Journal of Otology 17 (2022) 130–135

Contents lists available at ScienceDirect

Journal of Otology

journal homepage: www.journals.elsevier.com/journal-of-otology/

Impact of Auditory-Verbal Therapy on executive functions in children with Cochlear Implants

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ARTICLE INFO

Article history:
Received 21 February 2022
Received in revised form
8 April 2022
Accepted 12 April 2022

Keywords:
Auditory-verbal therapy
Early intervention
Executive functions

ABSTRACT

Objective: Auditory-Verbal Therapy (AVT) can be considered one of the best practices for children with Cochlear Implants (CIs) who show impairments in cognitive skills such as executive functions. Hence, this research examined the impact of AVT on the executive functions in children with CIs.

Methods: This was a randomized case control study with pre- and post-intervention assessments. The participants were 36 children with CIs and their mothers. They were randomly selected from rehabilitation centers and deaf pre-schools, and randomly allocated to a control ($n = 18$) and a study ($n = 18$) group. The mean age of the children in the study and control groups was 3.11 ± 0.31 years and 3.20 ± 0.29 years, respectively. Participants in the study group received 20 sessions of AVT over 10 weeks at twice a week, while those in the control group did not. All mothers completed the Behavior Rating Inventory of Executive Function Pre-school Version (BRIEF-P) before and after children in the study group completed their AVT intervention. Data were analyzed by MANCOVA.

Results: The results suggest that AVT significantly influenced executive functions and all subscales including shifting, inhibition, emotional control, working memory and organization/planning in children with CIs.

Conclusions: These findings suggest that AVT may be effective in resulting in positive outcomes and may play an important role in improving executive functions in children with CIs.

1. Introduction

The goal of education is, in general, equal opportunities in life and full participation in society (Hendar and O'Neill, 2016). Deafness is a highly prevalent sensory impairment associated with changes in cognitive and metacognitive processes (Ashori, 2022; Jayakody et al., 2018). This term applies not only to hereditary and pre-lingual deafness, but also to acquired hearing impairment (Cardin, 2016). Given these definitions, educational placement for deaf students range from special sections to regular schools (Marschark and Knoors, 2012). Deafness, or even hearing loss, often places a child in a problematic place (Ashori et al., 2019). Even mild hearing loss can lead to changes in neural flexibility and executive functions (Rudner et al., 2019).

Executive functions are conceptualized as an umbrella term, including a set of cognitive abilities. It consists of shifting, inhibition, emotional control, working memory and organization/planning (Gioia et al., 2003). Shifting can be described as moving freely from one activity or condition into another activity or situation (Nilsen et al., 2017). Inhibition refers to the capability to resist impulses and stop their behaviors at the appropriate time (De Greeff et al., 2018). Emotional control refers to the effect of executive function problems on emotional expression and the child's capability to control or adjust one's emotional responses (Beer et al., 2014). Working memory can be described as the online representative memory, that is, the ability to hold information in memory for the aim of completing a task and coding data to obtain aims (Isquith et al., 2005). Organization/planning is defined as the child's capability to manage current and future-oriented task requests (Hall et al., 2017).

Executive functions play a critical role in the lifetime performance of children (Cortés Pascual et al., 2019). These functions appear in the early years of life. Indeed, behaviors representing working memory, shifting tasks and inhibitory control emerge

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Peer review under responsibility of PLA General Hospital Department of Otolaryngology Head and Neck Surgery.

https://doi.org/10.1016/j.joto.2022.04.002

before the age of two (Reznick et al., 2004). Executive functions facilitate the development of social, emotional, and cognitive skills (Nilsen et al., 2017). Pre-school years may be one of the essential times in executive functions development (Sasser et al., 2015). Pre-school children can retain more information for a longer time than infants. They have considerable skills in manipulating their mental information (Garon et al., 2008). For these reasons, we focused on the ages 2–4 years. Moreover, children at this age can change their attention from one task to another. They can combine the necessary skills of executive functions and create more complex behaviors.

