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(Central) auditory processing in schoolers in initial literacy grades

Processamento auditivo (central) em escolares das séries iniciais de alfabetização

Keywords

Hearing
Auditory Perception
Hearing Tests
Child
Schooling

Descritores

Audição
Percepção Auditiva
Testes Auditivos
Criança
Escolaridade

ABSTRACT

Purpose: To characterize and compare behavioral tests of central auditory processing of schoolers of initial grades in two stages, test and retest; and correlate the variables age and gender with the results of these tests. **Methods:** Cohort, analytical, observational, longitudinal and prospective study; developed in a public school. The sample included 36 schoolers, divided into two groups considering the schooling: G1- Thirteen children of first grade and G2- Twenty-three children of second grade. The inclusion criteria were audiological assessment within normality patterns and being enrolled in the first or second year of elementary school and, as exclusion criteria, presence of neurological, cognitive and behavioral disorders. The audiological assessment and application of the behavioral tests of central auditory processing occurred in two different moments, with an interval of six months, called test and retest. **Results:** The test with the highest prevalence of change, in both steps and groups, was Dichotic Digits. It is noteworthy that no schoolers from G1 and some from G2 understood RGDT at the test stage and that even after six months this difficulty remained in both groups. In the retest stage, a significant improvement was noticed in the schoolers' performance of both groups. It was still noticed a correlation between the age variable and dichotic digits test in the left ear in both stages. **Conclusion:** There was a high incidence of alteration in the tests and, a performance improvement was noticed in the retest stage, mainly in the tests of sound localization, dichotic digits and RGDT.

RESUMO

Objetivo: Caracterizar e comparar os testes comportamentais do processamento auditivo central de escolares das séries iniciais nas etapas, teste e reteste; e correlacionar as variáveis idade e gênero com os resultados destes testes. **Método:** Estudo coorte, analítico, observacional, longitudinal e prospectivo; desenvolvido em uma escola da rede pública. Compuseram a amostra 36 escolares, subdivididos em dois grupos considerando a escolaridade: G1- 13 crianças do primeiro ano e G2- 23 crianças do segundo ano. Adotaram-se como critérios de inclusão: avaliação audiológica dentro dos padrões de normalidade e estar matriculado no primeiro ou segundo ano do ensino fundamental; e, como critérios de exclusão, presença de alterações neurológicas, cognitivas e comportamentais. A avaliação audiológica e a aplicação dos testes comportamentais do processamento auditivo central ocorreram em dois momentos distintos, com um intervalo de seis meses, denominados etapas teste e reteste. **Resultados:** O teste com maior prevalência de alteração, em ambas as etapas e grupos, foi o Dicótico de Dígitos. Cabe ressaltar que nenhum escolar do G1 e alguns do G2 compreenderam o RGDT na etapa teste e que, mesmo após seis meses, esta dificuldade se manteve nos dois grupos. Na etapa reteste, notou-se melhora significativa no desempenho dos escolares de ambos os grupos. Observou-se também, correlação entre a variável idade e o teste dicótico de dígitos na orelha esquerda, em ambas etapas. **Conclusão:** Houve uma alta incidência de alteração nos testes e; se observou melhora no desempenho na etapa reteste, principalmente nos testes de localização sonora, dicótico de dígitos e RGDT.

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INTRODUCTION

Central auditory processing is the term used to describe a series of mental operations that the individual performs in dealing with information received via the sense of hearing and which depend on an innate biological capacity, maturation process and experiences and stimuli in the acoustic environment⁽¹⁾.

Alterations in this processing can lead to impairments in academic performance, language delay, difficulty in properly understanding what is said and learning difficulty.

In recent years, there has been an increasing interest in studying children's auditory abilities, because there is evidence that children with alterations in these abilities are more susceptible to language and learning disorders⁽²⁻⁴⁾.

The literature has highlighted the importance of considering the influence of comorbidities related to neurodevelopment, as well as cognitive factors in the behavioral evaluation of central auditory processing^(5,6), but it is emphasized the need to establish a consensus among researchers in order to improve the test reliability or find alternative approaches so that the diagnosis of this disorder is not influenced by these factors⁽⁶⁾.

In the literature review, no epidemiological studies which had evaluated auditory abilities in schoolers aged six and seven were found. In addition, there is no consensus on the battery of standardized behavioral tests that should be used in the central auditory processing evaluation in this population.

