# CHARACTERIZATION OF TYPES OF ERRORS COMMITTED IN THE EVALUATION OF AUDITORY PROCESSING THROUGH *STAGGERED SPONDAIC WORD TEST*

## *Caracterização dos tipos de erros cometidos na avaliação do processamento auditivo por meio do Staggered Spondaic Word Test*

**Nubia Maria Verdun[(1)], Iuberi Carson Zwetsch[(1)], Maria Inês Dornelles da Costa-Ferreira[(1)]**

**ABSTRACT**

**Purpose:** to characterize the types of errors committed in Staggered Spondaic Words testing by patients undergoing auditory processing evaluation, and correlate these findings with age, gender, educational level and auditory processing disorder (APD) sub-profile. **Methods:** the *Staggered Spondaic Words* test results were obtained from a private database, which evaluated patients aging from 7 to 19 years, between June 2011 and September 2013. **Results:** the most frequent types of errors detected were: word omission (76.66%), word substitution (45%) and replacement by an adjacent word (20%). The APD sub-profiles observed were auditory decoding deficit coupled with integration deficit (38.33%), auditory decoding deficit (23.33%), normal result (20%), and others (18,34%). When the conditions were compared, we observed a greater number of errors in competing conditions. In relation to age and educational level, the errors occurred in greater number among younger patients with lower levels of educational. The correlation between the total number of errors and gender was not statistically significant. **Conclusion:** the types of errors made in the Staggered Spondaic Words test were characterized and correlated with the proposed variables (gender, age, educational level and APD sub-profile), emphasizing the importance of the test, which is frequently used in auditory processing evaluations for the diagnosis of human communication disorder, and in the identification of children at risk for learning disorders.

**KEYWORDS:** Hearing; Hearing Loss, Central; Language Development Disorders

## INTRODUCTION

The sense of hearing is of fundamental importance in the social development of human beings, in learning how to speak and in passing on ideas and lived experiences. Thus, hearing and speech are essential to communication and learning. As a result, hearing disorders impair the command of spoken language. In this context, the processing of information received by the auditory pathway is characterized as a set of skills that the individual needs to: interpret, acknowledge, discriminate, recognize, store and understand received auditory information[1-5].

(1) Centro Universitário Metodista – IPA, Porto Alegre, RS, Brasil.

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The processing of acoustic information shows that the perception of sounds is not immediate, because it is necessary that the auditory system receives and transmits the received acoustic signal. To accomplish this task, the acoustic signal is transformed, organized, coded and recoded by auditory structures. This entire process is called Auditory Processing (AP) [2,5,6].

AP can be defined as the set of mechanisms and processes responsible for lateralization and location of a sound. This is achieved by; auditory discrimination, recognition of auditory patterns, the temporal aspects of hearing (resolution and temporal ordering), integration and binaural separation abilities and hearing abilities utilize with competitive and degraded acoustic signals. These complex functions are evaluated using a battery of behavioral AP tests[3].

The AP changes are classified into categories called sub-profiles. These sub-profiles are classified as primary: auditory decoding deficit, integration deficit, and prosodic deficit; and, as secondary: auditory association deficit and output-organization deficit[4,5].

The SSW test, the focus of this study is one of the most used AP assessment techniques and is classified as a dichotic listening task using as verbal stimulus, two-syllable words organized into 40 sequences composed of 4 disyllables each, which totals 160 stimulus words, divided between the conditions: Right Non-Competing (RNC), Right Competing (RC), Left Competing (LC) and Left Non-Competing (LNC) [4,5].

The skills assessed in the SSW test are: binaural integration, which is the ability to integrate stimuli presented simultaneously or alternately to the ears, and binaural separation which is the ability to process auditory messages that are received only by one ear, ignoring the information that reaches the opposite ear [6,7].

Extensive research, using the SSW test for evaluating AP, has been carried out on clinical populations assessing: difficulties in learning to read and write [1,4,8-11], the relationship between phonological disorder and AP [12-18]; the relationship between oral breathing and the central auditory system [19]; dyslexia [20]; comorbidity between attention deficit hyperactive disorder (ADHD) and dyslexia [21]; the relationship between performance in cognitive tests and AP tasks [22]; listening skills in students aged 7 to 10 years, from different socioeconomic and cultural levels [23] and effectiveness of an informal program of specific auditory training for Auditory Processing Disorders (APD) in a group of [24] patients with this alteration.

