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Association Between Laterality Configuration and Intelligence and Neuropsychological Profile

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Author Details

*Rosario Nuño Valverde and Silvia Álava Sordo**

Faculty of Psychology, Alfonso X El Sabio University, Spain

*Corresponding author

Silvia Alava Deaf, Alfonso X El Sabio University, Faculty of Psychology, Álava Reyes Psychology Center, Spain

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Abstract

Laterality is one of the main manifestations of lateralitation [1]. It is a voluntary, conscious and peripheral function that can be modified through training. It is expressed through the preferential use of the hand, leg, eye and ear [2]. The association between laterality and the cognitive hability or the neuropsychological profile is an issue that creates a lot of uncertainty. Because of that, the main target of this study is to explore the association between the laterality obtained in the tests of homogeneity and lateral preference [3] and the Intelligence Quotient (IQ) obtained in the Weschler intelligence battery for children WISC-IV [4] of a clinical sample of 518 subjects from six to sixteen years old. The obtained results showed that there isn't a statistically significant difference between the different types of laterality and the CIT, but statistically significant differences were found in the Fluid Reasoning Index, specifically in the test of Cubes in favor of subjects with homogeneous laterality. This implies a possible impact form laterality's configuration in cognitive development and learning; being a matter of importance to attend it in subjects with learning problems.

Introduction

Lateralization, also known as hemispheric specialization, is the tendency of one of the cerebral hemispheres to be dominant and specialized in several functions or processes, which determines the subsequent preference for use and a greater aptitude of one of the two parts of the body for carrying out tasks [3]. This non-specific function of the human being [3] implies that each hemisphere attends to different information, processes sensory inputs in a different way and controls different types of motor behaviors [5]. This process begins to take place from before birth, being able to see from that moment interhemispheric neuroantatomical asymmetries, and progressively consolidates, ending in adolescence or adulthood [6]. Throughout its development it is affected by external stimuli and cognitive demands that occur throughout the life of the subject.

In the field of neuropsychology, lateralization gained importance due to studies of language and brain injury. In 1710, the crossing of the motor pathways was demonstrated, and with it the contralateral motor control. Later, with Broca and Wernicke, the expressive language center was located in the left frontal lobe and the comprehensive language center in the temporal lobe on the same side. This caused the left hemisphere to be called the dominant hemisphere, leaving the right in the background. It was found that this hemisphere was responsible for the dextrality of more than 90% of the world population [7]: language was lateralized to the left in 88% of right-handed individuals and in 78% of left-handed individuals, presenting 95% of the population with a predominance of the left hemisphere [6]. In fact, the correlation between manual laterality and language asymmetry is quite low, with most left- and right-handed people presenting left- hemisphere dominance for language [8]. Later on, it was confirmed that both hemispheres participate as a whole, not subject to dissociations, functioning in a complementary manner [9]. Here the corpus callosum plays a fundamental role, which allows said interhemispheric connection.

Laterality [1] is one of the main manifestations of brain dominance or lateralization. It is a conscious, voluntary and peripheral function that can be modified through training and is expressed through the preferential use of the hand, leg, eye and ear [2]. The definition by David, et al. [10], is in line with the first, stating that it is a component of perceptual-motor behaviors and structures that influence learning processes and motor acts. Hildreth already defined in 1949 laterality oscillates towards right-handedness around 2-3 years of age and towards left-handedness around 3-4 years of age; usually defined at 6-7 years.

Types of Laterality

As previously mentioned, laterality is expressed through the preferential use of the hand, leg, eye and ear [2]. The establishment of the laterality formula is done through the possible combinations in the 3 evaluated lateral segments (hand, leg, eye) and the categories shown in Table 1 are classified. The intensity of this lateral preference is understood as the greater or lesser degree of definition of the preference manifested by a subject. The less ambidexterity in the execution of the lateral gestures, the more the intensity of the lateral preference. Otherwise, we are faced with laterality without defining or consolidating.

As can be seen in Table 1, four types of laterality can be determined: homogeneous, heterogeneous, crossed and inverted.

