

ULOGA VREMENSKO-ORGANIZACIJSKIH ASPEKATA HABILITACIJE U RAZVOJU RECEPTIVNOG JEZIKA DJECE S UMJETNOM PUŽNICOM

TIMING MATTERS: THE ROLE OF TEMPORAL AND ORGANISATIONAL ASPECTS OF HABILITATION IN RECEPTIVE LANGUAGE DEVELOPMENT IN CHILDREN WITH COCHLEAR IMPLANTS

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Sažetak: Rani razvoj jezika djece s umjetnom pužnicom snažno je između ostalog povezan s audiološkim čimbenicima, osobito dobi implantacije i postignutom čujnošću. U sustavima u kojima su ti audiološki preduvjeti visoko standardizirani, manje je poznato u kojoj mjeri organizacija i vremenski raspored rehabilitacije dodatno doprinose varijabilnosti jezičnih ishoda. Cilj ovog istraživanja bio je ispitati povezanost obilježja organizacije rehabilitacije i obiteljskih resursa s razinom receptivnog jezika djece s umjetnom pužnicom, uz kontrolu konteksta u kojem su audiološki uvjeti u najvećoj mjeri osigurani.

U istraživanju je sudjelovalo 35 djece s umjetnom pužnicom u dobi od 6,0 do 15,9 godina, implantirane prije četvrtne godine života, bez dodatnih razvojnih teškoća. Receptivni jezik procijenjen je Peabody slikovnim testom rječnika (PPVT-III-HR) i Testom razumijevanja gramatike (TROG-2:HR). Kao prediktori analizirani su intenzitet rane i kasne rehabilitacije, obrazovanje roditelja, primanja kućanstva, veličina kućanstva, uni- ili bilateralno slušanje te prisutnost timske pomoći. Primijenjene su Spearmanove korelacije, robusna linearna regresija i kvantilna regresija.

Rezultati su pokazali da je intenzitet rane rehabilitacije, kao i izvedeni indeks vremenskog rasporeda rehabilitacije

Abstract: Early language development in children with cochlear implants is, among other factors, strongly associated with audiological factors, particularly age at implantation and post-implantation hearing ability. In healthcare systems where these audiological prerequisites are highly standardised, less is known about the extent to which the organisation and timing of habilitation further contribute to variability in language outcomes. The aim of this study was to examine the relationship between habilitation-related organisational characteristics, family resources, and the level of receptive language in children with cochlear implants, while controlling for a context in which audiological conditions are largely ensured.

The study included 35 children with cochlear implants (aged 6.0 to 15.9 years), who received implants before the age of four years and did not exhibit additional developmental difficulties. Receptive language was assessed using the Croatian version of the Peabody Picture Vocabulary Test (PPVT-III-HR) and the Test for Reception of Grammar (TROG-2:HR). Predictors included the intensity of early and later habilitation, parental education, household income, household size, unilateral or bilateral hearing, and the presence of interdisciplinary team-based care. Spearman correlations, robust linear regression, and quantile regression were applied.

(razlika između rane i kasne habilitacije), pozitivno povezan s razinom receptivnog jezika. U multivarijantnim modelima indeks vremenskog rasporeda habilitacije pokazao se kao jedini statistički značajan prediktor, dok kasnije povećanje intenziteta habilitacije nije imalo kompenzacijski učinak. Obiteljski resursi i organizacijski čimbenici nisu pokazali neovisnu povezanost s ishodom.

Dobiveni nalazi upućuju na ključnu važnost ranog i intenzivnog ulaganja u habilitaciju te podržavaju modele rane intervencije usmjerene na optimalan vremenski raspored habilitacije, s ciljem dugoročnog unapređenja jezičnih ishoda djece s umjetnom pužnicom.

Ključne riječi: umjetna pužnica, kohlearni implantati, receptivni jezik, rana intervencija, habilitacija, organizacija usluga, djeca

UVOD

Djeca s prirođenim ili rano stečenim oštećenjem sluha u kategoriji teške naglušnosti ili gluhoće u Republici Hrvatskoj danas se u velikoj većini slučajeva otkrivaju pri rođenju zahvaljujući nacionalno organiziranom probiru sluha u rodilištima (Marn i Kekić, 2016; Marn, 2005). U preostalim slučajevima, u kojima se radi o oštećenju sluha s kasnijim početkom ili s egzogenim uzrocima, ono se otkriva sustavnim praćenjem rasta i razvoja u sklopu pedijatrijske skrbi, kojim je relativno rano moguće potvrditi ili odbaciti roditeljske sumnje u prikladnost djetetovih reakcija na zvučne podražaje ili očekivano napredovanje govorno-jezičnog razvoja (Marn, 2005). Takav višeslojni sustav ranog otkrivanja omogućuje započinjanje habilitacije u vrlo ranoj dobi, često unutar prvih mjeseci života (Yoshinaga-Itano i sur., 2018).

U Hrvatskoj je rana intervencija za tu djecu usmjerena na postizanje najveće moguće čujnosti, ponajprije kohlearnom implantacijom te na habilitaciju govorenog jezika. U takvom kontekstu, audiološki čimbenici – osobito stupanj postignute čujnosti i dob ugradnje umjetne pužnice – pokazuju se najjačim prediktorima ishoda jezično-govornog razvoja i ti su nalazi u Hrvatskoj (Šimić, 2025) dosljedni međunarodnoj literaturi (Illg i sur., 2024; Jafari i sur., 2024; Almomani i sur., 2021; Davidson i sur., 2014; Nicholas & Geers, 2013; Geers & Nicholas, 2013; Percy-Smith i sur., 2013; Boons i sur., 2012; Kral i Sharma, 2012). Iako su audiološke varijable snažni prediktori, nisu jedini čimbenici relevantni za jezični razvoj djece s umjetnom puž-

The results showed that the intensity of early habilitation, as well as a derived habilitation timing index (the difference between early and later habilitation intensity) were positively associated with receptive language outcomes. In multivariate models, the habilitation timing index emerged as the only statistically significant predictor, while later increases in habilitation intensity did not demonstrate a compensatory effect. Family resources and organisational factors were not independently associated with receptive language outcomes.

These findings highlight the critical importance of early and intensive habilitation and support early intervention models focused on optimal early intervention timing, with the aim of improving long-term language outcomes in children with cochlear implants.

Keywords: cochlear implants, receptive language, early intervention, habilitation, services organisation, children

INTRODUCTION

In the Republic of Croatia, most children with congenital or early-acquired severe to profound hearing loss are identified at birth through a nationally organised newborn hearing screening programme implemented in maternity hospitals (Marn & Kekić, 2016; Marn, 2005). Children whose hearing loss has a later onset or an exogenous cause are typically identified through systematic monitoring of growth and development within paediatric care. This process allows for the relatively early confirmation or exclusion of parental concerns regarding a child's responses to auditory stimuli and the expected course of speech and language development (Marn, 2005). Together, these multi-layered early detection pathways enable the initiation of intervention/habilitation at a very young age, often within the first months of life (Yoshinaga-Itano et al., 2018).

In Croatia, early intervention for these children is primarily oriented towards achieving the highest possible level of audibility, predominantly through cochlear implantation, and towards the habilitation of spoken language. In this context, audiological factors – particularly the level of achieved audibility and the age at cochlear implantation – have consistently been identified as the strongest predictors of speech and language development outcomes, and findings from Croatia (Šimić, 2025) are in line with the international literature (Illg et al., 2024; Jafari et al., 2024; Almomani et al., 2021; Davidson et al., 2014; Nicholas & Geers, 2013; Geers & Nicholas, 2013; Percy-Smith et al., 2013; Boons et al., 2012; Kral & Sharma, 2012). Although audiological vari-

nicom. Dosadašnja istraživanja također potvrđuju da, uz audiološke čimbenike, važnu ulogu imaju i osobni kognitivni, obiteljski i rehabilitacijski čimbenici (Šimić, 2025; Lee i sur., 2025; Mueller i sur., 2025; Nittrouer, 2024; Holzinger i sur., 2022; McGregor i Goldman, 2022). U hrvatskom kontekstu, a i šire, suvremena rehabilitacija podrazumijeva ranu, obitelji usmjerenu ranu intervenciju za djecu s oštećenjem sluha. U modelima takve rane intervencije, stručnjaci i roditelji (obitelj) postaju partneri u planiranju i dosezanju rehabilitacijskih ciljeva, s time da roditelji postaju glavni poticatelji dječjeg komunikacijskog i govorno-jezičnog razvoja kroz intenzivni stručni rad s multidisciplinarnim timom stručnjaka. Izgledno je da će veći broj sati rane rehabilitacije pozitivno djelovati na roditeljske kompetencije u poticanju jezičnih i govornih vještina djeteta s umjetnom pužnicom.

Primjenjujući to dobro dokumentirano znanje na hrvatski sustav u kojem je audiološka intervencija u velikoj mjeri standardizirana i visokokvalitetna – kako u pogledu indikacija, tako i u pogledu tehnoloških mogućnosti – za još kompletniji uvid u odrednice uspjeha jezično-govornog razvoja ove djece važno je imati informaciju o onim aspektima rehabilitacije, koji su realno promjenjivi jer podliježu organizacijskim, profesionalnim i obiteljskim razlikama (Šimić, 2025; Mueller i sur., 2025). Upravo ti čimbenici predstavljaju potencijalne poluge za daljnje unapređenje intervencijskih ishoda unutar postojećeg hrvatskog sustava, koji je u drugim obilježjima pružanih rehabilitacijskih usluga za djecu s umjetnom pužnicom i njihove obitelji uglavnom ujednačen. Važno je naglasiti da su ovi organizacijski i obiteljski čimbenici često višestruko povezani te ih se često ne može izolirano promatrati kao isključive čimbenike koji samostalno snažno utječu na jezične ishode ove populacije. Stoga, u ovom se radu polazi od konceptualnog pomaka jer mu cilj nije utvrditi čimbenike koji predviđaju jezične ishode djece s umjetnom pužnicom, već ispitati kako jezični ishod varira u odnosu na način organizacije i provedbe rehabilitacije, uz kontrolu konteksta u kojem su audiološki preduvjeti već u najvećoj mjeri osigurani. Poseban naglasak u radu stavljen je na dinamiku rehabilitacije, odnosno na raspored i

ables are strong predictors, they are not the only factors relevant to the language development of children with cochlear implants. Previous research has consistently demonstrated that, in addition to audiological factors, individual cognitive, familial, and intervention factors play a significant role (Šimić, 2025; Lee et al., 2025; Mueller et al., 2025; Nittrouer, 2024; Holzinger et al., 2022; McGregor & Goldman, 2022). In the Croatian context, as well as more broadly, contemporary habilitation implies early, family-centred intervention for children with hearing loss. Within such models, professionals and parents (i.e., the family) function as partners in planning and achieving habilitation goals, with parents assuming the role of primary facilitators of the child's communicative and speech-language development through intensive collaboration with a multidisciplinary team of professionals. It is, therefore, plausible that a greater number of early habilitation hours may positively influence parental competencies in supporting the language and speech development of implanted children. When this well-documented body of knowledge is considered within the Croatian context — where audiological intervention is largely standardised and of high quality, with respect to both clinical indications and technological resources — further progress in understanding the determinants of successful speech and language development in these children depends on examining aspects of habilitation that are realistically modifiable. These include factors shaped by organisational practices, professional decision-making, and family-related differences (Šimić, 2025; Mueller et al., 2025). Such factors constitute key opportunities for optimising intervention outcomes within the existing Croatian system, which is otherwise relatively uniform in the nature and scope of habilitation services provided to children with cochlear implants and their families. It is important to emphasise that these organisational and family-related factors are often interrelated and cannot be considered in isolation as independent determinants that can have a strong influence on language outcomes in this population. Accordingly, the present study adopts a conceptual shift: its aim is not just to identify predictors of language outcomes in children with cochlear implants, but rather to examine how language out-