This study aims to highlight the importance of SSW test in the diagnosis of human communication disorders and to identify children at risk for learning disorders and specific complications which can be overcome or minimized with concomitant auditory training and speech therapy [1,4, 8-12,18].

With foundation in the presuppositions presented in the literature, the objective of this study is to characterize the types of errors committed in Staggered Spondaic Words test (SSW) for patients undergoing auditory processing evaluation and correlate these results with age, gender, education and APD sub-profile.

## METHODS

This study was approved by the Research Ethics Committee of the IPA Methodist University Center, under the protocol 334 026/2013. It is a cross-sectional, retrospective, observational study, utilizing contemporary data taken from a private database, compiled from the collection of SSW test results used in the evaluation of AP. All patients were evaluated by the same professional who used AC33 audiometer from *Interacoustics*, with *TDH-39* headphones in a soundproof booth.

This test used as verbal stimulus two-syllable words. 40 sequences were composed of 4 disyllables each, totaling 160 stimulus words. All words in the test were presented at 50 dB SL, based on average tone thresholds. The 40 sequences were numbered from 1-40 with the 20 sequences with odd numbers presented starting with the right ear and the 20 sequences with even numbers delivered starting with the left ear.

The first word of the odd sequences was presented only to the right ear and constitutes the right non-competing condition. The subject was then presented with two different words, one for each ear, simultaneously forming the right and left competitive condition. The last word was then presented solely in the left ear, forming a left non-competing condition.

The even sequences followed the same criteria, except that they started in the left ear. Therefore, the first word of the sequence was presented solely to the left ear forming the left non-competing condition. Followed by the left and right competitive conditions, formed by the second and third words presented one to the left ear and the other to the right simultaneously. Finally, the right non-competing condition was tested, with the presentation of the last word solely to the right ear.

This study included all AP SSW tests performed on patients 7-19 years of age, from June 2011 to September 2013, totaling 55 tests. All tests outside the selected age group and the stipulated time period were excluded. The lower age limit was justified by the range in which the full assessment of auditory processing can be performed. In addition the time period of the study marks the start of activities at the clinic until the end of data collection.

After approval from the Ethics Committee, an Excel spreadsheet was prepared with all SSW test words, documenting each word and the respective errors made in the pronunciation of these words. Errors were classified as follows: By phonemic substitution (Ex. boring → pouring), by word omission, by word replacement by another adjacent word in the sequence (Ex. following words: bargain

– brandy – party – handy, the patient speaks brandy rather handy).

For statistical analysis, the computer program The SAS System for Windows, version 9.2 was used. To describe the sample profile, in relation to the study variables, frequency tables were made for categorical variables, and descriptive statistics for continuous variables. To compare the number of errors between competitive and non-competitive conditions, and between right and left ears, we used the Wilcoxon test for related samples. For comparison among four types of errors, we used the Friedman test. To compare the numerical variables between two groups, the Mann-Whitney test was used and for comparing three or more groups the Kruskal-Wallis test was utilized due to the lack of normal distribution of variables. To analyze the relationship between numerical variables, we used the Spearman correlation coefficient due to the absence of normal distribution of variables. The significance level adopted for the statistical tests was 5% ($p < 0.05$).

## RESULTS

Of the total number of examinations (n = 55), 37 (67.27%) were male and 18 (32.72%) were female. In terms of age, 28 (50.90%) were 7-10 years old and 27 (49.10%) were between 11 and 19 years. The average age was 10.25 years (±2,59).