Table 1: Laterality according to its eye-hand-leg expression.

Look	Hand	Leg	Laterality
0	0	0	Homogeneous
1	1	1	
1	1	0	Heterogeneous
0	0	1	
1	0	1	Crossed
0	1	0	
1	0	0	Inverted
0	1	1	

** 0= right-handed, 1= left-handed

In homogeneous laterality, the predominance affects the same lateral segment; that is to say, both the eye and the hand and leg present the same laterality; This can be totally left-handed or totally right-handed.

In the case of heterogeneous laterality, the eye and the hand present the same laterality, while the leg is different. On the other hand, in the case of crossed laterality, the laterality of the eye and the leg coincide, with manual laterality being discordant.

Crossed laterality refers to the presence of a change in dominance in any of the three body segments evaluated (hand/ eye/foot). However, due to the greater repercussion of the non-homogeneity referred to the dominant hand with respect to the directing eye, crossed laterality is used restrictively for this case [3].

Inverted laterality refers to cases of left-handedness (children with left hemispheric predominance, but they carry out many of their gestural activities with the right) and at the opposite extreme, cases of right-handed children who carried out graphic activities with their left hand. This type of laterality is given by the teaching of the use of the hand that is not the natural dominant of the child. It has been observed that this type of profile presents numerous dysfunctions and disturbances in the field of literacy.

Neuromyths on Laterality

Neuroscientific studies have received much attention since 1990-2000, when the ''Decade of the Brain" was declared in the US [11]. However, the precise neuropsychological language makes it difficult to transfer scientific discoveries to other contexts, often misinterpreting empirical evidence, giving rise to the well-known neuromyths.

The first to use the term neuromyth was the neurosurgeon Alan Crockard, who coined the term in 1980, referring to non-scientific ideas about the brain in medical culture [12]. In 2002, the Brain and Learning Project of the Organization for Economic Co-operation and Development (OECD) from the UK, drew attention to the misconceptions about the mind and brain that are flourishing outside of medical scientific communities. They redefined the term neuromyth as ''a misinterpretation that finds its origin in misquoting or a misunderstanding of scientific findings, used to apply it in education or other contexts" [13]. It has been analyzed that cultural conditions, such as differences in terminology and language used by neuroscientists and educators, may be implicated in the process that transforms scientific knowledge into neuromyths [14]. As corroborated by numerous studies [15], the relationship between laterality and cognitive ability or neuropsychological profile is an issue that creates a lot of uncertainty among professionals, being especially important among teachers. Dekker, et al. found in their study in the United Kingdom and the Netherlands that it was common for teachers interested in the possible application of neuroscientific discoveries in the classroom to confuse pseudoscientific facts with scientific facts. This lack of understanding gives rise to neuromyths, which are widespread among faculty. An example of this is seen in a past survey of teachers; where their beliefs regarding manual dominance and the Total Intelligence Quotient (CIT) are analyzed. The CIT is a value that results from the completion of a standardized test to measure the cognitive abilities and intellectual capacity of a person (intelligence) in relation to their age group. In this survey, it was observed that up to 1/3 of teachers believed that left-dominant subjects have a higher IQC compared to right-handed ones. It was observed that having a better general knowledge about the brain was not a protective factor for them. This corroborated Weisberg's [16] experiments, where it was shown that people with an introductory level in cognitive neuroscience were also misled by neuroscientific explanations.

These teacher judgments can lead to differential treatment between students, which has been shown to determine a person's life up to 40 years later. This may be related to the Pygmalion effect or self-fulfilling prophecy, demonstrated by Rosenthal and Jacobson in a behavioral experiment carried out in a public school in 1965, where they tried to determine the degree to which the change of expectations in the teachers produced changes in the academic results of the students. For this reason, it is especially important to reduce the number of myths that proliferate in educational centers. To this end, it would be useful to offer neuroscience training to teachers and improve communication between scientists and practitioners; with the aim of improving the neuroscientific literature on teachers.