Although executive functions have apparent implications for early development, little research has been conducted on executive functions in pre-school children with CIs (Beer et al., 2014). Executive functions are higher-level cognitive skills that can be influenced by hearing impairment (Peelle and Wingfield, 2016). The best early implanted children may progress well in language and literacy without specialized intervention, although educational interventions can be extremely helpful (Trussell et al., 2016). Several rehabilitation approaches have been designed for people with hearing loss (Kaipa and Danser, 2016). These approaches are classified as: 1) Visual approach such as sign language; 2) Total communication approach, which combines methods emphasizing natural gestures, lip-reading, speech-reading, spoken language and signs; 3) Auditory-oral approach, which combines the use of residual hearing, speech-reading and speech; and 4) Auditory-verbal therapy (AVT) approach, which uses listening as the primary method for language and speech development (Hallahan et al., 2018).

AVT is one of the best programs for improving speech, language, and hearing development in children with hearing loss (Tejeda-Franco et al., 2020). It is a family-oriented listening and spoken language program used for these children, initially coined by Pollack and Ling (Rosenzweig, 2017). In AVT, language, speech and sound problems are addressed by focusing on cochlear reserve or residual hearing (Brennan-Jones et al., 2014). AVT intervention differs from other approaches, because in this intervention, the parent of the child must be present during all rehabilitation sessions (Estabrooks et al., 2020). Moreover, this program is planned based on the individual needs of children with hearing loss and the expectations of their parents (Tejeda-Franco et al., 2020).

The main principles of AVT include hearing assessment and early identification of hearing levels, familial education and support, suitable hearing amplification, listening to sounds and voices, continuous assessment of listening, speech, language and cognition development, improving communication with individualized teaching and spoken language, and support of educational integration and mainstreaming (Pollack, 1993). The AVT approach can help children with hearing loss in speech, cognition, executive functions and learning (Marschark and Knoors, 2012). It seems that children with hearing loss have significantly more executive function problems than normal-hearing children (Luckner and Movahedazarhouligh, 2019). For example, the results by Tejeda-Franco et al. (2020) demonstrated that auditory rehabilitation with the AVT approach improved speech parameters in children with hearing loss. Chatterjee et al. (2019) found that AVT had significant effects on the auditory skills, working memory, linguistic processing, planning and organization in children with CIs. The finding by Hall et al. (2017) showed that children with hearing loss experienced considerably more executive functions problems than their hearing peers. The findings by Kaipa and Danser (2016) indicated that AVT had significant effects on auditory perception, speech perception, receptive language, expressive language and mainstreaming in children with hearing loss. The results by Beer et al. (2014) suggested that the executive functions in pre-school children with CIs were lower than in their hearing peers.

Over the past two decades, improving executive functions in children with hearing loss has been one of the most important goals of intervention programs designed for this population (Maller and Braden, 2011). There have been few studies conducted on the effect of AVT on executive functions in children with CIs. According to reports in the literature, it is better to use an AVT program to improve executive functions in pre-school children with CIs. Therefore, the current study was guided by the question: Is there a significant difference in executive functions and subscales between AVT treated and non-AVT treated children?

2. Materials and methods

2.1. Participants

Thirty-six children with CIs aged 2–4 years and their mothers participated in this study. The participants were selected from rehabilitation centers and deaf pre-schools by a simple random sampling method in Isfahan, Iran. They were randomly assigned to a control ($n = 18$) or a study ($n = 18$) group. All of the children had worn one cochlear implant for longer than one year for bilateral profound hearing loss. The parents of the participants had normal hearing. The inclusion criteria were: onset of hearing impairment before age six months, bilateral hearing impairment (aided thresholds from 30 to 42 dB HL at 500, 1000 and 2000 Hz), using a Med-El, Advanced Bionic or Cochlear brand CI, and Persian as the first language at home and in school. Children were excluded from the study if they received educational services from other centers. See Table 1 for demographic information. It should be noted that children with CIs aged 2–4 years go to a rehabilitation center or deaf pre-school in Iran. The children and their families had received auditory training intervention before starting this study.