intenzitet rane i kasnije habilitacije, zatim na obiteljske resurse (razinu obrazovanja roditelja i primanja kućanstva), veličinu kućanstva, upotrebu jednog ili dva slušna pomagala (uni- ili bilateralno slušanje) te na organizacijske aspekte poput timskog rada. Ovaj pristup izravno proizlazi iz prijašnjeg domaćeg istraživanja receptivnog jezika djece s umjetnom pužnicom koje je provela Šimić (2025), u kojem se naglašava potreba za analizom organizacije habilitacijskih usluga, pravodobnim prepoznavanjem djece kod koje napredovanje odstupa od očekivanog te ranim povećanjem intenziteta (npr. povećanjem broja tjednih termina habilitacije) i kvalitete habilitacije. Naslanjajući se na spomenuto domaće istraživanje te na međunarodne smjernice za organizaciju rane intervencije za djecu s oštećenjem sluha (Joint Committee on Infant Hearing [JCIH], 2019) u kojima je istaknuto da njezini ishodi ne ovise samo o audiološkim parametrima, nego i o modificirajućim sastavnicama sustava usluga (pravovremenosti i kontinuitetu skrbi, kvaliteti i kompetencijama pružatelja usluga te obiteljski usmjerenoj ranoj intervenciji), ovaj rad primjenjuje i testira model pružanja usluga, u kojem se audiološke varijable svjesno izostavljaju zbog: a) već stečene potvrde njihovih učinaka na receptivni jezik u spomenutom istraživanju te b) stjecanja komplementarne razine objašnjenja načina na koji ekološki čimbenici samostalno doprinose jezično-govornoj habilitaciji.

CILJ I HIPOTEZE

U radu se polazi od nekoliko istraživačkih pretpostavki. Prvo, pretpostavlja se da je dinamika habilitacije – osobito razlika rane, intenzivne habilitacije u odnosu na kasnije „nadoknađivanje” – povezana s razinom receptivnog jezika (Šimić, 2025; Illg i sur., 2024; Farag i sur., 2024; Busch i sur., 2022; Chweya i sur., 2021). Ova pretpostavka oslanja se na razvojne modele usvajanja jezika koji naglašavaju vremensku osjetljivost ranih jezičnih iskustava te na klinička opažanja da djeca s intenzivnom ranom habilitacijom često postižu stabilnije jezične temelje uz manju potrebu za kasnijim povećanjem broja terapijskih termina (Yoshinaga-Itano i sur., 2020; JCIH, 2019), a isto potvrđuju i recentni rezultati Aaberg i suradnika

comes vary in relation to the organisation and implementation of habilitation, while controlling for a context in which audiological prerequisites have already been fulfilled to a large extent. Particular emphasis is placed on the dynamics of oral habilitation, namely the timing and intensity of early and later habilitation, as well as on family resources (parental education level and household income), household size, the use of one or two hearing devices (unilateral or bilateral listening), and organisational aspects of intervention such as teamwork.

This approach builds directly on earlier research on receptive language development in children with cochlear implants conducted by Šimić (2025), which highlighted the importance of examining the organisation of habilitation services, the timely identification of children whose developmental trajectories diverge from expectations, and the early increases of habilitation intensity and quality when needed. Informed by this national evidence and by international guidelines on early intervention for children with hearing loss (Joint Committee on Infant Hearing [JCIH], 2019) — which emphasise that outcomes are shaped not only by audiological factors, but also by modifiable components of the service system, such as timeliness and continuity of care, provider competence, and family-centred practices – the present study applies and empirically tests a service delivery model that deliberately excludes audiological variables. This decision is based on (a) prior confirmation of their effects on receptive language in the aforementioned study and (b) the aim of providing a complementary level of explanation by examining how ecological and service-related factors independently contribute to speech and language habilitation outcomes.

AIM AND HYPOTHESES

The study is based on several research assumptions. First, it is assumed that the dynamics of habilitation – particularly the difference between early, intensive habilitation and later “catch-up” habilitation – are associated with receptive language levels (Šimić, 2025; Illg et al., 2024; Farag et al., 2024; Busch et al., 2022; Chweya et al., 2021). This assumption is grounded in developmental models of language acquisition that emphasise the temporal

(2025), koji su pokazali da djeca s ranijim početkom i duljim trajanjem rehabilitacije dugoročno postižu značajno bolje jezične ishode u usporedbi s onima s kasnijim početkom i kraćim trajanjem rehabilitacije. Drugo, očekuje se da razina obrazovanja roditelja i primanja kućanstva imaju dodatnu ulogu u objašnjenju receptivnog jezika, ponajprije kroz empirijski bitnu mogućnost kvalitetnije generalizacije jezičnih vještina u prirodnom okruženju, dostupnost dodatnih resursa te kvalitetu jezičnog inputa u obitelji (Lee i sur., 2025; Mueller i sur., 2025; Holzinger 2020; Quittner i sur., 2013; Holt 2012). Treće, timski rad i tehnološki čimbenici kao što je upotreba jednog ili dvaju elektroakustičkih rješenja za pomoć slušanju (npr. bilateralni nasuprot unilateralnom slušnom rješenju) razmatraju se kao elementi organizacije i pristupa skrbi koji mogu imati povoljan učinak na jezične ishode, iako se njihov doprinos u različitim uzorcima razlikuje i često je ovisan o varijabilnosti unutar uzorka i snazi statističkih analiza (Alshahrani i sur., 2024; Wie i sur., 2020).

Na opisani način, ovaj rad nastoji doprinijeti razumijevanju onih aspekata rehabilitacije koji su unutar postojećeg sustava promjenjivi i potencijalno optimizabilni, s ciljem pružanja smjernica za organizaciju intervencije kod (na)gluhe djece koja koriste umjetne pužnice, pri čemu se uvažava obiteljski-orijentiran pristup ranom otkrivanju i intervenciji te organizacijski i sustavni faktori koji mogu utjecati na ishode (Maluleke i sur., 2021; JCIH, 2019; Yoshinaga-Itano, 2014).

METODE ISTRAŽIVANJA

Sudionici

U istraživanju je sudjelovalo 35 djece (16 dječaka i 19 djevojčica) s umjetnim pužnicama, u dobi između 6,0 i 15,9 godina ($M = 10,7$; $SD = 3,16$), s prirođenim teškim zamjedbenim oštećenjem sluha ili gluhoćom. Svi sudionici bili su implantirani relativno rano, odnosno prije navršene 4. godine života (Kral & Sharma, 2012), imali su urednu neverbalnu inteligenciju, procijenjenu Ravenovim progresivnim matricama, nisu imali dodatne razvojne, neurološke ili senzorne teškoće te su bili uključeni u redovni obrazovni program.

sensitivity of early language experiences, as well as in clinical observations indicating that children receiving intensive early habilitation often develop more stable language foundations with a reduced need for later increases in therapy frequency (Yoshinaga-Itano et al., 2020; JCIH, 2019). This is further supported by recent findings by Aaberg et al. (2025), demonstrating that children with an earlier onset and longer duration of habilitation achieve significantly better long-term language outcomes than those with later onset and shorter duration of habilitation. Second, parental education level and household income are expected to play an additional role in explaining receptive language outcomes, primarily through empirically relevant mechanisms such as improved generalisation of language skills in natural environments, access to additional resources, and the quality of linguistic input within the family (Lee et al., 2025; Mueller et al., 2025; Holzinger, 2020; Quittner et al., 2013; Holt, 2012). Third, teamwork and technological factors such as the use of one or two hearing devices (e.g., bilateral versus unilateral hearing) are considered as organisational and care-related elements that may have a beneficial effect on language outcomes, although their contribution varies across samples and is often dependent on within-sample variability and statistical power (Alshahrani et al., 2024; Wie et al., 2020).

In this way, the present study seeks to contribute to the understanding of those aspects of habilitation that are modifiable and potentially optimisable within the existing system, with the aim of providing guidance for the organisation of interventions for deaf and hard-of-hearing children using cochlear implants. In doing so, it acknowledges a family-oriented approach to early detection and intervention, as well as organisational and systemic factors that may influence outcomes (Maluleke et al., 2021; JCIH, 2019; Yoshinaga-Itano, 2014).

METHODS

Participants

The study included 35 children (16 boys and 19 girls) with cochlear implants, aged between 6.0 and 15.9 years ($M = 10.7$; $SD = 3.16$), with congenital severe sensorineural hearing loss or deaf-

Audiološke karakteristike uzorka bile su relativno ujednačene. Dob ugradnje umjetne pužnice kretala se u rasponu od 14 do 44 mjeseca ($M = 26,8$; $SD = 7,88$; medijan = 26), dok je prosječni postimplantacijski prag sluha na implantiranom uhu (PTA) iznosio $M = 35,5$ dB ($SD = 6,79$; medijan = 40), uz raspon od 20 do 50 dB. Prosječno trajanje korištenja umjetne pužnice, odnosno čujnosti (od uključivanja govornog procesora do starosti djeteta u vrijeme prikupljanja podataka) kretalo se od 3,11 do 13,6 godina, a u prosjeku je iznosilo osam godina i tri mjeseca. Sudionici istraživanja upotrebljavali su umjetne pužnice tvrtke Cochlear s unutarnjim komponentama Freedom CI24RE, CI422 i CI512 te procesorima govora Nucleus 6 (CP910 i CP920) i CP850 ili tvrtke MED-El s unutarnjim komponentama Pulsar, Maestro i Sonata te procesorima govora Opus 1, Opus 2, Sonnet i Rondo. Implantati su imali sve elektrode aktivne, bili su programirani redovito, odnosno barem jednom godišnje i upotrebljavali su se sve budne sate. Spomenute audiološke varijable razmatrane su isključivo sa svrhom opisa uzorka te kao kontekst osiguranih audioloških preduvjeta optimalne čujnosti za pojedinog sudiionika istraživanja.

Demografski i habilitacijski podaci numerički i deskriptivno su predstavljani u poglavlju Rezultati te su ovdje spomenuti tek općenito, u svrhu opisa uzorka. Većina djece sluša unilateralno umjetnom pužnicom, dok ostatak sluša bilateralno s pomoću dvije umjetne pužnice ili kombinacijom umjetne pužnice i slušnog pomagala. Majke i očevi uglavnom su imali srednjoškolsko obrazovanje, iako su u uzorku bile zastupljene sve razine obrazovanja – od osnovnoškolskog do poslijediplomskog. Primanja kućanstva za većinu obitelji nalazila su se u kategoriji prosječnih primanja, ali je uzorak obuhvatio i obitelji s ispod- te iznadprosječnim primanjima, što upućuje na njegov relativno homogen, ali ne i jedinstven socioekonomski kontekst. Većina djece živjela je u višečlanim kućanstvima te su bila uključena u habilitaciju uglavnom četiri ili pet puta tjedno u predškolskoj dobi, odnosno većinski samo jednom tjedno u školskoj dobi. Prema iskazima roditelja, u uzorku nije bilo djece s redovitim, kontinuiranim tiskim radom, dok je

ness. All participants were implanted relatively early - before the age of 4 years (Kral & Sharma, 2012) - they had typical nonverbal intelligence as assessed by Raven's Progressive Matrices, they had no additional developmental, neurological, or sensory impairments, and were enrolled in mainstream education.

