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Lexical Preferences in Greek-Learning Children with Cochlear Implants: A Retrospective Analysis of Sonority-Based and Prosodic Lexical Structures

--Manuscript Draft--

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Keywords:	Sonority; Cochlear implants; children; Greek-speaking; lexical development; CYLEX; word preferences
Abstract:	Sonority and its language-universal sonority-sequencing principle (SSP) define an important dimension of phonological grammar which aids in the segmentation of words into syllables (Clements, 1990). Studies have yielded contradictory findings on sonority and SSP phonotactics in lexical perception of speech by children with cochlear implants (CI) (Hamza et al., 2018; Hamza et al., 2020). The present study aimed to investigate whether sonority-based and prosodic word aspects guide the lexical preferences of children with CI in comparison with two groups of normally-hearing ones, who were matched based on chronological and hearing age to children with CI, respectively. A retrospective analysis of real words was undertaken, obtained from a-CYLEX, a parent-reporting tool of receptive and expressive vocabulary which was completed for 17 children with CI, aged from 21-71 months (Oktapoti et al., 2016). The data for each word was re-coded into sonorous-loaded,nonsonorous-loaded and neutral words, and also into five word categories based on number of syllables. Metrical values were obtained following normalization of data. Results indicated similar trends in sonority and prosodic word categories based on normalized scores, in children with CI and NH peers, for both receptive and expressive vocabulary. Yet, differences in vocabulary size among the three groups were noted.

Letter of Response to the Reviewers

manuscript : JOPR-D-22-00310
Title : Lexical Preferences in Greek-Learning Children with Cochlear Implants: A Retrospective Analysis of Sonority-Based and Prosodic Lexical Structures

The authors would like to thank the Reviewer for their positive comments but most importantly for their insightful and thorough work and detailed revisions suggested for our manuscript. Every effort was made to follow the comments and make the suggested revisions in order to improve the manuscript. Below we provide a response on a comment-to comment basis.

Also, all changes in the manuscript are highlighted with yellow.

Comment from editorial team:
"When reporting age (as 4 years and 6 months) throughout the manuscript, check the punctuation used (e.g., 4;6) as it is a bit confusing for the reader....Advise the author to follow the APA publication manual in this regard"

Response: We could not find anything relevant to change the notation of age. However, we provided an explanation at the first time the notation was used. See P. 3, L. 8.

Re
Comments from Reviewer #1:
"The manuscript "Lexical Preferences in Greek-Learning Children with Cochlear Implants: A Retrospective Analysis of Sonority-Based and Prosodic Lexical Structures" presents very interesting work that has the potential to be a valuable contribution to the research literature. Studies of clinical populations with speech disorders in Greek are much needed. This research aims to investigate the trajectory of lexical acquisition of Greek children with CI by looking at the effect of well-founded phonological complexity indices, such as sonority and word length characteristics. Overall, it is evident that the authors have put significant effort to this study in terms of both its theoretical foundation and its methodological approach. Still, I think that some changes are needed, as described in detail below.

1) Research questions should be reorganized in more clear, consistent and less repetitive manner.

Response: Reorganized and rephrased the research questions and avoided repetitiveness.

2) Regarding the sonority categorization of the data, certain issues are at play: It will help if you give some examples of words categorized as sonorous, non-sonorous loaded and neutral. Also, you need to show the distribution of the CYLEX words in terms of the sonority groups overall and across the semantic categories. More

importantly, you should explain how you selected this ratio. As a result you have a small number of S items and a great number of neutral items (that are not included in the analysis) which weakens the significance of your findings. Wouldn't a small ratio be more functional? Please explain. Also, I was wondering whether the inclusion of the neutral words in the results would reveal any patterns.

Response: We provided examples of sonorous, non-sonorous loaded and neutral words and created Table 3, to show the distribution of the CYLEX words in terms of the sonority groups overall, in raw numbers and in percentages. Data on semantic categories was not presented as this analysis was not made in the paper at all. Based on the fact that the CYLEX items corresponding to the two sonority-related categories were vastly different, we totally agree with the Reviewer's important comment that the results of the a) measure may be misleading. Thus, we have deleted the analysis on the a) measure and only kept the b) measure, which yields a smaller ratio and which effectively addresses our research questions. This led to changes in the statistical design, so we performed an ANOVA instead of a MANOVA. Moreover, the design of analysis is more orthogonal for both variables examined in the study, i.e. sonority-related categories and word length categories.

As for neutral words, this analysis was not part of the study. To address the comment, in this version, we have performed additional statistical analysis on the total words which revealed some differences between the total scores and the scores obtained for the sonority-related categories. In the discussion we incorporated some comments regarding these findings and the issue of neutral words by comparing the total scores to the scores obtained from the sonority-related categories. We thank the reviewer for this comment.

3) The participant groupings are presented in a somewhat confusing manner throughout the paper. Try be more clear and consistent. Please provide additional information for the control groups. Groups. The CI-6 group is part of the main CI group. How the two experimental groups differ in performance? Were they comparable?

Response: We have incorporated more information about the participants in Methods. Additional information on gender and background information (residence region) was provided for the NH group. Also, we tried to improve clarity by describing the groups in the Methods, stressing out that CI_6 is part of CI, and keeping consistent naming throughout the text, subtitles, tables and figures.

As for the two experimental groups, one is part of the other. To address the comment we provided a description of how they compare via descriptive statistics.

4) Results would be more clear and easy to follow if you were more consistent and clear in terms of the quantitative measures used. You tend to change the terminology

and you do not apply the same type of analysis for sonority and word length. Also, part of the results are very repetitive.

Response: We substantially revised the text in the results section, made consistent use of terminology and applied a similar analysis for sonority and word length. We have also reduced the repetitiveness.

5) The discussion section is comprehensive and thorough. However, and most importantly, the fact that you analyze phonological aspects of acquisition without actual production data is a major weakness that needs to be discussed and justified clearly and in detail.

Response: We have revised text in the relevant sections to emphasize this limitation. See last paragraphs on P.22 and P. 24.

OTHER COMMENTS
P.3, L. 15: "word-learning abilities": It is not clear what this means, please explain in more detail

Response: Replaced term with “vocabulary growth, see P.3, L. 6.
P.3, L. 27: "A variety…awareness": Please rephrase, also explain the initials EOWPVT.

Response: Rephrased see P.3, L. 11-13. Explained initials and inserted the reference for this test, P.3 L.11.
P.3, L.48: "(Fagan, 2010;)": Delete semicolon.

Response: Done
P.3, L.51: "…younger children with NH whose….": Please rephrase from this point to the end of the sentence

Response: Revised, see P. 3 l. 22-24.
P.3, L.55: "In a case study….": The rate of acquisition reported is based on the period with CI, after age 3, is the period of the hearing aid use included?

Response: We assume it is as it is a case study all information is taken into account.
P.4, L.1: "fell below": Significantly below, please add

Response: Done, see P.4, L.3.
P.4, L.10: "which impact": Which impacts

Response: Done, see P.4, L.6.
P.4, L.29: "8; 6": Delete space

Response: Done, see P.4, L.15
P.4, L.49: "…due to temporal envelop…": I think a "the" is needed here.

Response: Done, see P.4, L.24
P.5, L.19: "…some of which are universal, unmarked and facilitate word learning.": Rephrase

Response: Done, see P.5, L.11

P.5, L.43: "…based on their degree…": Use "the" instead of "their"

Response: Done, see P.5, L.21
P.5, L.45: Please delete "that is" and put the items in parenthesis instead

Response: Done, see P.5, L.33
P.6, L.35: "Very few studies…and reported…": Please rephrase

Response: Done, see P.6, L.21.
P.7, L.21: "In Hamza et al. (2018)…": Please rephrase sentence

Response: Done, see P.7, L.15-20.

P.7, L.54: "…that highly audible segments…": You mean thus?

Response: No, corrected to 'that is'. P. 8, L. 5.
P.8, L.38: "…which lie in their…": Rephrase

Response: Rephrased, see P. 8, L. 23.
P.8, L.52: "…since children": You mean children with CI? Please clarify

Response: Yes, clarified, see P.9, L. 3.
P.9, L.12: "(Parizi et al., 2013)": I think it is not included in the ref list

Response: Inserted reference, see P. 30.
P.10, L.5: "…15 to 4 months": 4 to 15 months?

Response: No matches found in current version.
P. 10, L.2: ".. the mean chronological age…": here you report age in months and in the next paragraph in years, it is a bit confusing

Response: Have converted to years (yrs;mo), see P. 10, L.6-8.
P.11, L.4: "…Cypriot-Greek Lexical Acquisition Checklist": This was not introduced/described before in the paper and you do not explain it use .

Response: Inserted description , see P.9, L.10-14. See also P.11 L. 21, where we changed the term to 'a-CYLEX'.
P.11, L.23: "… coded as SVNNVNV": I am afraid I do not understand this example.
Response: Revised see P.12 L. 6.
P. 11, L. 47: "…and also for comparisons within groups": Why not use the a) measure for across group comparisons?

Response: The a) measure and all relevant analysis was deleted as per your major comment of applying similar analyses for sonority and word length and using smaller ratios.
P.11 L. 50: "Word length preferences were examined…": Why didn't you use also two measures for word-length preferences as you did for sonority-loaded?

Response: Based on your #2 comment, we deleted the a) measure.
P.12, L.14: I think you should clarify the different groups used and explain that the

small CI group is a part of the larger CI group and it does not involve different participants. Also it is not clear if you treat this as a separate group or not, you include it in tables 3,4 but not in the figures…

Response: Clarifications were made throughout the text and in subtitles regarding the small group pf age-matched children with CI (CI_6). Two figures were created to depict the results of CI_6 for receptive (Figure 2) and expressive vocabulary (Figure 6), respectively.

P.12 "Comparison of Sonority-Based Lexical Acquisition in CYLEX": The SD is high for the measures in table 3 for most groups… I think this should be mentioned.

Response: Done, see P.13 L.11.

P.12, L.36: "The mean percentage and standard deviations…": This is measure a), right? Do you have a separate table for measure b)?

Response: Measure a) was deleted.

P.12, L.53: …(N=222) as compared to S words (N= 27).: I think this disproportionately higher number of NS word items is also a factor for the patttern of the raw data in table 2. Overall, I think this discrepancy makes the a) measure problematic.

Response: Based on this comment which is similar to #2 general comment, the measure a) was deleted along with its results.