However, not only neuromyths generate confusion regarding this issue; Rather, as mentioned in the studies by Papadatou-Pastou, et al. and Ferrero [17], the scientific studies themselves show great controversy in their results. Many of them analyze laterality, assessing only left- and right-handed dominant laterality. Within these, some studies have associated left lateral dominance with lower cognitive ability [18]; others with cognitive superiority and others have not found a relationship between laterality and cognitive ability.

There are some studies that incorporate the degree variable in addition to directionality; therefore obtaining crossed, inverted and heterogeneous dominances, in addition to the homogeneous left-handed and right-handed variables. Here we also find contradictory results. Papadotu-Pastou and Leconte [18] found in their meta- analysis high levels of ''mixed" laterality in individuals with intellectual disabilities compared to the mean. These authors define mixed laterality as that obtained by performing more than 3 test items with the non-preferred hand. On the other hand, they also found that gifted individuals are less likely to be left-handed compared to the mean, but just as likely to be non-right-handed (cross and mixed laterality). Dean, et al. studied children with learning disabilities, detecting that they had more inconsistencies in lateral preference. When studying the eye-hand combination, Leconte [18] observed that the crossed eye- hand preference (which in this study could be equivalent to crossed laterality or inverted laterality) is more frequent among children with intellectual deficit compared to children with regulatory development.

Various studies show a positive correlation between undefined laterality (those in which the subjects are ambidextrous) and learning difficulties [18] or literacy difficulties [3]. However, authors such as Langoni; Sulzbacher and Witelson, et al. found no association between laterality and literacy problems. Others like Sulzbacher or Sappington also found no association between it and academic difficulties. On the other hand, there have also been studies that find a negative correlation between laterality without establishing (ambidextrous), crossed laterality (those where the ocular and foot configuration coincide, but not the manual one) and learning or reading-writing difficulties. Therefore, the evidence between the relationship between the degree of dominance and intelligence is scarce.

As for the analysis of intelligence, it is a very broad term to be related to Laterality, since it is made up of numerous cognitive abilities, such as verbal comprehension, perceptual reasoning, processing speed, and working memory [4]. The result of the CIT is an average of all these factors; For this reason, even if two subjects have the same CIT, they can have completely different scores in the different cognitive abilities, that is, a different neuropsychological profile. That is why, in order to better understand the consequences of laterality, we consider it especially important to specify its effect on different cognitive abilities. Batchelor finds that the neuropsychological functions most related to laterality were discrimination and organization of spatial elements (TPT), visual tracking, motor integration and psychomotor speed (Trails A time), fine motor speed (Tapping) and gross motor strength (grip strength).

In relation to the reading and writing variables, while Rosa finds significant evidence of lower performance in reading and writing in subjects with crossed laterality (understanding cross as the same lateral preference of hand and foot and the opposite of the eye), Longoni and Bryden did not find a statistically significant relationship between laterality and these verbal abilities.

The relationship between lateral dominance and intelligence and neuropsychological profile continues to be a topic of wide debate today. Given the controversy found in previous research, the present study aims to explore how the different configurations of laterality are related to the neuropsychological profile.

Objectives and Hypotheses

As previously mentioned, in the 1970s numerous theories on lateralization began to rise and spread throughout various fields. Around the 2000s, some of these theories began to be considered as a neuromyth due to the propagation of a series of speculative beliefs that did not comply with an experimental verification or even their ideas had been refuted. However, the scientific investigations themselves show confusing and conflicting results, thus, not all authors define crossed, mixed or unsupported laterality in a homogeneous way, nor is the same intelligence construct being used.

This study aims to provide information in this field through the assessment of intelligence and neuropsychological profile using the Weschler tests (specifically the WISC-IV [4]), in a sample of children with learning problems between 6 and 16 years with different laterality configurations.

There are three specific objectives: firstly, to explore the relationship between the laterality obtained in the homogeneity and lateral preference tests [3] with the IQC obtained by the Weschler intelligence battery for children (WISC -IV [4]) from a clinical sample made up of children from 6 to 16 years of age.