The audiological characteristics of the sample were relatively homogeneous. Age at cochlear implantation ranged from 14 to 44 months ($M = 26,8$; $SD = 7,88$; Median = 26), while the average post-implantation hearing threshold in the implanted ear (PTA) was $M = 35.5$ dB ($SD = 6.79$; Median = 40), with a range of 20-50 dB. The average duration of cochlear implant use, that is, auditory experience (from speech processor activation to the child's age at data collection), ranged from 3.11 to 13.6 years, with a mean of 8 years and 3 months. Participants used cochlear implants manufactured by Cochlear with the following internal components - Freedom CI24RE, CI422, and CI512, along with Nucleus 6 speech processors (CP910 and CP920) and CP850, or cochlear implants manufactured by MED-El with internal components Pulsar, Maestro, and Sonata, along with Opus 1, Opus 2, Sonnet, and Rondo speech processors. All implants had all electrodes activated, were programmed regularly (at least once per year), and were used during all waking hours. These audiological variables were considered solely for the purpose of describing the sample and as contextual indicators of already established audiological prerequisites for optimal audibility for each participant.

Demographic and habilitation data are presented numerically and descriptively in the Results section and are only briefly summarised here for the purpose of sample description. Most children used a unilateral cochlear implant, while the rest listened bilaterally using either two cochlear implants or a combination of a cochlear implant and a hearing aid. Mothers and fathers predominantly had completed secondary education, although all education levels – from primary to postgraduate – were represented in the sample. Household income for most families fell within the average income category, but the sample also included families with below- and above-average income,

za većinu djece bio organiziran povremeno, a za otprilike trećinu uopće ne.

Mjerni instrumenti i način prikupljanja i obrade podataka

Audiološki, demografski i rehabilitacijski podaci prikupljeni su izravno od roditelja i uvidom u medicinsku dokumentaciju djece, a nakon dobivanja odobrenja Etičkog povjerenstva Sveučilišta u Zagrebu Edukacijsko-rehabilitacijskog fakulteta i Poliklinike SUVAG te potpisanog informiranog pristanka roditelja. Podaci su prikupljeni individualnim testiranjem djece u kontroliranim kliničkim uvjetima te prikupljanjem demografskih i rehabilitacijskih informacija iz medicinske dokumentacije te putem roditeljskih upitnika.

Podaci o razvijenosti receptivnog jezika (*Receptivni jezik*) djece s umjetnom pužnicom, koja je u ovom radu određena kao zavisna varijabla, prikupljeni su Peabody slikovnim testom rječnika (PPVT-III-HR; Kovačević i sur., 2009) i Testom razumijevanja gramatike (TROG-2:HR; Bishop i sur., 2014), uz certificirane ispitivače i sukladno protokolu njihove administracije. Varijabla *Receptivni jezik* operacionalizirana je kao kompozit standardnih rezultata na PPVT-III-HR i TROG-2:HR za pojedinog sudionika istraživanja.

S obzirom na potvrđeni snažni prediktivni učinak praga čujnosti nakon implantacije i dobi implantacije u prethodnoj analizi razine receptivnog jezika istih sudionika (Šimić, 2025) iste audiološke varijable u ovom su radu izostavljene iz analize, dok su kao nezavisne varijable uzete kontinuirane (*Dinamika rane rehabilitacije*, *Dinamika kasne rehabilitacije* i *Veličina kućanstva*), ordinalne (*Obrazovanje majke*, *Obrazovanje oca* i *Primanja kućanstva*) i kategoričke (*Uni-* ili *Bilateralno slušanje* i *Timski rad*) rehabilitacijske i obiteljske varijable. Sve varijable kodirane su tako da veće vrijednosti označavaju višu razinu promatrane karakteristike, a smjer povezanosti s ishodom interpretiran je empirijski.

Razina obrazovanja majki i očeva bila je kodirana u šest ordinalnih kategorija: niža, srednja, specijalist sa srednjom stručnom spremom, završen prijediplomski studij, završen diplomski

indicating a relatively homogeneous, but not uniform socioeconomic context. Most children lived in multi-member households and were primarily involved in habilitation four or five times per week during preschool age, and predominantly once per week during school age. According to parental reports, none of the children received regular, continuous teamwork-based support; for most children, teamwork was organised occasionally, while for approximately one third of the sample, opportunities for teamwork were mostly absent.

Measurement instruments and data collection and analysis procedures

Audiological, demographic, and habilitation data were collected directly from parents and through review of the children's medical records, following approval from the Ethics Committees of the Faculty of Education and Rehabilitation Sciences, University of Zagreb, and the SUVAG Polyclinic, as well as written informed consent from the parents. Data were collected through individual testing of children in controlled clinical settings, as well as through extraction of demographic and habilitation information from medical records and parent questionnaires.

Data on receptive language development (Receptive Language) in children with cochlear implants, which served as the dependent variable in this study, were obtained using the Peabody Picture Vocabulary Test (PPVT-III-HR; Kovačević et al., 2009) and the Test for Reception of Grammar (TROG-2:HR; Bishop et al., 2014), administered by certified examiners in accordance with standardised administration protocols. The Receptive Language variable was operationalised as the composite of standardised scores on the PPVT-III-HR and TROG-2:HR for each participant.

Given the previously confirmed strong predictive effect of post-implantation hearing threshold and age at implantation on receptive language level in a prior analysis of the same participants (Šimić, 2025), these audiological variables were excluded from the present analysis. Independent variables included continuous variables (Early Habilitation Dynamics, Late Habilitation Dynamics, and Household Size), ordinal variables

studij, završen poslijediplomski studij. Primanja kućanstva mogla su biti kodirana u četiri ordinalne kategorije: ispod 500 eura, između 500 i 1.000 eura, između 1.000 i 1.600 eura te iznad 1.600 eura (iznosi su preračunati iz kuna koje su promatrane u izvornom istraživanju, zaokruženi radi čitljivosti), no u analizi su svedena na tri kategorije radi stabilnosti procjena, budući da kategorija „ispod 500 eura“ nije bila zastupljena u uzorku.

Veličina kućanstva bila je izražena brojem članova, a dinamika rane i kasne habilitacije brojem tjednih termina jezično-govorne habilitacije u predškolskoj, odnosno školskoj dobi. Timski rad bio je definiran kao multidisciplinarna podrška obitelji, to jest zajednički habilitacijski rad dvaju ili više različitih stručnjaka s pojedinim djetetom (logopeda, audiorehabilitatora, psihologa, edukacijskih rehabilitatora, radnih terapeuta), a u analizi je bio izražen dihotomno – „nije ga bilo“ ili „bilo ga je povremeno“ – jer je pri izvještavanju o timskom radu nijedan roditelj nije naveo da je treća opcija, odnosno redoviti timski rad, bila ostvarena.

Primarni cilj analize bio je ispitati doprinos obilježja organizacije habilitacije i obiteljskih resursa varijabilnosti receptivnog jezika u uzorku djece s umjetnom pužnicom, uz pretpostavku da će viši intenzitet rane habilitacije u odnosu na kasnu biti povezan s boljim jezičnim ishodom. Važno je naglasiti da je intenzitet habilitacije u ovom istraživanju operacionaliziran isključivo kao broj tjednih terapijskih termina. Ova mjera obuhvaća kvantitativni aspekt intervencijskih resursa, ali ne odražava kvalitativne aspekte poput terapijskog pristupa, stručnosti provoditelja, sadržaja intervencije ili uključenosti obitelji.

U skladu s navedenim, u *primarnom multivarijatnom modelu* je, umjesto pojedinačne analize tih habilitacijskih varijabli, ispitan pokazatelj odnosa rane i kasne habilitacije oblikovanjem izvedene varijable *Indeks vremenskog rasporeda habilitacije*, izračunate kao razlika između intenziteta rane i kasne habilitacije (indeks = rana habilitacija – kasna habilitacija). Pozitivne vrijednosti indeksa označavale su veći intenzitet habilitacije u predškolskoj dobi, vrijednost 0 jednak intenzitet, a negativne vrijednosti relativno veće oslanjanje

(Mother's Education, Father's Education, and Household Income), and categorical variables (Unilateral vs. Bilateral Listening and Teamwork) related to habilitation and family characteristics. All variables were coded such that higher values indicated a higher level of the observed characteristic, and the direction of association with the outcome was interpreted empirically.

Parental education levels were coded into six ordinal categories: lower, secondary, specialised secondary qualification, completed undergraduate degree, completed graduate degree, and completed postgraduate degree. Household income was originally coded into four ordinal categories: below 500 €, 500-1,000 €, 1,000-1,600 €, and above 1,600 € (amounts converted to Euros from Croatian kuna used in the original study, and rounded for clarity), but was reduced to three categories in the analysis for estimation stability, as the “below 500 €” category was not represented in the sample.

Household size was expressed as the number of household members, while early and late habilitation dynamics were expressed as the number of weekly speech and language therapy sessions during preschool and school age, respectively. Teamwork was defined as multidisciplinary family support, that is, joint habilitation provided by two or more different professionals working with an individual child (speech-language pathologists, audiological rehabilitation specialists, psychologists, educational rehabilitation specialists/special education teachers, occupational therapists). In the analysis, teamwork was expressed dichotomously – “not present” or “occasionally present” – since no parent reported the presence of regular teamwork.

The primary aim of the analysis was to examine the contribution of habilitation organisation characteristics and family resources to variability in receptive language outcomes in children with cochlear implants, under the assumption that, relative to later habilitation, higher intensity of early habilitation would be associated with better language outcomes. It is important to highlight that habilitation intensity in this study was operationalised exclusively as the number of weekly therapy sessions. This measure captures the quantitative aspect of intervention resources, but does not

na kasnije povećanje intenziteta rehabilitacije („nadoknađivanje”). Na primjer, dijete koje je pohađalo pet terapijskih sesija tjedno u predškolskoj dobi i dvije u školskoj dobi imalo bi indeks vremenskog rasporeda rehabilitacije od +3, dok bi dijete koje je imalo dvije tjedne terapije u predškolskoj dobi i četiri tjedne terapije u školskoj dobi imalo vrijednost indeksa -2. Vrijednosti indeksa kretale su se u rasponu od -4 do +4, pri čemu su više vrijednosti označavale relativno veći intenzitet rane u odnosu na kasnu rehabilitaciju.

Tako je bilo moguće izravno testirati prvu hipotezu, smanjiti rizik multikolinearnosti u analizi te dobiti koeficijent povoljan za kliničku i organizacijsku interpretaciju.

S obzirom na malu veličinu uzorka, ordinalnu prirodu većine nezavisnih varijabli i utvrđena odstupanja od normalne distribucije (vizualnom inspekcijom distribucija i provedbom Shapiro-Wilkovog testa), u radu su primijenjene neparametrijske i robusne statističke metode. Analize su odabrane i provedene s ciljem ispitivanja varijabilnosti jezičnih ishoda unutar konteksta već osiguranih audioloških preduvjeta, sa svrhom stjecanja uvida u utjecaj trenutačnog načina organizacije i pružanja rehabilitacijskih usluga u Hrvatskoj na receptivne jezične ishode.

