ARITHMETICAL ABILITIES IN BRAZILIAN DEAF SIGNERS OF ELEMENTARY SCHOOL

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The present study investigated the effect of Sign Language acquisition period in deaf signaling students on their linguistic, arithmetic and cognitive skills. Participants were 58 students (24 female) with pre-lingual deafness enrolled from 2nd to 5th grades from Brazilian Institute for Deaf Students Education (INES). They were divided into two groups (early versus late) according to the age at the beginning of Sign Language acquisition. Standardized tests were applied: The Raven's Progressive Matrices; School Achievement Test; Sign Language Assessment Instrument. The results were evaluated in both, quantitative and qualitative ways. Statistical analysis showed that children who learnt sign language before age four performed better in basic mathematical concepts and language skills. There was also academic progression throughout scholar levels in this population as a whole, regarding arithmetic knowledge and expressive language.

Numerical Cognition is influenced by biological, cognitive, educational, and cultural factors (Santos et al., 2012), and involves three main systems: The *Number Sense (NS)* (Dehaene, 2009); the *calculation (CA) itself, and Number Processing* (McCloskey, Caramazza & Basili, 1985). At the beginning, numerical cognition development is universal and observed in infants as part of an evolutionary predisposition; gradually starting to vary according to mutual interactions and experiences (Dehaene, 2009; Hyde & Spelke, 2011; Starkey & McCandliss, 2014).

The language has a role in the construction of cognitive abilities, and among them, those that are specifically mathematically-based (Göbel et al., 2014). According to Salillas and Carreiras (2014) exact arithmetic is acquired in a language-specific format as well as number concepts. In addition, language areas are activated during some numerical tasks. This could be observed by the use of specific Sign Language strategies as the signed algorithm (Nunes & Moreno, 1998).

Hearing is an essential channel responsible for the oral language acquisition. Thus the hearing loss will interfere significantly in the interdependent language processes such as: thought development, memory, concepts in number, measurement, operations and problem solving, and patterns, reasoning, among others especially for those born or become deaf in the pre-lingual period (Pagliaro & Kritzer, 2013; Pénicaud et al., 2013).

Around 90% of deaf children belong to listener families (Silva, Pereira & Zanolli, 2007), which usually cannot offer a favorable linguistic environment to develop the Sign Language. Unfortunately, the time relapsed between hearing loss detection and initiation of appropriate care in Brazil is still high (around three years), which further compromises the children possibilities for acquiring oral communication (Silva, Llerena & Cardoso, 2007). In contrast, deaf children whose parents are deaf users of Sign Language develop their communication earlier, being able to perform as well as the hearing children (Quadros & Cruz, 2011). Thus it seems inappropriate to associate the deaf children's cognitive level to their language skills.

The Brazilian Sign Language (*LIBRAS*) was recognized as an official language in Brazil since 2002. In the few bilingual deaf schools available in the country, the Sign Language is the main language of education, and the children enter at the school with different levels of Sign Language proficiency.

Our previous results revealed the presence of heterogeneous mathematics performance levels for students in the same scholar grade (Madalena, Marins & Santos, 2012). Nevertheless it was not clear if language performance could explain those differences. The present study aimed to explore the relationships between the period of Sign

Language acquisition in deaf students and their linguistic and arithmetic abilities. We hypothesize that students with late Sign Language acquisition will perform worse in arithmetic, even in mathematic questions presented in Sign Language.

METHOD

Participants

Initially 63 students were assessed. However five participants were excluded: one because of her age (18 years old) and the other four students due to associated comorbidities. Therefore, statistical analysis can rely on a casuistic of 58 students.

The study included all students enrolled in the 2nd to 5th grade at Brazilian National Institute of Deaf Education (INES) in Rio de Janeiro. At INES, *LIBRAS* is the main language of instruction and the students use the Oral Language only occasionally in isolated words during vocalizations or as support. Participants aged between 9 and 16 years old (34 male, Table 1). About 73% (n=42) of the students had their hearing loss diagnosed up to 24 months old. About hearing loss, only one student has severe bilateral loss, six have severe loss in their right ear and profound in the left, while the other 51 participants have bilateral profound hearing loss. In this sample there were no students with cochlear implants.

Procedures

Students were tested individually in INES classroom in this order: the arithmetic performance, intellectual ability and skills of receptive and expressive language. Each participant answered one test a day and the new test began after the complete evaluation of the sample on the previous one.

The Raven's Coloured Progressive Matrices (MPCR; Raven, 1992) was used for students aged under 12 years old and the Raven's Progressive Matrices (RPM; Raven, 2008) for those above this age. The test was carried out by a licensed psychologist, bilingual in Portuguese and *LIBRAS*.

