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Evaluation Of The Impact Of The Phonological Loop On Attentional Control In Deaf Children With Cochlear Implants Attending Primary School

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Abstract:

The interest of the present study is to understand the impact that the phonological loop could have on attentional control in deaf children with cochlear implants. We selected two groups, each composed of 20 children. The first group is made up of hearing children, the second group of children with cochlear implants, all of whom are enrolled in primary education. We subjected both groups to tests of working memory in its phonological loop aspect, as well as the STROOP attentional control test. The results of the comparison of the average scores show an inferiority in terms of scores relating to the phonological loop for group 1 with much higher scores in terms of interference. The correlation study of the scores of group2 shows a strong correlation proportionally inverse to the interference scores. The limited capacity of the phonological loop would explain attentional control below the norm. The nature of fairly automated language in these children seems to explain these results.

Keywords: Phonological loop; Attentional control; Deaf child with cochlear implant.

Introduction:

Social interaction is an important operation in all human beings, isolation from the community can have serious consequences on mental and cognitive health (Cacioppo & Hawkley, 2009; Podury et al, 2023), This isolation can be favored in situations of deaf or hard of hearing (Graven & Browne, 2008; Tomblin et al, 2015). This disability clearly impacts the quality of life in these people (Stevenson et al, 2015). It can range from a simple deficit compared to the norm to profound deafness, in this sense a person who does not hear as well as a person with normal hearing at the hearing threshold of 20 dB or better in the two ears is said to have hearing loss. Hearing loss can be mild, moderate, severe or profound. This can affect one or both ears and cause difficulty hearing a conversation or loud sounds. Hard of hearing refers to people with hearing loss ranging from mild to severe. People with hearing loss typically communicate through spoken language and may benefit from hearing aids, cochlear implants and other assistive devices as well as closed captioning. Deaf people mostly have profound hearing loss, which means very little or no hearing. They often use sign language to communicate. (WHO, 2024). The majority of implanted children are congenitally deaf. They have had very little, if any, sound information since birth (Yaalaoui & Makhloufi, 2018). Remember that cochlear implantation was introduced in Algeria in 2006 at the Mustapha university hospital center (Djennaoui, 2006).

According to WHO estimates (2024), More than 5% of the world's population, or 430 million people, need rehabilitation to correct their disabling hearing loss (including 34 million children). Disabling hearing loss refers to hearing loss greater than 35 decibels (dB) in the better-hearing ear. According to a study carried out in Algeria at the Tizi ouzou university hospital center by Boudjenah (2014), in the neonatal department, 3.2% of newborns present deafness.

Cognitive development is multidimensional and depends on the development of other aspects, psychological, biological and social; a delay or deficit in one of them can slow down or affect the overall development of the child (Psaltis & Duveen, 2006; Broadbent et al, 2018). An attack in an early period can have serious and irreversible consequences (Ptok, 2011) and promote cognitive decline in old age (Bisogno et al, 2021), as we can see in deafness (DiGiacomo et al, 2013), which negatively affects the cognitive sphere. Indeed, some authors (Meinzen-Derr et al, 2011) put a direct link between early auditory deprivation and cognitive limitation, thus a limitation of participation in the auditory verbal world would explain these difficulties from a socio-developmental point of view. Other authors extend this negative impact to the psychomotor, behavioral and brain programming levels (Aubuchon et al, 2015), with all their consequences on social autonomy (Marschark & Knoors, 2012). Deafness does not only affect language but also cognitive functions, defined by Cristofori et al (2019), as all functions relating to language, memory, attention, reasoning, working memory, executive functions and problem solving. Executive functions are defined by Diamond (2013), as an umbrella term used to designate a set of high-level functions (Top down), which are involved in behavioral and emotional regulation, generally limited to working memory, inhibition, mental flexibility, planning as well as attentional control (Barkley, 2012).

The complexity of cognitive functioning in deaf children could be explained by the multidimensional nature in which each element influences the others, as highlighted by Kral et al (2006), for language and attentional control, in fact the auditory experience allows the development of language which constitutes a tool for attentional control, which presents itself as the internal voice (self talk), which allows the visualization of objectives and the sequences of tasks and to assist working memory, in order to keep information active and to represent ideas (Zelazo et al, 2003; Fatzer & Roebers, 2012). This interaction between working memory and linguistic processes was highlighted by Nouani (2007).