Najprije su izračunate Spearmanove korelacije između receptivnog jezika i pojedinih rehabilitacijskih i obiteljskih varijabli. Multivarijatni robusni linearni regresijski model primjenjivao se kako bi se ispitao neovisni doprinos obilježja demografskih i rehabilitacijskih resursa varijabilnosti receptivnog jezika uz istodobnu kontrolu više međusobno povezanih prediktora te smanjio utjecaj odstupanja od pretpostavki normalnosti i homogenosti varijanci. Kvantilna regresija za medijan receptivnog jezika primjenjivala se kako bi se ispitao doprinos demografskih i rehabilitacijskih čimbenika s naglaskom na središnju tendenciju ishoda, uz smanjenje utjecaja ekstremnih vrijednosti i heterogenosti distribucije receptivnog jezika u uzorku. Analiza osjetljivosti provedena je kako bi se provjerila stabilnost glavnog nalaza o važnosti vremenskog rasporeda rehabilitacije usporedbom modela s izvedenim indeksom i modela u kojem su intenzitet rane i kasne rehabilitacije uvršteni kao

reflect qualitative aspects such as therapeutic approach, provider expertise, intervention content, or family engagement.

Instead of analysing individual habilitation variables separately, the primary multivariate model examined an indicator of the relationship between early and late habilitation by constructing a derived variable, the Habilitation Timing Index, which is calculated as the difference between early and late habilitation intensity (index = early habilitation - late habilitation). Positive index values indicated greater habilitation intensity during preschool age, a value of zero indicated equal intensity, and negative values indicated a relatively greater reliance on later increases in habilitation intensity (“catch-up”). For example, a child receiving 5 sessions per week in preschool and 2 sessions per week at school age would have a Habilitation Timing Index of + 3, whereas a child receiving 2 sessions per week in preschool and 4 sessions per week at school age would have an index score of - 2. Index values ranged from - 4 to + 4, with higher values indicating relatively greater early versus late habilitation intensity. This approach enabled direct testing of the first hypothesis, reduced the risk of multicollinearity, and yielded a coefficient suitable for clinical and organisational interpretation.

Given the small sample size, the ordinal nature of most independent variables, and deviations from normality (identified through visual inspection and the Shapiro-Wilk test), non-parametric and robust statistical methods were applied. Detailed analyses were conducted to examine variability in language outcomes within the context of already established audiological prerequisites, with the aim of gaining insight into the impact of current habilitation organisation and service delivery in Croatia on receptive language outcomes.

First, Spearman correlations between receptive language and individual habilitation and family variables were calculated. A multivariate robust linear regression model was then used to examine the independent contribution of demographic and habilitation resources to variability in receptive language, while simultaneously controlling for multiple interrelated predictors and reducing the influence of violations of normality and homoge-

odvojeni prediktori. Kombinacijom robusne linearne regresije, kvantilne regresije i analize osjetljivosti nastojalo se osigurati da su dobiveni nalazi metodološki stabilni, interpretativno pouzdani i primjenjivi unutar heterogenog kliničkog uzorka.

Zadana razina značajnosti za sve provedene analize bila je $p < 0,05$.

REZULTATI I RASPRAVA

Rezultati

Većina djece ili njih 27 (77 %) unilateralni su korisnici umjetne pužnice, četiri djeteta (11,5 %) sluša binauralno pomoću dvije umjetne pužnice, a četiri djeteta (11,5 %) kombinacijom umjetne pužnice i slušnog pomagala.

Prosječna razina obrazovanja majki iznosila je $M = 3,17$ ($SD = 1,52$; medijan = 2), a očeva $M = 3,06$ ($SD = 1,47$; medijan = 2). Frekvencije odgovora o obrazovanju majki i očeva dane su slikom 1.

neity of variance assumptions. Quantile regression for the median of receptive language was used to examine the contribution of demographic and habilitation factors with an emphasis on the central tendency of the outcome, while reducing the influence of extreme values and distributional heterogeneity. Sensitivity analysis was conducted to assess the stability of the main finding regarding the importance of habilitation timing by comparing the model using the derived index with a model including early and late habilitation intensity as separate predictors. By combining robust linear regression, quantile regression, and sensitivity analysis, the study aimed to ensure that the findings were methodologically stable, interpretatively reliable, and applicable within a heterogeneous clinical sample. The significance level for all analyses was set at $p < .05$.

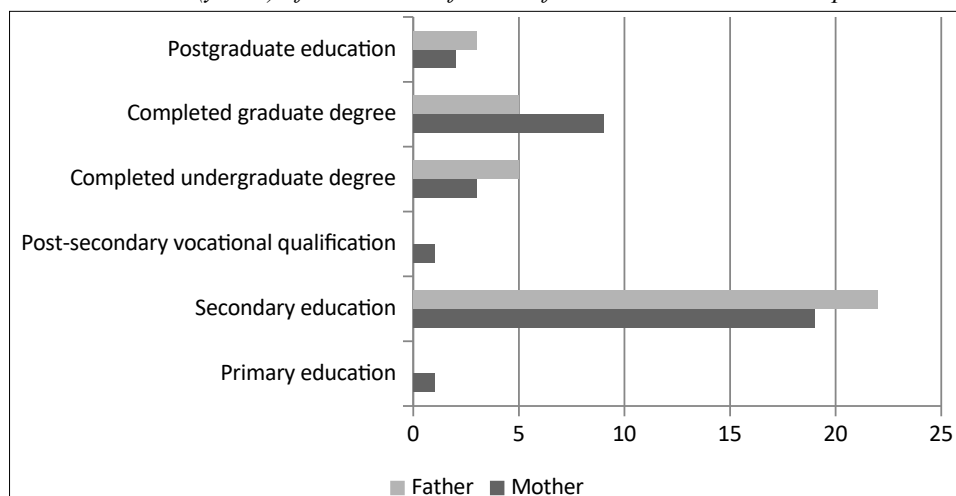
RESULTS AND DISCUSSION

Results

The majority of children ($n = 27$; 77%) were unilateral cochlear implant users; four children (11.5%) listened binaurally using two cochlear implants, and four children (11.5%) used a combination of a cochlear implant and a hearing aid.

The mean maternal education level was 3.17 ($SD = 1.52$, Median = 2), and the mean paternal education level was 3.06 ($SD = 1.47$, Median = 2). Frequencies of maternal and paternal education levels are presented in Figure 1.

Slika 1. Frekvencije odgovora (x-os) o razini obrazovanja (y-os) majki i očeva djece s umjetnim pužnicama / **Figure 1.** Educational level (y-axis) of mothers and fathers of children with cochlear implants.



Većina obitelji (57 %) nalazila se u kategoriji primanja između 1.000 i 1.600 eura, s primanjima između 500 i 1.000 eura ili iznad 1.600 eura zastupljenima kod manjeg dijela obitelji (17 %, odnosno 26 % obitelji).

Veličina kućanstva kretala se od dva do sedam članova, s prosječnom vrijednošću $M = 4,20$ ($SD = 0,93$; medijan = 4).

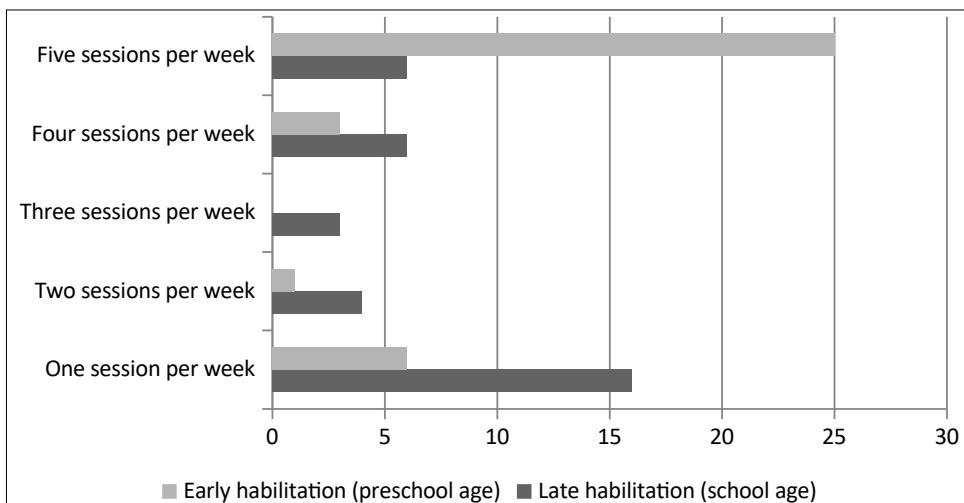
Intenzitet rane rehabilitacije u predškolskoj dobi iznosio je $M = 4,14$, $SD = 1,56$, medijan = 5, uz raspon 1–5 termina tjedno. Intenzitet kasne rehabilitacije u školskoj dobi iznosio je $M = 2,49$, $SD = 1,62$, medijan = 2, uz raspon 1–5. Djeca su u prosjeku bila uključena u rehabilitaciju četiri puta tjedno, pri čemu je 71,4 % djece u predškolskoj dobi pohađalo terapiju pet puta tjedno. U školskoj dobi zabilježeno je smanjenje intenziteta rehabilitacije, a 45,7 % djece bilo je uključeno u terapiju jednom tjedno. Frekvencije odgovora o dinamici rane i kasne jezično-govorne rehabilitacije prikazane su Slikom 2.

Most families (57%) were in the household income category of EUR 1,000-1,600, while incomes between EUR 500 and 1,000 or above EUR 1,600 were reported by a smaller proportion of families (17% and 26%, respectively).

Household size ranged from 2 to 7 members, with a mean of 4.20 ($SD = 0.93$, Median = 4).

The mean intensity of early habilitation during preschool age was 4.14 sessions per week ($SD = 1.56$, Median = 5), with a range of 1 to 5 sessions per week. The mean intensity of late habilitation during school age was 2.49 sessions per week ($SD = 1.62$, Median = 2), with a range of 1 to 5 sessions per week. On average, children participated in habilitation four times per week, with 71.4% attending therapy five times per week during preschool age. During school age, a reduction in habilitation intensity was observed, with 45.7% of children receiving therapy once per week. Frequencies of responses for early and late habilitation dynamics are shown in Figure 2.

Slika 2. Frekvencije odgovora (x-os) o dinamici rane i kasne rehabilitacije izražene brojem tjednih termina (y-os) jezično-govorne rehabilitacije / **Figure 2.** Frequency distribution of weekly speech-language habilitation sessions during preschool (early) and school age (late)



Povremeno uključivanje djece u timski rad prijavilo je 71,4 % roditelja, a 28,6 % navelo je da timskog rada nije bilo, dok u kontinuirani timski rad prema roditeljskim iskazima nije bilo uključeno nijedno dijete.

Receptivni jezik sudionika u prosjeku je iznosio $M = 73,66$ ($SD = 13,88$, medijan = 72,5), uz

Occasional involvement of children in teamwork was reported by 71.4% of parents, while 28.6% indicated that teamwork was mostly absent; according to parental reports, no child was included in continuous teamwork.

The mean receptive language score of the participants was 73.66 ($SD = 13.88$, Median = 72.5),

raspon od 55,5 do 104. Shapiro–Wilkov test normalnosti za varijablu receptivnog jezika bio je značajan ($W = 0,932$, $p = 0,032$), što upućuje na odstupanje od normalne distribucije i opravdava primjenu neparametrijskih i robusnih postupaka.

Izvedena varijabla Indeks vremenskog rasporeda habilitacije imala je $M = 1,66$, $SD = 2,45$, medijan = 2, uz raspon -4 do $+4$ (pozitivne vrijednosti označavaju relativno veći intenzitet rane habilitacije, a negativne vrijednosti relativno veće oslanjanje na kasnije „nadoknađivanje“).

