The acquisition of verbal morphology in coclear-implanted and specific language impaired children

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SECTION 5.1
CI children in comparison to HA children[4]

1. Abstract

In this study, we compared the development of Dutch verb morphology in 48 4 to 7 year-old cochlear-implanted (CI) children to that of 31 hearing aided (HA) children by analyzing spontaneous speech samples. Both groups had similar aided hearing thresholds. Standardized language testing was used to compare both populations with their TD peers. Measures involved Mean Length of Utterance (MLU), finite verb production and verbal agreement errors.

The results revealed that CI and HA children did not significantly differ on language outcomes and were both able to catch up with their TD peers on MLU and finite verb production. We found that CI and HA children have persistent problems in verbal agreement marking. Additionally, we found that both hearing-impaired groups did not have a greater error rate on the low salient verb morphemes as compared to the omission of the high salient inflected verb in obligatory contexts. No significant correlations were found between age at implantation and hearing age on MLU and verbal agreement errors. As for finite verb production, hearing age was a predicting factor, whereas age at implantation was not.

This study provides evidence that CI children are able to acquire verb morphology and that hearing age is a crucial variable in their acquisition process.

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[4] This section has been submitted for publication in the Journal of Speech, Language and Hearing Research (On the relation between early implantation and verbal morphology production, A. Hammer, M. Coene, S. Gillis, J. Rooryck & P. Govaerts).

2. Introduction

Spoken language perception and verbal morphology

It is well known that predominant acoustic elements in speech production are more easily perceived as compared to those that are acoustically less salient. Maintained by literature on the subject, it has been shown that in developing children, perceptual salience plays an important role in the acquisition process: highly salient elements typically emerge earlier in the child's grammar than non-salient ones (Zobl & Liceras 1994; Goldschneider & De Keyser, 2001). In this view, with respect to verb morphology, free verb morphemes will be more noticeable than bound morphemes and verb stems will be more salient than verbal inflection. It is therefore expected that short, unstressed and bound verb morphemes will be easily missed in incoming speech and will therefore be particularly challenging for the acquisition process.

The reduced perceptual salience of bound morphemes is expected to have an even higher impact on the acquisition of verbal morphology in children with auditory deficits. Different degrees of perceptual salience of free/bound verbal morphology may explain their different order of acquisition. This is commonly known as the Perceptual Prominence Hypothesis (Svirsky et al., 2002). Under this hypothesis, monosyllabic unbound morphemes such as the copula '*is*' (e.g. John *is* nice) will emerge before bound ones, such as *–s* (e.g. John sing*s* a song) or *–ed* (e.g. John work*ed* hard yesterday).

Important delays in the acquisition of morphology have indeed been reported for profoundly deaf children wearing classical hearing aids (henceforth HA) (Cooper, 1967; Quigley, 1976; Brown, 1984; Norbury et al., 2001). At an average age of 9 years, HA children have been shown to perform as accurately as 4-year-olds with typically developing hearing (henceforth TD) (Brown, 1984). Improvements in the production of verbal morphology are found alongside an increase in the children's age with 8 to 10-year-olds showing better performance on tasks eliciting verbal morphemes (e.g. third person *–s* and past tense *-ed*) than 6-year-olds (Norbury et al., 2001; Hansson et al., 2007). Despite these improvements, not all HA children have been found to catch up with their hearing peers: by the age of 11 to 15 years, more than 30% of the HA adolescents will have lower than normal scores on expressive grammar and grammatical judgment tasks (Delage & Tuller, 2007). As the order of verbal morpheme acquisition does not differ from that found in younger TD children, HA children may be seen to demonstrate a delayed rather than deviant acquisition pattern.