As can be seen in Table 1, the mean age was 3.11 ± 0.31 years in the study group and 3.20 ± 0.29 years in the control group ($t = 0.63$, $p > 0.05$). The mean hearing threshold before CI was 91.32 ± 1.90 dB HL and 90.67 ± 2.04 dB HL for the two groups, respectively ($t = 1.13$, $p = 0.08$), while the mean CI-aided threshold was 27.19 ± 1.72 dB HL and 26.54 ± 1.80 dB HL, respectively ($t = 1.09$, $p = 0.09$). The mean age at implantation was 9.72 ± 0.53 years in the study group and 9.38 ± 0.66 in the control group ($t = 0.41$, $p > 0.05$).

2.2. The Behavior Rating Inventory of Executive Function Pre-school Version (BRIEF-P)

This inventory was proposed by Gioia et al. and includes 63 questions (Gioia et al., 2003). The BRIEF-P has a teacher and a parent version and is developed to evaluate executive functions in children based on everyday behavior at home and in pre-school setting. It is designed for pre-school children aged 2–6 years, including children with traumatic brain injuries, learning disorders, autism and attention disorders (Dzambo et al., 2018). The BRIEF-P includes five subscales: inhibition (16 questions), shifting (10 questions), working memory (17 questions), emotional control (10 questions) and planning/organization (10 questions). Each question, is answered as Never, Sometimes or Often (scored from “1” to “3”). Low BRIEF scores indicate strong executive functions. The BRIEF-P is a reliable and valid tool for measuring executive functions in pre-school children. Internal consistency by Cronbach's alpha for this inventory ranges from 0.80 to 0.97 (Gioia et al., 2003). For this study, we used the parent version with a Cronbach's alpha of 0.94 and test-retest correlation of r = 0.79 to 0.84.

2.3. Procedure

This study was approved by the Exceptional Education

Table 1
Demographic information of the children.

Variable	Category	Intervention group	Control group	*t*-test	P
Sex	Male	9 (50%)	10 (56%)	–	–
	Female	9 (50%)	8 (44%)	–	–
Race/ethnicity	Iranian/Persian	18 (100%)	18 (100%)	–	–
Age (years)	2–3	8 (44%)	8 (44%)	–	–
	3–4	10 (56%)	10 (56%)	–	–
Mean age (years)	M (SD)	3.11 (0.31)	3.20 (0.29)	0.63	0.17
Hearing thresholds (dB HL)	M (SD)	91.32 (1.90)	90.67 (2.04)	1.13	0.08
CI-aided thresholds (dB HL)	M (SD)	27.19 (1.72)	26.54 (1.80)	1.09	0.09
Age of implantation (months)	M (SD)	9.72 (0.53)	9.38 (0.66)	0.41	0.11

M: Mean SD: Standard deviation.

Organization in Tehran, Iran (ID 97000-20223). Study goals were explained to the managers of the rehabilitation centers and deaf pre-schools. Study procedures were explained to all mothers of the participating children before signing a written informed consent. The mothers were informed that participation in the study was confidential and anonymous.

The mothers were given instructions on how to complete the BRIEF-P. They completed the BRIEF-P prior to intervention and returned it to the researchers before the participants were randomly divided into the control and study groups. Children in the study group participated in the 20-session AVT over 10 weeks at their rehabilitation centers or deaf pre-schools, and received support from 2 AVT therapists. Children in the control group did not participate in this intervention. Two days after children in the study group completed the AVT intervention, all mothers of the children in both groups completed the BRIEF-P again as the post-intervention assessment.

2.4. AVT intervention

AVT was developed by Pollack and Ling in 1993 (Chatterjee et al., 2019; Tejeda-Franco et al., 2020). Although all AVT based programs may adhere to all of the principles by the Bell Association for Listening and Speaking Language, programs may differ in details (Estabrooks et al., 2020). Table 2 gives an overview of the aims and content of the 20 therapy sessions in this study. For example, Session 17 included memory and hearing sequence, acoustic highlighting, small function words, running speech, self-monitoring and short-term memory, whereas Session 18 included emphasizing, rewording, vocabulary, rephrasing, syntax, speech modeling, perception-production loop and long-term memory. Yet Session 19 covered auditory memory span, pragmatic and social language, asking questions, self-advocacy skills, and working memory.

