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Original articles

Clustering and switching in hearing-impaired Brazilian Portuguese speakers: semantic and phonemic verbal fluency

Clustering e switching em deficientes auditivos usuários do português brasileiro: fluência verbal semântica e fonológica

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ABSTRACT

Purpose: to describe clustering and switching characteristics in semantic and phonetic verbal fluency of hearing-impaired adults - Brazilian Portuguese speakers – and to verify if there is relation between this characteristics and the total number of words evoked and biosocial factors.

Methods: 42 hearing-impaired adults, Brazilian-Portuguese speakers, were included. All performed the verbal fluency test by semantic and phonemic clue ("animals" and "letter F", respectively). We analyzed: (a) total words evoked, (b) Number of categories evoked, (c) average cluster size, (d) number of switches. And evaluated the relationship of this data with biosocial information, hearing loss and hearing device characteristics.

Results: total number of words evoked was 16.38±6.18 for semantic test and 10.88±6.1 for phonetic on average. All categories established were retrieved by participants. The average cluster size was 1.41±0.8 for semantic verbal fluency and 0.71±0.73 for phonetic. The average number of switches was 7.14±3.69 for semantic fluency and 6.36±4.17 for phonetic. For both tests the number of switches was strong and positively related to the total number of words ($p<0.001$); the average cluster size was related only for phonetic test ($p=0.011$). Educational level influenced the total number of words, clustering and switching. The hearing loss degree, age of hearing loss acquisition and the use of hearing devices did not present relation with any of evaluated variables.

Conclusion: clustering and switching abilities in hearing-impaired subjects are influenced by educational level, without clear relation with hearing loss characteristics.

Keywords: Hearing Loss; Language; Hearing Aids; Cognition

RESUMO

Objetivo: descrever as características de *clustering* e *switching* da prova de fluência verbal semântica e fonológica de deficientes auditivos adultos – usuários do português brasileiro – e verificar sua relação com o total de palavras evocadas e fatores biossociais.

Métodos: 42 indivíduos deficientes auditivos adultos, usuários do português brasileiro oral participaram desta pesquisa. Realizaram as provas de fluência verbal semântica ("animais") e fonológica ("palavras com 'F'") e foram contabilizados: (a) número total de palavras, (b) número de categorias evocadas, (c) tamanho médio do *cluster* e (d) número de *switches*. Comparou-se aos dados biossociais e às características da deficiência auditiva e do dispositivo auditivo eletrônico.

Resultados: o total de palavras evocadas foi de 16,38±6,18 para prova semântica e 10,88±6,1 para fonológica, sendo acessadas todas as categorias previamente estabelecidas. A média do tamanho do *cluster* foi de 1,41±0,8 para fluência verbal semântica e 0,71±0,73 para fonológica. O número médio de *switches* foi de 7,14±3,69 para fluência semântica e 6,36±4,17 para fonológica. Em ambas as provas, o número de *switches* apresentou relação forte e positiva com o total de palavras ($p<0,001$); e o tamanho do *cluster* com o total da prova fonológica ($p=0,011$). A escolaridade influenciou o total de palavras evocadas, o *clustering* e *switching*. O grau e época de aquisição da deficiência auditiva, bem como o uso de dispositivo auditivo eletrônico não tiveram relação com as variáveis avaliadas.

Conclusão: as habilidades de *clustering* e *switching* nos deficientes auditivos são influenciadas pela escolaridade, sem relação direta com as características da deficiência auditiva.

Descritores: Perda Auditiva; Linguagem; Auxiliares de Audição; Cognição

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INTRODUCTION

The language is defined as an organized system of linguistic symbols and rules for combining them that allow the expression of language. Words, gestures or signs that supports a language are organized in a mental lexicon, accessed by the individual when you want to represent a particular object or action. Access to the name of an object depends on the phonological abilities, semantic and memory, while the acquisition is related to the experiences and the ability to understand and give them different meanings[1].

There is a bidirectional link between a word and categorization since to categorize depends on the existence of mental representations of meanings that are mapped in words to form lexical items. These provide linguistic labels that help categorization to provide additional signals[2]. Thus, the organization of the mental lexicon is intrinsically connected to the vocabulary wealth.