Verbal morphology production in CI children

Conventional HAs are hearing devices worn outside the body and are best suited for mild to moderate hearing impairments. Today, many profoundly deaf children are given access to spoken language by means of a cochlear implant (henceforth CI), an implantable electronic device that bypasses the cochlea by means of direct stimulation of the auditory nerve, providing the sensation of hearing. CIs are known to both amplify and fine-tune sounds, providing a highly qualitative acoustic signal. Thanks to this device, many deaf-born children, provided they are implanted early in life, are able to develop oral language in a similar fashion and at the same rate as their hearing peers (Robbins, Svirsky & Kirk, 1997; Hammes et al., 2002; Geers, Nicholas & Sedey, 2003; Svirsky et al., 2004; Geers, 2004; Nicholas & Geers, 2007).

If CIs indeed provide profoundly deaf children with qualitatively better speech input than classical HAs, it is expected that improved language outcomes will be found in the first group as compared to the second. With respect to the acquisition of verbal morphology, the expectation is borne out that CI children who have similar amounts of hearing loss have been shown to use more verbal morphemes in their conversational speech than HA children (Spencer, Tye-Murray & Tomblin, 1998).

Additionally, it has been claimed that the use of a CI positively influences language growth rates. Profoundly deaf children wearing a CI develop oral language faster than their profoundly deaf peers wearing a classical HA (Robbins et al., 1997; Tomblin, Spencer, Flock, Tyler, Gantz., 1999; Svirksy, Robbins, Kirk, Pisoni, Miyamoto, 2000). However, it should be noted that with duration of use of the device held as a constant, a significant amount of variability with respect to language growth rates in CI children is apparent. About half the CI children have growth rates in morphology that are comparable with their TD peers, whereas the other half develop morphology at a slower rate (Szagun, 2002).

Effects of age at implantation and of hearing age

As most CI children are not implanted before the second half of their first year of life, their access to spoken language input will inevitably be delayed, thus triggering. a negative influence on the onset of language development.

At least two factors may influence the language outcomes in CI children: (i) the duration of aural language experience with the device, i.e. the children's hearing age; and (ii) the age at which the children are given first access to spoken language input by means of a CI, i.e. the age at implantation. In terms of the impact of the duration of hearing on verbal morphology production, it has been shown that CI children with longer aural language experience produce more verbal morphemes as compared to children with shorter spans of experience (Spencer et al., 1998; Tomblin et al., 1999). With respect to the time at which deaf children are given first access to oral language by means of a CI, studies show that early implantation is positively related to language learning rates (Kirk et al., 2000; Tomblin et al., 2005; McDonald Connor, Craig, Raudenbush, Heavner & Zwolan, 2006; Holt & Svirsky, 2008). Svirsky et al. (2004) report that CI children receiving their implant at the age of 2 are respectively 6 and 10 months ahead in their language development as compared to CI children implanted at 3 and 4 years.

Significantly, as seen in the relevant literature, the positive effect of timely access to linguistic input on language outcomes has been advanced as an argument in favor of the existence of a so-called sensitive period for language development. A few studies report oral language deficits within hearing individuals deprived of linguistic input during childhood (Itard, 1962; Curtiss, 1977). Studies based on populations of oral deaf children with a CI show that language learning declines after the second year of life (Svirsky in Nature News, 2005), and that children receiving CIs in the third and fourth years of life demonstrate important general language delays as compared to children implanted before that age (Waltzman & Cohen, 1998; Geers et al., 2003). More recent work indicates that the language levels of CI children who are implanted between at 12 and 16 months are likely to fall within the normal range when they are 4.5 years of age. By this point, owing to steep language-learning rates experienced early in life, these children are able to match their TD peers in their variety of morphology production (Nicholas & Geers, 2007). Previous research by our team confirms the perceived advantage of early implantation. Children implanted before 15 months have faster than normal language-learning rates (Coene et al., to appear/a). This raises the possibility that early implanted CI children close the gap with their TD peers in later childhood.

3. Research purposes

CI children have a perceptual deficit, which could make it difficult to perceive verbal morphemes, as these morphemes are short, non-salient items. Although studies have shown that CI children are able to acquire verbal morphology with their implant (Szagun, 2000, 2002; Nicholas & Geers, 2007), it can be expected that they will experience a significant delay in the production of verbal morphology, especially with respect to the least salient type of morphology.