An example of a session content is as follows: At the beginning of the session, mothers of participants answered these questions: “How was the last week?” “Did your child hear or say anything new?” We used Ling Six Sound Check for troubleshooting the child's CI to ensure that children have optimal access to sound. Most of the intervention session is spent on program aims. The program was spelled in two different ways. Activities of the program might vary from child to child, although with the same target areas that included: 1) Audition: training by Erber's method including auditory memory; 2) Speech: training on the production and articulation of phonemes and syllables through listening; 3) Language: training on syntax and receptive and expressive language; 4) Communication: training on self-advocacy, asking questions, pragmatic and social language; 5) Cognition: training on cognitive and academic skills. Aims of the session were discussed with the mothers along with a debriefing on how the child did. Mothers were given time to ask questions before the session ended. Example pictures of the intervention group are shown in Fig. 1.

Table 2
Aims and content of AVT sessions.

No	Aim	Content
1	Audition, attending, recognizing, and	Diagnostic therapy, auditory sense, awareness of environmental, and vocal sounds.
2	cognition	Showing sound sources; use of visual, motor, and auditory clues; and Recall.
3		Identification of events and objects through their sounds, and respond to sounds.
4		Attending to distinct speech sounds or voices, auditory clues, and auditory memory.
5	Early vocalizing, speech, and cognition	Reinforcement of vocalizations, active sounds, accurate repetition, and recognition.
6		Stimulation for vocalizations, word retelling, feedback loop, and ask what you heard.
7	Auditory skills and Memory	Foreground-background, and recognizing from sound as the first information source.
8		Locating source of sounds in space, and stimulation of all attempts to discriminate.
9		Auditory closure, and discrimination and comprehension of sounds or voices.
10	Vocalizing with inflection, auditory, and	Producing vowels, vocalization with different intensity, pitch, and duration.
11	speech skills	Producing consonants, speech rate, segmenting words, and breathing speech.
12		Production and articulation of phonemes and syllable shapes through listening first.
13	Auditory, speech-language, and cognition	Cognitive listening skills, locating sound sources at different levels and distances, phonetics, and memory span.
14	skills	Phonological processes, morphology, stimulation of speech attempts, and auditory feedback.
15		Stimulation with meaningful words, auditory processing, and receptive language.
16		Hand cue, feedback loop, pause, prosody, rhythm, and tonally expressive language.
17	Auditory, speech-language, communication, and cognition skills	Memory and hearing sequence, acoustic highlighting, small function word, running speech, self-monitoring, and short-term memory.
18		Emphasizing, rewording, vocabulary, rephrasing, syntax, speech modeling, perception-production loop, and long-term memory.
19		Auditory memory span, pragmatic and social language, asking questions, self-advocacy skills, and working memory.
20		Paying attention to the development of the whole child and cognitive/academic skills, shared reading of a book, readiness to communicate, and formal education.

Fig. 1. Example pictures of the intervention group in an AVT session.

2.5. Data analysis

Descriptive indicators were analyzed. The normality of these data was examined by the Shapiro-Wilk test. ANCOVA was run to determine the differences between the study and control groups on executive functions, and to determine intervention effect. Differences between the two groups on executive functions subscales were determined using MANCOVA.

3. Results

Table 3 shows descriptive statistics of executive functions and subscales before and after AVT intervention. It should be noted that mothers of children in the control group returned to the rehabilitation center at the same time as mothers of children in the study group two days after children in the study group completed their AVT intervention, and completed the BRIEF-P for the second time, which is also marked as “post-intervention”.

In Table 4, pre-intervention scores were treated as the covariates of executive functions in both groups ($F = 17.01$, $p < 0.001$). ANCOVA showed significant group effect by AVT intervention based on post-intervention executive functions scores ($F = 57.65$, $p < 0.001$). Also, Eta square value indicated that 62% of the variation in executive functions was due to the intervention. In other words, the executive functions score in the study group improved significantly with a moderate effect size.