Secondly, to check if there are differences in the factors of the Weschler WISC-IV intelligence scale for children [4] (CV: Verbal Comprehension Index; RP: Perceptual Reasoning Index; MT: Working Memory Index and VP: Processing Speed Index) according to the type of laterality obtained in the test of homogeneity and lateral preference [3].

Third, once the results have been obtained in the different factors of the WISC-IV [4], the aim is to explore the association between the results of the execution of the subtests that are part of each factor and the laterality configuration of the subjects. .

Regarding the comparison between Laterality and CIT

Hypothesis 1: The group with undefined laterality (crossed or heterogeneous) will show a lower IQC than the group with homogeneous laterality.

Regarding the neuropsychological profiles obtained on the Weschler scale:

Hypothesis 2: Subjects with undefined laterality (crossed or heterogeneous) will have poorer development in RP than subjects with homogeneous laterality.

Regarding the tests that comprise each factor:

Hypothesis 3: Subjects with undefined laterality (crossed or heterogeneous) will have poorer performance on the Cubes test; belonging to the RP factor.

Method

Participants

The sample is made up of 518 children and adolescents who attend the Álava Reyes Psychology Center for learning problems between April 2003 and August 2015; 326 men and 192 women. These people were selected from among the 679 subjects evaluated at the center between April 2003 and August 2015, who attended due to school difficulties and who underwent a psychological evaluation. The age ranged from 6 to 16 years, with the mean age being 10.64 (SD = 3.05). Of the total sample, 136 (22.7%) present heterogeneous laterality; 273 (45.7%) homogeneous laterality; 94 (15.7%) inverted laterality and 95 (15.9%) crossed laterality.

Instruments

Laterality tests: Laterality was measured using the Homogeneity and Lateral Preference test [3]. It is a technical instrument that allows to quickly and accurately assess the degree of consolidation of the homogeneity of the child's laterality for hand/eye/foot. It does this by combining quantitative and qualitative elements. The evaluation of manual dominance consists of 6 items, applied through two controls. On the other hand, ocular dominance is evaluated through 3 items applied with different hands, to avoid the influence of manual dominance. Finally, the evaluation of foot dominance consists of 4 items, applied as in the manual evaluation with different controls to have greater precision in the information obtained. The contingency coefficient for test-retest is ''C"= 0.88; the contingency coefficient for the test-criterion is C= 0.80 and the validity for the abbreviated version is C= 0.7169.

Tests to obtain the neuropsychological profile and CIT

The Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) is an intelligence battery for children between the ages of 6 and 16 years and 11 months. It consists of 15 subtests, 10 main and 5 optional. These 10 mandatory tests form the scores of four factors: CV, RP, MT and VP. They also form the CIT.

ANNEX I shows the subtests belonging to each factor.

The WISC-IV indices have an M = 100 (SD = 15). The tests have an M = 10 (SD = 3;[4,19]). The average internal consistency coefficients of the indices are: .92 in CV, .91 in RP, .89 in MT, .86 in VP and .95 in the CIT [19].

The legal guardians of the minors, made a clinical history through a semi-structured interview of one hour, where data of the anamnesis, psychomotor, linguistic, school development, current state of health, etc., were specified.

Analysis of data: The scores of the neuropsychological profile and the tests of the different factors were described by mean (M) and standard deviation (SD). Comparisons of means were first made in the different factors (CV, MT, RP, VP and CIT). by means of ANOVA of a factor with *post-hoc* comparisons and later of the tests carried out on each factor. Prior to the ANOVA, the principles of homogeneity of variances and normality of the sample distribution were verified.

To analyze the normality of the sample, the Shapiro Wilk test was used; with non-normal distributions, the robust Kruskal Wallis test was used. Regarding the homogeneity of variances, it was analyzed using the Levene statistic. The results whose variances were heterogeneous were analyzed using the robust Welch statistic. Data analyzes were performed using SPSS 20.