Authors report doubts as to the test reliability that evaluate these abilities, since the performance in the evaluation can be influenced by the age⁽⁷⁾, auditory experience⁽⁸⁾, or by the cognitive competences required to the performance of the auditory processing⁽⁹⁾.

Considering that the auditory abilities are fundamental for understanding the spoken message, it is evident the need to know the children's central auditory processing at the beginning of the literacy process, since the investigation and monitoring of the auditory abilities of this population can aid in the choice of appropriate conducts to eliminate or minimize alterations that may adversely affect the learning process.

Thus, the purposes of this study were: to characterize and compare the schoolers' performance of initial grades in the behavioral tests used to evaluate central auditory processing in test and retest stages; and to correlate the variables age and gender with the tests results.

METHODS

This was a cohort, analytical, observational, longitudinal and prospective study.

This study was developed in a public school of a small town in the interior of the State of São Paulo. The audiological and behavioral evaluation of central auditory processing was performed in the school amphitheater, after authorization from the Municipal Education Secretary. It should also be emphasized that the place where the evaluations were carried out was silent and that during the procedures, only the evaluator and the child remained in the place.

The sample was composed of 36 schoolers and these were grouped according to schooling in:

Group 1 (G1): composed of 13 schoolers who attended the first grade of elementary school, ranging in age from six years to six years and nine months (average of six years and two months). There were four male and nine female schoolchildren.

Group 2 (G2): composed of 23 schoolers who attended the second grade of elementary school, with age ranging from six years and eleven months to seven years and ten months (average of seven years and four months). There were eight male and fifteen female schoolers.

In order to compose the sample, the following inclusion criteria were established: signature of informed consent form, to be regularly enrolled in the first or second grade of elementary school and audiological assessment within normality patterns in the test and retest stages. As exclusion criteria, the presence of neurological, cognitive and behavioral alterations was considered based on the analysis of answers of the questionnaire (Annex A) sent to the parents and/or guardians and the information obtained in an interview with the teachers.

It should be noted that, despite the presence of signs that some children had speech alterations and/or language alterations/learning difficulties, it was decided not to analyze these variables due to the fact that they were in the acquisition process, the parents did not notice any pathological process that require intervention and the purpose of this study was to know the central auditory processing of schoolers in the public school system.

The audiological assessment consisted of the following procedures: external auditory meatus inspection; immittanciometry, pure tone audiometry; and behavioral evaluation of central auditory processing.

The audiological assessment was performed using the Interacoustics AC-33 audiometer, with TDH-39 headphones and calibrated according to ANSI-69 standards. For the central auditory processing evaluation, compact discs (CDs) containing the recorded tests were used, and these were presented through a DVD player coupled to the audiometer. The equipment used to perform the immittanciometry was the Interacoustics AT-235 tympanometer, with a probe tone of 226 Hz.

As a normality criterion for the audiological assessment in both stages, test and retest, it was considered: hearing thresholds equal to or lower than 20 dBHL in the frequencies of 250Hz to 8 kHz (ANSI 69 standard) bilaterally, tympanometric curve of type A bilaterally and presence of ipsilateral and contralateral acoustic reflexes in the frequencies of 500, 1000 and 2000 Hz⁽¹⁰⁾.

For the central auditory processing evaluation, the following behavioral tests were applied: Sound Localization, Sequential Memory for Verbal and Non-Verbal Sounds; Dichotic Digits Test (DDT), Pediatric Speech Intelligibility (PSI) with ipsilateral competitive message and Randon Gap Detection Test (RGDT). The application of each test and the analysis of the results was according to the proposal of the specialized literature^(11,12).

Considering the age range of the evaluated schoolers, the analysis of the central auditory processing evaluation was based

on the description and the number of altered auditory abilities, since the schoolers are in the developmental stage of the auditory abilities and there is no consensus about the evaluation and/or diagnosis in children under seven years of age⁽¹³⁾.

In the second stage of the study, called “retest”, the participants were reevaluated after a period of six months at the beginning of the second school semester, in August and September. It should be emphasized that no schooler had any alteration in the audiological assessment in the retest; and therefore, the behavioral evaluation of the CAP was applied in all participants of the test stage.

The protocol of this study was approved by the Research Ethics Committee with Human Beings, under the protocol of approval n° 957.964 and according to resolution of the National Council of Health NCH 466/2012. Previously to the beginning of the evaluations, the legal representatives responsible for the selected participants signed the informed consent form.