The problem of the phonological loop and language processing that arises in the implanted deaf is dependent on several factors (Forli et al, 2011; Davidson et al, 2019), in this sense working memory and its phonological loop component intervene in the storage and retrieval of language information at the phonological and lexical level (Baddeley, 2012). The age of implantation plays an important role, the study by Gökay et al (2023), demonstrates that performance in phonological loop and phonemic processing is much better in subjects implanted at an early age compared to subjects implanted at a later age. The capacity of the phonological loop in the cochlear implanted subject clearly impacts their capacity for auditory discrimination, particularly at the consonant level (El Ghazaly et al, 2021).

In this study, we will attempt to evaluate performances at the phonological loop level and their impact on executive functions limited to attentional control which manifests itself during tasks which involve a strong memory load and solicit the inhibition mechanism, in deaf children with cochlear implants, enrolled in primary school.

1- Method :

The interest of the present study is to understand whether cochlear implanted subjects present an inferiority at the level of the phonological loop in comparison with hearing subjects. But also, if their performance in the phonological loop impacts their capacity for inhibition in tests that challenge phonological and lexical processing.

2- Participants :

For the purposes of our research, we selected two working groups, made up of cochlear implanted children (Group1) and hearing children (Group2), enrolled in primary school classes, as summarized in Table 1.

Table 1. Characteristics of work groups.

Group	Number (N)	Girls	Boys	Age (Years)	Average Implantation Duration	Schooling
1	20	6	14	6-12 years	5 years	Classes 1AP-2AP
2	20	6	14	6-12 years	//////////////////	Classes 1AP-5AP

As shown in table 1, each group is made up of 20 students, enrolled in the primary cycle, with a similar proportion of girls and boys.

The cochlear implanted students were selected from primary schools in the wilaya of Tizi ouzou, in specialized classes supervised by speech therapists. Note that the duration of the implantation and the speech therapy follow-up seems sufficient to us for the applicability of our evaluation tests.

3- Assessment tools:

3-1- Phonological loop test:

This is the test of repetition of series of numbers, which constitutes one of the working memory tests in the Wechsler battery (WISC), to assess intelligence in children aged 6 to 16. The test consists of two parts:

- Digit span forward (DSF): allows you to evaluate the passive aspect relating to short-term memory (STM). The test consists of eight sets of numbers consisting of 2 to 9 digits with two answer attempts. The subject must reproduce the series in order.
- Digit span backward (DSB): makes it possible to evaluate the active aspect relating to working memory, via its phonological loop component. The test consists of eight sets of numbers consisting of 2 to 9 digits with two answer attempts. The subject must reproduce the series in reverse.

Scoring is one point per series with a total of eight for each game. The candidate must succeed in both attempts.

3-2- Evaluation of inhibition:

The STROOP test. This test assesses inhibition, which refers to the ability to prevent the generation of an automatic response. The test consists of three boards A, B and C:

- Board A: Read as quickly as possible as many words as possible printed in black and white on-board A in 45 seconds.
- Board B: Read as quickly as possible as many words as possible printed in various colors on board B in 45 seconds
- Board C: Name the color of as many rectangles as possible on board C in 45 seconds. Matches naming results.
- BoardB: Presentation of board B a second time. The subject must name as many colors as possible on card B in 45 seconds. Corresponds to interference results.

The interference score is the difference between the naming results, minus the interference results.

4- Results:

After applying the aforementioned tests on the two working groups, we collected the raw data relating to the variables: Phonological loop: DSB, DSF and inhibition (Stroop). These results were entered into the IBM SPSS software package version 20.0, in order to carry out an intergroup comparison for all of the variables and then a correlation analysis between the DSB, DSF and inhibition scores.

4-1- Intergroup comparison:

The intergroup comparison by T test for independent samples allows tables 2 and 3 to emerge.

Table 2. Average per group.