Korelacijska analiza između receptivnog jezika i glavnih prediktora (Tablica 1) pokazala je jedan značajan Spearmanov koeficijent: onaj koji ukazuje na pozitivnu povezanost s dinamikom rane habilitacije. Povezanost indeksa vremenskog rasporeda habilitacije s receptivnim jezikom isto je bila pozitivna, ali nije dosegla razinu statistički značajne povezanosti s receptivnim jezikom, kao ni dinamika kasne habilitacije, obrazovanje majki i očeva, primanja kućanstva, veličina kućanstva, uni-/ bilateralno slušanje i timski rad.

Tablica 1. Spearmanova korelacijska analiza između receptivnog jezika te demografskih i habilitacijskih prediktora / **Table 1.** Spearman correlation analysis between receptive language and demographic and habilitation predictors.

	Receptive language	
	Spearman's correlation coefficient (ρ)	Significance (p)
Mother's education	0.052	.766
Father's education	0.048	.786
Household income	– 0.048	.785
Household size	0.031	.860
Unilateral/bilateral listening	0.111	.525
Teamwork	0.135	.440
Early habilitation dynamics	0.365	.031
Late habilitation dynamics	– 0.208	.231
Habilitation Timing Index	0.308	.072

Radi ispitivanja neovisnog doprinosa pojedinih varijabli proveden je robusni regresijski model s receptivnim jezikom kao zavisnom varijablom te Indeksom vremenskog rasporeda habilitacije, obrazovanjem majke i oca, primanjima kućanstva, veličinom kućanstva, uni-/ bilateralnim slušanjem i timskim radom kao prediktorima. Rezultati robusnih i kvantilnih regresijskih analiza prikazani su u Tablici 2.

with a range from 55.5 to 104. The Shapiro–Wilk test of normality for the receptive language variable was significant ($W = 0.932$, $p = .032$), indicating deviation from a normal distribution and justifying the use of non-parametric and robust analytical procedures.

The derived variable, the Habilitation Timing Index, had a mean of 1.66 ($SD = 2.45$, Median = 2), with a range of -4 to $+4$ (positive values indicate a relatively higher intensity of early habilitation, whereas negative values indicate a relatively greater reliance on later “catch-up” habilitation).

Correlation analysis between receptive language and the main predictors (Table 1) revealed a single statistically significant coefficient, indicating a positive association with early habilitation dynamics. The association between the Habilitation Timing Index and receptive language was also positive, but it did not reach statistical significance, nor did late habilitation dynamics, parental education, household income, household size, unilateral/bilateral listening, or teamwork.

To examine the independent contribution of individual variables, a robust regression analysis was conducted with receptive language as the dependent variable and the Habilitation Timing Index, mother's and father's education, household income, household size, unilateral/bilateral listening, and teamwork as predictors. The results of the robust and quantile regression analyses are presented in Table 2.

U prvom dijelu Tablice 2 prikazan je multivarijatni robusni linearni regresijski model s receptivnim jezikom kao zavisnom varijablom. Model je objasnio 20,3 % varijance receptivnog jezika, pri čemu ukupni model nije dosegnuo razinu statističke značajnosti ($p = 0,426$). Unatoč tome, Indeks vremenskog rasporeda rehabilitacije pokazao se kao jedini statistički značajan prediktor receptivnog jezika, pri čemu su više vrijednosti indeksa, koje označavaju relativno veći intenzitet rane u odnosu na kasnu rehabilitaciju, bile povezane s višom razinom receptivnog jezika.

Ostali uključeni prediktori, uključujući obrazovanje roditelja, primanja kućanstva, veličinu kućanstva, način slušanja te timski rad u rehabilitaciji, nisu pokazali statistički značajnu povezanost s ishodom.

Drugi dio Tablice 2 prikazuje rezultate kvantilne regresije za medijan receptivnog jezika. Kvantilna regresija za medijan receptivnog jezika objasnila je 20,6 % varijabilnosti ishoda (pseudo $R^2 = 0,206$). U ovom modelu Indeks vremenskog rasporeda rehabilitacije zadržao je pozitivan smjer povezanosti s receptivnim jezikom, uz vrijednost blisku razini statističke značajnosti, dok ostali prediktori nisu pokazali značajne učinke. Dobiveni obrazac upućuje na stabilnost učinka vremenskog rasporeda rehabilitacije i u središtu distribucije jezičnih ishoda.

U trećem dijelu Tablice 2 prikazana je analiza osjetljivosti u kojoj su intenzitet rane i intenzitet kasne rehabilitacije uvršteni kao odvojeni prediktori, bez ostalih kovarijata uključenih u prethodne modele. Rezultati ove analize pokazali su da je intenzitet rane rehabilitacije statistički značajno povezan s razinom receptivnog jezika ($p = 0,031$), dok intenzitet kasne rehabilitacije nije pokazao značajnu povezanost s ishodom. Značajan neregresijski koeficijent (B) intenzitet rane rehabilitacije upućuje da je svaki dodatni tjedni termin rane rehabilitacije povezan s povećanjem rezultata receptivnog jezika za približno 3,5 boda na kompozitnoj jezičnoj mjeri.

The first part of Table 2 presents the multivariate robust linear regression model with receptive language as the dependent variable. The model explained 20.3% of the variance in receptive language, although the overall model did not reach statistical significance ($p = .426$). Nevertheless, the Habilitation Timing Index emerged as the only statistically significant predictor of receptive language, with higher index values – indicating a relatively higher intensity of early versus late habilitation – being associated with higher levels of receptive language.

The remaining predictors, including parental education, household income, household size, listening mode, and teamwork in habilitation, did not show statistically significant associations with the outcome.

The second part of Table 2 presents the results of the quantile regression for the median of receptive language. The quantile regression model explained 20.6% of outcome variability (pseudo $R^2 = 0.206$). In this model, the Habilitation Timing Index retained a positive direction of association with receptive language, with a value close to the threshold of statistical significance, while the remaining predictors showed no significant effects. This pattern suggests stability of the effect of habilitation timing at the centre of the outcome distribution.

The third part of Table 2 presents the sensitivity analysis in which early and late habilitation intensity were entered as independent predictors, without the additional covariates included in the previous models. Results showed that early habilitation intensity was significantly associated with receptive language level ($p = .031$), whereas late habilitation intensity did not show a significant association with the outcome. The significant unstandardised coefficient (B) for early habilitation intensity indicates that each additional weekly early habilitation session was associated with an increase of approximately 3.5 points on the composite receptive language measure used.

Tablica 2. Multivarijatni modeli povezivanja receptivnog jezika kod djece s umjetnim pužnicama prema obiteljskim i habilitacijskim varijablama / **Table 2.** Multivariate models of associations between receptive language in children with cochlear implants and family and habilitation variables.

Robust linear regression (ordinary least squares with HC3 robust standard errors) with receptive language as the dependent variable					
Coefficient of determination (R ²): 0.203					
Adjusted coefficient of determination: - 0.004					
Predictor	Unstandardised coefficient (B)	Robust standard error (HC3)	t value	Significance (p)	95% confidence interval (CI)
Habilitation Timing Index	2.29	0.97	2.36	0.018	0.39 – 4.18
Mother’s education	0.79	2.24	0.35	0.726	- 3.60 – 5.17
Father’s education	- 0.90	2.68	- 0.34	0.737	- 6.16 – 4.36
Household income	- 1.45	5.70	- 0.26	0.799	- 12.61 – 9.72
Household size	0.64	4.42	0.15	0.885	- 8.02 – 9.30
Unilateral/bilateral listening	8.23	8.01	1.04	0.304	- 7.46 – 23.92
Teamwork	8.08	7.13	1.15	0.257	- 5.90 – 22.05
Quantile regression (median receptive language)					
Pseudo coefficient of determination: 0.206					
Predictor	Regression coefficient (B)	Standard error (SE)	Significance (p)	95% confidence interval (CI)	
Habilitation Timing Index	2.40	1.29	0.073	- 0.24 – 5.05	
Mother’s education	- 1.18	2.32	0.615	- 5.94 – 3.58	
Father’s education	- 0.83	2.73	0.763	- 6.43 – 4.77	
Household income	- 3.60	5.97	0.551	- 15.84 – 8.64	
Household size	2.66	3.78	0.488	- 5.10 – 10.41	
Unilateral/bilateral listening	4.46	7.90	0.578	- 11.76 – 20.68	
Teamwork	7.83	7.54	0.308	- 7.63 – 23.30	
Sensitivity analysis: early and late habilitation as independent predictors (robust linear regression)					
Predictor	Unstandardised coefficient (B)	Robust standard error (HC3)	Significance (p)	95% confidence interval (CI)	
Early habilitation intensity	3.55	1.64	0.031	0.33 – 6.77	
Late habilitation intensity	- 0.94	1.69	0.577	- 4.26 – 2.37	

RASPRAVA

Cilj ovog istraživanja bio je ispitati ulogu organizacijskih obilježja habilitacije i nekih obiteljskih varijabli u objašnjenju varijabilnosti receptivnog jezika djece s umjetnom pužnicom u kontekstu u kojem su temeljni audiološki preduvjeti već u najvećoj mjeri osigurani. Dobiveni nalazi dosljedno upućuju da vremenski raspored habilitacije, osobito relativno veći intenzitet rane u odnosu na kasniju habilitaciju, ima značajnu ulogu u objašnjenju jezičnih ishoda, dok se kasnije povećanje intenziteta habilitacije ne pokazuje kao učinkovit mehanizam nadoknađivanja ranijeg manjka jezično-habilitacijskih iskustava.

DISCUSSION

The aim of this study was to examine the role of organisational characteristics of habilitation and selected family variables in explaining the variability of receptive language in children with cochlear implants, within a context in which basic audiological prerequisites have already largely been ensured. The findings consistently indicate that the timing of habilitation – particularly a relatively higher intensity of early versus later habilitation – plays a significant role in explaining language outcomes, whereas later increases in habilitation intensity do not appear to function as an effective compensatory mechanism for earlier deficits in language-habilitation experience.

Središnji nalaz rada – stabilna povezanost indeksa vremenskog rasporeda rehabilitacije s razinom receptivnog jezika – u skladu je s neurobiološkim i razvojnim modelima koji naglašavaju postojanje vremenski ograničenih razdoblja povećane plastičnosti za jezičnu obradu u ranoj dobi (Kral & Sharma, 2012; Kral i sur., 2016). Iako je u uzorku zabilježeno smanjenje intenziteta rehabilitacije u školskoj dobi, rezultati pokazuju da kasnije povećanje broja terapijskih termina ne kompenzira u potpunosti relativno niži intenzitet rane rehabilitacije. Ovaj obrazac upućuje na razliku između ranih i kasnijih jezičnih iskustava, pri čemu rana rehabilitacija djeluje kao temelj za kasniji razvoj, dok se čini da kasnija rehabilitacija ima više potporni, nego kompenzacijski učinak. U tom je kontekstu važno naglasiti da se značenje vremenskog rasporeda rehabilitacije jasnije očituje u multivarijantnim analizama koje istodobno uzimaju u obzir širi obiteljski i organizacijski kontekst, nego u pojedinačnim bivarijantnim usporedbama. Indeks vremenskog rasporeda rehabilitacije pritom ne opisuje samo njezinu količinu, već i način njezine raspodjele kroz razvojno osjetljiva razdoblja, što postaje vidljivo tek kada se promatra u odnosu na druge relevantne čimbenike. Zato činjenica da ukupni model nije bio statistički značajan ne umanjuje važnost promatranog nalaza, jer se u istraživanjima s manjim uzorcima stabilni pojedinačni učinci mogu prepoznati i u odsustvu značajnosti na razini cijelog modela (Babyak, 2004).

