Neuropsicología de la atención. Conceptos, alteraciones y evaluación. Revista Argentina de Neuropsicología 2007; 25: 1-28.

8. Portellano, J. A. Neuropsicología Infantil. Madrid: Editorial Síntesis, 2007.

9. Ramos, C. Secuelas Neuropsicológicas en el Daño Cerebral Adquirido: Análisis de Casos. Quito: Universidad Indoamérica del Ecuador, 2018.

10. Universität-Düsseldorf. (2018). G*Power: Statistical Power Analyses. Retrieved on February 2, 2018 from: http://www.gpower.hhu.de/.

11. Ostrosky, F., Gómez, E., Matute, E., Rosselli, M., Ardila, A., & Pineda, D. Neuropsi-Atención y Memoria. México, D.F.: Manual Moderno, 2012.

12. Wechsler, D. WISC-IV Escala Wechsler de Inteligencia para Niños- IV. Sierra-México: Manual Moderno, 2007.

13. Maggiolo, M. Test de Articulación a la Repetición (TAR). Revista Chilena de Fonoaudiología 2017; 16 (22): 1-14.

14. Rosselli, M., Matute, E., & Ardila, A. Neuropsicología del desarrollo infantil. Bogotá: Manual Moderno, 2010.

15. Colomé, R., López, A., Boix, C., & Sans, A. Traumatismo craneoencefálico. In M. Arnedo, J. Bembibre, A. Montes, & M. Triviño, Neuropsicología infantil (págs. 359-372). Madrid: Editorial Médica Panamericana, S.A., 2015.

16. Ellis, A., & Young, A. Neuropsicología Cognitiva Humana. Barcelona: Masson, 1992.

17. Ardila, A., & Rosselli, M. Neuropsicología Clínica. México D.F: Manual Moderno, 2007.

18. Arango, J. Rehabilitación Neuropsicológica. México D.F: Manual Moderno, 2006.

19. Stein, D. Desarrollo y plasticidad en el sistema nervioso central. Nueva York: Basic Books, 1989.

20. Blázquez, J., González, B., & Paúl-Lapedriza, N. Evaluación neuropsicológica. In J. Tirapu, M. Ríos, & F. Maestú, Manual de Neuropsicología. Barcelona: Viguera, 2008.

21. Ramos-Galarza, C. Concussion: El daño cerebral adquirido en la práctica deportiva. Cuadernos de Neuropsicología, 10(1), 111-119.

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