In this study, we intend to compare the acquisition of verbal morphology in profoundly deaf CI children (110dBHL SD 11) to that of HA children with a moderately severe hearing loss (67dBHL SD15), but with a similarly aided hearing loss (CI=33dBHL 7SD, HA=28dBHL 5SD). The motivation behind such a comparison is to be found in previous studies that have reported equivalent outcomes with respect to speech perception between profoundly deaf CI children and severely hearing-impaired HA children (Snik et al., 1997; Blamey et al., 2001). By comparing these two populations of hearing-impaired children with similar aided-hearing levels, we will be able to determine the possible effect of the specific devices on language outcomes. If the outcomes are different for both populations, they may be considered to be an effect of qualitative differences in speech input resulting from a difference in the processing of the acoustic signal. If, on the other hand, no such differences are found, comparable aided-hearing levels may be understood to yield similar language outcomes irrespective of the type of device used by the hearing-impaired individual.

The second aim of this study is to compare the verbal morphological development of CI children with that of their TD age-matched peers. Standardized data from TD children indicate that hearing children produce a large variety of verbal morphemes between the ages of 4 and 7. Moreover, the accuracy of verbal morpheme production is increasingly rapid over the years. Therefore, if CI children have difficulties with verbal morphology, these difficulties should be evidenced within the accuracy of verbal morpheme production.

The third aim is to analyze the verbal morphology production of CI children as a function of the age at implantation and hearing age. Several studies report better language outcomes for young implanted children as compared to older implanted children (Geers et al., 2003; Geers, 2004; Nicholas & Geers, 2007). In addition, based on normative data coming from age-matched TD peers, it is possible to determine which CI children will be able to catch up with their hearing peers by the age of 4 to 7. It has been reported that early implanted children have faster than normal language-learning rates, which result in age-appropriate language outcomes for children aged 4 to 5 (Coene et al., to appear/a). Therefore, we expect early implanted children to close the gap with their TD peers by the age of 4.

In this study, language outcomes will be measured using the Mean Length of Utterance (MLU) in words and by means of the production of bound and unbound verb morphemes. In the light of the Perceptual Prominence Hypothesis discussed in section 1, we expect to find a larger error rate for bound verb morphemes as compared to the omission of inflected verbs, i.e. the complex morpheme consisting of a lexical stem followed by a bound morpheme. The rationale behind this expectation is that language items containing a lexical stem (in combination or not with a bound morpheme (e.g. *walks*) are perceptually more salient than the bound inflection by itself (e.g. *-s*).

Alternatively, one could hypothesize that, due to the underspecification of inflection in young children's grammar (Hyams, 1996), an equal number of both inflected verbs and bound verbal morphemes will be dropped. Under the latter hypothesis, once inflection is acquired, the child should be able to produce all types of verbal agreement markings, regardless of their perceptual prominence status.

In this study, we make use of MLU as a broad, general measure of language development. Studies of the content validity of MLU generally agree that syntactic growth is visualized in sentence lengthening up to a MLU of 4.0

(measured in morphemes), which corresponds to a chronological age of approximately 3 years. Longer MLU's lose their indicative value for syntactic growth, as the development of syntactic complexity does not necessarily result in longer utterances (Miller & Chapman, 1981; Klee & Fitzgerald, 1985; Rondal, Ghiotto, Bredart & Bachelet, 1987). Despite its lack of robustness for content validity, MLU has a broad concurrent validity that persists into middle childhood (5 to 9 years). The longitudinal data of Rice, Redmond & Hoffman (2006) have shown that MLU is a stable discriminator between children with low language production and children with normal language production up to the age of 9. Therefore, we take MLU to be a general indicator of language production, but do not interpret its subsequent outcomes as reflections of syntactic competence.