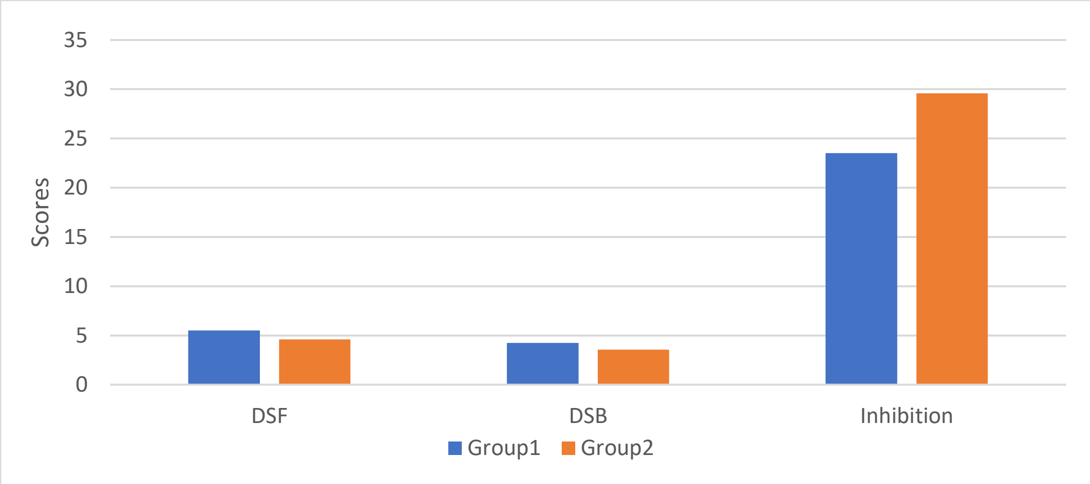
	Band	N	Average	Standard deviation	Average standard error
DSF	1.00	20	**5.5000**	1.14708	0.25649
	2.00	20	**4.6000**	1.09545	0.24495
DSB	1.00	20	**4.2500**	1.01955	0.22798
	2.00	20	**3.5500**	1.14593	0.25624
STROOP	1.00	20	**23.5000**	2.56495	0.57354
	2.00	20	**29.6000**	4.39378	0.98248

Table 3. Intergroup comparison T test.

		Levene's test for equality of variances					
		F	Sig.	t	ddl	Sig. (bilateral)	Average difference
DSF	Assumption of equal variances	0.009	0.923	**2,538**	**38**	**0.015**	**0.90000**
	Assumption of unequal variances			2,538	37,920	0.015	0.90000
DSB	Assumption of equal variances	0.523	0.474	**2,041**	**38**	**0.048**	**0.70000**
	Assumption of unequal variances			2,041	37,493	0.048	0.70000
STROOP	Assumption of equal variances	3,460	0.071	**-5,362**	**38**	**0.000**	**-6.10000**
	Assumption of unequal variances			-5,362	30,602	0.000	-6.10000

As shown in Table 1 then 2, the intergroup scores for DSF and DSB are in favor of group 1 with significant differences ($P<0.05$), respectively 0.90 and 0.70. The interference score favors group2, with a difference of 6.10 ($P<0.05$). It is possible to visualize these differences in Figure1.

Figure 1. Average scores for group 1 and 2.



4-2- Correlation between DSF, DSB and inhibition:

In order to understand whether the scores recorded in DSF and DSB impact those of inhibition, we carried out a Pearson correlation analysis, as shown in Table 4.

Table 4. Correlation between DSF, DSB and inhibition.

		DSF	DSB	STROOP
DSF	Pearson correlation	1	**0.981****	**-0.472***
	Sig. (bilateral)		0.000	0.035
	N	20	20	20
DSB	Pearson correlation	**0.981****	1	**-0.508***
	Sig. (bilateral)	0,000		0.022
	N	20	20	20
Inhibition	Pearson correlation	**-0.472***	**-0.508***	1
	Sig. (bilateral)	0.035	0.022	
	N	20	20	20

**. The correlation is significant at the 0.01 level (two-tailed).

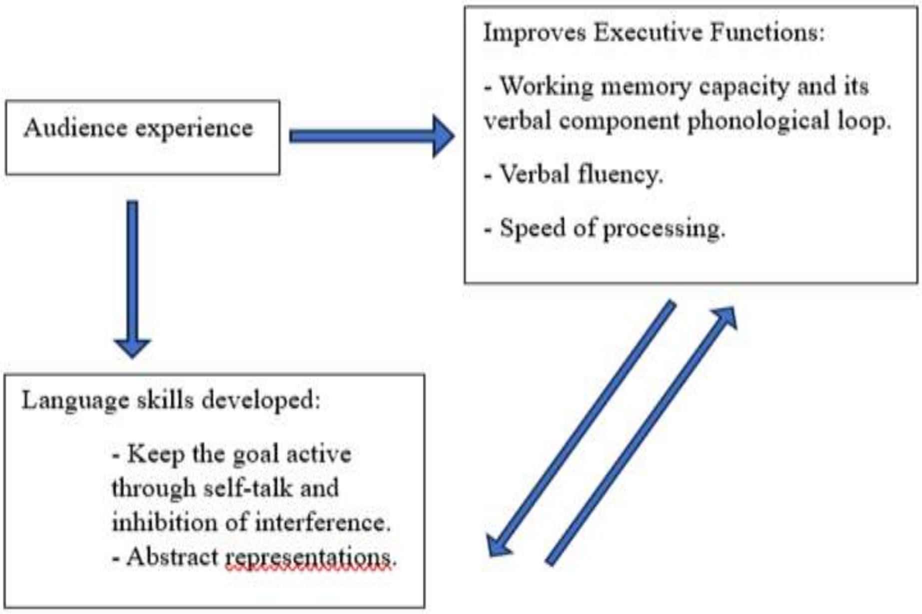
*. The correlation is significant at the 0.05 level (two-tailed).