As for education, 38 (60.09%) were enrolled in the early years of elementary school (ES), 12 (21.81%) were enrolled in the final years of ES and 5 (9.09%) had a high school education (HS) completed or uncompleted. Table 1 shows the descriptive analysis of errors made, by condition, in the SSW test. The descriptive analysis of the types of errors can be seen in Table 2 –

**Table 1 – Descriptive analysis of the errors committed by condition in the *Staggered Spondaic Words* test (n=55)**

| No. of errors | Average | SD | Minimum | Maximum |
|---|---|---|---|---|
| RNC | 2,73 | 2,68 | 0,0 | 9,0 |
| RC | 7,32 | 6,1 | 0,0 | 23,0 |
| LC | 8,35 | 6,88 | 0,0 | 33,0 |
| LNC | 1,75 | 2,16 | 0,0 | 8,0 |

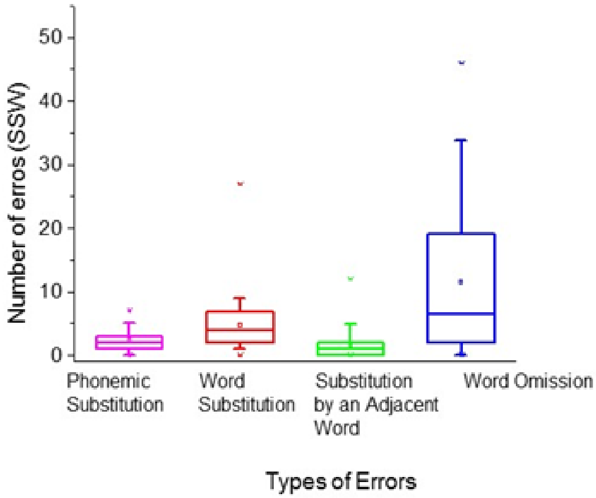
Key: RNC = right non-competing; RC = Right competing, LC = left competing, LNC = left non-competing, SD= standard deviation

**Table 2 – Descriptive analysis of the types of errors committed in the *Staggered Spondaic Words* test.**

| Types of errors | Average | SD | Minimum | Maximum |
|---|---|---|---|---|
| Phonemic substitution | 2,37 | 1,86 | 0,0 | 7,0 |
| Word substitution | 4,7 | 4,44 | 0,0 | 27.0 |
| Substituion by an adjacent word | 1,58 | 2,54 | 0,0 | 12,0 |
| Word omission | 11,4 | 12,79 | 0,0 | 46,0 |

Key: SD= standard deviation

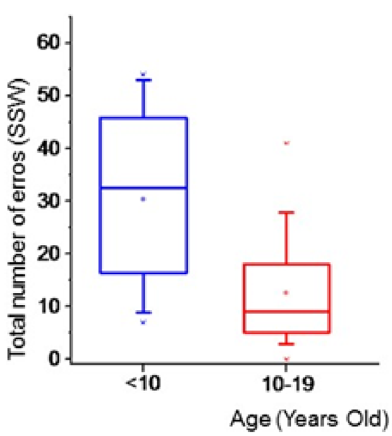
The comparative analysis between the types of errors was also statistically significant ($p < 0.001$). It should be highlighted that most errors which occurred were by word omission followed by word substitution, phonemic substitution and replacement by an adjacent word, as shown in Figure 1.




P-Value refers to the Friedman test

**Figure 1 – Comparative analysis between the types of errors committed in the *Staggered Spondaic Words***

When comparing the total number of errors with gender, there was no statistically significant difference (p> 0.05 for all variables). Regarding age groups, comparative analysis was statistically significant for all variables, word replacement (p = 0.003), phonemic substitution (p = 0.010), and other variables (p <0.001). The comparison between the total number of errors and age can be viewed in Figure 2 where it can be observed there was a

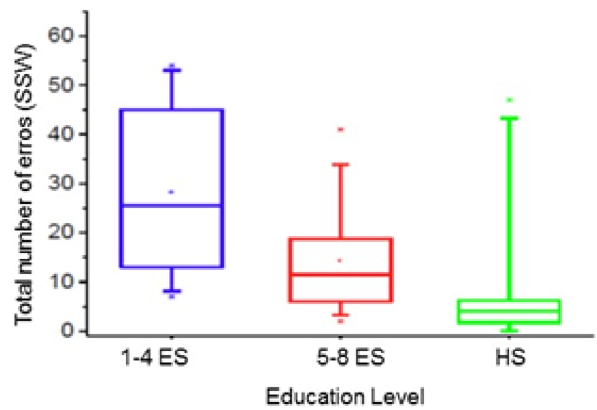



P-value refers to Kruskal-Wallis test

**Figure 2 – Comparative analysis between age and the total number of errors committed in the *Staggered Spondaic Words test***

higher incidence of errors in tests of children under 10 years, followed by patients aged 10 to 19 years.