Statistical analysis was performed using the Spearman correlation to verify the degree of relationship between the variables age and gender and central auditory processing evaluation. To compare the results of the central auditory processing evaluation obtained in the test and retest stages, the Wilcoxon Signed Post Test was applied. The correlation coefficients were classified according to their magnitude: weak (< 0.4), moderate (≥ 0.4 to < 0.5) and strong (≥ 0.5), and it was adopted the significance level of 5% ($p \leq 0.05$).

RESULTS

The analysis of the behavioral tests of central auditory processing applied in schoolers of initial grades, in the test stage, showed that the test with the highest prevalence of alteration in both groups was the dichotic digits test. In relation to the RGDT, the schoolers of both groups presented difficulties in understanding it. In G1, no schooler was able to perform it, and in G2 only a few schoolers were able to perform it. The only test that was not showed altered in both groups was the sound localization test (Figures 1 and 2).

In the retest stage, it was noticed that the schoolers of both groups showed improvement in the performance of the Dichotic Digits test, but this ability remained mainly altered in schoolers of G1. In relation to the RGDT, it was observed that schoolers of G2 had a higher alteration rate, but it is worth emphasizing that this test was not applied in most G1 schoolers because they did not understand it (Figures 1 and 2).

When comparing the schoolers’ performance in the behavioral tests of central auditory processing in test and retest stages, it was observed that in the test stage, the mean number of altered tests was 2.00 and, in the retest step, it was 1.61, that is, there was an improvement in the schoolers’ performance in the retest stage and this was statistically significant.

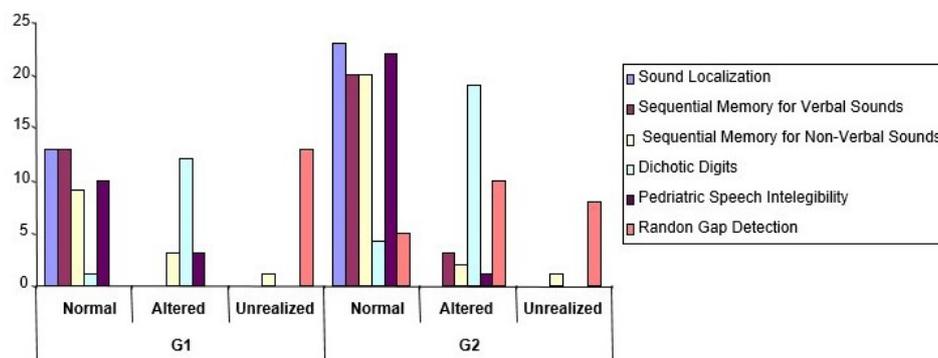


Figure 1. Behavioral tests of Central auditory processing in schoolers in test stage

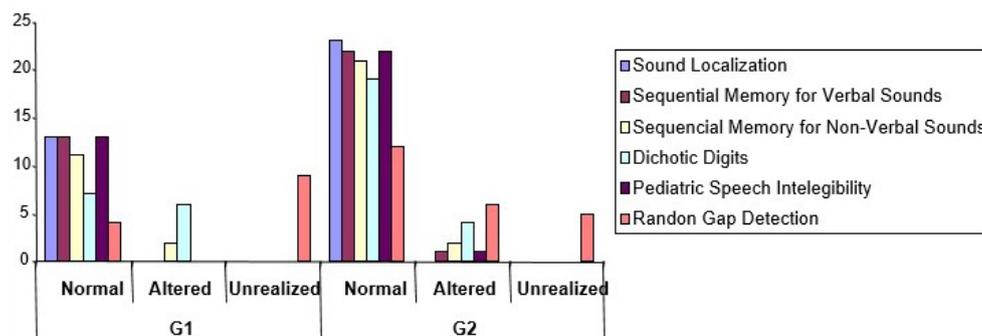


Figure 2. Behavioral tests of Central auditory processing in schoolers in retest stage

In relation to the analysis of schooler's performance, in each of the tests applied, an improvement in the performance in the retest stage was noticed, but it was statistically significant only in the tests of sound localization, dichotic digits in both ears and RGDT (Table 1).

In the correlation between the behavioral tests of central auditory processing and the age and gender variables, a significant moderate positive correlation was observed between the age and the result of the dichotic digits test in the left ear in the test stage and a significant weak positive correlation in the retest (Tables 2 and 3).