From Table 4, we notice that there is a proportionally inverse correlation between the DSF, DSB and interference scores, the more the phonological memory span decreases, the more the inhibition scores increase and vice versa.

5- Analysis and discussion :

The comparison of the means between group 2 and group 1, at the level of the phonological loop, show scores in favor of the latter group, cochlear implanted subjects present lower scores than healthy subjects with a respective difference of -0.90 and -0.70 for the scores, DSF and DSB, deaf subjects present more difficulties in the active side (DSB) of the phonological loop than in the passive side (DSF). Note that even if these scores remain slightly lower than the norm, they show the existence of a retention capacity which could be explained by two factors, firstly the average age of implantation being between 3 and 4 years for 18 children in the group2, except two others with implantation at 7 and 9 years old. The second factor could be attributed to speech therapy supervision in a special class within a school establishment with all that this implies in terms of social interaction and stimulation. Although some authors (Kronberger et al, 2014) favor pre-linguistic implantation between 18 and 24 months for optimal cognitive gain, others emphasize that any early intervention in terms of diagnosis and treatment would be cognitively saving. (Gathércole & Baddeley, 1993; Williams, 2009). In this sense, the study by Almomani et al (2021), relates early intervention and the progression of reasoning and memory in cochlear implanted subjects, thus children implanted between 4 and 6 years old would be much better than those implanted with 7 to 9 years old. We note that cochlear implanted subjects present more interference than healthy subjects with an average difference of +6.10, in fact in the incongruent task of the STROOP test, the subject must keep the instruction of the cochlear implant active and in a loop. examiner where he must give the printed color of the word and not read the printed word, this contradiction requires a sufficient memory load to guarantee appropriate attentional control; the correlation study shows that the interference scores are strongly correlated with those of the phonological loop in its passive (DSF) and active (DSB) form, the lower than standard saving capacity could explain the superiority of interference in the subjects implanted, in this sense Kronberger (2019), explains this lack at the level of inhibition by the limited and fairly automated nature in implanted subjects with very limited spontaneous language, which in turn limits attentional control relating to execution of a task, as in the case of the present STROOP test. Kronenberger (2019), proposes the ANM (Auditory-Neurocognitive Model), as summarized in Figure 2.

Figure 2. Auditory-Neurocognitive Model.



As shown in the ANM model, auditory experience improves executive functions in terms of working memory, verbal fluency and processing speed, which helps develop the language skills essential for active maintenance of speech. objective of the task and the inhibition of interference by the phonological loop mechanism which manifests itself through self talk. A substandard auditory experience in cochlear implanted subjects would reflect less effective attentional control with increasing interference.

Conclusion:

Profound deafness has for a very long time constituted a major handicap for the social integration of deaf people. Advances in medicine have made it possible to limit this aspect through cochlear implantation which seems to give good results if it is carried out at an early age and with the appropriate speech therapy and psychological monitoring. As our results show, cochlear implanted subjects have a memory span lower than the norm, this translates on the cognitive level into difficulties linked to the management of conflict situations as we have noticed for the effect of STROOP, which requires memory load and continuous verbal recall during the task. Limited language is automated in the care of these children in the sense that the primary objective of speech therapy care is to provide a basic and operational language base on a social level, but which seems in view of the lack of spontaneity, pose a problem on the cognitive level linked to adaptation to conflict situations which require adapted memory capacity. These results remind us as speech therapists to take into consideration the interest of language stimulation particularly in its spontaneous form in the care of cochlear implanted subjects, particularly at the early stages.

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