P.12, L.57: Data were subsequently normalized…": Is this measure b) mentioned in the beginning of the results section? Response: It is now moved to the beginning as measure a) was deleted.

P. 13, L.1: "…children with CI, age-matched children…": the groups here are presented in a confusing way.

Response: A systematic effort was made to clarify the groups.

P.13, L. 2: "…Figures 3, 4 and 5": I think these are fig. 1,2,3 and subsequent figure numbers 6,7,8 later on should also change.

Response: Figures were renumbered and Figures 2 and 6 were added, leading to a total of 8 Figures.

P. 14, L.5: DV1 and DV2 stand for dependent variables and refer to the two measures a) and b) in the beginning of the results sections? It would be more clear if you used consistent terminology.

Response: Text was revised, as measure a) and its dependent variable DV1 were deleted.

P.12- P.16: "Comparison of Sonority-Based Lexical Acquisition in CYLEX": Try not to be too repetitive when you describe the results in the expressive and receptive sections.

Response: Effort was made to improve writing to make it less repetitive and more concise.
P. 17, L. 57: "and the interaction": change to and their interaction

Response: Done P. 16, L.10
P. 18, L.17: "Overall, it was concluded that children with CI achieved higher normalized scores of expressive vocabulary than younger children with NH": This was also true for receptive. I think the overall findings in this section should be presented more clearly.

Response: It has been revised, see P.19, L.18-19.
P.18, L. 28: "…prosodic structures": change to prosodic structure.

Response: It has been revised, see P.19, L.20.
P.19, L. 7: "…the differences were attributed to the earlier auditory exposure of the Flemish speaking children with CI in the sample who were implanted around 14 months old":

Response: Rephrased, see P. 20 L.14-18
P.19, L.16: "… follow phonological grammar principles": change to universal phonological grammar principles.

Response: Revised, see P.20, L.21
P.19, L.12: "…and also educational policies": change to and different educational policies .

Response: Revised, see P.20, L.19

P.19, L.57: "The results partly…": this sentence should be rephrased.

Response: It was rephrased P. 20, L. 15-17

P.20, L.38: "…who suggested that children with CI perform similarly in their vocabulary skills to NH children with equivalent hearing age": rephrase

Response: Sentence was not found in current version.

P.20, L. 50: "other demographic characteristics": different instead of other.
Response: Deleted it in text due to content revision.

P. 20, L.57: "19-20 months": comma

Response: Deleted it in text due to content revision.

P.21, L.1: "Hence, it is concluded that in both cases, children with CI are expected to perform better than NH counterparts whose age precisely matches the auditory experience of the former.": rephrase

Response: Deleted it in text due to content revision.

P.22, L.21: "This conclusion has connotations for preschool programs at inclusive settings, as it denoted that language-facilitative programs for children with CI do not need to incorporate special instruction for certain phonological word structures to emerge in their receptive and expressive lexicon": rephrase

Response: Rephrased, see P. 24 L. 20-23.

Tables/figures:

Some of the tables need formatting

Response: Not sure if successfully met

Include total # of words in table 2

Response: Revised

Table 3: rephrase/format title

Response: Rephrased title

Table 4: include %

Response: Done, Table 4 is now renumbered to 5. Also, inserted percentages in Table 6.

Figures: change numbering"

Response: Done

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Author Note

We have no conflict of interest to disclose.

Abstract

Sonority and its language-universal sonority-sequencing principle (SSP) define an important dimension of phonological grammar which aids in the segmentation of words into syllables (Clements, 1990). Studies have yielded contradictory findings on sonority and SSP phonotactics in lexical perception of speech by children with cochlear implants (CI) (Hamza et al., 2018; Hamza et al., 2020). The present study aimed to investigate whether sonority-based and prosodic word aspects guide the lexical preferences of children with CI in comparison with two groups of normally-hearing ones, who were matched based on chronological and hearing age to children with CI, respectively. A retrospective analysis of real words was undertaken, obtained from a-CYLEX, a parent-reporting tool of receptive and expressive vocabulary which was completed for 17 children with CI, aged from 21-71 months (Oktapoti et al., 2016). The data for each word was re-coded into sonorous-loaded,nonsonorous-loaded and neutral words, and also into five word categories based on number of syllables. Metrical values were obtained following normalization of data. Results indicated similar trends in sonority and prosodic word categories based on normalized scores, in children with CI and NH peers, for both receptive and expressive vocabulary. Yet, differences in vocabulary size among the three groups were noted.

Keywords: sonority, cochlear implants, children, Greek-speaking, lexical development, CYLEX, word preferences

Lexical Preferences in Greek-Learning Children with Cochlear Implants: A Retrospective Analysis of Sonority-Based and Prosodic Lexical Structures

The restoration of hearing ability followed by cochlear implantation in prelingually-deafened children has led to improved communication, speech intelligibility and language skills (Govaerts et al., 2002; McDonald Connor et al., 2006; Svirsky et al., 2004; Tomblin et al., 1999). Yet, language performance, as well as rate of its acquisition by children with cochlear implants (CI), remained highly variable (Kral & O'Donoghue , 2010; Tomblin et al., 2005; van Wieringen & Wouters, 2015). Pimperton and Walker (2018) found that when children were implanted prior to three years, their vocabulary growth matched those of NH peers after four years of CI use. In contrast, Nicolas and Geers (2007) indicated that even for children who were implanted below 24 months of age, the expressive Preschool Language Scale (PLS) standard score at age 4;6 (4 years and months) was at least one standard deviation below the mean. A study by Nittrouer et al. (2014), assessed the language skills of children with CI who had just completed Kindergarten (mean age 82 months) and compared them with NH peers (mean age 80 months). A variety of language measures wereused, that is,, spontaneous samplesfrom narratives standardized test scores of expressive vocabulary based on EOWPVT (Expressive One Word Picture Vocabulary Test) (Martin & Brownell, 2011) and tasks on phonological awareness. Based on comparison of mean scores, children with CI fell below one standard deviation on all language measures as compared with children with NH. In addition, greater lags were noted for phonological awareness skills where children with CI lagged behind by two standard deviations from their NH peers in tasks of phonemic structure.

The variability in language performance has been attributed to several factors related to background history, such as age of implantation, residual or amplified hearing prior to implantation, audiological monitoring, communication method and parental involvement (Fryauf-Bertschy et al., 1997; O'Donoghue et al., 2000; Sharma et al., 2002; Geers et al., 2003; Nikolopoulos et al., 2004). Several investigators (Nicolas & Geers, 2006; Pimperton & Walker, 2018; Pisoni & Fagan, 2010) suggested that the duration of cochlear implant use is a determining factor for language outcomes because children with CI achieved vocabulary scores equivalent to those of younger children with NH whose chronological age matched the 'hearing age'. of children with CI; 'hearing age' is usually defined as the number of years of implant use (Pisoni & Fagan, 2010). However, the finding was not confirmed by other studies who found that the performance of children with CI is either higher or lower than their hearing age. In a case study of a 4-year-old child who was fitted at 14 months with hearing aids and subsequently implanted at age 3;0, Willis and Edwards (1996) reported that she acquired receptive and expressive vocabulary at approximately twice the rate of the hearing children. Two studies in Greek-speaking children with CI indicated that the receptive and expressive scores of children with CI fell significantly below the scores obtained by younger children with NH with chronological age equivalent to the hearing experience of children with CI (Oktapoti et al., 2016; Talli et al., 2018).

Apparently, auditory deprivation in the first year(s) prior to implantation impedes the formation of early phonological representations of children with CI, which impacts negatively on lexical development (Edwards et al., 2004). A line of research has focused on the lexical acquisition skills of children with CI (Davidson et al., 2014; Houston et al., 2005; Houston & Miyamoto, 2010; Oktapoti et al., 2016; Robertson et al., 2017; Schwartz et al., 2013; Stelmachowicz et al., 2004; Talli et al., 2018) and on the factors that affect their course of development. Researchers found that children with CI are lagging behind their NH peers in vocabulary size (Oktapoti et al., 2016), in word fast-mapping skills (Davidson et al., 2014) as well as word learning ability, i.e. their ability to acquire new words in their mental lexicon (Davidson et al., 2014; Houston et al., 2005; Houston & Miyamoto, 2010; Robertson et al., 2017; Stelmachowicz et al., 2004). The difficulty of children with CI in learning the phonological features of new words (Stelmachowicz et al., 2004) may be attributed to their reduced phonological short-term memory skills (Talli et al., 2018). Talli et al. (2018) revealed that Greek-speaking children with CI (age range from 4;6 to 8;6 years) had slower vocabulary acquisition rates which were coupled with developmental lags in their phonological short-term memory skills, attested by nonword repetition task scores. Furthermore, inconsistent findings exist with respect to whether early implantation eliminates deficits in word learning. Houston et al. (2012) found that children implanted under 14 months performed well on lexical tasks involving learning of novel-word/novel-object pairs whereas Hamza et al. (2020) reported developmental lags in word learning of novel words in Flemish-speaking children with CI that were implanted early, i.e. under age two, even though most of them were fitted with bilateral implants.

The barriers in achieving normal language development can also stem from the nature of the acoustic signal that children receive through their implant. Limitations of the speech signal transmitted via the implant device include a) low resolution of temporal fine structure due to the temporal envelop extraction algorithms of the speech processor, b) reduction of effective stimulation channels due to signal overlap in the surrounding electrodes (Wilson & Dorman, 2008). Further degradation of the auditory signal may result from incomplete neural survival and frequency-electrode placement misalignment (Wilson & Dorman, 2008). It becomes apparent that, overall, children with CI would show decreased sensitivity in the encoding and decoding of phonological structure of words since some spectral details will not be accessible (Spencer & Tomblin, 2009; Johnson & Goswami, 2010; Nittrouer et al., 2012).

During development, hearing children acquire words by establishing a connection between the spoken word and the referent object and later on by storing the lexical representation into memory (Markson & Bloom, 1997). Prior to storage, a substantial amount of processing takes place on the phonological properties of the words, which at early ages are perceived holistically in a template manner (Hallé & de Boysson-Bardies, 1994; Vihman & Croft, 2007) but later on are broken down into smaller units that connect with the existing mental lexicon network structures (Marslen-Wilson, 1993; Coady & Aslin, 2003; Vihman, 2017). At this later stage, children facilitate their lexical acquisition by tapping into the phonological grammar properties of words, some of which are universal and unmarkedstructures. In addition, based on lexical access models (Gaskell & Marslen-Wilson, 1997; Marslen-Wilson, 1990) the organization and access of the mental lexicon for word recognition or production is guided by acoustic analysis of phonological entities.