Table 1. Comparison of the schoolers' performance of G1 and G2, in the test and retest stages, in the behavioral evaluation of central auditory processing

Tests	Stage	n	Mean	Standard Deviation	Minimum	Maximum	Sig. (p)
Sound Localization	Test	36	4.89	0.32	4.00	5.00	0.046*
	Retest		5.00	0.00	5.00	5.00	
Sequential Memory for Verbal sounds	Test	36	2.67	0.79	0.00	3.00	0.271
	Retest		2.78	0.59	0.00	3.00	
Sequential Memory for Non-verbal sounds	Test	34	2.41	0.89	0.00	3.00	0.248
	Retest		2.47	0.77	0.00	3.00	
Dhictic Digits correctness RE (%)	Test	36	72.78	18.47	27.50	97.50	< 0.001*
	Retest		90.63	9.01	67.50	100.00	
Dhictic Digits correctness LE (%)	Test	36	70.83	16.21	35.00	97.50	< 0.001*
	Retest		82.29	16.63	32.50	100.00	
Pediatic Speech Intelligibility RE S/N= -15dB	Test	32	80.31	10.62	60.00	100.00	0.340
	Retest		82.00	10.79	60.00	100.00	
Pediatic Speech Intelligibility LE S/N= -15dB	Test	32	75.00	11.07	60.00	100.00	0.050
	Retest		80.29	11.50	60.00	100.00	
Randon Gap Detection (Average Final Score)	Test	15	16.82	7.48	5.50	28.75	0.001*
	Retest		9.14	4.84	3.50	22.50	

*Statistically significant relation

Caption: RE = Right ear; LE = Left ear; p = significance level; S/N = Signal/ Noise Ratio; n = number of schoolers

Table 2. Correlation between the behavioral tests of central auditory processing and the age variable in the test and retest stage

Tests	Test Stage			Retest Stage		
	n	r	p	n	r	p
Sound Localization	36	-0.162	0.345	36	—	—
Sequential Memory for Verbal Sounds	36	-0.22	0.198	36	-0.177	0.301
Sequential Memory for Non-Verbal Sounds	34	0.223	0.205	36	0.108	0.529
Dhictic Digits correctness RE (%)	36	0.272	0.108	36	0.188	0.273
Dhictic Digits correctness LE (%)	36	0.467	0.004*	36	0.364	0.029*
Pediatic Speech Intelligibility RE S/N= -15dB	32	0.036	0.845	35	0.264	0.125
Pediatic Speech Intelligibility LE S/N= -15dB	32	-0.141	0.441	35	-0.037	0.831
Randon Gap Detection (Average Final Score)	15	-0.204	0.467	22	-0.193	0.388

*Statistically significant relation

Caption: RE = Right ear; LE = Left ear; p = significance level; S/N = Signal/ Noise Ratio; r = correlation coefficient; n = number of schoolers

Table 3. Correlation between the behavioral tests of central auditory processing and the gender variable in the test and retest stage

Tests	Test Stage			Retest Stage		
	n	r	p	n	r	p
Sound Localization	36	-0.063	0.717	36	—	—
Sequential Memory for Verbal Sounds	36	0.095	0.583	36	-0.009	0.96
Sequential Memory for Non-Verbal Sounds	34	0.221	0.21	36	0.072	0.676
Dhictic Digits correctness RE (%)	36	0.156	0.363	36	0.284	0.094
Dhictic Digits correctness LE (%)	36	-0.045	0.792	36	0.208	0.223
Pediatic Speech Intelligibility RE S/N= -15dB	32	0.146	0.425	35	-0.059	0.736
Pediatic Speech Intelligibility LE S/N= -15dB	32	0.007	0.968	35	-0.034	0.845
Randon Gap Detection (Average Final Score)	15	-0.158	0.575	22	0.097	0.668

Caption: RE = Right ear; LE = Left ear; p = significance level; S/N = Signal/ Noise; r = correlation coefficient; n = number of schoolers

DISCUSSION

Children, upon entering school, are susceptible to new academic learning and social coexistence different from the acoustic experiences offered in the family context.

Morphological changes in the brain, dependent on age, determine on a large scale the child's ability to perform certain auditory activities. Central nervous system structures, although present and functioning at birth, continue to form new synaptic connections and increase efficiency until adolescence, and possibly until early adulthood⁽¹⁴⁾.