In terms of language processing, lexical memory is divided into clusters: groups performed automatically during the learning process according to the degree of semantic similarity or phonological elements[3], this form of organization enhances information retrieval speed according to a given context. Associated with clustering ability, the ability to change strategy and lexical access in different groups according to changes in demand or facing new stimuli is known as switching, and is related to attention and reasoning[4].

Due to the dynamics and flexibility language, expansion and restructuring occurs throughout life, depending on the experiences of each. Thus, it seems possible to hypothesize that any sensory deficit that might affect the experiences can interfere with the construction of knowledge.

Specifically, deprivation of hearing in their different degrees restricts the stimulation entry of the spoken language in everyday situations, reducing incidental learning conditions of spoken language[5] or even changing the receipt and understanding and therefore impacting the acquisition of the oral lexicon and its update in vocabulary routine[1].

The impact of hearing deficits in oral language will vary according to biological characteristics and compensation developed by each individual.

Age that hearing loss occurs is decisive in the acquisition and development of oral language, in which the worst impact is observed when acquired early in life. However, recent data have shown that even in adulthood there is reflection of auditory deprivation on cortical organization[6].

On the other hand, the education and the use of electronic devices, hearing aids and cochlear implant (CI), may expand the experiences and learning situations facilitating the development and expansion of the lexicon.

Thus, the aim of this study was to describe the characteristics of clustering and switching on hearing-impaired adults - users of the Brazilian Portuguese - and verify its relationship with verbal fluency and sociobiological factors.

METHODS

This study was approved by the Research Ethics Committee of the Universidade Federal de São Paulo, under protocol number 1366/11. All participants signed a consent form.

Participants

It is a cross-sectional study, consisting of 42 hearing impaired individuals aged between 18 and 60 years (mean = 42.8; standard deviation - SD = 12.9), patients in the center of the Hearing-Impaired of the institution.

The participants were recruited by convenience by the researchers during their annual monitoring, from November 2011 to November 2012. All patients underwent scheduled a pre-selection through analysis of medical records, and were invited to attend the search those who met the following inclusion criteria: having a diagnosis of hearing loss obtained by audiological examination, use oral language to communicate, and present domain routine vocabulary. Subjects with preferential use Brazilian Sign Language (LIBRAS) everyday were excluded.

To the exclusion of cognitive impairment that could influence the results of this study and in order to standardize the sample, all participants responded to the Mini Mental State Examination test (MMSE)[7], and excluded those who did not meet the test cutoff scores, according to the recommendations of the Brazilian Academy of Neurology[8].

In this sample, there was a prevalence of female participants (54.8%), with mean schooling of 7.4 years (SD = 4.7). Regarding the characteristics of hearing loss and electronic hearing device used: 33.3% (n = 14) of the subjects were diagnosed with mild to moderate hearing loss and 66.6% (n = 28), severe or profound; 47.6% (n = 20) did not use electronic hearing device

and 9.5% (n = 4) were users of cochlear implant. The mean age at the hearing loss onset was 26.7 years (SD = 16.6).

Material and Procedure

All the study subjects took the test of verbal fluency in two categories: semantic and phonological. The semantic verbal fluency (SVF) was analyzed by means of speech, in a minute, of words in the category "animals". This category is the most widely used and that test is highly sensitive for the evaluation of access and organization of semantic mental lexicon[9]. Participants received instruction: "Tell me as many animals as you can remember, is worth any kind of animal."

The phonological verbal fluency (PVF) was then evaluated after the first test, the words recalled beginning with the letter "F" in a minute. This phoneme was selected by their frequency of occurrence in Brazilian Portuguese, being part of the FAS - phonemic fluency test, in which they also use the letters "A" and "S"[10]. In this evaluation, participants received instruction: "Tell me as many words beginning with the letter F, is worth any word except for proper names."

Both tests were timed with a common clock, the vocal emission being recorded in audio file for later analysis and transcription by the researchers.

The test was analyzed in four aspects: (a) total number of words recalled, (b) the number of categories mentioned, (c) the mean size of the cluster and (d) number of switches.