Sonority constitutes an important property of phonological grammar, as the phoneme-by-phoneme fluctuations of sonority-related features modulates the syllabification of words (Clements, 1990; Ohala & Kawasaki-Fukumori, 1997; Pater, 2009). The speech signal is modulated by a time-driven, low-frequency fluctuation pattern of energy, containing peaks and valleys that correspond to the syllable peaks and boundaries of the speech stream. The syllable's integrity is crucial for intelligibility, and blurring the boundaries of contiguous syllables hampers the understanding of spoken language (Drullman et al., 1994). Therefore, at input level, there is a perceptual need for syllable prominence. Sonority refers to the relative loudness, perceptibility or acoustic intensity of the sound (Harris, 2006) and it classifies sounds based on the degree of openness of the vocal tract (Goldsmith, 1992). Hence, vowels are highly sonorous and consonants vary in their sonority from non-sonorous (fricatives, affricates, and plosives) to highly sonorous (glides, liquids, such as flaps and laterals, and also nasals) (Selkirk, 1984). The intra-syllabic phonemic sequences are composed of both high-energy segments, such as vowels, that occupy the syllable peak, i.e. the nucleus, and low-energy segments such as consonants that occupy the syllable margins. Parker (2008) provided acoustical evidence for the physical realization of sonority in the speech signal, as measured at signal upper and lower extremes for vowels and consonants, respectively. Apparently then, the jaw cycles of openings and closing of the vocal tract place constraints on the segment/phonetic sequencing. These constraints can best be described by employing sonority-based grammatical rules, such as the sonority sequencing principle (SSP) (Browman & Goldstein, 1989; Lindblom, 1983; Selkirk, 1984), which defines universal language phonotactics. According to SSP, an unmarked syllable contains a highly sonorous sound at its nucleus, i.e. a vowel, and a least sonorous sound at its onset, so that sonority increases steeply from the onset to the vowel (Clements, 1990).

Martohardjono (1989) first proposed that children use the SSP rule, by stating that the "sonority cycle" is a property that children use to build words into their lexicon. Based on Ohala (1999), the patterns of the sonority cycle are found crosslinguistically in early child speech data. Typically-developing infants and children show preference for unmarked syllables which follow the SSP phonotactics, where a non-sonorous sound at syllable onset is followed by a sonorous sound closer to or at the nucleus (Friederici & Wessels, 1993; Ohala & Kawasaki-Fukumori, 1997; Pater, 2009). Similar evidence was also obtained from 9-month old infants who favored syllables starting with consonants clusters that adhered to SSP, e.g. blif, over the ones that violated it, such as lbif (Friederici & Wessels, 1993). Other studies reported that during the phonological acquisition of consonant clusters, in cluster reductions, the more sonorous consonantwas omitted and the less sonorous consonant was retained (Gierut, 1999; Ohala, 1999). Papakyritsis et al. (2020) indicated that Greek-speaking preschool-aged and first-grade children rely on SSP phonotactics during a phonological awareness task of consonant cluster reduction, where they omitted the sonorous consonant and retained the non-sonorous one.

There are few studies which investigated aspects of sonority hierarchy and sequencing in the phonology of children with CI (Chin & Finnegan, 2000; Chin, 2006; Kim & Chin, 2008). Their findings suggested that sonority-related hierarchy is realized fairly well in their speech production system. Kim and Chin (2008) investigated fortition and lenition errors patterns in their productions and reported that error trends were similar to NH peers. Chin and Finnegan (2002) examined realizations of word-initial consonant clusters by 12 children who had used cochlear implants for at least five years. The sonority constraints call for onsets of rising sonority so that the second consonant of the initial cluster is of higher sonority than the first one. Children with CI retained the least sonorous segment during cluster reduction, resembling the developmental NH pattern and also universal language trends. However, Chin (2006) noted variations in CI children's production of clusters which deviated from the sonority sequencing principle (SSP) and were attributed to different rankings of the constraints as posed by Optimality Theory. Finally, a case study by Adi-Bensaid & Tobin (2010) revealed that a Hebrew-speaking child with CI showed production preferences for highly sonorous segments, such as production of vowel /a/, by deleting syllables containing other vowels regardless of stress. The fact that the most sonorous vowel was retained suggests a trend for maximizing syllable prominence via maximizing its peak.

Recent work has focused on investigating the role of sonority in word learning by children with CI (Hamza et al., 2018; Hamza et al., 2020). Based on Martohardjono's pioneering work (Martohardjono, 1989), which advocated the idea that early lexical acquisition is guided by sonority-related constraints of syllable formations, it was assumed that children with NH employ the phonological grammar rule of SSP in their word-learning process and later on learn to accept more complex structures which may violate the SSP rule. In contrast, it was hypothesized that children with CI do not readily acquire the SSP as a result of their early period of auditory deprivation, but instead show preferences to lexical units composed of highly sonorous segments which are more acoustically prominent and carry more perceptual energy via the integration of loudness over time (Gordon, 2002). A study byHamza et al. (2018) examined lexical preferences via a lexical identification forced-choice task and compared the performance of 15 Greek-speaking children with CI, aged 4;11 – 15;2 years old, with a mean post-implant age of 6;10 years, 25 age- and gender-matched children with NH and 50 hearing adults . The study was based on the methodological paradigm of Schwartz and colleagues (Schwartz et al., 2013). A psycholinguistic task was developed in E-Prime, in which novel CV-CV words were matched with funny objects and were subsequently presented via a fast mapping procedure. Participants made choices via a touch screen and both accuracy and reaction times were measured. Four types of novel words served as targets: i) words composed of two highly sonorous syllables, i.e. containing sonorous consonants at onset (SS-SS), ii) words composed of two non-sonorous syllables (NS-NS) containing non-sonorous consonants at onset, iii) words with an initial non-sonorous syllable followed by a highly-sonorous one, NS-SS, and iv) the reverse SS-NS. Results indicated that the word-recognition accuracy performance of children with CI did not differ significantly from their hearing peers; however, children with CI exhibited a preference for SS-SS words, as revealed by within-group comparisons and by their superior, adult-like performance which was achieved only in the SS-SS condition. Moreover, a comparison of accuracy scores obtained by a subgroup of children with CI that were matched in hearing experience with younger children with NH led to similar outcomes, where children with CI showed the same preference for words that consist of highly sonorous, that is, highly audible segments(SS-SS). The findings, however, were not replicated in a study with Flemish-speaking children with CI who had been implanted at an earlier age, and by majority were fitted with bilateral implants. In Hamza et al. (2020), most Flemish-speaking children in the sample were implanted under 12 months, as opposed to Greek-speaking children in the Hamza et al. (2018) who were implanted between 2 to 3 years of age. It is concluded that when the effects of auditory deprivation are minimized, children with CI readily follow the phonological grammar rules, such as the SSP, that enable them to build their lexicon. Yet, it should be noted that the performance of children with CI in receptive vocabulary was significantly lower than their NH peers (Hamza et al., 2020), suggesting that the factors that underlie lexical development warrant further investigation.

Both studies have employed novel words and investigated word recognition performance via an experimental task. Performance on novel words sometimes is different than real words, as the later are acquired in naturalistic as opposed to laboratory settings and are also part of the surrounding language. Studies have shown better performance in word repetition than non-word repetition in children aged from 2 to 8 years old (Casalini et al., 2007; Chiat & Roy, 2007). A study using event-related evoked potentials in 12-month old infants, demonstrated that factors such as lexical priming and phonotactic familiarity affected their processing of acoustic stimuli (Friedrich & Friederici, 2005).

An alternative route of investigation on the factors that facilitate or inhibit lexical development in children with CI is to look into the characteristics of their mental lexicon and examine the phonological properties of words they have already acquired in the receptive and expressive vocabulary. It has been long established that children build their lexicon based on certain phonological preferences during the early stages of language development, i.e. they acquire words that are composed of phonemes which belong to their phonetic repertoire (Schwartz & Leonard, 1982). Furthermore, they construct phonological templates which act as filters for the lexical input and spur further lexical growth (Macken, 1979). A remaining question is to examine whether the already acquired vocabulary is the end-product of cognitive processes involving, at least partly, the incorporation of sonority-driven principles. These “biases” in the lexical repertoire of children with CI can either be the same as the ones adopted by NH peers or different, since previous research (Hamza et al., 2018) has shown tendencies for better processing of sonority-loaded word patterns by children with CI. Furthermore, since children with CI have difficulty with phonological memory (Casserly & Pisoni, 2013; Talli et al., 2018), it is hypothesized that they may show preference for words with smaller length rather than long words. Recent evidence suggested that children with CI process disyllabic and trisyllabic words similarly well during non-word recognition tasks but their production performance differs as a function of word length (Adamidou, 2019).

The aim of this study was to investigate whether children with CI show any phonological preference patterns in the word items they acquire in their receptive and expressive vocabulary, with respect to sonority hierarchy characteristics, and also, word length. A retrospective analysis of receptive and expressive vocabulary data as recorded in a parental-reporting vocabulary tool for Greek-speaking children, a-CYLEX, was undertaken. The a-CYLEX parental-reporting checklist samples the lexical items (adult-like forms of real words) that children have acquired in their mental lexicon and also the ones they use during expressive language, regardless of their speech production output. It is similar to the MacArthur-Bates CDI (Communicative Development Inventories) and it was originally developed for Cypriot-Greek speaking children by Petinou and colleagues (Petinou et al., 2011). Subsequently, CYLEX was adapted in Standard Greek (a-CYLEX version) (Parizi et al., 2013) and has been used to investigate the language skills of Greek-speaking children with CI (Oktapoti et al., 2016).

The research questions were:

1. Are there differences in the phonological composition of words contained in the receptive and/or expressive vocabulary of children with CI as compared to children with NH, with respect to sonority-based structure?
2. Do the lexical patterns of children with CI resemble those of younger children with NH, matched in hearing age to children with CI, with respect to sonority-based composition?
3. Are there prosodic word differences with respect to word length in the receptive and expressive vocabulary of children with CI as compared toto age-matched children with NH?
4. Is word length in the receptive and expressive vocabulary of children with CI comparable to younger children with NH, matched in hearing age to children with CI?

Method

Participant Characteristics in CYLEX Data Corpus

Data from 17 children with CI, ten girls and seven boys, who participated in the Oktapoti et al. study (Oktapoti et al., 2016) were used for the retrospective analysis of prosodic and sonority structures of their a-CYLEX data.