In determining the effects of AVT on subscales of executive functions, Box's M test indicated the equality of multiple variance-covariance (*Box's M* = 0.68, $p = 0.37$). Bartlett's test of sphericity confirmed a good correlation between the variables ($p = 0.001$), and Levene's test indicated the homogeneity of the variances ($p > 0.05$). Therefore, the assumptions of MANCOVA were met. To investigate the difference between groups in executive functions subscales, Roy's test was run ($F = 15.08$, $p = 0.001$), which demonstrated inter-group differences, as also shown by MANCOVA (Table 5).

Table 5 shows the group effect by AVT intervention, as evidenced by post-intervention scores for inhibition ($F = 87.32$, $p < 0.001$), shifting ($F = 76.25$, $p < 0.001$), emotional control ($F = 86.09$, $p < 0.001$), working memory ($F = 91.17$, $p < 0.001$) and planning/organization ($F = 97.98$, $p < 0.001$). Based on Eta square test, it can be stated that a significant portion of the change in these variables (62%, 58%, 61%, 63% and 64%, respectively) resulted from the effects of AVT intervention. In other words, executive functions subscales score in the study group improved post-intervention with a moderate effect size.

Table 3
Descriptive statistics of variables.

Variables	Test	Intervention group		Control group	
		M	SD	M	SD
Inhibition	Pre-intervention	33.92	2.64	33.23	2.27
	Post-intervention	26.11	2.05	31.08	2.14
Shifting	Pre-intervention	22.88	2.59	22.00	2.73
	Post-intervention	16.38	2.10	21.92	2.13
Emotional control	Pre-intervention	23.34	1.99	23.08	1.72
	Post-intervention	17.12	1.98	22.01	1.66
Working memory	Pre-intervention	35.24	3.28	35.02	3.61
	Post-intervention	26.16	3.05	33.13	3.44
Planning/organization	Pre-intervention	24.32	2.27	24.28	2.03
	Post-intervention	17.19	2.15	23.05	2.01
Executive function	Pre-intervention	139.70	7.14	137.61	7.28
	Post-intervention	102.96	6.99	131.19	7.19

Shapiro-Wilks test confirmed data normality ($p > 0.05$). Homogeneity of regression was also confirmed ($F = 1.37$, $p > 0.05$). Levene test indicated variance homogeneity ($F = 0.29$, $p > 0.05$). Therefore, the assumptions of ANCOVA were met. Results are presented in Table 4.

Table 4
Results of ANCOVA for executive functions.

Source	SS	df	MS	F	Sig.	Eta^2	power
Pre-intervention	181.19	1	181.19	17.01	0.001	0.31	0.92
Group	603.37	1	603.37	56.65	0.001	0.62	0.97
Error	351.68	33	10.65				
Total	1197.52	35					

SS: Sum of squares df: Degrees of freedom MS: Mean of squares.

4. Discussion

The present study aimed to identify the impact of AVT on executive functions in children with CIs. Findings suggest that AVT enhanced executive functions in the participants. These findings were similar to those by Chatterjee et al. (2019), who reported that AVT improved auditory skill, short-term memory, working memory, linguistic processing, planning and organization in children with CIs. This study is also consistent with the study by Hall et al. (2017), which concluded that children with hearing loss experience significantly more executive functions problems than their same-age hearing peers. The finding of this study agrees with Beer et al. (2014), who concluded that executive functions in pre-school children with CIs are lower than those with typical hearing.

From these studies, it can be concluded that executive functions are an area where children with hearing loss often have difficulties (Ashori, 2022). It is thus vital to formulate appropriate programs for promoting executive functions in these children. Some programs have been effective in enhancing executive functions in children with hearing loss. One program that helps these children is AVT (Estabrooks et al., 2020). The AVT approach includes individual diagnostic sessions emphasizing the use of hearing in meaningful

Table 5
MANCOVA of executive function subscales.