The comparison of the behavioral tests used in the central auditory processing evaluation of schoolers of the initial grades in both stages showed that the test with the highest prevalence of alteration was the dichotic digits. In addition, it is worth emphasizing the difficulty understanding the RGDT, especially in younger children, which made impossible the application of the test in most of these children.

The correlation of these findings with the literature was impaired, since epidemiological studies focusing on the central auditory processing profile in this age group are scarce. The majority of conducted studies have as purpose to differentiate the central auditory processing of children with or without the presence of other associated pathologies.

In accord with these results, authors confirmed that the tests with the highest number of altered results in the behavioral evaluation were those that evaluated temporal processing and dichotic listening^(15,16). The author stated that tests to evaluate the mechanism of dichotic listening, dichotic digits test and temporal processing are recognized as important tools to define alterations of the central auditory processing⁽¹⁷⁾.

In a study carried out with children, born term and preterm, aged between four to seven years, the authors applied a test battery to the central auditory processing evaluation composed of simplified assessment of auditory processing, speech with white noise, PSI and dichotic digits. In preterm infants, temporal ordering, auditory closure, and figure-ground abilities for verbal sounds were the most impaired, and to term children, the most altered abilities were those of figure-ground and auditory closure⁽¹⁸⁾. In other study, the SSW (Staggered Spondaic Words - Portuguese version) was added in the test battery, the purpose of the study was to evaluate the central auditory processing of children between five and seven years old with and without phonological disorder; the authors observed that auditory abilities of figure-ground with auditory-visual association and auditory closure were not sensitive to differentiate groups⁽¹⁹⁾.

In relation to the application of RGDT, there are controversies in the literature, one of the studies verified that more than 80% of the children in the age group of five and six years presented altered results and suggested that it should not be administered in children under age of seven years due to the fact that other reduced capacities influenced their performance, among them the attention⁽¹⁸⁾. On the other hand, authors have reported the feasibility of applying this test in children under seven years of age^(20,21).

In the population of this study, the result analysis of the dichotic digits test and the RGDT allows inferring that the most altered auditory abilities were those of figure-ground for

linguistic sounds and temporal resolution. The literature reports that deficits in these abilities may interfere with the proper information processing and, consequently, affect the normal development of the schooler⁽²²⁾.

In this way, it can be stated that the dichotic digits test was the most sensitive test to detect central auditory processing disorders in this age group and it showed to be the most indicated for screening children who should be referred for complete evaluation.

It was also verified a statistically significant improvement in the performance of the auditory abilities of sound localization, figure-ground for linguistic sounds and temporal resolution, after six months, which can be justified by influence of developmental process and plasticity related to learning⁽²³⁾.

All schoolers, from both groups, did not present alterations in sound localization test, as in the test as in the retest stage. However, it was noticed an increase in the number of correct answers in retest stage, that is, the schoolers correctly located all the directions.

The auditory abilities depend on the neural function and, therefore, consider the neuromaturation process, which is found closely related to the child's age⁽²⁴⁾.

During pre-literacy, attention should be paid to a lower performance for expected auditory abilities for each age group, because alterations in these abilities may indicate poor school performance in long term⁽²⁾.

The analysis of the correlation between the behavioral tests of central auditory processing and the age variable showed positive correlation, in both stages, only for the dichotic digits test in the left ear; which allows inferring that the increase of the children's age is related to the better performance in the left ear in this test. The findings of this study corroborate those of the literature^(15,16,25).

One study reported that the sensitivity of the results in dichotic digits test of the right ear was 34.54% and the left ear was 60% and concluded that the results of the left ear in this test show a greater tendency of alteration in children with learning difficulty⁽²⁵⁾.

The influence of the ear variable only in the dichotic digits test allows hypothesizing the fact that students present greater difficulty in dichotic tests can be justified by the late maturation of the structures responsible for the inter-hemispheric transference. It is worth emphasizing that the children in this study were younger than the age group of seven years. Such fact may have interfered with their performance, because the brain structures were in development.

The author refers that poor performance in the central auditory processing evaluation may be associated with a possible late maturation of the corpus callosum which, according to the literature, has its fully maturation only after seven years of age. During dichotic stimulation, the ipsilateral auditory pathways are suppressed promoting the contralateral pathways, which present a greater number of fibers. The disadvantage of the left ear is the result of the longer transmission time of the verbal information presented in this ear, since it must be transported from the right hemisphere to its processing in the left hemisphere through the corpus callosum. Therefore, the left ear needs a

greater participation of the corpus callosum to be efficient in the linguistic information processing⁽¹⁷⁾.