Children with CI came from monolingual families and the majority resided in Macedonia, Northern Greece. The demographic information is listed in Table 1.

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Table 1

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The mean chronological age of children with CI was 4;2months, ranging from 1;9 to 5;11 months. They were implanted at a mean age of 2;6months, with age of implantation ranging from 1;4 to 4;1 months. Their mean hearing age which corresponded to years of implant use was 1;7months, ranging from 0;5 to 3;10 months. All of the children with CI were unilaterally implanted with a Freedom SP CI24RE(CA) cochlear implant device with a full insertion of the electrode array, and none was bi-modally fitted with a hearing aid in the non-implanted ear. They were orally trained and came from monolingual homes. Four out of 17 children had additional disabilities, i.e. two had been diagnosed with psychomotor delay/developmental delay, one child with encephalitis and another child with meningoencephalitis. As reported in Oktapoti et al. (2016), their CYLEX scores were not lower from the other children with CI and when they were included in the CI group, the group results did not differ statistically from those of typically developing children whose age matched the hearing age of the CI group. A subset of six children with CI from the above sample, four girls and two boys, was used as a second experimental group (CI_6), for comparisons with age-matched and gender-matched children with NH. The mean age was 2;6 years, ranging from 1;9 to 3;10.

Moreover, two control groups of hearing children were extracted from CYLEX database, which consisted of 200 children with normal hearing and no developmental disabilities ages 0;7 to 3;6 years old: a) six children with NH (group NH_CA) who were matched in age and gender to group CI_6 and b) 17 gender-matched children with NH (group NH_HA), ten girls and seven boys, whose chronological age matched the hearing age (post-implant age) of the 17 children with CI group CI) NH_HA. One girl with NH, aged 1;9 years was included in both control groups. The mean age of age-matched children with NH (NH_CA) was 2;5 years, ranging from 1;9 to 3;10 and was not statistically different from the mean age of the CI_6 group, based on a t-test for independent samples ($t(10) = 0.255$, $p= .80$). The mean age of younger children with

NH (NH_HA) was 1;8 years, ranging from 0;4 to 3;9 and was similar to the mean hearing age of the CI group, 1;7 years with ranges from 0;5 to 3.10 (t-test for independent samples: $t(32) = -0.339$, $p = .74$). Children with NH were recruited from private or public nursery schools or from private homes via advertisement and parents signed a consent before completing the CYLEX questionnaire. Moreover, all of them came from monolingual homes in the region of Macedonia in Northern Greece and based on parental and teacher reports they had normal hearing and no developmental or other disabilities.

Description of a-CYLEX

The a-CYLEX version used in the Oktapoti at al. study (2016) consisted of 583 words most frequently found in children's books and in Cypriot-speaking children's speech. They are separated into the following 18 semantic categories: baby words, animal sounds, animal names, food/drink, body parts, actions, places (outside things), household objects, rooms, personal items, people, vehicles, clothes, concepts, adjectives, tools, toys and other words. In addition, a - CYLEX contains sections where parents fill out additional words that their child understands or says and also provide examples of sentences. These sections were not analyzed in the present study. The a-CYLEX takes about 30 minutes to complete.

Data Re-coding Methodology

The collected data from the questionnaires were inserted in a Microsoft Excel file, for analysis. In addition to the data, the Microsoft Excel file included a digitalized version of a-CYLEX. . Two worksheets were created for each child's performance, one for the receptive and one for the expressive vocabulary. The first classification of words on the list was made according to their prosodic structure (i.e. the number of syllables per word); consequently, the lexical categories were monosyllables, disyllables, trisyllables, tetrasyllables and pentasyllables. The second classification aimed in coding sonority word structure. For this purpose, each word was first analyzed according to its segmental structure, that is, words were broken down into their constituent phonemes and were coded as either consonants (C) or vowels (V) For example, the word /ku'nupi/ meaning 'mosquito' was coded as CV'CVCV. Subsequently, each consonant was further categorized as either sonorous (nasals, flaps, laterals) or non-sonorous (stops, fricative, affricates). In this case, the word /ku'nupi/ 'mosquito' was coded as SVNNVNV (where V stands for vowel, 'S' for sonorant consonants and 'N' for non-sonorant consonants). Lastly, the words were categorized into three categories, i.e. sonorous-loaded words , non-sonorous-loaded words and words that were neutral because they did not fit in either category. The sonorant or non-sonorant load was determined using the following criterion: at least a 3:1 ratio of sonorant to non-sonorant consonants, or vice versa, is required in order for a word to be considered as sonorous-loaded or non-sonorous-loaded respectively. An example of a sonorous-loaded word is /mɐkɐˈɾoɲɐ/ ‘spaghetti’ , coded as SVNVSVSV. It contains three sonorous consonants and one non-sonorous (ratio of sonorant to non-sonorant consonants is 3:1). An example of a non-sonorous-loaded word is /kɐɾˈpuzi/ ‘watermelon’, coded as NV'SNVNV, containing three non-sonorant consonants and one sonorant (ratio of non-sonorant to sonorant consonants is 3:1). Finally, an example of a neutral word is /'vutiro/ ‘butter’, coded as 'NVNVSV, where the ratio of non-sonorous to sonorous consonants is 2:1.

Results

CYLEX contains and uneven number of word items in each of the five prosodic word categories, as shown in Table 2. In addition, there is an uneven distribution of CYLEX words in terms of the sonority groups (sonorant-loaded, non-sonorant-loaded and neutral), as shown in Table 3.

Sonority-related preferences were examined by estimating the number of words acquired in each sonority word category over the number of words listed in CYLEX in that category. These normalized scores enabled comparisons across the sonority-related categories which differ in the number of word items that are included in CYLEX. Between-group and within-group comparisons were made separately for receptive and expressive levels of CYLEX.

Word length preferences were also normalized by calculating the number of words acquired in each prosodic word category over the number of words listed in CYLEX for that category. Subsequently, each prosodic word category was compared across groups differing in hearing status and within-group comparisons were made across the prosodic word categories.

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Insert Tables 2 and 3

Effects of hearing status and age on lexical Acquisition in CYLEX

CI_6NH_CANH_HAFor each group (CI_6, NH_CA, CI, NH_HA), the average raw number and standard deviations of CYLEX words acquired receptively and expressively across all items are listed in Table 4. Children with CI showed great variability in their performance, as revealed by the large standard deviations.

For both receptive and expressive vocabulary, children with NH (NH_CA group) (mean age 2;5 years) achieved higher scores than their age-matched children with CI (CI_6 group) (mean age 2;6 years). Data was normally distributed, thus, t tests for independent groups were performed. The group differences in receptive scores were not statistically significant [t(10) = -1.78, p=.11]. However, the CI_6 group achieved significantly lower expressive scores than NH_CA [t(10) = -2.33, p<.05}. Moreover, the hildren with CI (CI group) attained higher receptive and expressive scores than younger children with NH (NH_HA group) (1;8 years), yet the differences were not statistically significant [receptive level: t(32)=1.45, p=.16; expressive level: t(32)=1.68, p=.10}. NH_HA Furthermore, the CI_6 group (2;6 years) scored lower than the CI group across receptive and expressive levels, due to the younger mean age of the former.

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Insert Table 4

Effects of Sonority-based lexical preferences in CYLEX

For each group (CI_6, NH_CA, CI, NH_HA), the average raw number and standard deviations of CYLEX words acquired receptively and expressively across all items within the categories of NS and S words are listed in Table 4.

CI_6NH_CANH_HACI_6***Receptive level***

Normalized receptive vocabulary scores for each lexical category of CYLEX, i.e. words with non-sonorant load (NS words) and words with sonorant load (S words) were obtained for each of the four groups, namely CI_6 , CI_6 NH_CA,CI and NH_HA. . These normalized values are depicted in Figures 1-4respectively. In each group, the percentage of words with sonorant load was higher than those with non-sonorant load. Moreover, the NH_CA group, with mean age 2;5 years, acquired a greater percentage of words receptively in both lexical categories as compared to the overall sample of children with CI, with mean age 4;2 years, and to the younger children with NH (NH_HA), with mean age 1;7 years. In both lexical categories, the performance of children with CI was greater as compared to younger children with NH (NH_HA) and also to CI_6 group.

Insert Figures 1,2,3,4

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CI_6 and NH_CA groups The sample size for the statistical comparison of children with CI (CI_6) with age-matched children with NH was very small (N=6), therefore nonparametric tests were performed. Mann-Whitney U tests indicated that the percentage of receptive NS words acquired within the NS category of CYLEX was not significantly greater in children with CI (CI_6) as compared to age-matched children with NH (NH_CA)(U=9.00, Z= - 1.361, p=.173). Moreover, no significant group differences were noted in the percentage of receptively acquired S words within the S category of CYLEX (U=8.00, Z= -1.521, p=.128).

Within-group comparisons revealed that CI_6NH_CACI_6NH_CAthe percentage of receptive S words acquired within the S category of a-CYLEX was significantly greater than the percentage of receptive NS words acquired within the NS category of CYLEX (CI_6 group: Wilcoxon Z= 2.201, p= 0.028; NH_CA group: Wilcoxon Z= 2.201, p= 0.028).

CI and NH_HA groups

The sample size (N=17) was suitable for parametric statistics. Levene's test, revealed homogeneity of variance for the percent of receptive words acquired per word category of CYLEX (F=1.685, p=.180). Data were normally-distributed (K-S d=.132, p<.20). A2x2 factorial mixed ANOVA with hearing status as a between factor, i.e. children with CI (CI) and children with NH matched in hearing age (NH_HA), and lexical category as a within factor, and onedependent variable, i.e.percent of receptive words acquired per word category of CYLEX was performed. The main effect of hearing status was significant, yielding a medium effect size [(F(1,1)-5.55, p< .05, partial $\eta^2 = 0.09$]. The percentage of words acquired per lexical category was significantly greater for children with CI (NS word mean: 58.64; S word mean: 69.72) as compared to younger children with NH who were matched to the hearing age of children with CI (NH_HA group) (NS word mean: 40.14; S word mean: 48.15). Moreover, the main effect of word category and their interaction were not significant.