Total number of words was analyzed excluding errors (words beyond the requested category) and repetitions. For phonological verbal fluency test were also excluded: names, conjugations of one verb and diminutives / augmentative of a word, which was not a new term – for example, "*faca*" ("knife") and "*faquinha*" ("little knife") were considered as an element only, while "*faca*" ("knife") and "*facão"* ("machete") accounted for two, because they are different objects.

To calculate the number of categories, clustering and switching, the following words groupings were used:

- Semantic fluency "animals": domestic / farm; wild; insects; fish; birds; and reptiles / amphibians[11].
- Phonological fluency "F": first letters – words initiated by the same two letters as *"faca"* ("knife") and "*famoso*" ("famous"); rhymes – words with the same ending, as "facão" ("machete") and "furacão" ("hurricane"); and minimal pairs – words that differ by only one letter, such as "*faca*" ("knife") and "*foca*" ("seal")[12].

For the analysis of the number of categories were not counted the repetitions, totaling a maximum of six categories for semantic fluency and three phonological fluency that could be evoked by each individual.

The mean cluster size was estimated by counting from the second word of each grouping (i.e., only one word clusters had score = 0, with two words = 1, and so on). Number of switches was calculated as the total number of transitions between clusters, including those of zero length (single words).

It is important to emphasize that the repetitions and errors were included in the analysis of the cluster size and number of switches, for providing information on processing strategy and evocation used[12].

In addition to the result of the test, the characteristics of the population, such as age, gender, education, type and degree of hearing loss, the period of its onset and use of an electronic hearing device (hearing aids or Cochlear Implant - CI) were recorded from a questionnaire with closed questions.

The collected data were statistically analyzed by studying the correlation between the variables: age, education, level and age of hearing loss onset and the use of electronic hearing device, with the total of recalled words and number of clusters and switches in verbal fluency tests, as well as correlation and comparison between the two categories evaluated through the Spearman correlation analysis and Wilcoxon signed rank test. The significance level was 0.05 with 95% confidence intervals.

RESULTS

The mean performance of the subjects in verbal fluency tests is shown in Table 1. Comparing the tests, the subjects had superior performance in the number of recalled words and cluster size when using semantic category (Table 1).

Table 1. Mean performance of the subjects in the tests of semantic verbal fluency (animals) and phonological (letter"F")

Variables	Verbal fluency	n	Meam	SD	Mnimum	Maximum	Median	(p)
Total words	Semantic	42	16.38	6.18	7.00	32.00	16.00	<0.001*
	Phonological	42	10.88	6.10	0.00	22.00	10.00	
Nmber of switches	Semantic	42	7.14	3.69	1.00	15.00	8.00	0.258
	Phonological	42	6.36	4.17	0.00	16.00	6.50	
Mean of cluster	Semantic	42	1.41	0.80	0.29	4.50	1.21	<0.001*
	Phonological	42	0.71	0.73	0.00	3.00	0.50	

* statistically significant value of p <0.05. Wilcoxon Signed Rank test.
Legend: SD=standard deviation; p=significance.

Table 2. Correlation analysis between the total words recalled in semantic (animals) and phonological ("F") categories, the mean cluster size and the number of switches

Variables		Mean cluster		Number of switches	
		(r)	P	(r)	p
Total words	Semantic Verbal Fluency	-0.193	0.220	+0.872	<0.001*
	Phonological Verbal Fluency	+0.388	0.011*	+0.781	<0.001*

* statistically significant value of p <0.05. Spearman correlation Analysis.
Legend: (r)= correlation coefficient; p=significance.

As for the categories analyzed, words of all previously established groups were mentioned, the most common being: "domestic animals / farm animals" (43.4%) followed by "wild animals" (30.8%) in the semantic test; and "first letters" (93.4%) in the phonological test. On average, the subjects evoked 2.86 (SD = 1.05) categories for semantic clue in a total of six categories; and 1.05 (SD = 0.53) for phonological clue in a maximum of three categories.

The total number of words recalled, relates to the clustering and switching abilities, as shown in Table 2.