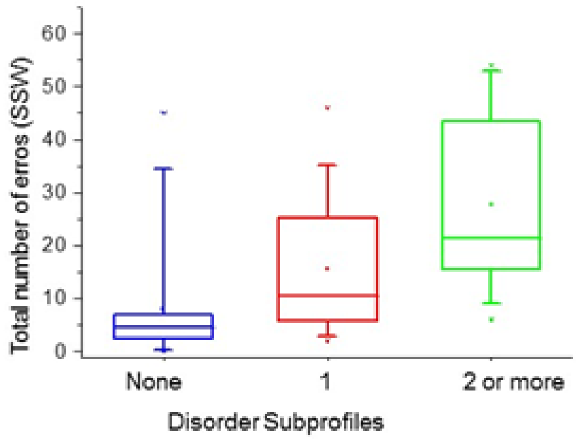
Comparison of the variables studied in relation to education was statistically significant for the variables: word replacement (p = 0.005), phonemic substitution (p = 0.026), number of errors in left non-competing condition (p = 0.006), and the other variables (p <0.001). Only the relationship with the variable substitution by an adjacent word was not statistically significant (p = 0.058). Figure 3 shows that children who were in the early years of ES made more errors in the SSW test, followed by the subjects that were in the last years of ES, and young people who attended HS.




P-value refers to Kruskal-Wallis test

**Figure 3 – Comparative analysis of the research variables in relation to educational level.**

Regarding characterization of the SSW test results by APD sub-profiles, 23 (38,33%) patients were affected with decoding and integration sub-profiles, followed by 12 (21.81%) with decoding, 9 (16.36 %) with normal results, 6 (10.0%) with decoding and output organization and finally 5 (8.34%) with other sub-profiles or combinations thereof. Similarly, Figure 4 presents a statistically significant relationship when comparing the SSW test results and the number of sub-profiles identified, in that there are more errors when there is more than one sub-profile identified in the diagnosis. This relationship was also found to be statistically significant when analyzing number of errors and word substitution by an adjacent word (p = 0.023), the number of errors committed in the left non-competing condition (p = 0.005), and for the other variables (p <0.001). Only phonemic substitution variable was not statistically significant.




P-Value refers to Kruskal-Wallis test

**Figure 4 – Comparative analysis of the auditory processing disorder sub-profiles with the no. of errors committed in the SSW test**

## DISCUSSION

According to the data obtained in this study there was a statistically significant relationship between language disorders and gender, being more prevalent in males, totaling 2/3 of the sample population. These results corroborate the findings of other studies that indicate similar results, explaining that boys have more language and learning disorders than girls [1,8,17].

Academic performance in reading and writing in children who attend Elementary School (ES), is a major qualm for parents and teachers and is characterized as the main motive for AP assessment referral. Alterations in auditory processing can occur alone or be found in association with other learning disorder comorbidities as demonstrated in other studies [1,8-12]. In this sense, early detection is essential to the minimization of the linguistic, cognitive and psychosocial impact of APD, as well as to organize appropriate speech rehabilitation. In this study, APD was identified in most children in the sample population who were between the ages of 7 and 10 years old, attending the ES.

In the present study we found a higher incidence of the word omission type errors, followed by word replacement, replacement by an adjacent word and phonemic substitution. It was also observed that the occurrence of these errors is directly proportional to the number of APD sub-profiles. When two or more sub-profiles were found, the number of omissions found was greater than in tests which found just 1 sub-profile. This increase was also seen for word replacement type errors, replacement by an adjacent word and phonemic substitution.

The ability to listen to a word and repeat it correctly, especially in a competing condition, reflects the integrity of the peripheral and central auditory system and cognitive functions necessary for the task. In cases where a word is completely omitted, it is possible to infer the presence of a disorder in one of these systems to a greater degree. Conversely the substitution of one word with another may indicate that the alteration has occurred to a far greater extent in some area of AP and to a lesser extent in attention and linguistic systems, allowing the individual to understand the occurrence of a failure in the system and correct it according to the context. Additionally in phonemic substitutions, it is possible to infer the occurrence of alterations solely in AP because usually only a single linguistic feature is replaced [4].