Expressive Level

Normalized values of words acquired expressively within each lexical category of CYLEX are depicted for each group, that is , CI, CI_6, NH_CA and NH_HA, respectively in Figures 5, 6, 7 and 8. In each group, the percentage of words with sonorant load was higher than those with non-sonorant load. Moreover, age-matched children with NH (NH_CA) have acquired a greater percentage of words at expressive level in both lexical categories as compared with children with CI and younger children with NH (NH_HA). Also, the performance of children with CI in expressive vocabulary was superior to that of younger children with NH (NH_HA) and also to the CI_6 group.

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Insert Figures 5, 6, 7, 8

CI_6 and NH_CA groups CI_6. Mann-Whitney U tests indicated that CI_6NH_CAthe percentage of expressive NS words acquired within the NS category of CYLEX was not significantly different in the CI_6 group as compared to NH_CA (U=7.00, Z= - 1.681, p=.093). Similar fndings were obtained forCI_6NH_CAthe percentage of expressively acquired S words within the S category of CYLEX (U=7.00, Z= -1681, p=.093).

Within-group comparisons were made, comparing performance in NS vs. S words in each group, i.e. CI_6 and NH_CA. For both groups, Wilcoxon tests revealed that the percentage of expressive S words acquired within the S category of CYLEX was significantly greater than the percentage of expressive NS words acquired within the NS category of CYLEX (CI_6 group: Wilcoxon Z= 2.201, p= .028; NH_CA group: Wilcoxon Z= 2.201, p= .028).

CI and NH_HA groups The sample size (N=17) was suitable for parametric statistics and Levene's test confirmed the homogeneityof the data, i.e. the percentages of receptive words acquired per word category of CYLEX (F=1.505, p=.222) which was also normally distributed (K-S d=.124, p<.20). A a 2x2 mixed factorial ANOVA, with hearing status as a between facto rand word category as the within factor, was performed. All main effects and interactions were not significant. . In sum, there was no difference in percentage of words acquired per word category for children with CI as compared to younger children with NH (NH_HA). Moreover, there was no difference between S and NS words. The above findings suggest that the two types of words, S and NS, are acquired expressively in a similar fashion and to the same degree across the two groups, CI and NH_HA.

Effect of Word Length in CYLEX

CI_6 and NH_CAA comparison of receptive and expressive vocabulary normalized scores for each prosodic word category, i.e. monosyllables, disyllables, trisyllables tetrasyllables, pentasyllables, was made between aged-matched children with CI (CI_6) and their age-matched NH children (NH_CA). The mean percentages were compared between the CI_6 and NH_CA groups via nonparametric tests, i.e. Mann_Whitney U tests as a function of prosodic word type. Regarding both receptive and expressive vocabulary, no significant differences were observed among aged-matched children with CI and NH in the percentage of words acquired within each prosodic word category (Table 5).

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Insert Table 5

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CI and NH_HAA comparison of receptive and expressive vocabulary normalized scores for each prosodic word category, i.e. monosyllables, disyllables, trisyllables tetrasyllables, pentasyllables, was made between children with CI (CI group) and younger NH children, matched in hearing age to the CI group (NH_HA).

Two factorial mixed ANOVAs, one for receptive and one for expressive vocabulary, were performed with hearing status as the between-group factor, prosodic word type as the within-group factor and normalized vocabulary scores, as the dependent variable. Regarding receptive vocabulary, the assumption of homogeneity of variance based on Levene'e test was met for both factors (Hearing Status: $F= 1.81$, $p=0.181$; Word type: $F= 1.41$, $p=.232$). The main effect of hearing status was significant [$F (1,4) = 44.14$, $p<.001$], with a strong effect size (partial $\eta^2 =.22$) with children with CI achieving higher normalized scores than younger children with NH. However, the main effect of prosodic word category and the interaction were not significant. Thus, it was concluded that performance on receptive vocabulary in the two groups did not vary as a function of prosodic word type. Planned comparisons confirmed significantly higher performances in receptive vocabulary normalized scores for chidren with CI as compared to younger children with NH (NH_HA) for each prosodic word type (as shown in Table 6). Similar findings were obtained from the ANOVA performed on expressive vocabulary normalized scores, i.e. a significant main effect of hearing status ($F= 16.01$, $p<.001$) with medium effect size (partial $\eta^2 =.09$) and nonsignificant effects for word type (and interaction). Yet, none of the planned comparisons per prosodic word type with Bonferroni correction were significant (Table 6). Overall, it was concluded that children with CI achieved higher normalized scores of both receptive and expressive vocabulary than younger children with NH but the effect was not strong as in expressive vocabulary.

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Insert Table 6

Discussion

The present study conducted a retrospective phonological analysis of sonority and prosodic structure in the receptive and expressive vocabulary a-CYLEX scores of children with CI, a parent-reporting tool, that were collected in the Oktapoti et al. (2016) study. Comparisons of children with CI with age- and gender-matched children with NH as well as with younger gender-matched NH children, with ages equivalent to the auditory exposure time of children with CI following cochlear implantation, were made by extracting data from the a-CYLEX database of typically-developing children. The purposes were to explore lexical preferences in the acquired vocabulary related to phonological structure characteristics such as sonority-ranked phonemic composition and word length, and also, to examine whether children with CI have different lexical preferences in the above phono-prosodic structural characteristics as compared to hearing children.

Motivation for studying sonority-related preferences was drawn from recent findings in Greek-speaking children with CI, implanted at ages between 2;0-3;0, which denoted that children with CI -- although they performed similarly to age-matched NH peers in word recognition -- showed a preference for highly sonorous words which have greater audibility than words containing non-sonorous consonants (Hamza et al., 2018). This pattern runs counter to language universal rules of phonological grammar such as the sonority-sequencing principle (SSP) which postulates that syllables with a nonsonorous consonant onset and a steep sonority rise towards the sonorous vowel nucleus (NS syllables) constitute the unmarked structures, and therefore, words composed of NS syllables are processed easier by both adults and children (Friederici & Wessels, 1993; Martohardjono, 1989; Ohala & Kawasaki-Fukumori, 1997; Pater 2009). Notably, the word preferences by Greek-speaking children with CI were not replicated at a subsequent study in Flemish-speaking children with CI (Hamza et al., 2020). It was concluded that the earlier auditory exposure of the Flemish-speaking children with CI in the sample, who were implanted around 14 months old, yielded similar results to children with NH. Nevertheless, since early implantation is not always achieved in different countries with disparate health and economy systems, and also different educational policies, the question remains of whether children who are implanted past infancy, after a period of auditory deprivation, follow universal phonological grammar principles, such as the SSP, once their hearing is activated. The benefit of adopting a phonological rule-driven processing strategy which conforms to the universal properties of spoken language undoubtedly spurs lexical growth and may serve as a prognostic indicator for language acquisition. Moreover, Greek language contains multisyllabic words and the present study set out a second line of investigation, to examine whether children with CI have difficulties in acquiring words of increased length.

Since previous research in Greek-speaking children with CI explored issues of phonological processing and word learning by adopting experimental paradigms with non-words as stimuli (Hamza et al., 2018; Adamidou, 2019; Adamidou et al., 2023), the present study aimed to examine issues of word learning in real words, drawing data from parent-reporting vocabulary checklists. Several studies attested that performance on lexical tasks involving real words is different from non-words (Casalini et al., 2007; Chiat & Roy, 2007; Friedrich & Friederici, 2005).

In relation to sonority characteristics of acquired word structures, the findings of the present study suggested that overall the lexical processing of children with CI relies on similar preferences to the ones adopted by NH peers. In both receptive and expressive vocabulary, the results via planned comparisons indicated a significantly higher percentage of sonority-loaded words as compared to words with non-sonorant load, across groups. It can be concluded that the two types of words, S and NS, are acquired receptively and expressively in a similar fashion by aged-children with CI (CI_6), age-matched children with NH (NH_CA), children with CI and younger children with NH (NH_HA). Hence, even after a period of auditory deprivation, children with CI who are implanted before three years of age, learn to process word patterns of their language that carry different loads of sonority-related phonemic composition with a similar facility to NH children. The results agree with Hamza et al. (2018) in thatno differences occurred between groups; yet, within-group comparisons in the present study revealed that both CI and NH groups -- instead of the CI group alone -- showed a preference for S than NS words.. This suggests that young children in general, regardless of hearing status, may initially prefer words of high audibility while they begin to discover the phonological grammar rules of language, such as the SSP.

However, one should note that the data on real words was collected via parental reports and future studies need to be conducted in order to validate this finding by directly assessing children’s receptive and expressive vocabulary skills. Furthermore, the present study did not provide data onchildren’s phonological output of expressed words, as data was based on the target forms of S and NS words that were listed in CYLEX items. In that sense, the study’s findings may only relate to assumptions regarding the representation level of the children’s expressive vocabulary Future studies should explore sonority-based patterns in the speech production of children with CI vs. NH, in order to further validate the present findings. Moreover, another difference in the data set examined in the present study, as compared to Hamza et al. (2018), lies in the ages of all groups. In the present study, all hearing Greek-speaking children were in early preschool age, i.e. 0;7 to 3;6 years old, and as young learners they may show different lexical preferences in the sonority-related phonological parameters than the ones observed in the Hamza et al. study (2018) which had participants with ages ranging from 4;11 to 15;2 years old. The findings of the present study suggest that the early templates are composed of both types of words (S, NS) with a significant preference for highly sonorous words in Greek-speaking children emerging around 2;6 years of age, regardless of hearing status.

Notably, the comparison of the total number of CYLEX words acquired across hearing status revealed that the expressive vocabulary of age-matched children with CI (CI_6) was significantly lower as compared to their hearing peers (NH_CA) but such differences were not significant at the receptive level. This finding is also supported by a recent study (Adamidou et al., 2023) which found that children with CI achieved similar scores to their NH peers in a word identification task of lexical stress.