4. Research method

Participants

Forty-eight CI children and 31 HA children participated in this study. The CI and HA children were drawn from special schools for deaf children and from an audiology centre, all located in Flanders, Belgium. The CI children were aged between 47 and 93 months, the HA children between 48 and 95 months. All of them were monolingual speakers of the Dutch language. A summary regarding age characteristics (i.e. chronological age and age at implantation/hearing age for the CI children) is presented in Table 1 for the CI children and in Table 2 for the HA children. The CI children were evenly distributed across age groups with respect to age at implantation ($F(3.44)=.279$, $p=.841$).

Table 1. Mean, SD and ranges for chronological age, age at implantation and hearing age of CI children.

	chronological age			*age at implantation*			*hearing age*		
	M	SD	Range	M	SD	Range	M	SD	Range
4 yrs (N15)	50.9	4.8	46.8-59.7	14.8	7.3	5.2-34.8	36.1	5.5	23.9-41.6
5 yrs (N14)	63.2	4.1	59.7-70.2	17.7	10.2	5.2-34.5	45.5	8.6	29.5-58.8
6 yrs (N10)	73.5	2.5	72.1-80.6	15.5	10.8	5.2-43.2	58.0	11.4	29.5-70.3
7 yrs (N9)	85.8	2.7	84.0-92.9	15.6	6.7	5.2-25.5	70.2	6.2	59.9-79.2

Table 2. Mean, SD and range for chronological age of HA children.

	chronological age		
	M	SD	Range
4 yrs (N10)	51.9	4.5	47.6 – 59.7
5 yrs (N9)	63.7	5.4	60.2 – 74.5
6 yrs (N6)	76.6	4.1	72.4 – 81.9
7 yrs (N6)	88.7	4.9	83.9 – 95.4

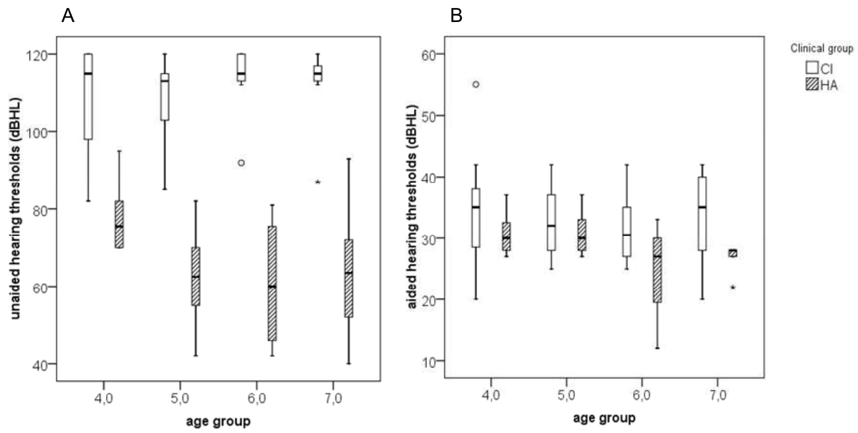
For each age group, the minimum unaided hearing loss (i.e. hearing thresholds averaged over 500, 1000 and 2000Hz for the best ear) of the CI children is between 82-92dB. Such thresholds are expected, given that in Flanders, a hearing loss within this range is one of the prerequisites for cochlear implant candidacy. As a consequence, significantly lower unaided hearing thresholds are found for the CI children as compared to the HA children and partially explain the choice for this particular hearing device. Importantly, both hearing-impaired groups are equivalent in aided hearing thresholds, see Figure 1 and Table 3 for statistical results (unaided and aided hearing threshold means, standard deviations and ranges are placed in Table 1 of the Appendix).

For all CI and SLI children selected for the present study, informed consent was obtained from the parents prior to participation. For an overview of all CI and HA children see Appendix Table 3 and 4 respectively.