Variables	Source	SS	df	MS	F	Sig.	Eta^2
Inhibition	Pre-intervention	38.06	1	38.06	7.73	0.003	0.34
	Group	430.24	1	430.24	87.32	0.001	0.62
	Error	142.68	29	4.92			
	Total	691.38	35				
Shifting	Pre-intervention	34.07	1	34.07	7.08	0.004	0.31
	Group	367.19	1	367.19	76.25	0.001	0.58
	Error	139.49	29	4.81			
	Total	562.27	35				
Emotional control	Pre-intervention	18.16	1	18.16	5.05	0.009	0.29
	Group	309.32	1	309.32	86.09	0.001	0.61
	Error	104.11	29	3.59			
	Total	473.15	35				
Working memory	Pre-intervention	13.22	1	13.22	2.72	0.04	0.19
	Group	446.06	1	446.06	91.17	0.001	0.63
	Error	141.81	29	4.86			
	Total	602.87	35				
Planning/organization	Pre-intervention	24.00	1	24.00	6.97	0.002	0.31
	Group	337.54	1	337.54	97.98	0.001	0.64
	Error	99.76	29	3.44			
	Total	476.50	35				

and optimal situations hence emphasizing on developing hearing as an active sense (Ling, 1993). It emphasizes facilitating and promoting the optimal acquisition of expressive language through listening (Chatterjee et al., 2019; Nandurkar and Susmitha, 2017). The listening environment in AVT can be enhanced in various ways, such as having the therapist sitting in front of a child and using appropriate techniques including acoustic highlighting, pausing and providing alternatives (Dornan et al., 2007). It is therefore possible that AVT may positively influence executive functions in children with CIs.

Hearing loss is associated with some problems in areas such as communication, cognition and psychological wellness (Lederberg et al., 2019). These issues can affect executive functions in children (Nilsen et al., 2017). On the other hand, executive functions facilitate the development of cognitive, emotional, behavioral and social skills in deaf children (Ashori and Tajvar Rostami, 2020; Hall et al., 2017). Deficits in executive functions are implicated in child psychopathologies (Hawkey et al., 2018). With early identification, proper amplification and effective AVT with parents' participation, up to 80% of deaf children can be successful in regular education (Fobi and Oppong, 2019). Besides, appropriate use of AVT helps to improve executive functions.

In this regard, AVT may support children with CIs to become more aware of their language skills and cognitive abilities. Given that these children often face problems in speech and cognition, they may benefit from a program that focuses on AVT to regulate and manage their executive functions. Since AVT emphasizes attending, early vocalizing, recognition, feedbacks, sound locating, memory, sound distance and levels, producing vowels and consonants, speech discrimination and comprehension, short and long-term memory and memory span, it may significantly affect executive functions. AVT can therefore contribute to improvement of executive functions in children with CIs.

There were several limitations to this study. Although parents were part of both the study and control groups, they were not necessarily matched otherwise. The sample size was small, and only the parent version of the BRIEF-P was used in this study. The intervention program was conducted in 20 sessions and it was not possible to have a follow-up visit. Executive functions in children with deaf parents seem to be different from children with normal hearing parents. Therefore, findings should be generalized with precaution.

The critical strength of this study was the focus on children with CIs aged 2–4 years and their mothers. Audiologists and teachers can use AVT to enhance executive functions in children with CIs. They can do this during the pre-school years. The more monitoring, the better the results. Therefore, proper use of the AVT program has been associated with desirable outcomes. It is recommended that audiologists use the AVT program for children with CIs. These children can further develop their language skills and cognitive abilities, and strengthen their executive functions. Finally, the same program may improve executive functions for children with mild to profound hearing impairment.

5. Conclusion

The growing number of people with CIs has led to an interest in the impact of AVT, specifically the utility of this approach. We know that children with CIs cope with many challenging issues, and often they cannot find a suitable solution. AVT, through influencing language skills, can lead to improved speech performance and cognitive ability, and may play a beneficial role in enhancing executive functions in children with CIs.

Funding sources

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was registered by the Research Information Management System in Iran (ID 13768–170254) and was supported by the Exceptional Education Organization in Tehran, Iran (ID 97000-20223).

Declaration of competing interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgements

We would like to thank all of the participants for their participation in this research.

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