Another interesting finding was that children with CI acquired a significantly greater number of receptive and expressive words in both sonority-related categories than younger children with NH whose chronological age matched the hearing age of children with CI. Taken together with the significantly superior performance of NH peers (age-matched) relative to children with CI, it is concluded that children with CI, once implanted acquire these two types of words at a greater rate than the one expected based on their years of hearing experience. This finding contrasts with the study's results obtained when the total number of CYLEX words acquired (including the neutral words) were compared across hearing status. In that case, children with CI (CI group) did not significantly differ from the younger children with NH (NH_HA). The latter finding corroborates with Pisoni and Fagan (2010) and Oktapoti et al. (2016) who suggested that the vocabulary skills of children with CI are similar to those of NH children with equivalent hearing age. However, it is opposite to the study by Talli et al. (2018) in Greek-speaking children with CI who found that the receptive vocabulary performance of children with CI, as measured via direct assessment, falls slightly below the one of children with NH, matched in hearing age. Apparently, the contradictory findings may relate to the type of methodology employed for data collection, i.e. parental reports vs. direct lexical assessment, ,and also, to the types of words measured (sonority-related vs. total CYLEX words), which yielded differing outcomes in the present study. Regarding preferences in word length, the differences between the CI_6 and NH_CA groups in percentage of words acquired within each prosodic word category of CYLEX were not statistically significant. Thus, children with CI showed a similar distribution of the different prosodic word structures in both receptive and expressive vocabulary to the one exhibited by NH peers. However, the group with CI acquired a significantly greater percentage of monosyllabic, disyllabic, trisyllabic and pentasyllabic words, at the receptive level, as compared to children with NH who had similar hearing experience (NH_HA). This finding denotesa greater rate of acquisition of receptive language, as revealed by receptive vocabulary scores. Regarding expressive vocabulary, thedifferences between CI and NH_HA groups were diminished.

In conclusion, a novel finding from the present study is that the differences in the acquisition of receptive and. expressive vocabulary between children with CI and children with NH, younger or age-matched, are quantitative and not qualitative in nature, with respect to both acquisition of word prosodic structure and sonority-related preferences. Since the scores obtained were based on parental reporting of acquisition of word target forms, it is important to underscore that the similar acquisition of lexical items with different word length in the CI vs. NH_CA groups does not exclude the case that children with CI may make articulatory/phonological errors when learning to produce these target words. An analysis of articulatory/phonological errors in the productions of disyllabic and trisyllabic non-words revealed that Greek-speaking children with CI made significantly more errors than their NH peers (Adamidou et al., 2023). Future studies should explore the effect of word length on speech production of multisyllabic words.

Limitations of the study relate to the type of data analysed on a retrospective basis. The parent-reporting tool of vocabulary development, a-CYLEX, contains an uneven number of word items in the categories for which comparisons were made in the present study, i.e. the sonority-related and the prosodic word categories. The categories that contain greater number of items can be considered to yield more representative results, i.e. results that are closer to the population mean and its characteristics. Even though care was taken to normalize the data, results need to be further validated by future investigations.

Another limitation relates to the small sample size used for comparison of children with CI with aged-matched children with NH. This is also attributed to the type of data that was available in the retrospective analysis. Since CYLEX is designed to investigate early vocabulary inventory, the children with NH in the a-CYLEX database were as old as 3;6 years, hence only 6 cases were found as possible age NH matches to children with CI.The rest of the children in the CI group were older than those listed in the database. This limitation did not affect the data obtained for the younger group of children with NH, who were matched with all 17 children with CI based on years of auditory experience, as their ages corresponded well to the specification characteristics of the a-CYLEX database.

In conclusion, children with CI showed similar preferences for phono-prosodic lexical patterns to age-matched and younger NH groups with respect to both sonority-related and word-length parameters. Any observed differences were quantitative and not qualitative. Both groups showed a preference for words of high audibility, i.e. sonority-based structures, but also acquired words that followed the SSP principle. This finding has connotations for facilitating access to early language, as children may benefit from lexical models of child-directed speech that contain non-sonorant word structures which signify phonological grammar rules, such as the SSP. Most importantly, the findings suggest that preschool programs at inclusive settings do not need to incorporate special instruction for children with CI in order to facilitate the acquisition of certain phonological word structures in their receptive and expressive lexicon. The CI processor capabilities seems to tap fairly well to the phonetic characteristics of both types of structures. The sonority cycle is a low-frequency time-varying signal of peaks and valleys, employs only temporal and intensity acoustic cues which form the temporal envelope of the signal. The temporal envelop is accessed well by the cochlear implant. The fact that children with CI can follow well the sonority cycle can be validated by the fact that they have shown good facility in acquiring the different prosodic structures of Greek language, i.e. words with varying number of syllables, similarly to children with normal hearing. Hence, it is assumed that children with CI can detect syllable borders and perform lexical breakdown routines to store and retrieve sublexical internal structures, thereby makingefficient use of phonological grammar principles, such as the SSP. The above findings have positive implications for the development of phonological awareness and the detection of morphological markers which can be further explored.

Overall, the retrospective analysis of sonority-related preferences in children's vocabulary as a function of hearing status and age yielded useful findings, suggesting that children with CI acquire words in a similar fashion to hearing children.

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Table 1

Demographic Characteristics of Children With CI in a-CYLEX Database

Children with CI	**Age**	**AoI**	**Hearing Age (PIA)**	**Age hearing aid fitting** *(months)*	**Etiology of Hearing Loss**	**Additional disability**
CI1P1HA46F_6	5;11	2;1	3;10	No	Congenital	No
CI2P2HA37F_5	4;8	1;7	3;1	no	Congenital	Psychomotor delay/
CI3P3HA36F_6	5;7	2;6	3;0	7	Congenital	developmental delay
CI4P4HA33M_5	5;3	2;5	2;9	6	Congenital	No
CI5P5HA26F_5	5;2	3;0	2;2	6	Congenital	No
CI6P6HA23M_5	4;10	2;11	1;11	Missing	Congenital	No
CI7P7HA23F_5	4;6	2;7	1;11	20	Congenital	No
CI8P8HA21F_4	4;3	2;5	1;9	No	Encephalitis	Encephalitis
CI9P9HA15M_3	2;10	1;6	1;3	No	Congenital	No
CI10P10HA13F_3	2;6	1;4	1;1	6	Meningo-encephalitis	Menigo-encephalitis
CI11P11HA12M_5	4;8	3;8	1;0	No	Cytomegalo-virus	No
CI12P12HA10M_3	3;1	2;2	0;10	14	Missing	No
CI13P13HA10M_5	4;11	4;1	0;10	No	Missing	Psychomotor delay/develop

						mental delay
CI14P14HA8F_2	2;3	1;7	0;8	No	Peripheral asphyxia	No
CI15P15HA6M_6	5;11	5;4	0;6	Missing	Congenital	No
CI16P16HA7F_3	2;8	2;1	0;7	No	Congenital	No
CI17P17HA5F_2	1;9	1;3	0;5	8	Congenital	No
Mean	**4;2**	**2;6**	**1;7**			
Max	**5;11**	**5;4**	**3;10**			
Min	**1;9**	**1;3**	**0;5**			

Table 2

Distribution of Prosodic Word Categories in a-CYLEX

Prosodic word categories in CYLEX	Number of word items
Monosyllables	19
Disyllables	253
Trisyllables	206
Tetrasyllables	83
Pentasyllables	22
Total	583

Table 3

Distribution of Sonority-related Categories in a-CYLEX

Sonority-related categories in CYLEX	Number of word items	(%)
Total number of words in CYLEX	583	
Sonorant-loaded words	27	(4.63%)
Non-sonorant-loaded words	222	(38.08%)
Neutral words	334	(57.29%)

Table 4

Averages and Standard Deviations (in Parentheses) of CYLEX Words Acquired Receptively and Expressively. The Total Number of Words, and the Number of Wordsa in the Categories of NS and S Words, are shown for Each Group.

Groups	Receptive total words	Receptive NS words	Receptive S words	Expressive total words	Expressive NS words	Expressive S words
CI_6	276.00	106.00	16.83	125.83	50.50	11.33
	(209.08)	(76.70)	(8.91)	(169.40)	(60.71)	(8.31)
NH_CA	457.50	174.83	24.33	382.83	146.83	21.17
	(136.39)	(52.75)	(5.20)	(209.90)	(79.42)	(9.89)
CI	337.47	130.18	18.82	261.29	101.65	17.00
	(202.47)	(76.56)	(7.67)	(209.68)	(78.46)	(7.87)
NH_HA	232.35	89.12	13.00	232.35	53.00	9.06
	(220.43)	(82.75)	(10.58)	(220.43)	(76.09)	(10.66)

Table 5

Mann-Whitney U Tests for Comparison of Percentages of Receptive and Expressive Words Acquired per Prosodic Word Category in CI_6 vs. NH_CA Groups

CYLEX	Prosodic word type	CI_6 (%)	NH_CA	U	Z	p
Receptive vocabulary	Monosyllables	56%	73%	11.00	-1.04	.298
	Disyllables	52%	82%	10.00	-1.20	.230
	Trisyllables	44%	76%	9.00	-1.36	.173
	Tetrasyllables	41%	74%	10.00	-1.20	.230
	Pentasyllables	38%	77%	8.50	-1.44	.150
Expressive vocabulary	Monosyllables	38%	71%	6.00	-1.84	.066
	Disyllables	27%	70%	9.00	-1.36	.173
	Trisyllables	17%	63%	7.00	-1.68	.093
	Tetrasyllables	13%	61%	6.00	-1.84	.066
	Pentasyllables	17%	61%	7.50	-1.60	.109

Table 6

Planned Comparisons of Percentages of Receptive and Expressive Words Acquired per Prosodic Word Category in CI vs. NH_HA Groups

CYLEX	Prosodic word type	CI %	NH_HA %	F	df	p
Receptive vocabulary	Monosyllables	65%	30%	9.39	1, 160	.003*
	Disyllables	62%	26%	9.23	1, 160	.003*
	Trisyllables	55%	26%	8.30	1, 160	.005*
	Tetrasyllables	52%	21%	7.08	1, 160	.009*
	Pentasyllables	55%	17%	10.31	1, 160	.002*
Expressive vocabulary	Monosyllables	56%	20%	5.40	1, 160	.021
	Disyllables	50%	26%	4.22	1, 160	.042
	Trisyllables	42%	21%	3.04	1, 160	.083
	Tetrasyllables	37%	21%	1.87	1, 160	.174
	Pentasyllables	34%	17%	2.13	1, 160	.146