Results

The comparisons of mean scores of the neuropsychological profile and the CIT between the different groups of the sample are presented in Table 5. From Table 2 to Table 8, the descriptive statistics of the scores, the comparisons of means and the sizes are shown. effect of differences. The results were initially grouped according to the different factors of the WISC-IV and the

CIT and in a second place according to the component subtests of each factor. Tables 2 and 3 show the means and standard deviations of the scores for each factor.

Prior to the ANOVA, the principles of equality of variance and normality of the sample distribution were verified. The variables MT and inverted laterality (sig.005), CIT and crossed laterality (sig.006) and IG and inverted laterality (sig. 013) obtained a significance lower than .005, being considered in the Shapiro Wilk Test; considering abnormal distributions.

In the Kruskal Wallis test, it is observed that the configuration of laterality is the same in the distributions of all the variables (CV, MT, VP, CIT, IGC) except in the distribution of the RP variable of the WISC-IV. In the RP-laterality variable, there are statistically significant differences between crossed laterality (164.27) and homogeneous laterality (208.24) with χ^2 43.97 and significance .022. Obtaining a better score for subjects with homogeneous laterality (χ^2=208.24) in RP compared to crossed laterality (χ^2=164.27).

On the other hand, to analyze the homogeneity of variances, the Levene statistic was used. CV, RP, VP, CIT and IGC had a significance > .05, while MT had a significance of .011, being analyzed using the robust Welch statistic. When performing the independent samples T test, the significance is .717. It is concluded that laterality does not significantly influence working memory.

With the measurements that met the principles of homoscedasticity, equality of variance and normality of the distribution, an ANOVA of one factor was performed. Below, Table 4 shows the results obtained.

Table 4 shows the analysis of variance of the WISC-IV Factor scores [4]. In the ANOVA it was seen that there was a difference between groups in the variables RP (sig.: .019), and CIT (sig.: .048). In both variables the effect size was small, with a partial η2 of .026 and .021 respectively. To compare the group with the rest, Tukey's *post-hoc* test was applied. Here, statistically significant differences are obtained in the RP variable between the homogeneous and crossed laterality configuration (sig.: .016). On the other hand, in the CIT variable, we do not obtain

Statistically Significant Differences

Once the analyzes of the CIT and of the four factors were carried out, we proceeded to the analysis of the main and optional tests of each factor; shown in Tables 5-8.

Table 5 shows that the subtests that make up the CV factor (Similarities, Vocabulary, Comprehension, Information, and Riddles) presented homogeneous variances, which is why the ANOVA was used. In this analysis, statistically significant differences were only obtained in the Information test (sig.<.001), with a small effect size (partial η2>.047). When Tukey's *post-hoc* test was applied, statistically significant differences were seen within the Information subtest, between the homogeneous laterality-heterogeneous laterality configurations (with a mean difference of 1.76 with superiority of the homogeneous and a significance of .001). and the homogeneous-crossed configurations (with a mean difference of 1.25 with superiority of the homogeneous with respect to the crossover and a significance of .037).

On the other hand, as seen in Table 6, in the subtests that are part of the MT factor (Letters and Numbers, Digits and Arithmetic) they present homogeneous variances in the Levene test and there are no statistically significant differences in any of them in the ANOVA.

On the other hand, in the RP subtests (Matrixes, Cubes, Concepts, and Incomplete Figures) shown in Table 7, there are statistically significant differences between the means of some variables. The Concepts subtest presented a significance of .01 in the Leven statistic, so the Wells statistic was applied for its interpretation.

In the application of the ANOVA, no statistically significant difference was found in any of the subtests, except for the tests of Cubes, whose significance is .000 and a small effect size (partial η2 > .06). When Tukey's *post-hoc* tests were applied, statistically significant differences were found in the mean scores of the Cubes subtest between the samples of homogeneous-heterogeneous laterality (with a mean difference of 1.38, being above homogeneous laterality and a significance of .007), and between the samples of homogeneous-crossed laterality (with a mean difference of 1.85 with superiority of the homogeneous sample and a significance of .000).

Finally, in the subtests of the VP factor (Search for symbols, Keys and Animals) there are no statistically significant differences, which is illustrated in Table 8.