Table 3. Statistical results for the comparison between CI and HA children on unaided and aided hearing thresholds. Comparisons are conducted using a one-way ANOVA and, in the case of unequal sample sizes, a Mann-Whitney U-test (Two-sided testing with alpha .01, corrected for multiple testing).

	unaided hearing thresholds (dB)	*aided hearing thresholds (dB)*
4 yrs	$F(1,21)=36.13$, $p<.01$	$F(1,21)=.92$, $p>.01$
5 yrs	$F(1,17)=55.37$, $p<.01$	$F(1,17)=.68$, $p>.01$
6 yrs	$U=.00$, $p<.01$	$F(1,11)=2.51$, $p>.01$
7 yrs	$F(1,13)=44.12$, $p<.01$	$U=11.0$, $p>.01$

Figure 1. Unaided hearing thresholds are presented in panel A for the CI and HA children. Panel B presents the aided hearing thresholds for both hearing-impaired groups.



Language assessment

Thanks to standardized language testing, normative data of 240 Dutch-speaking, hearing children between 4 and 7 years of age were available. The test assesses the children's morphosyntactic skills by analyzing 50-utterance spontaneous speech samples (STAP-test; Verbeek, Van den Dungen & Baker, 1999). It includes such aspects as quantitative and qualitative measurements of verbal morphological production. Regarding the measures under investigation in this study, we have previously shown that the internal consistency reliability for such a 50-utterance sample is high to very high (split-half method with Spearman-Brown formula, (Drenth & Sijtsma, 2006) coefficient .87 – .95, for more details see chapter 4, subsection 4.3).

The test procedure consisted of recording conversations between a child and an adult. The interacting adult was either one of the parents, a speech therapist or the first or second author of this paper. The topics of conversation varied from one sample to another, as the adults encouraged the children to discuss their own interests in an effort to reduce the number of possible silent periods during the registration session. All conversations were videotaped using a Panasonic NV-GS180 camera.

The spontaneous speech samples were transcribed by an experienced speech therapist familiar with listening to the speech of deaf children. Transcriptions were made according to the CHAT conventions, available through the Child Data Exchange System (MacWhinney, 2000). In agreement with the test procedure, the first 50 child utterances were analyzed. The following type of utterances were discarded: repeated and unintelligible utterances and idioms (e.g.

'weet ik niet' *I don't know*) as well as elliptical answers, i.e. answers to preceding questions without a finite verb and/or other utterance parts that can be inferred from the preceding question (e.g. adult: 'does it hurt' child: 'a little bit').

Mean Length of Utterance (MLU) was measured in words. For verbal morphological production, we used a quantitative and a qualitative measure. We counted the number of finite verbs produced in a 50-utterance sample as part of the quantitative measure for verbal morphology. The qualitative measure for verbal morphology builds on (i) the omissions of inflected verbs in an obligatory context such as in (1), defined as a context in which a finite verb needs to be present in order for the utterance to be grammatical; and (ii) the non-target like use of bound verb morphemes, for instance omission of the third person singular (see (2)) or plural morpheme or the mismatch between the bound verb morpheme and the subject (see (3)).

(1) Ikke *(ben) naar de film geweest
I *(am) to the movie been
'I have been to the movie"

Omission finite verb

(2) Die slaap*(t) in een bedje
That sleep*(s) in a little bed
'That one sleeps in a little bed'

Omission 3rd p. sg morpheme

(3) Hier *waren\ was het podium
There were the stage
'There was the stage'

Plural verb form in singular contexts

An overview of the Dutch verbal paradigm is presented in Table 4.

Table 4. Inflection morphology for the present tense subject-verb agreement, exemplified for the verb lopen (*to walk*).

person	*singular*	*plural*
1st	stem + ø loop	stem + en lop*en*
2nd	stem + t# loop*t*	stem + en lop*en*
3rd	stem + t loop*t*	stem + en lop*en*

Reliability

To examine the coding reliability, 10% of the grammatical annotations were reanalyzed by an independent, experienced coder. Correlations were calculated to determine the degree of correspondence between the first and the second coding. These were as high as .99 for MLU and finite verb production and .96 for verb agreement errors/omissions.