Bonferroni correction : a = .01

Figure 1

Percentage of Receptive Vocabulary in each Lexical Category- Children with CI

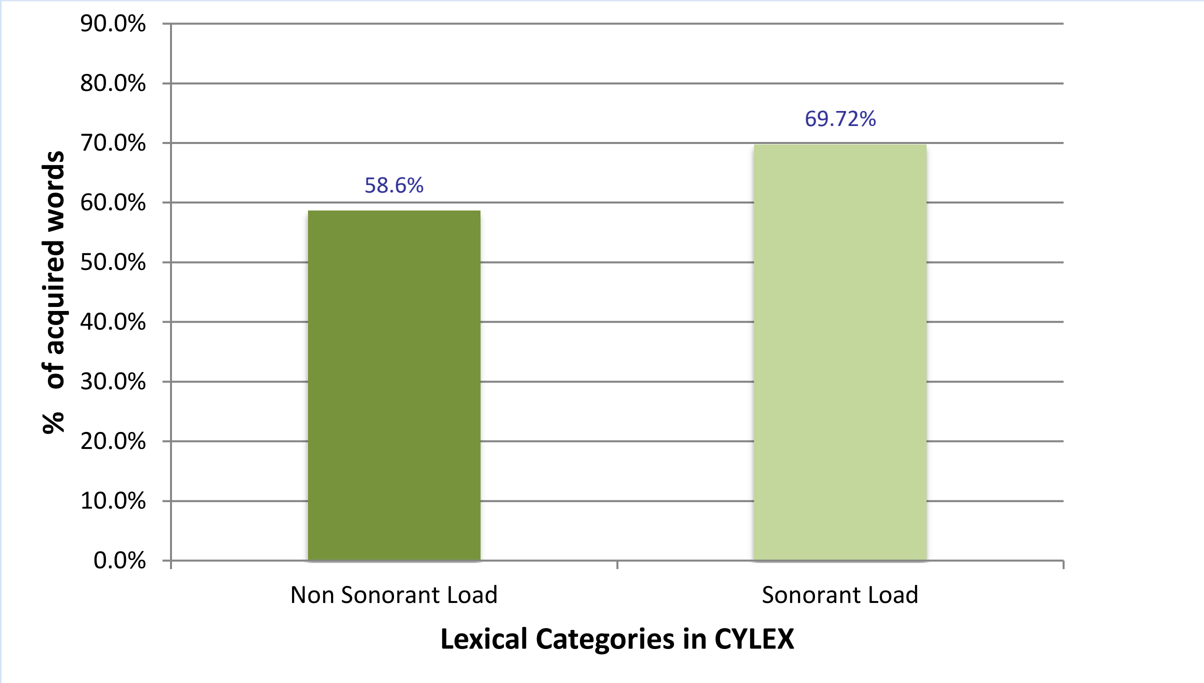

Figure 2

Percentage of Receptive Vocabulary in each Lexical Category- Aged-matched children with CI (CI_6)

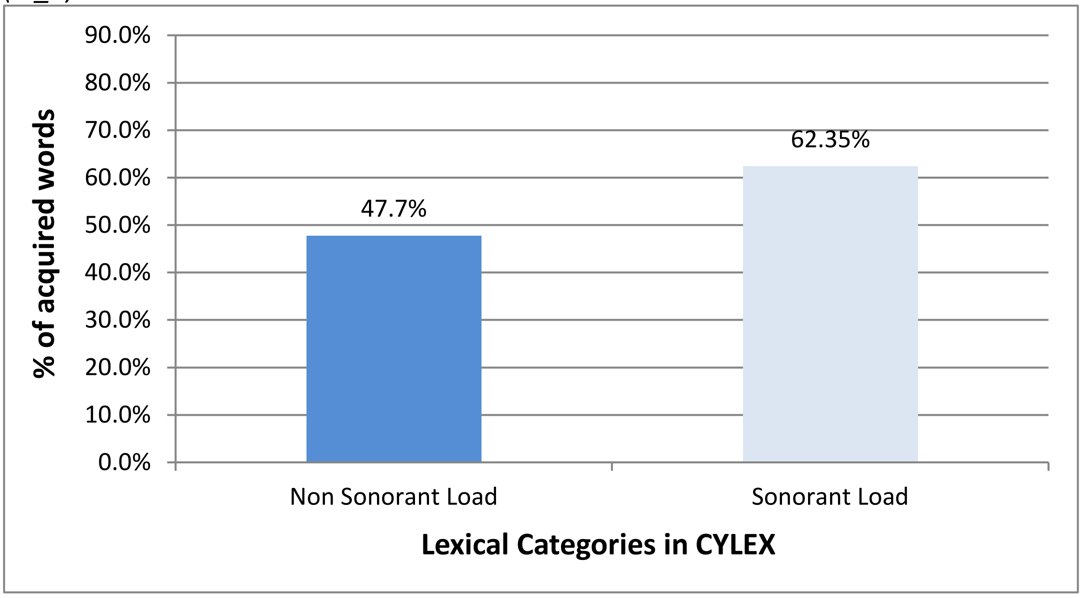

Figure 3

Percentage of Receptive Vocabulary in each Lexical Category - Age-matched Children with NH (NH_CA)

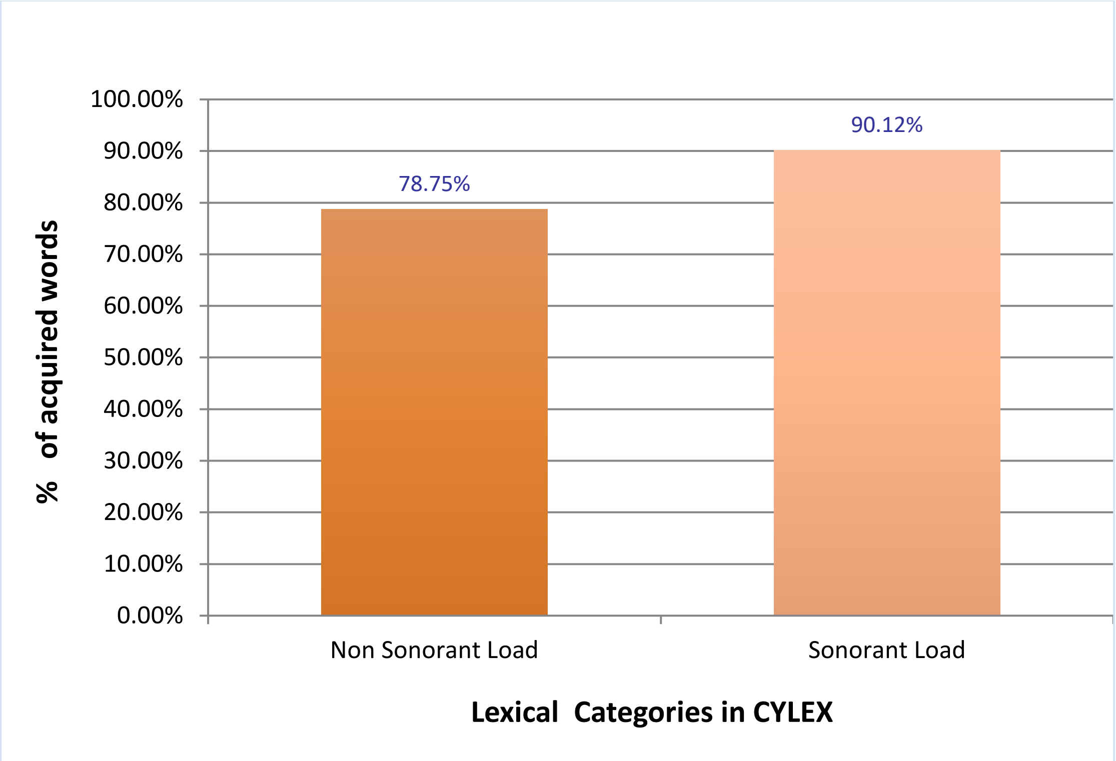

Figure 4

Percentage of Receptive Vocabulary in each Lexical Category - Children with NH matched in Hearing Age (NH_HA)