Conclusion and Discussion

In the first hypothesis, we wanted to check whether the sample group with undefined laterality (crossed or heterogeneous) would show a lower IQC than the group with homogeneous laterality [18]. The results obtained refute this hypothesis, not finding any statistically significant difference between the different lateralities. The results of this research refute this hypothesis, because although the significance in the ANOVA marks .048, in the *post-hoc* tests there is no statistically significant difference between the different types of laterality.

In the second hypothesis, it was anticipated that subjects with undefined laterality (crossed or heterogeneous) would have a poorer performance in the PR Index compared to subjects with homogeneous laterality. This hypothesis is in line with the data obtained by Batchelor, where he classifies discrimination and organization of spatial elements as one of the neuropsychological functions most closely related to laterality.

The results of this investigation support this hypothesis, with a significance of .019 in the ANOVA test. In the *post-hoc* tests, it is seen that the differences statistically

Significant in the PR test, they occur between the configuration of homogeneous and crossed laterality; that is, where the hand and leg preferences in the subject do not coincide.

Once the factors were analyzed, the component subtests of each one were analyzed; in order to understand the influence of each test on the result. Here the third hypothesis takes place; where, taking into account the data provided by Batchelor, it was expected that the subjects with undefined laterality (crossed or heterogeneous) would have a poorer performance in the Cubes test; belonging to the RP factor. The data obtained support this hypothesis, Cubos being the only RP factor test where differences are found in the execution of said test depending on laterality. Specifically, there are differences in the performance of the test between homogeneous and heterogeneous laterality and between homogeneous and crossed.

In both intergroup comparisons, the homogeneous lateralization groups achieved better performance of the test. This data could be relevant for a future study. Supporting these results is the testimony of the examiner of the subjects, Silvia Álava Sordo; who commented that subjects with both crossed and heterogeneous laterality performed this mirror test.

Likewise, statistically significant differences were observed in the Information subtest within the CV factor, where a lower performance is found in the heterogeneous and crossed laterality groups compared to the homogeneous one. One of the hypotheses considered is that in the WISC-IV for these results it is the strong component of temporal organization in some of the questions of the information subtest. An example of these are questions number 8. How many days does a week have?, 9. What day comes after Thursday?, 10. What are the four seasons of the year?, 11. What month comes after March?, 12. How many things are necessary to make a dozen?, 14. How many days does a year have?, 17. What month has one more day every four years? . The evaluator refers to the fact that within the test, they were the questions that failed the most. To broaden the knowledge about this association, it is advisable to explore the relationship between the spatial and temporal organization and carry out the evaluation using the WISC-V, a more up-to-date tool.

In view of the results obtained, it can be concluded that they are heterogeneous and crossed lateralizations, where inferior results have been seen in certain aspects of the neuropsychological profile with respect to homogeneous and inverted lateralizations, where if the hand and foot coincide preferentially: the RP factor and subtest Cubes of said profile and Information (integral of the CV factor). However, it is obtained that both lateralities present the same CIT, results that do not support the lines obtained by Papadotu Pastou and Leconte [18]; which find high levels of mixed laterality in individuals with intellectual deficiency with respect to the average.

As it has been observed in the literature found on laterality, there is a very limited number of studies that associate it with the neuropsychological profile; being the most common to investigate it regarding intelligence [17,18] and literacy problems [3]. As Papadatou-Pastou, et al. and Ferrero [17] the studies found on laterality and cognitive ability report confusing and contradictory results [19-25]. This is partly due to the little consensus among studies when operationalizing a definition of laterality and the classification of its different types. An example of this is the numerous studies that use laterality and lateralization interchangeably; as is the study by Carvajal & Muñiz which leads to error, since they are different terms. In addition, numerous ways of measuring laterality have been observed. As can be seen in Annex II, there have been studies that measure laterality with great rigor and others that apply a single test to determine it. On the other hand, regarding the measurement of cognitive abilities, different tests have also been used to determine them, which can affect the results; this is also illustrated in ANNEX II. As for the samples where the studies have been carried out, they have also been heterogeneous, ranging from a normalized sample to samples with Intellectual Deficits or literacy problems. This is a very useful variable because a relationship can be found between laterality and each interest group in the population; but it is very important that this variable is very controlled [25-29].