Ovaj je podatak konzistentan s longitudinalnim i retrospektivnim istraživanjima djece s umjetnim pužnicama koja pokazuju da rana, sustavna rehabilitacija – osobito kada obuhvaća ranu implantaciju i dulje trajanje rehabilitacijskog programa – vodi stabilnijim jezičnim razvojnim putanjama, uključujući dugoročne koristi za receptivni i ekspresivni jezik (Aaberg i sur., 2025; Wie i sur., 2020; Binos i sur., 2021; Boons i sur., 2012; Geers i sur., 2011; Moog & Geers, 2010). Noviji longitudinalni i (neuro)razvojni pregledi ukazuju da rana rehabilitacija – osobito u okviru osjetljivih razvojnih perioda za auditivnu plastičnost i jezik – daje trajnu prednost u jezičnim ishodima koje jednostavno nije moguće u potpunosti nadoknaditi samo povećanjem intenziteta rehabilitacije u ka-

The central finding of the study – a stable association between the Habilitation Timing Index and receptive language level – is consistent with neurobiological and developmental models that emphasise the existence of time-limited periods of heightened plasticity for language processing in early childhood (Kral & Sharma, 2012; Kral et al., 2016). Although a reduction in habilitation intensity during school age was observed in the sample, the results indicate that later increases in the number of therapy sessions do not fully compensate for a relatively lower intensity of early habilitation. This pattern suggests a qualitative distinction between early and later language experiences, whereby early habilitation functions as a foundation for subsequent development, while later habilitation appears to have a more supportive role, rather than a compensatory one. In this context, it is important to note that the significance of habilitation timing becomes more apparent in multivariate analyses that simultaneously consider the broader family and organisational context, rather than in isolated bivariate comparisons. The Habilitation Timing Index captures not only the quantity of habilitation, but also its distribution across developmentally sensitive periods, a feature that becomes evident only when examined in relation to other relevant factors. Consequently, the fact that the overall model did not reach statistical significance does not diminish the importance of the observed finding, as research with smaller samples can identify stable individual effects even in the absence of overall model significance (Babyak, 2004).

This finding is consistent with longitudinal and retrospective studies of children with cochlear implants showing that early, systematic habilitation – particularly when combined with early implantation and longer intervention programme durations – leads to more stable language developmental trajectories, including long-term benefits for both receptive and expressive language (Aaberg et al., 2025; Wie et al., 2020; Binos et al., 2021; Boons et al., 2012; Geers et al., 2011; Moog & Geers, 2010). More recent longitudinal and (neuro)developmental reviews indicate that early habilitation – especially within sensitive developmental periods for auditory plasticity and language – confers a lasting advantage in language outcomes that cannot be fully compensated for by simply increasing habilitation intensity later in de-

snijim razdobljima razvoja (Illg i sur., 2024; Jafari i sur., 2024; McGregor & Goldman, 2022; Yoshinaga-Itano i sur., 2020; Kral & Sharma, 2012).

Nalazi ovog istraživanja imaju izravne implikacije za organizaciju habilitacijskih usluga, a time i za donošenje organizacijskih odluka u sustavu javnog zdravstva i obrazovanja. U sustavima u kojima su audiološki aspekti skrbi visoko standardizirani, kao što je hrvatski sustav, prostor za dodatno unapređenje ishoda nalazi se prvenstveno u načinu organizacije i raspodjele habilitacijskih resursa. Pritom je svakako bitno naglasiti da je intenzitet habilitacije, koji se operacionalizira kao broj tjednih terapija, samo jedan, ali često najmjerljivi čimbenik koji može utjecati na jezične ishode djece s oštećenjem sluha (Wiggin i sur., 2021). Drugi habilitacijski, osobni i okolinski čimbenici, kao što su uključenost roditelja u ranu intervenciju, te kvaliteta habilitacije, te kognitivne karakteristike djeteta s umjetnom pužnicom svakako značajno doprinose varijabilitetu budućih jezičnih ishoda. U skladu s međunarodnim smjernicama (JCIH, 2019; WHO, 2021), rezultati podupiru modele rane intervencije koji daju prednost većem intenzitetu habilitacije u predškolskoj dobi. Umjesto reaktivnog pristupa, u kojem se intenzitet terapije povećava tek nakon što se uoče razvojni zaostaci, dobiveni nalazi idu u prilog preventivnom modelu pružanja usluga, usmjerenom na rano „ulaganje” u razvoj jezičnih temelja.

S gledišta organizacije sustava, takav pristup implicira potrebu za (McConkey Robbins, 2018; Robbins, 2005):

- ranijim i sustavnijim praćenjem napredovanja djece s umjetnom pužnicom,
- jasnim kriterijima za privremeno povećanje intenziteta habilitacije u ranoj dobi,
- fleksibilnijim planiranjem terapijskih kapaciteta i raspodjele stručnog kadra.

Ovi zaključci u skladu su s recentnim analizama sustava rane intervencije koje naglašavaju da kvaliteta, pravovremenost i vremenska struktura usluga imaju jednako važnu ulogu kao i sama dostupnost intervencije (Maluleke i sur., 2021; WHO, 2021; Ching i sur., 2018; Cupples i sur., 2018).

velopment (Illg et al., 2024; Jafari et al., 2024; McGregor & Goldman, 2022; Yoshinaga-Itano et al., 2020; Kral & Sharma, 2012).

The findings of the present study have direct implications for the organisation of habilitation services and, consequently, for organisational decision-making within public health and education systems. In systems where audiological aspects of care are highly standardised, such as the Croatian system, the main opportunity for further outcome improvement lies in the organisation and allocation of habilitation resources. It is important to emphasise that habilitation intensity, operationalised as the number of weekly therapy sessions, represents only one, albeit frequently measured, factor that may influence language outcomes in children with hearing impairment (Wiggin et al., 2021). Other habilitation-related, individual, and environmental factors, such as parental involvement in early intervention, the quality of habilitation, and the cognitive characteristics of children with cochlear implants, also make a substantial contribution to the variability of subsequent language outcomes. In line with international guidelines (JCIH, 2019; World Health Organization [WHO], 2021), the results support early intervention models that prioritise higher habilitation intensity during preschool age. Rather than a reactive approach in which therapy intensity is increased only after developmental delays become apparent, the findings favour a preventive service delivery model focused on early “investment” in the development of language foundations.

From a systems organisation perspective, such an approach implies the need for (McConkey Robbins, 2018; Robbins, 2005):

- earlier and more systematic monitoring of progress in children with cochlear implants,
- clear criteria for temporary increases in habilitation intensity in early childhood,
- more flexible planning of therapy capacity and allocation of professional staff.

These conclusions are consistent with recent analyses of early intervention systems emphasising that the quality, timeliness, and temporal structure of services are as important as the availability of

Za razliku od dinamike rehabilitacije, obiteljski resursi i organizacijski čimbenici poput tinskog rada i uni-/binauralnog slušanja nisu se pokazali kao značajni prediktori u multivarijatnim modelima. Ovaj nalaz ne proturječi postojećoj literaturi, već ga treba tumačiti u kontekstu relativno homogenog uzorka i ograničene varijabilnosti pojedinih obilježja. Empirijska istraživanja pokazuju da obiteljsko okruženje i kvaliteta roditeljskog jezičnog inputa značajno doprinose funkcionalnim jezičnim ishodima djece s umjetnom pužnicom (Quittner i sur., 2013); istodobno, nalazi longitudinalnih istraživanja velikih kohorti upućuju na to da se u sustavima s ranom i standardiziranom intervencijom varijabilnost ishoda povezanih s okolišnim čimbenicima može smanjiti (Ching i sur., 2018). Slično tome, izostanak značajnog učinka tinskog rada vjerojatno odražava činjenicu da u uzorku nije bilo djece s kontinuiranim, sustavno organiziranim tinskim pristupom (barem prema roditeljskim navodima), što ograničava mogućnost procjene njegovog punog potencijala. Također, moguće je da je timska suradnja postojala na razini sustavne multidisciplinarnе koordinacije planiranja usluga te je uočeno da timski rad različitih profila stručnjaka u rehabilitaciji nije bio nužan kod svih ispitanika. Stoga, postoji mogućnost da pitanja o timskom radu upućena roditeljima nisu bila dovoljno osjetljiva kako bi obuhvatila kompleksnost multidisciplinarnog pristupa ranoj intervenciji djece s umjetnom pužnicom iz roditeljske perspektive.

Dobiveni rezultati izravno se nadovezuju na prethodno domaće istraživanje receptivnog jezika djece s umjetnom pužnicom (Šimić, 2025), u kojem je potvrđena ključna uloga audioloških varijabli. Ovaj rad proširuje te nalaze pružajući dodatnu razinu objašnjenja, usmjerenu na promjenjive aspekte sustava rehabilitacije. Time se doprinosi pomaku s pitanja „što predviđa ishode” prema pitanju „kako organizacija usluga može unaprijediti ishode unutar postojećih audioloških okvira”.

Što se tiče ograničenja ovog istraživanja, važno je napomenuti da relativno mali uzorak ($N = 35$) ograničava statističku snagu, osobito pri istovremenom ispitivanju više prediktora. Posljedično, neke potencijalno značajne povezanosti – osobito

the intervention itself (Maluleke et al., 2021; WHO, 2021; Ching et al., 2018; Cupples et al., 2018).

In contrast to habilitation dynamics, family resources and organisational factors such as teamwork and unilateral/binaural listening did not emerge as significant predictors in the multivariate models. This finding does not contradict the existing literature, but it should be interpreted in the context of the relatively homogeneous sample and limited variability in certain characteristics. Empirical research shows that the family environment and the quality of parental language input make a substantial contribution to functional language outcomes in children with cochlear implants (Quittner et al., 2013). At the same time, findings from large-cohort longitudinal studies suggest that in systems with early and standardised intervention, variability in outcomes associated with environmental factors may be reduced (Ching et al., 2018). Similarly, the absence of a significant teamwork effect likely reflects the fact that no children in the sample received continuous, systematically organised team-based interventions (at least according to parental reports), which limits the ability to assess its full potential. It is also possible that team collaboration existed at the level of systematic multidisciplinary coordination in service planning, and it was observed that not all participants required the inclusion of different professionals as team members in habilitation interventions. Therefore, it is possible that the questions on teamwork posed to parents were not sufficiently sensitive to capture the complexity of a multidisciplinary approach to early intervention in children with cochlear implants from a parental perspective.

The results of the present study directly build on earlier national research on receptive language in children with cochlear implants (Šimić, 2025), which confirmed the key role of audiological variables. Our study extends those findings by providing an additional explanatory layer focused on modifiable aspects of the habilitation system. In doing so, it contributes to a shift from asking the question “what predicts outcomes” to the question “how can service organisations improve outcomes within already established audiological frameworks”.

one koje se odnose na obiteljske i organizacijske varijable – možda nisu dosegnule statističku značajnost. Stoga rezultate treba tumačiti s oprezom te se preporučuje njihovo daljnje istraživanje u budućim studijama s većim uzorcima.