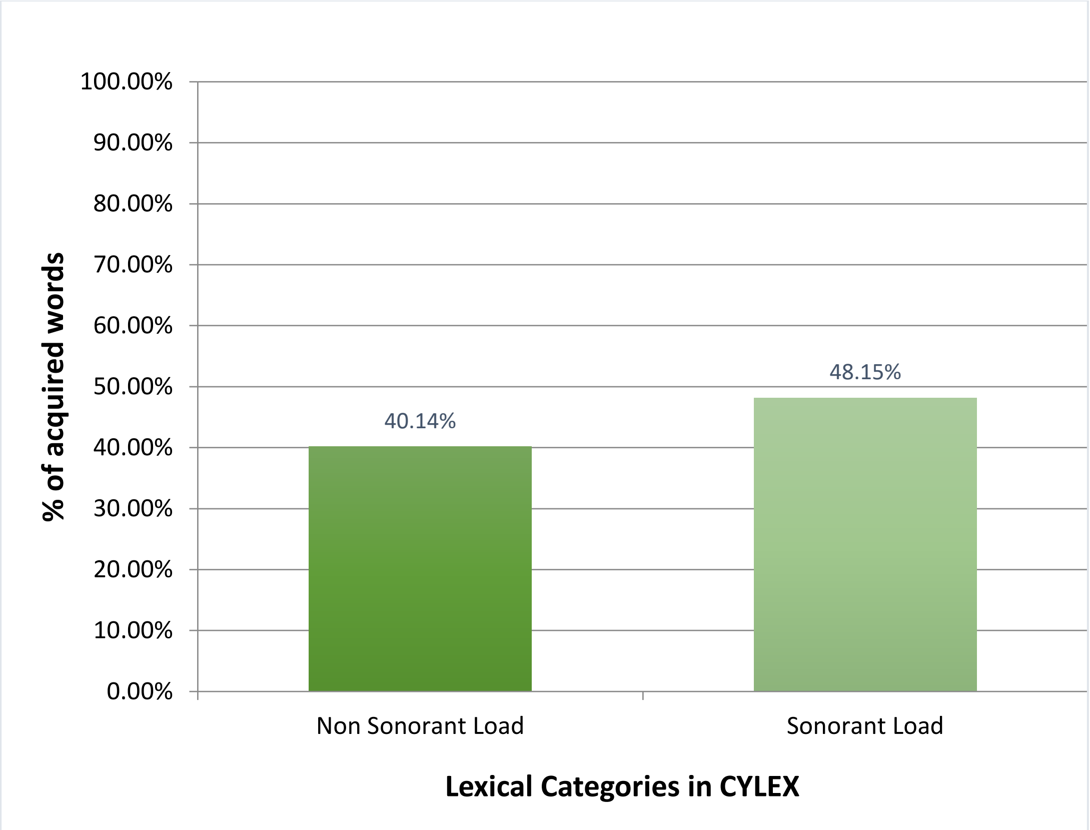

Figure 5

Percentage of Expressive Vocabulary in each Lexical Category- Children with CI

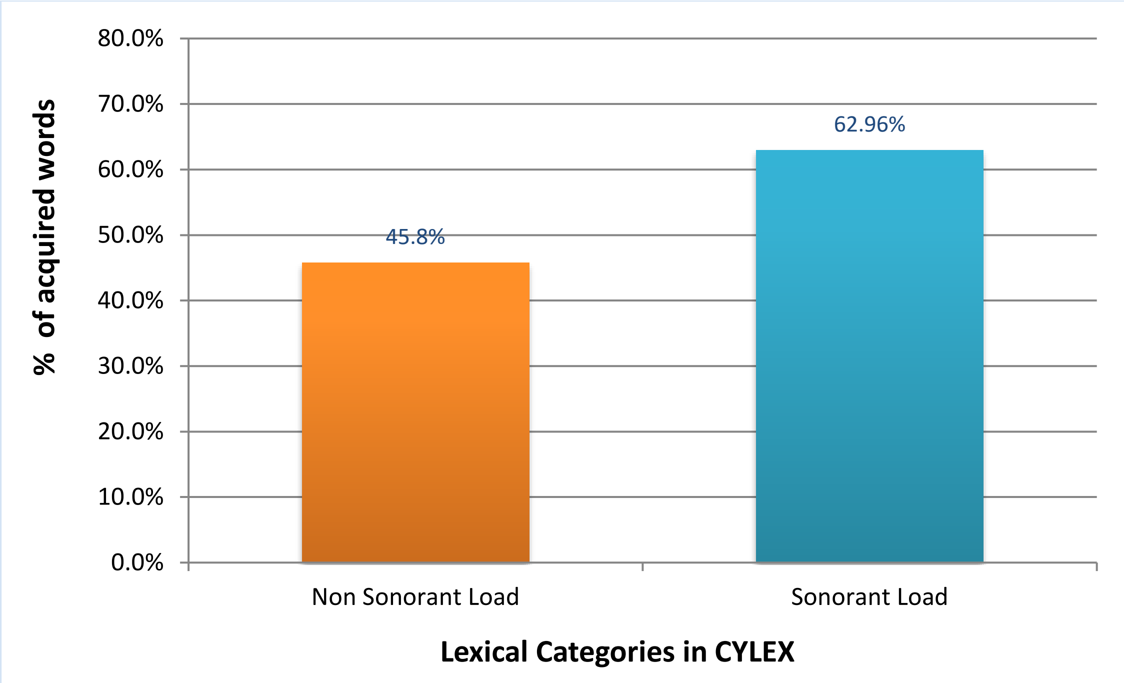

Figure 6

Percentage of Expressive Vocabulary in each Lexical Category- Aged-matched children with CI (CI_6)

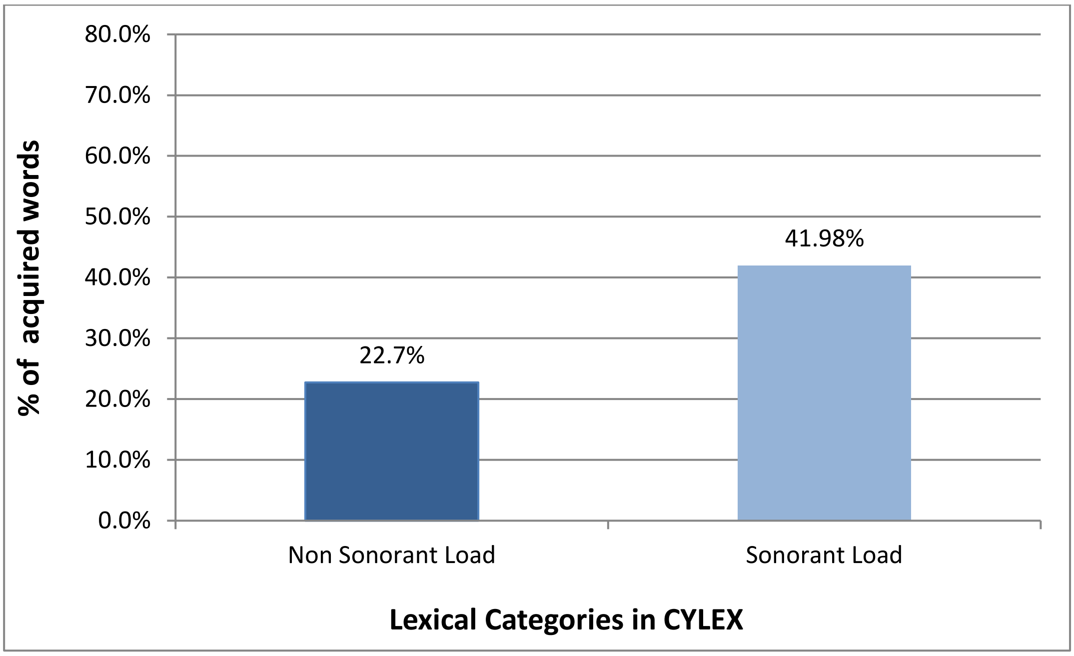

Figure 7

Percentage of Expressive Vocabulary in each Lexical Category - Age-matched Children with NH (NH_CA)

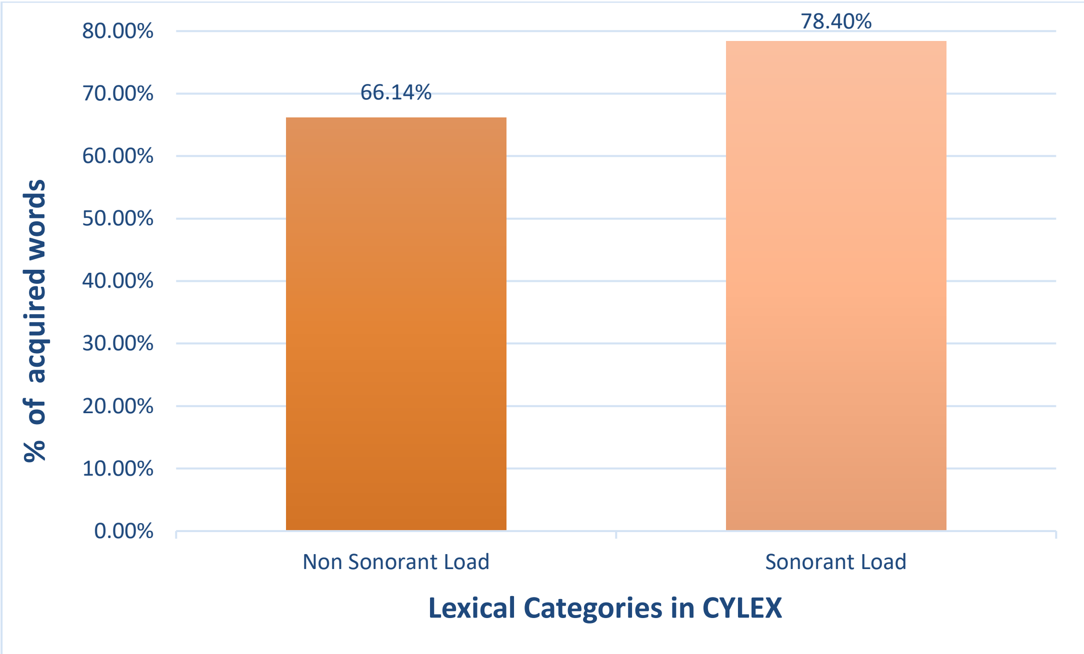

Figure 8

Percentage of Expressive Vocabulary in each Lexical Category - Children with NH matched in hearing age (NH_HA)

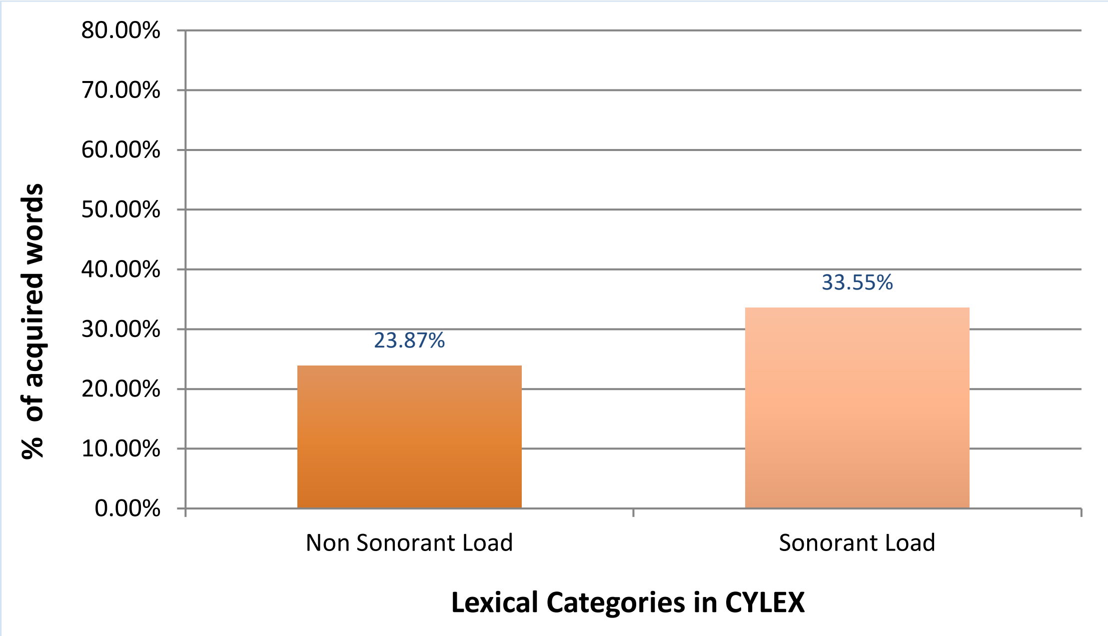

Figure 1. Mean percentages of words acquired receptively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by children with CI.

Figure 2. Mean percentages of words acquired receptively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by children with aged-matched children with CI *(CI_6).*

Figure 3. Mean percentages of words acquired receptively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by age-matched children with NH.

Figure 4. Mean percentages of words acquired receptively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by children with NH matched in hearing age to children with CI.

Figure 5. Mean percentages of words acquired expressively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by children with CI.

Figure 6. Mean percentages of words acquired expressively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by children with aged-matched children with CI *(CI_6).*

Figure 7. Mean percentages of words acquired expressively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by age-matched children with NH.

Figure 8. Mean percentages of words acquired expressively within each lexical category of CYLEX i.e. words with non-sonorant load and words with sonorant load, by children with NH matched in hearing age to children with CI.