The scholar achievement test (TDE; Stein, 1994) aims to assess the skills of reading, writing and arithmetic of children from the 2nd to 7th grade of elementary school. In the present study, only arithmetic subtest was used, which is composed by 3 oral and 35 written questions. The main goal of TDE is to assess whether the student's performance is consistent with the school grade, which can be measured regardless the chronological age.

In this research oral questions (a comparison, an addition, and a subtraction) were adapted to *LIBRAS* and called ***LIBRAS*-TDE**. Children's performance was classified into three categories: "low" (missed all the questions or hit only one question), "medium" (hit two questions), and "total" (hit all the questions).

All questions scores (written plus *LIBRAS)* will be called **TDE-complete**. Participants performed at first *LIBRAS*-TDE (previously recorded), and then received the writing questions. Students were instructed to stop the test when the difficulty level was beyond their knowledge.

The Assessment Instrument for Sign Language (IALS; Quadros & Cruz, 2011) is divided into two subtests: first the receptive language assessment and second the expressive language evaluation. The first one is composed by three phases with increasing difficulty levels, each one preceded by training tasks and all questions are provided as videos in the DVD test. Phases I and II are formed by multiple-choice tests, in which the participant selects from among three options, the picture that corresponds to the statement signaled. In phase III participants watch an indicated story and select the five correct out of eight pictures. The selected scenes must be organized in logical sequence, according to the narrative made by the deaf teacher (DVD).

The second subtest assesses expressive language without prior task demonstration. Children attend individually a "Tom and Jerry" cartoon (1:10 min.). Then each one is encouraged to narrate the story to a guest who doesn't know it. Videotaped narratives were evaluated qualitatively by four *LIBRAS* proficient teachers (two deaf). Narrative aspects were organized in "present", "absent" or "inconsistent" for classifiers usage, spatial references, and logical sequence. The number of facts narrated and vocabulary were classified into "poor", "fair", "good" and "very good".

It was given to each student's parent a questionnaire with questions regarding the mothers' education level, month family income, presence of comorbidities, age in which deafness was detected and its etiology, including the age in that the student began his/her exposition to the *LIBRAS*.

Groups were compared regarding intellectual abilities, language and arithmetic. The socio-demographic data, organized into table with average and rates. The normal distribution of variables was assessed using the Kolmogorov-Smirnov test. Significant differences emerged from using the Student's *t* test or ANOVA, wherever applicable. Categorical data (qualitative) was analyzed by Chi-square test (alpha <0.05) or Fisher's exact test (alpha <0.05), in appropriate conditions.

RESULTS

Participants were divided into two groups (all results are expressed in table 1) regarding the age at the beginning of Sign Language acquisition (ab*LIBRAS*): Early (before 54 months old, EG; Quadros &Cruz, 2011) and Late (after this age, n=32, LG). In this context MPR results showed no statistic difference between the groups (Fisher's exact test, p = 0.09). This analysis revealed the sample homogeneity, but indicated intellectual difficulty for most participants. However, there was a weak relationship between the MPR results and other skills. The MPR results related to receptive language (Spearman, r = 0.29, p = 0.022) was significant, while tests of arithmetic and expressive language revealed only trends.

Since, other factors could also contribute to their mathematics achievement; the socio-demographic data was investigated. Both groups showed equivalency regarding gender (Fisher's exact test, p = 0.59), income (Fisher's exact test, p = 1.0), mothers' education level (Fisher's exact test, p = 1.0), age at detection (Chi-square test, p = 0.65) and etiology of deafness (Chi-square test, p = 0.56).

The scores in all three phases were added and used for statistical analysis. The comparison of results in receptive language revealed that students from the EG group performed significantly better (Mann-Whitney test, p = 0.0021).

We chose to eliminate three items from the final analysis: classifiers, spatial references, and phonological aspects, since two groups had very similar results. Regarding to vocabulary and events narrated, results were grouped to form two major alternatives: low and high. Then "poor" and "fair" were added into low, and "good" and "very good" were contained in high. There was no statistical difference between the two groups for all analyzed aspects (vocabulary, p=0.26, events narrated, p=0.10).

Despite the absence of difference between groups, the students had significant academic progression throughout scholar years, but not in a linear pattern. The academic progress was present regarding vocabulary (p = 0.0019) and number of narrated fates (both Kruskal-Wallis test and Dunn's posttest, p = 0.0032).

Statistical analysis revealed that the EG group showed significantly better performance in the *LIBRAS*-TDE (Mann Whitney test, p = 0.006). Regarding to TDE-complete there was no difference among groups (Mann Whitney test, p = 0.36).

Similar to the academic progression observed in expressive language students also improved significantly their arithmetic performance with the scholar grades increase (one-way ANOVA, p<0.017, Tukey's test). Then the student's evolution was significant from 2nd and 3rd grades in relation to 4th and 5th grades. Besides that, this performance was not correlated with participants' chronological age (Spearman r = 0.107, p = 0.42).