According to the standardized test, language development may be identified as being deviant or not, with deviance representing language outcomes that correspond to a 2.5 percentile or less in hearing controls. To determine the degree of correspondence between the two coding sessions in this deviant/non-deviant categorization, we calculated Kappa coefficients (Landis & Koch, 1977). Here, a coefficient of 1 was found for MLU (in words) and .75 and .71 for finite verb production and verb agreement errors/omission respectively.

Data analysis

The raw scores on each measure have been standardized according to the norms of the TD children. This standardization consists of transforming each individual's raw score into a z-score. A z-score denotes the distance to the mean of the population of TD children. The mean of this population is indicated by a z-score of 0 and the 95% confidence interval lies within the z-scores of -1.96 and 1.96. If a child obtains a z-score lower then -1.96, the child has performed significantly below age expectations. Statistical testing between the CI and HA children at each age is done with a one-way ANOVA if the assumption of equal variances is met. If not, the non-parametric Mann-Whitney U-test was utilized. To adjust for multiple testing, we lowered alpha to .01.

In order to determine the effect of Perceptual Prominence in the acquisition of free versus bound morphemes, a comparison was made between the percentage of finite verb use in obligatory contexts and that of target-like use of bound morphemes as a function of the total number of finite verbs. A significantly higher percentage of inflected verbs as compared to target-like agreement morphemes would indicate that perceptual salience plays an important role in the acquisition of verbal morphology.

To examine the effect of age at implantation and of hearing age on language outcomes, we performed linear regression analyses across age groups. In all regression analyses, the two factors, i.e. age at implantation and duration of CI use, (i.e. hearing age) were entered together.

5. Results

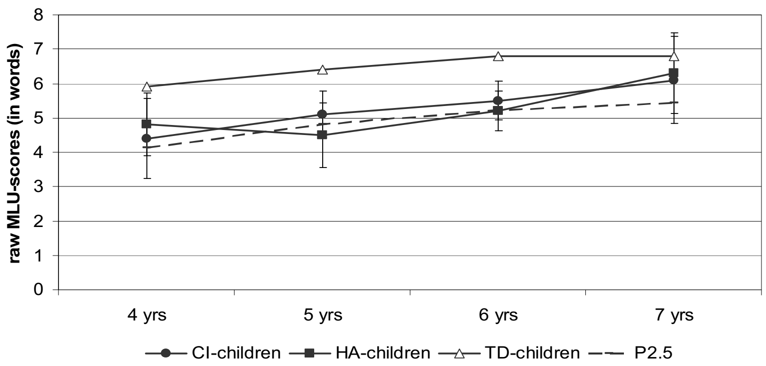
General language and verbal morphology production

MLU

The mean raw scores and standard deviations for MLU are presented in Figure 2. The results of the CI and HA children are plotted against the mean scores of the TD children. The dotted line indicates the lower boundary of the 95% confidence interval of the TD children (P2.5).

The TD children show an increase in MLU up to the age of 6. After this age, their scores level off. Mean age group scores for the CI and HA children are within the lower boundary of the 95% confidence interval at 4 years of age. The CI and HA children increase their MLU over the years and therefore approach the mean MLU of the TD children at the age of 7.

Figure 2. Mean raw MLU scores and SD per age group for the CI children and HA children. Reference scores are plotted in each graph, with the dotted line indicating the lower boundary of the 95% confidence-interval in TD children (P2.5).



The raw scores have been standardized for all age groups by transforming them into z-scores. These are plotted in Figure 3. These data give more information about the variation within each age group for both CI and HA children. Here, the horizontal line indicates the lower and upper boundary of the 95% confidence interval (P2.5 and P97.5) in hearing controls. The dotted horizontal lines indicate the boundaries of the 68% confidence interval (P31 and P68) in hearing controls

With respect to Mean Length of Utterance, no significant differences were observed between the CI and HA children at any age (see Table 5). A closer inspection of the data shows that for the CI children, the median MLU improves with the increasing age of the children. For the HA children, no such improvement is observed before 7 years of age.