Iako je u ovom radu veličina uzorka ograničena, dosljednost nalaza kroz korelacijske analize, robusne regresijske modele i kvantilnu regresiju upućuje na stabilnost uočenog obrasca. Također, unatoč tome što je uzorak ispitanika obuhvaćao relativno širok dobní raspon, potencijalna varijabilnost povezana s dobi kontrolirana je primjenom kompozitnog indeksa dobno standardiziranih jezičnih mjera. Budući da su ovi rezultati normirani prema dobi, omogućuju usporedbe djece različite kronološke dobi jer odražavaju izvedbu u odnosu na razvojna očekivanja. Buduća istraživanja s većim uzorcima i longitudinalnim dizajnom mogla bi dodatno razjasniti optimalne pragove intenziteta rane habilitacije te ispitati dugoročne učinke različitih organizacijskih modela. No rezultati ovog rada ipak pružaju empirijski utemeljenu potporu politikama i praksama koje naglašavaju važnost rane, intenzivne i strateški organizirane habilitacije kao ključne sastavnice sustava rane intervencije za djecu s umjetnom pužnicom.

Nadalje, veličina učinka rane habilitacije u ovom istraživanju izražena je u bodovima kompozitne mjere receptivnog jezika, a ne u standardiziranim razvojnim kvocijentima, što može ograničiti izravnu usporedivost dobivenih učinaka s nalazima studija koje upotrebljavaju normirane ili z-standardizirane mjere jezika. Dodatno ograničenje odnosi se na način operacionalizacije intenziteta habilitacije, koji je u ovom istraživanju kvantificiran isključivo brojem tjednih termina. Takva mjera ne zahvaća kvalitativne aspekte terapije, poput kompetencija pružatelja usluga, sadržaja i ciljeva intervencije te stupnja obiteljskog uključivanja, koji isto mogu imati utjecaj na jezične ishode. Stoga dobivene nalaze treba tumačiti kao odraz kvantitativne raspodjele habilitacijskih resursa kroz vrijeme, a ne kao procjenu kvalitete same intervencije. S tim na umu, ranu habilitaciju ne treba tumačiti isključivo kao veći broj stručnih terapijskih termina, nego prvenstveno kao razvojno osjetljivo razdoblje u kojem je ključno inten-

As for limitations of this study, it is noteworthy to mention that relatively small sample size ($N = 35$) limits statistical power, particularly for evaluating multiple predictors simultaneously. As a result, some potentially meaningful associations - especially those related to family and organisational variables - may not have reached statistical significance. The findings should, therefore, be interpreted with caution warranting further exploration of these associations in future research with larger samples.

Although the sample size in this study is limited, the consistency of findings across correlational analyses, robust regression models, and quantile regression suggests stability of the observed pattern. Also, despite the fact that the participant sample encompassed a relatively wide age range, potential age-related variability was addressed through the use of a composite of age-standardised language measures. As these scores are norm-referenced, they enable comparisons across children of different ages by reflecting performance relative to developmental expectations, thereby reducing the confounding influence of chronological age. Future studies with larger samples and longitudinal designs could further clarify optimal thresholds for early habilitation intensity and examine the long-term effects of different organisational models. Nevertheless, the present findings provide empirically grounded support for policies and practices emphasising early, intensive, and strategically organised habilitation as a core component of early intervention systems for children with cochlear implants.

Furthermore, the effect size of early habilitation in this study is expressed in points on a composite receptive language measure, rather than in standardised developmental quotients, which may limit direct comparisons with studies using norm-referenced or z-standardised language measures. An additional limitation relates to the operationalisation of habilitation intensity, which in the present study was quantified solely by the number of weekly sessions. Such a measure does not capture qualitative aspects of therapy, including provider competencies, intervention content and goals, or the degree of family involvement, all of which may also influence language outcomes. Accordingly, the pres-

zivno raditi s obiteljima da bi se osnažile za svakodnevno stvaranje bogatog jezičnog okruženja. Naime, s obzirom na razvojne zakonitosti ranog usvajanja jezika, formalna terapija, čak i kada je intenzivna, ne može u potpunosti nadomjestiti količinu i raznolikost jezičnog inputa koji se ostvaruje kroz svakodnevne obiteljske interakcije, a koje omogućuju kontinuiranu stimulaciju, generalizaciju i funkcionalnu uporabu jezika (Szarkowski i sur., 2024).

S obzirom na izneseno, nalaz da kasnije povećanje intenziteta rehabilitacije ne pokazuje kompenzacijski učinak može se djelomično tumačiti kao posljedica propuštenih prilika za jezično učenje u razdoblju najveće neuroplastičnosti. Naravno, ovakva interpretacija nije isključiva i jedina relevantna, s obzirom na to da je poznato da cijeli niz osobnih i okolinskih varijabli utječe na kasnije jezične ishode. Ipak, razvojna neuroznanost ukazuje da rana dječja dob predstavlja razdoblje povećane osjetljivosti za jezični input, čije su dugoročne posljedice za razvoj jezičnih mreža teško u potpunosti nadoknadive u kasnijim fazama razvoja (Romeo i sur., 2021; Hall, 2017; Kral & Sharma, 2012). Iako kasnija rehabilitacija može imati potporni učinak na pojedine jezične vještine, ona ne može u potpunosti zamijeniti iskustvo kontinuirane, bogate izloženosti jeziku u najranijoj dobi.

S aspekta organizacije rehabilitacijskih usluga, dobiveni rezultati podupiru modele u kojima se rana intervencija jasno definira kao obiteljski usmjerena, roditelji se prepoznaju kao primarni nositelji svakodnevne rehabilitacije, a stručni rad strukturira oko savjetovanja, praćenja i osnaživanja obitelji, uz smanjeno oslanjanje na kasnije „nadoknađivanje“ terapijom.

ZAKLJUČAK

Nalazi ovog istraživanja podupiru usmjeravanje rehabilitacijskih politika prema ranoj, obiteljski usmjerenoj intervenciji, u kojoj se naglasak stavlja na pravodobno savjetovanje roditelja i stvaranje bogatog jezičnog okruženja u najranijoj dobi. Takav pristup ne samo da je razvojno utemeljen, nego ima i jasne implikacije za održivost sustava, jer rano ulaganje u kvalitetnu rehabilitaciju smanju-

ent findings should be interpreted as reflecting the quantitative distribution of habilitation resources over time rather than the quality of the intervention itself. With this in mind, early habilitation should not be understood exclusively as a higher number of professional therapy sessions, but primarily as a developmentally sensitive period during which intensive work with families is essential in order to empower them to create rich everyday language environments. Given the developmental principles of early language acquisition, formal therapy – even when intensive – cannot fully replace the quantity and diversity of linguistic input provided through everyday family interactions, which enable continuous stimulation, generalisation, and functional language use (Szarkowski et al., 2024).

In light of these considerations, the finding that later increases in habilitation intensity do not have a compensatory effect can be partially interpreted as a consequence of missed opportunities for language learning during periods of maximal neuroplasticity. Naturally, such an interpretation is not exclusive or the only relevant one, given that a range of individual and environmental variables are known to influence later language outcomes. Developmental neuroscience indicates that early childhood represents a period of heightened sensitivity to language input, with long-term consequences for the development of language networks that are difficult to fully compensate for at later developmental stages (Romeo et al., 2021; Hall, 2017; Kral & Sharma, 2012). Although later habilitation may have a supportive effect on specific language skills, it cannot fully replace the continuous, rich language exposure in the earliest years of life.

This interpretation is consistent with international guidelines and empirical findings emphasizing that early intervention outcomes depend primarily on the quality of parental language input and family interaction, rather than exclusively on the frequency of professional sessions (Yoshinaga-Itano et al., 2021; JCIH, 2019). From the perspective of habilitation service organisation, the results support models in which early intervention is clearly defined as family-centred, parents are recognised as the primary agents of everyday habilitation, and professional work is structured around counselling, monitoring, and family empowerment, with

je potrebu za kasnijim intenzivnim, dugotrajnim i skupljim oblicima intervencije. Rezultati upućuju da kasnije povećanje intenziteta habilitacije ne djeluje kao učinkovit kompenzacijski mehanizam, što dodatno naglašava važnost optimalnog vremenskog rasporeda habilitacije. U tom smislu, reorganizacija usluga prema modelima koji favoriziraju ranu, kontinuiranu i obiteljski usmjerenu habilitaciju predstavlja racionalan razvojni i ekonomski izbor za sustave rane intervencije. Nalazi dobiveni ovim radom dodatno potvrđuju da optimizacija ishoda kod djece s umjetnom pužnicom u suvremenim sustavima skrbi sve više ovisi o strateškom upravljanju vremenom i strukturom intervencije, a ne isključivo o povećanju intenziteta habilitacije.

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Izjava o dostupnosti podataka: podaci su dostupni na zahtjev.

reduced reliance on later therapeutic “catch-up” interventions.

CONCLUSION

The findings of this study support the orientation of habilitation policies towards early, family-centred interventions, with an emphasis on timely parental counselling and the creation of rich language environments in early childhood. Such an approach is not only developmentally grounded, but also has clear implications for system sustainability, as early investment in high-quality habilitation reduces the need for later intensive, prolonged, and more costly forms of intervention. The results indicate that later increases in habilitation intensity do not function as an effective compensatory mechanism, further underscoring the importance of optimal habilitation timing. In this sense, reorganising services towards models that prioritise early, continuous, and family-centred habilitation represents a rational developmental and economic choice for early intervention systems.

The findings of this study further confirm that optimisation of outcomes for children with cochlear implants in contemporary care systems increasingly depends on the strategic management of the timing and structure of intervention, rather than solely on increasing habilitation intensity.