To the exception of education, which was related to all aspects analyzed in the tests, the other biosocial factors showed no consistent relationship to the total number of words, cluster size or number of switches, although there is evidence of some correlation between the age of hearing loss onset and test performance (Table 3).

Table 3. Correlation analysis between biosocial variables and performance on tests of semantic ("animals") and phonological ("letter f") verbal fluency

Variable	Statistic	Number of words		Cluster Size		Number of switches	
		Semantic	Phonological	Semantic	Phonological	Semantic	Phonological
	n	42	42	42	42	42	42
Schooling	(r)	+0.550	+0.588	+0.346	+0.168	+0.570	+0.364
	(p)	<0.001*	<0.001*	0.025*	0.288	< 0.001*	0.018*
Degree of HL	(r)	-0.043	+0.118	-0.080	+0.189	+0.246	+0.014
	(p)	0.734	0.582	0.617	0.232	0.116	0.929
Age of onset of HL	(r)	-0.237	-0.309	+0.326	+0.056	-0.346	-0.159
	(p)	0.106	0.032*	0.035*	0.725	0.025*	0.314
Use of EHD	(r)	+0.006	-0.010	+0.070	+0.194	-0.036	-0.095
	(p)	0.998	0.948	0.662	0.218	0.821	0.549

* statistically significant value of p <0.05. Analysis Spearman correlation.
Legend: HL-hearing loss; EHD- Electronic Hearing Device; (r)= correlation coefficient; p=significance.

DISCUSSION

In a study previously published by this group of researchers[1] has reported the behavior of hearing-impaired adult users of the Brazilian Portuguese in the tests of semantic and phonological verbal fluency, and what are the determinants of this performance. In this article, we attempted to analyze, in this same group of individuals, factors related to the category grouping and evocation abilities - clustering - and strategy changing during evocation – switching.

The qualitative analysis of the organization and flow of words in verbal fluency test is less frequently used in the literature that the total number of words evoked, which typically is part of tests for cognition and language evaluation. However, some studies of young adults[11-15], elderly and neurological diseases[16,17], provided data regarding the abilities of clustering and switching of these populations, arguing that this analysis provides aditional information in regard to the cognitive flexibility, executive function and lexical organization. There is no normative data for these parameters for Brazilian Portuguese.

In the literature, the methodology for analyzing clusters and switches in verbal fluency test has high variability and have therefore widely different quantitative results presented. Some studies found in young adults without conditions, total words recalled that varied between 14.0 and 26.2 on average in the semantic test, and 9.5 and 15.1 in phonological test; already for the average cluster size, the values range between 0.75 and 1.7 for semantics, and phonological between 0.24 and 1.4. The number of switches varies in studies between 7.0 and 11.6 for the group “animals” and between 7.9 and 10.55 for letters[12,14-18].

Regarding the comparative performance of the two tests and the factors determining the results, there is greater agreement in the literature, and in this study has obtained similar data to studies cited, even analysing itself a different population.

A greater number of words evoked in the semantic category in relation to the phonological and the evocation of larger clusters for the first category had already been described in previous studies[16,17] and is mainly due to the form of lexical memory organization. The semantic category follow a hierarchical arrangement of clear subsets defined in most languages by similar physical and functional characteristics[19] (the category “animals,” for example, has as subgroups: “birds”, “fish”, “domestic animals”, etc). On the other hand, phonological categorization occurs by clusters of sound similarity: first equal letters, rhymes and similar words - minimal pairs -, which depend on some degree of formal learning and tend to be less reinforced by the context and natural conditions. It has been shown previously that even in the phonological tests there is a tendency to generate words with semantic correlations[15,20].

To this information, it adds that the ability of phonological clustering, ie, to evoke words with phonological similarity during verbal fluency test, reflected in a higher total number of words in this category. This suggests that the lexical organization strategy allows for faster processing and recall when held demand relies on phonological track.

This increased speed of evocation is evidenced in several studies[11-13] by the relation between cluster size and the increase in the total number of words recalled in the test of semantic verbal fluency category “animals”, similar to what was found in this study.