Table 1 Socio-demographic distribution, MPR, TDE, and IALS according to ab*LIBRAS*.

Variables		**EG** (n=26)	**LG** (n=32)	**p value**
Females		12(46.1%)	12(37.5%)	0.59[(a)]
Income		15(57.6%)	19(59.3%)	1.0[(a)]
Education		15(57.6%)	18(56.2%)	1.0[(a)]
Dd	<12	11	10	0.65[(c)]
	12-23	9	12	
	≥24	6	10	
De	Congenital	15	14	0.56[(c)]
	Acquired	4	6	
	Unknown	7	12	
Age		149.2± 4.3	175.4 ± 2.9	**<0.0001[(b)]**
MPR	Level V	14(53.8%)	25(78.2%)	0.09[(a)]
	Levels I-IV	12(46.2%)	7(21.8%)	
LIBRAS-TDE	low	2(7.6%)	9(28.1%)	**0.006[(a)]**
	medium	9(34.7%)	17(53.1%)	
	total	15(57.7%)	6(18.8%)	
TDE-Complete		14(7-20)	12.5(1-20)	0.36[(b)]
IALS-Receptive		12(8-12)	11(7-12)	**0.002[(d)]**
IALS-Voc.	low	15(57.6%)	24(75%)	0.26[(a)]
	high	11(42.4%)	8(25%)	
IALS-EN	low	7(26.9%)	16(50%)	0.10[(a)]
	high	19(73,1%)	16(50%)	

Note. Children were grouped by ab*LIBRAS*. Both groups were very similar except for age (months), expressed by average ± standard deviation. *LIBRAS*-TDE reports correct answers number: low, one; medium, two; and total, three. TDE-complete and IALS-Receptive results are expressed by median (minimum–maximal). IALS-Vocabulary (Voc.) and -Events Narrated (EN) are showed by frequency and percents (%) as well as the categorical variables. Deafness detection age (Dd) and etiology (De) present the number of students. Reference values: Income, ≤2 minimum wages; Education, to complete basic education.
[a] Fisher's exact test; [b] Unpaired Student's *t* test; [c] Chi-square test; [d] Mann-Whitney test.

DISCUSSION

The study investigated the effect of early (EG) or late (LG) Sign Language acquisition of deaf signaling students in linguistic, arithmetic and cognitive skills.

We found better language skills for the EG, contrasting with poor comprehension for the LG group. (Quadros & Cruz, 2011; Ramírez, Lieberman & Mayberry, 2013). We assumed this finding as directly related to ab*LIBRAS,* confirming previous study (Mayberry et al., 2013). It means that no matter the amount of time exposure to language, people with late acquisition have a persistent delay on language development (Mayberry et al., 2011; Pénicaud et al., 2013).

Despite the presence of heterogeneous language development stages inside each grade, participants exhibited an expressive language improvement throughout scholar grades as reported by Lange and colleagues (2013). Therefore, the formal bilingual schooling stimulation and other experiences inside the school could recover at least partially LG limitations.

However neither the *abLIBRAS* nor the *LIBRAS*' time of exposure could explain the participant's poor performance on nonverbal intelligence tests, as reported in the literature for deaf students (Nunes et al., 2009; Reesman et al., 2014), which should be addressed in future studies to shed light on this topic.

EG students performed better *LIBRAS*-TDE despite they are younger than LG, confirming the relationship between the construction of mathematical concepts and language development (Göbel et al., 2014).

LIBRAS-TDE deserves special attention for dealing with basic mathematical concepts (comparison, addition, and subtraction) and requires understanding of problem situations. In this context participant's errors could be attributed to the lack of understanding instead of the inability to calculate. This conclusion emerges from the fact the students who missed questions in the *LIBRAS*-TDE, hit other more complexes in the math written tasks with the same arithmetic operation. A possible explanation is that deaf children learn how to calculate, but fail to understand when to apply it (Nunes, 2004).

During the math written tasks, the signed algorithm (Nunes & Moreno, 1998) was used by some high scores students. Further investigations are required to evaluate if this strategy could facilitate the arithmetic skills development in deaf children.

TDE scores increased over the school grades. This means that as well as listeners, *LIBRAS* users show progressive refinement of numerical accuracy throughout childhood by the formal education (Berteletti et al., 2010; Santos et al., 2012). Therefore the hearing impairment, does not determine success or academic failure, but interacts with other factors (Mayberry, Lock & Kazmi, 2002). The sample academic achievement seems not to be due to the age development, since the chronological age factor showed inverse relationship in the *LIBRAS*-TDE: as younger, the better performance.

Thus the present results shows that early acquisition of sign language potentiates the learning of math and receptive language supporting the existence of the sensitive period for language acquisition.

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