The myelination process in the different areas of the cortex is not homogeneous. Cortical regions of early myelination control relatively simple movements or sensory analyses, while areas with late myelination control the higher mental functions. It can be stated, therefore, that the myelination works as an approximate index of the cerebral maturation⁽²⁶⁾.

The myelination of the corpus callosum is critical for the transference of information between the two hemispheres and continues through adolescence. The fact that several brain areas initiate the myelination at different times have profound implications for auditory processing⁽²⁷⁾.

Authors suggest that dichotic listening tests are the best method to evaluate the interhemispheric transference of information and maturity of the auditory nervous system. This is because, in this process, the contralateral way has priority of functioning⁽²⁸⁾.

The dominance of the left hemisphere for the speech and language processing and dichotic listening could explain the findings⁽²⁹⁾. It is known that, in dichotic listening tests, the contralateral way is the main responsible for information processing. Thus, for the left ear, a longer processing time is required since that the information, after arrival in the right hemisphere, must cross the opposite hemisphere through the corpus callosum⁽³⁰⁾.

In contrast to the variable age, there was no correlation between the gender variable and the behavioral tests that evaluated the central auditory processing, and these results are corroborated by the literature^(16,20).

This research indicates that it is possible to perform the central auditory processing evaluation in the age group between six and seven years, but it is suggested that the RGDT be applied only from the age of seven years, considering that no child of the GI (age varying between six years and six years and nine months) was able to understand the test.

The detection of alterations in auditory abilities in central auditory processing evaluation in school-age children will enable the audiologist to guide teachers in the planning of didactic activities, which involve the stimulation of auditory abilities, as this may minimize the harmful effects of the persistence of this disorder and improve the performance of these children.

New studies are needed to confirm these findings in larger samples and, thus, to assist the diagnosis process in this age group, in order to avoid and/or minimize academic difficulties.

CONCLUSION

The comparison of the behavioral tests (test and retest) to the central auditory processing evaluation of schoolers in initial grades showed that the test with the highest sensitivity to detect alterations in auditory abilities was Dichotic Digits. The RGDT, on the other hand, showed to be infeasible in children under seven years of age due to the difficulty of understanding of these children. The analysis of the schoolers' performance showed that, after six months, there was improvement in all auditory abilities evaluated, especially in the ability of sound localization, auditory figure-ground and temporal resolution.

It was also observed that there was no correlation between the gender variable and the test results, however, the age variable correlated only with the results of the left ear in the dichotic digits test.

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Author contributions

AATKS and CRD participated in the idealization of the study, data collection, analysis and interpretation and article writing; ACVC participated, as supervisor, in the idealization of the study, data analysis and interpretation and article writing.

AUDITORY PROCESSING EVALUATION

1. Identificaton

Name:		Age:		DB:
Evaluator:	Manual Preference:	Evaluation date:		
Schooling:	Referred by:	Gender	M ()	F ()
Address:		Phone:		

2. Anamnesis

- Do you listen well in a quiet environment? yes no Are you inattentive? yes no
- Do you listen well in a noisy environment? yes no Are you too quiet? yes no
- Do you locate the sound? yes no Are you agitated? yes no
- Do you understand the conversation well? yes no
- In what situation is the conversation more difficult?
- Quiet environment? In group With an interlocutor
- Noisy environment? In group With an interlocutor
- Does it oscillate independently of the environment?
- Do you present some difficulty in:
- Speech? yes no What: _____
- Reading/writing? yes no What: _____
- Others? sim no What: _____
- Did you take time to learn to talk? yes no Started with: _____
- Did you take time to learn to walk? yes no Started with: _____
- Did you have difficulty learning to read? yes no And to write? yes no
- Did you have other learning difficulties? yes no What? _____
- Did you fail school? yes no How many times and in what grade? _____
- Do you have a good memory? yes no Describe: _____
- Are you being medicated? yes no Describe: _____
- Have you had otitis, ear pain, especially in the first few years of life? yes no Describe: _____
- Did you have other diseases? yes no What and when? _____
- Are you in medical monitoring? yes no Start and reason: _____
- Are you in Speech-Language Therapy and Audiology monitoring? yes no Start and reason: _____
- Are you in psychological monitoring? yes no Start and reason: _____
- Are you in psychopedagogical monitoring? yes no Start and reason: _____