The results of this study have interesting implications for education. The evidence that there is a relationship between crossed and heterogeneous laterality, the RP factor and the Information subtest, indicates that in this type of subjects it is important that these areas be the object of direct intervention, to improve the cognitive abilities of said subjects [30-35].

On the other hand, it is also important to emphasize the lack of empirical evidence of the previously mentioned neuromyths, being especially important in the future, giving the option of training teachers on the neuropsychological area, to avoid falling into them.

Regarding future lines of research, it would be interesting to continue collecting information on the relationship between laterality configuration and the Information subtest within the CV factor of the WISC-IV; to be able to intervene directly on it and thus avoid difficulties in said area. Likewise, it would be beneficial for the scientific community to update the study using the WISC-V, since it is present since 2014. [36-39] On the other hand, the study of the different attentional processes, learning processes and reader-writers in relation to laterality configuration may be a field of interest.

However, it is important to consider the limitations of this study. The wide range of ages in the sample must be taken into account, since in future research it would be convenient to carry out analyzes focused on more specific age groups to study the nuances that may arise due to age. In addition, it is necessary to take into account that the sample is of convenience, not representing the general population. Therefore, it would be beneficial to include a more diverse sample and thus be able to obtain more generalizable results that better represent the population [40-43].

It is also important to mention that the effect sizes found in this study are small, possibly because the groups compared are quite similar, since they all have learning difficulties. This result is influenced by the fact that there was no control group in the study.

Finally, it is relevant to point out that this study used a clinical sample of more than five hundred participants, and was carried out before the appearance of DSM-5 and WISC V. Therefore, it is necessary that new studies based on these new tools replicate or refute these results [44-46].

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ANNEX I: Factors and subtests of the WISC-IV.

Verbal Comprehension	Working of memory	Reasoning Perceptual	Speed of Prosecution
Vocabulary	letters and numbers	Matrices	Symbol searches
Comprehension	digits	Cubes	Key of numbers
Similarities	Arithmetic(optional)	Concepts	Animals (optional)
Riddles (optional)		Incomplete figures (optional)	
Information (optional)			

ANNEX II: Compilation of intelligence and laterality measurement tools.

Author	Laterality		Intelligence
	Part of body	Tool	
Leconte [18]		Bishop's Card Raching Task Twelve-item laterality test	Raven's test
Batchelor, et al.		LDE: (lateral Dominance exam) WISC-R	
Bryden		Laterality development test (5 items)	Gates- MacGinitie Reading tests
Leconte [18]	Hand, Eye, Foot	Twelve item laterality test, card reaching task	Raven
Dunlop		Maddox Rod and wing tests, binocular vision, manual preference, preferential eye, controlling eye in binocular vision	Wisc
Gingras		2 items of eye preference, 2 items of foot preference, and 10 items of hand preference	Intelligence Standford-Binet
Other & Turner	hand, eye, foot	not standardized	The maze test of the Wechsler Scale
Night	hand, eye	Harris test	Lorge-Thorndike Intelligence Test
Balow & Barlow	hand, eye	Harris test	Lorge-Thorndike Intelligence Test
Bishop, et al.	hand, eye	not standardized	Wechsler Scale for Children-R
Bryden	Mano, oido	not standardized	The Otis Quick Scoring Mental Ability Test
Clymer & Silva	hand, eye, foot	Test Harris	WISC-R
Hillerich	Hand, look like	not standardized	California Short Form Test of Mental Maturity
Roszkowski, et al.	hand, eye, foot and ear	DKSLD	Otis-Lennon Test
Shaywitz, et al.	hand, eye, foot	not standardized	Wechsler Scale for Children-R
Stephens, et al.	thousand, look like	not standardized	California Test of Mental Maturity
Ullman	Hand, Eye, Foot	not standardized	Lorge-Thorndike Intelligence Test

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