The number of changes between clusters (switching) also showed a direct correlation with the total number of words, significant for the two tested categories, as reported in other studies[11-13]. Probably a higher switching speed represents the occurrence of smaller breaks and gaps during the recalling and the possibility of accessing a greater number of subgroups in each category.

Given the correlations, it appears that the total number of words is dependent on the combination of the abilities of clustering and switching in the time available. It is important to consider even that level of cerebral activation strategies of clustering and switching can be taken consciously or not during the examinations, being recruited areas of the parietal lobe of semantic memory for clustering, and frontal areas of executive function during the switching[21].

The language structure is a continuous construction, based on social and cultural experiences, and is not an individual but the collective composition, dependent on the environment and surrounding reinforcements. One category is formed when two or more objects or events are treated equivalently, for example when label two different objects with the same name and is held on them the same action, so although the situation or stimulus is unique, they are not treated in isolation, but respond according to the characteristics of the category created from past learning and experienced cultural situations[22].

In this study, subgroups most evoked by semantic category were also similar to another study conducted

with Brazilian subjects[11], in which the most common animals were "dog", "cat" and "horse" (all included in the category of "domestic animals"). However, studies have shown differences between animals raised by subjects of different educational levels and gender[11-13,23], highlighting the cultural role in lexical organization and the need to analyze sociobiological factors in cognitive-linguistic examination.

Education was reflected in a larger cluster size and a larger number of switches in both categories. As demonstrated in a previous study of these researchers[1] individuals with more years of schooling also have a higher total number of words. Possibly those individuals who produce larger clusters are able to generate more words in total[12].

Considering the categorization as a process that is greatly influenced by the formal learning is justifiable that education has a role in the formation of different clusters. Linked to this, the abilities of abstraction, reflection and reasoning provided with advance of regular study[24], can increase the strategy's ability to change during the execution of the test. Thus, the education functions as a protective factor which guarantees a larger number of experiences and linguistic contexts, allowing the maintenance of lexical and phonological organization before and after the hearing loss. Therefore, education facilitates semantic access, expanding the repertoire of vocabulary and subgroups[11] and has been indicated as a factor that provides greater cognitive and memory reserve during adulthood[25].

Age was shown to have influence in studies with children[23] and the elderly[16], but this study showed no correlation probably because they are adult subjects with hearing loss already at this stage of life. Studies with primary school students (6-15 years old)[18,23] concluded that around eight or nine years the ability of clustering and knowledge of lexical organization is already established closely to adulthood, while the number of correct answers already consolidated at 14 years old, although the vocabulary follow its expansion during adulthood.

The hearing related factors: hearing loss to a greater or lesser degree, the age of hearing loss onset and the use of electronic hearing device were not decisive in recalling skill in hearing-impaired. This lack of correlation may be due to sample variability in terms of education, whose influence has been described, and have encompassed only individuals with routine field of linguistic activity. These findings were similar to the previous study by these researchers, in which there was no correlation between total evoked words and auditory characteristics of the subjects[1]. Another recent study hypothesized that although there may be quantitative differences in recalled words, the qualitative aspect of lexical organization does not change in different pathologies[26].

From the discussion presented, it is believed that the results of this research provide indications of the behavior of the hearing-impaired population in verbal fluency tests, which still poorly studied in literature. It is noteworthy that this study was limited to the description of the hearing-impaired performance on the clustering and switching, without proposing to carry out a comparison with ordinary listeners. However, the population consisted of individuals who lost their hearing after language acquisition period, mostly already in adulthood and thus sensory deprivation would influence only the language enlargement period. It is important to not overlook the impact of a late hearing loss, as has already been pointed out in studies that evaluate the cortical changes in these subjects[6], and, therefore, further studies comparing with normal hearing participants are needed and can contribute data especially regarding changes in organization and semantic access.

CONCLUSION

Total evoked words, and the skills of clustering and switching in hearing impairment are influenced by education, and not directly related to the hearing impairment characteristics. The switching ability was reflected in the greater number of words recalled for semantic and phonological fluency. As well as the clustering ability influenced the total for the phonological category. Clustering is more easily accomplished for semantic test regarding phonological in subjects with hearing- loss.

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