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LITERATURA

- Aaberg, K., Friis, I. J., Slyng, C. B., Britze, A., & Devantier, L. (2025). Differences in language outcomes after cochlear implantation in children: Exploring the impact of auditory verbal therapy duration (0, 1, or 3 years). *International Journal of Pediatric Otorhinolaryngology*, 194, 112371. <https://doi.org/10.1016/j.ijporl.2025.112371>
- Almomani, F., Al-Momani, M. O., Garadat, S., Alquadah, S., Kassab, M., Hamadneh, S., Rauterkus, G., & Gans, R. (2021). Cognitive functioning in deaf children using cochlear implants. *BMC Pediatrics*, 21, 71. <https://doi.org/10.21203/rs.3.rs-43887/v1>
- Alshahrani, N. A., AlSufyani, N. H., Aldawish, R. A., Alrashdi, A. K., Moafa, R. H., Alqahtani, M. A. N., Aljabri, A. M., Alawad, F. H., & Alarfaj, A. A. (2024). A systematic review and meta-analysis comparing the effect of unilateral versus bilateral cochlear implantation in hearing impairment. *Journal of Advanced Trends in Medical Research*, 1(2), 363–368. https://doi.org/10.4103/ATMR.ATMR_156_24
- Babyak, M. A. (2004). What you see may not be what you get: A brief, nontechnical introduction to overfitting in regression-type models. *Psychosomatic Medicine*, 66(3), 411–421. <https://doi.org/10.1097/01.psy.0000127692.23278.a9>
- Binos, P., Nirgianaki, E., & Psillas, G. (2021). How effective is auditory-verbal therapy (AVT) for building language development of children with cochlear implants? A systematic review. *Life*, 11(3), 239. <https://doi.org/10.3390/life11030239>
- Bishop, D. V. M., Kuvač Kraljević, J., Hržica, G., Kovačević, M., & Kologranić Belić, L. (2014). *Test razumijevanja gramatike TROG-2:HR*. Naklada Slap.
- Boons, T., Brokx, J. P. L., Dhooge, I., Frijns, J. H. M., Peeraer, L., Vermeulen, A., Wouters, J., & Van Wieringen, A. (2012). Predictors of spoken language development following pediatric cochlear implantation. *Ear and Hearing*, 33(5), 617–639. <https://doi.org/10.1097/AUD.0b013e3182503e47>
- Busch, T., Brinckmann, E. I., Braeken, J., & Wie, O. B. (2022). Receptive vocabulary of children with bilateral cochlear implants from 3 to 16 years of age. *Ear and Hearing*, 43(6), 1866–1880. <https://doi.org/10.1097/AUD.0000000000001220>
- Ching, T. Y. C., Dillon, H., Leigh, G., & Cupples, L. (2018). Learning from the longitudinal outcomes of children with hearing impairment (LOCHI) study: Summary of 5-year findings and implications. *International Journal of Audiology*, 57(Suppl. 2), S105–S111. <https://doi.org/10.1080/14992027.2017.1385865>
- Chweya, C. M., May, M. M., DeJong, M. D., Baas, B. S., Lohse, C. M., Driscoll, C. L. W., & Carlson, M. L. (2021). Language and audiological outcomes among infants implanted before 9 and 12 months of age versus older children. *Otology & Neurotology*, 42(5), 686–693. <https://doi.org/10.1097/MAO.0000000000003011>
- Cupples, L., Ching, T. Y. C., Button, L., Leigh, G., Marnane, V., Whitfield, J., & Duncan, J. (2018). Language and speech outcomes of children with hearing loss and additional disabilities. *International Journal of Audiology*, 57(Suppl. 2), S93–S104. <https://doi.org/10.1080/14992027.2017.1424936>
- Davidson, L. S., Geers, A. E., & Nicholas, J. G. (2014). The effects of audibility and novel word learning ability on vocabulary level in children with cochlear implants. *Cochlear Implants International*, 15(4), 211–221. <https://doi.org/10.1179/1754762813Y.00000000050>
- Farag, H. M., Osman, D. M., & Safwat, R. F. (2024). Language profile of children with cochlear implants: Comparative study of age at implantation and duration of rehabilitation. *European Archives of Oto-Rhino-Laryngology*, 281, 4393–4399. <https://doi.org/10.1007/s00405-024-08689-8>
- Geers, A. E., & Nicholas, J. G. (2013). Enduring advantages of early cochlear implantation for spoken language development. *Journal of Speech, Language, and Hearing Research*, 56(2), 643–655. [https://doi.org/10.1044/1092-4388\(2012/11-0347\)](https://doi.org/10.1044/1092-4388(2012/11-0347))
- Geers, A. E., Tobey, E. A., Moog, J. S., & Brenner, C. (2011). Long-term outcomes of cochlear implantation in early childhood. *Ear and Hearing*, 32(1 Suppl), 2S–12S. <https://doi.org/10.1097/AUD.0b013e3181fa41fd>

- Hall, M. L. (2017). Early language experience and the brain: The role of sensitive periods. *Language Learning and Development*, 13(3), 232–247. <https://doi.org/10.1080/15475441.2016.1267847>
- Holt, R. F., Beer, J., Kronenberger, W. G., Pisoni, D. B., & Lalonde, K. (2012). Contribution of family environment to pediatric cochlear implant users' speech and language outcomes. *Journal of Speech, Language, and Hearing Research*, 55(3), 848–864. [https://doi.org/10.1044/1092-4388\(2011/11-0143\)](https://doi.org/10.1044/1092-4388(2011/11-0143))
- Holzinger, D., Dall, M., Sanduvete-Chaves, S., Saldaña, D., Chacón-Moscoso, S., & Fellingner, J. (2020). The impact of family environment on language development of children with cochlear implants. *Ear and Hearing*, 41(5), 1077–1091. <https://doi.org/10.1097/AUD.0000000000000852>
- Holzinger, D., Hofer, J., Dall, M., & Fellingner, J. (2022). Multidimensional family-centred early intervention in children with hearing loss. *Journal of Clinical Medicine*, 11(6), 1548. <https://doi.org/10.3390/jcm11061548>
- Illg, A., Adams, D., Lesinski-Schiedat, A., Lenarz, T., & Kral, A. (2024). Variability in receptive language development following bilateral cochlear implantation. *Journal of Speech, Language, and Hearing Research*, 67(2), 618–632. https://doi.org/10.1044/2023_JSLHR-23-00297
- Jafari, Z., Kolb, B. E., & Mohajerani, M. H. (2024). Altered resting-state networks in early deafness and implications for cochlear implantation outcomes. *European Journal of Neuroscience*, 59(10), 2596–2615. <https://doi.org/10.1111/ejn.16295>
- Joint Committee on Infant Hearing. (2019). Year 2019 position statement: Principles and guidelines for early hearing detection and intervention programs. *Journal of Early Hearing Detection and Intervention*, 4(2), 1–44. <https://doi.org/10.15142/fptk-b748>
- Kovačević, M., Padovan, N., Hržica, G., Kuvač Kraljević, J., Mustapić, M., Dobravac, G., & Palmović, M. (2009). *Peabody slikovni test rječnika PPVT-III-HR*. Naklada Slap.
- Kral, A., & Sharma, A. (2012). Developmental neuroplasticity after cochlear implantation. *Trends in Neurosciences*, 35(2), 111–122. <https://doi.org/10.1016/j.tins.2011.09.004>
- Kral, A., Kronenberger, W. G., Pisoni, D. B., & O'Donoghue, G. M. (2016). Neurocognitive factors in sensory restoration of early deafness. *The Lancet Neurology*, 15(6), 610–621. [https://doi.org/10.1016/S1474-4422\(16\)00034-X](https://doi.org/10.1016/S1474-4422(16)00034-X)
- Lee, C., Son, S. E., Moon, I. J., Chung, W.-H., Cho, Y.-S., Hong, S. H., & Cho, Y. S. (2025). The role of socioeconomic factors and third-party support in language development for children with cochlear implants. *Scientific Reports*, 15, 8750. <https://doi.org/10.1038/s41598-025-90073-5>
- Maluleke, N. P., Chiwutsi, R., & Khoza-Shangase, K. (2021). Family-centred early hearing detection and intervention. In K. Khoza-Shangase & A. Kanji (Eds.), *Early detection and intervention in audiology: An African perspective* (pp. 196–218). Wits University Press.
- Marn, B. (2005). Probir na oštećenje sluha u novorođenčadi – postupnik i prvi rezultati novog preventivnog programa u Hrvatskoj. *Zdravlje majki i djece*, 1(2), 1–8. <https://hrcak.srce.hr/file/430762>
- Marn, B., & Kekić, B. (2016). Praćenje ishoda sveobuhvatnog probira novorođenčadi na oštećenje sluha u Hrvatskoj od 2003. do 2014. godine. *Paediatrica Croatica*, 60(1).
- Robbins, A. M. (2005). *Clinical red flags for slow progress in children with cochlear implants* (Issue 1, pp. 1–8). Advanced Bionics.
- McConkey Robbins, A. (2018). Twelve guiding premises of pediatric cochlear implant habilitation. *World Journal of Otorhinolaryngology – Head and Neck Surgery*, 3(4), 235–239. <https://doi.org/10.1016/j.wjorl.2017.12.009>
- McGregor, S., & Goldman, R. D. (2022). Language outcomes after cochlear implant. *Canadian Family Physician*, 68(10), 737–738. <https://doi.org/10.46747/cfp.6810737>
- Moog, J. S., & Geers, A. E. (2010). Early educational placement and later language outcomes for children with cochlear implants. *Otology & Neurotology*, 31, 1315–1319. <https://doi.org/10.1097/MAO.0b013e3181e2a049>

- Mueller, L., Adkins, D., Kao, A., Munyemana, M., Kallogjeri, D., & Lieu, J. E. (2025). Social determinants of health and language and academic outcomes in pediatric cochlear implantation. *JAMA Otolaryngology–Head & Neck Surgery*, 151(1), 29–38. <https://doi.org/10.1001/jamaoto.2024.3564>
- Nicholas, J. G., & Geers, A. E. (2013). Spoken language benefits of extending cochlear implant candidacy below 12 months of age. *Otology & Neurotology*, 34(3), 532–538. <https://doi.org/10.1097/MAO.0b013e3182814d2c>
- Nittrouer, S. (2024). How hearing loss and cochlear implantation affect verbal working memory. *Journal of Speech, Language, and Hearing Research*, 67(6), 1850–1867. https://doi.org/10.1044/2024_JSLHR-23-00446
- Percy-Smith, L., Busch, G., Sandahl, M., Nissen, L., Josvassen, J. L., Lange, T., Rusch, E., & Cayé-Thomasen, P. (2013). Language understanding and vocabulary of early cochlear implanted children. *International Journal of Pediatric Otorhinolaryngology*, 77(2), 184–188. <https://doi.org/10.1016/j.ijporl.2012.10.014>
- Quittner, A. L., Cruz, I., Barker, D. H., Tobey, E., Eisenberg, L. S., & Niparko, J. K. (2013). Effects of maternal sensitivity and linguistic stimulation on cochlear implant users' language development. *Journal of Pediatrics*, 162(2), 343–348. <https://doi.org/10.1016/j.jpeds.2012.08.003>
- Romeo, R. R., Leonard, J. A., Robinson, S. T., West, M. R., Mackey, A. P., Rowe, M. L., & Gabrieli, J. D. E. (2021). Beyond the 30-million-word gap. *Journal of Neuroscience*, 41(9), 2020–2030. <https://doi.org/10.1523/JNEUROSCI.2568-20.2021>
- Szarkowski, A., Moeller, M. P., Gale, E., Smith, T., Birdsey, B. C., Moodie, S. T. F., Carr, G., Stredler-Brown, A., Yoshinaga-Itano, C., & Holzinger, D. (2024). Family-centered early intervention deaf/hard of hearing: Support principles. *Journal of Deaf Studies and Deaf Education*, 29(Suppl. 1), SI64–SI85. <https://doi.org/10.1093/deafed/enad039>
- Šimić, I. (2025). *Prediktori receptivnih jezičnih vještina djece s kohlearnim implantatom* (Doktorska disertacija). Sveučilište u Zagrebu, Edukacijsko-rehabilitacijski fakultet.
- Wie, O. B., von Koss Torkildsen, J., Schaubert, S., Busch, T., & Litovsky, R. Y. (2020). Long-term language development in children with early simultaneous bilateral cochlear implants. *Ear and Hearing*, 41(5), 1294–1305. <https://doi.org/10.1097/AUD.0000000000000851>
- Wiggin, M., Sedey, A. L., Yoshinaga-Itano, C., Mason, C. A., Gaffney, M., & Chung, W. (2021). Frequency of early intervention sessions and vocabulary skills in children with hearing loss. *Journal of Clinical Medicine*, 10(21), 5025. <https://doi.org/10.3390/jcm10215025>
- World Health Organization. (2021). *World report on hearing*. <https://www.who.int/publications/i/item/9789240020481>
- Yoshinaga-Itano, C. (2014). Principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Journal of Deaf Studies and Deaf Education*, 19(2), 143–175. <https://doi.org/10.1093/deafed/ent043>
- Yoshinaga-Itano, C., Sedey, A. L., Mason, C. A., Wiggin, M., & Chung, W. (2020). Early intervention, parent talk, and pragmatic language in children with hearing loss. *Pediatrics*, 146(Supplement3), S270–S277. <https://doi.org/10.1542/peds.2020-0242F>
- Yoshinaga-Itano, C., Sedey, A. L., Wiggin, M., & Mason, C. A. (2018). Language outcomes improved through early hearing detection and earlier cochlear implantation. *Otology & Neurotology*, 39(10), 1256–1263. <https://doi.org/10.1097/MAO.0000000000001976>