In the comparative analysis between the total number of errors and the age of test subjects it was observed that the lower the age, the higher the incidence of errors in the SSW test. This can be explained by the process of maturation of the corpus callosum and frontal areas of the brain involved in the increase of the cognitive resources of the individual as their age increases and they advance academically. Thus, a behavioral assessment may reflect such immaturity [25], and may be a key factor in diagnosis and management of the rehabilitation process. Individuals with complaints of difficulty in the learning process generally performed worse on AP tests due to the delay in the maturation of auditory skills. These skills are fundamental to the process of reading and writing [4]. Accordingly, the application of AP tests, such as the SSW test, emphasizes the importance of obtaining data on auditory development and aids in the early detection of a disorder that can interfere with the social and academic development of these individuals [11].

In this study, the decoding deficit and integration deficit sub-profiles occurred concomitantly in most of the sample tests, especially in patients from 7 to 10 years. The abilities altered in the decoding sub-profile are: selective attention, binaural interaction, auditory closure, temporal resolution and discrimination; and in the integration sub-profile, integration and binaural separation and appointment of a tonal pattern. These findings indicate that the abilities mediated by the brain stem and primary auditory cortex are altered along with the abilities mediated by the corpus callosum, requiring auditory training and specific intervention in the relationship between listening skills and other sensory modalities involved in the reading and writing process [4].

Additionally the decoding deficit sub-profile, occurring in isolation, points to specific auditory modality changes (8.24%), an alteration to which the intervention is performed solely at this level, with auditory training. According to the findings of this study, individuals with lower age and less education have auditory processing mechanisms compromised to a greater extent. A fact that highlights the importance of early diagnosis and therapeutic intervention to minimize learning and language problems, especially in the academic future of these individuals.

## CONCLUSION

Through the research conducted in this study it was possible to characterize the types of errors committed in the SSW test, with word omission being found to be the most common, followed by word replacement and phonemic substitution. Moreover, it was observed that with increase in age and educational advancement, the number of errors decreased. The most common sub-profile diagnosis was decoding in association with integration, followed by decoding. The comparison between the total number of errors and gender was not statistically significant. It was also possible to highlight the importance of the SSW test in the diagnosis of human communication disorders and in identifying children at risk for learning disorders and subsequent complications, which may be avoided or minimized with auditory training performed concomitantly (or not) with speech therapy .


**RESUMO**

**Objetivo:** caracterizar os tipos de erros cometidos no teste *Staggered Spondaic Words* por pacientes submetidos à avaliação do processamento auditivo e correlacioná-los com idade, sexo, escolaridade e subperfil de alteração. **Métodos:** foram incluídos os testes *Staggered Spondaic Words* pertencentes a um banco de dados particular, realizados em pacientes de 7 a 19 anos de idade, no período de junho de 2011 a setembro de 2013. **Resultados:** os tipos de erros mais frequentes foram: omissão de palavra (76,66%), substituição de palavra (45%) e substituição por palavra adjacente (20%). O subperfil de alteração encontrado foi decodificação acompanhado de integração (38,33%), seguido de decodificação (23,33%), resultado normal (20%), e outros (18,34%). Na comparação entre as condições, observou-se maior número de erros nas competitivas. Em relação à idade e à escolaridade, os erros ocorreram em maior número entre pacientes de menor idade e menor escolaridade. A correlação entre o número total de erros e a variável sexo não foi estatisticamente significante. **Conclusão:** foi possível caracterizar os tipos de erros cometidos no teste *Staggered Spondaic Words*, correlacioná-los às variáveis propostas (sexo, idade, escolaridade e subperfil de alteração) e ressaltar a importância deste teste, que é um dos mais utilizados para avaliar o processamento auditivo, para o diagnóstico dos transtornos da comunicação humana e na identificação de crianças com risco para transtornos de aprendizagem.



**DESCRITORES:** Audição; Perda Auditiva Central; Transtornos do Desenvolvimento da Linguagem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Mailing address:
Maria Inês Dornelles da Costa Ferreira,
Rua Luis Afonso 158 Apartamento 702
Bairro Cidade Baixa
Porto Alegre – RS – Brasil
CEP: 90050-310
E-mail: costa.ferreira@terra.com.br