Figure 3. Box plots represent the standardized MLU scores for the CI and HA children per age group. Reference values from hearing controls are depicted by dotted lines representing the area within one SD from the mean (z-scores -1 – 1), and by solid lines marking the 95% confidence interval (z-scores -1.96 – 1.96).

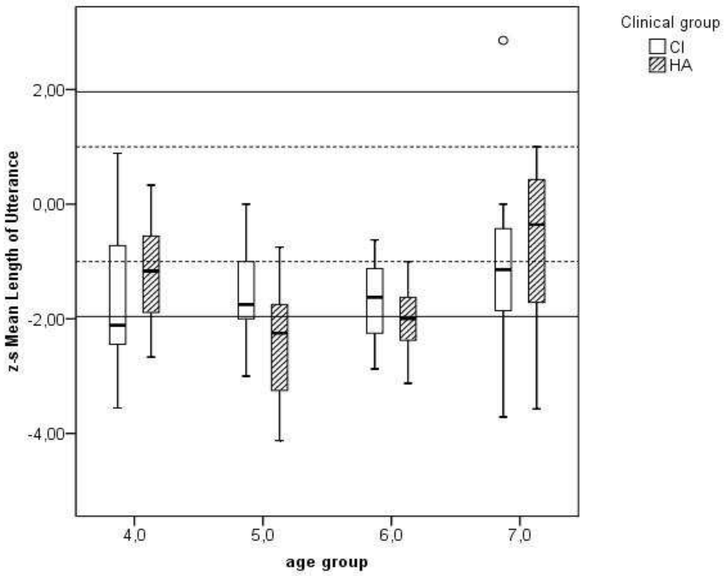


Table 5. Statistical results for the group comparison between CI and HA children on MLU.

	statistical results
4 yrs	F(1,23)=.869, p=.361
5 yrs	F(1,21)=3.313, p=.083
6 yrs	F(1,14)=1.093, p=.314
7 yrs	F(1,13)=.085, p=.775

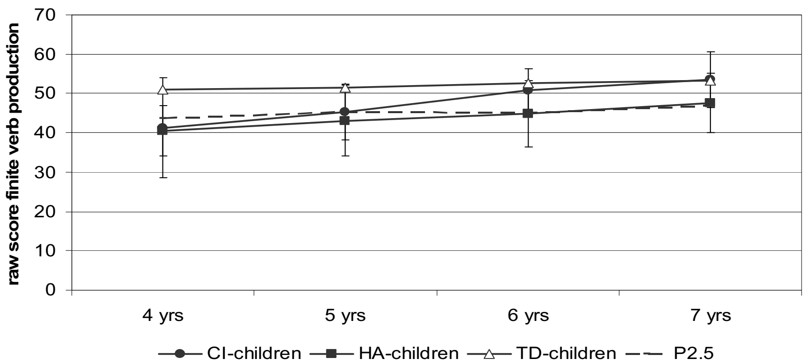
The data also shows that there is a large variation amongst children at all ages for both hearing-impaired populations, and that the proportion of children performing within normal range differs for the four age groups. At the age of 4, 46.7% of the CI children perform well within the 95% confidence interval, whereas 53.3% fall below the P2.5. At ages 5, 6 and 7, an increasing percentage of the children move within the 95% confidence interval. This indicates a steady growth in MLU scores over the years for about 75% of the CI children.

For the HA children, it can be seen that at age 4, 80% fall within the 95% confidence interval. Contrary to CI children, at age 5 and 6, there is no increase in the proportion of children performing within the 95% confidence interval. At 7 years, however, over 75% of the HA children perform within the normal range.

Finite verb production

With respect to finite verb production as detailed in Figure 4, the aged-4 TD children already perform at maximum capacity. At this age, the mean production of finite verbs for the CI and HA children falls below the P2.5. The CI children rapidly catch up with their TD peers, and by the age of 6, their mean finite verb production is comparable to that of TD children. In contrast, by age 6 the HA children barely reach the P2.5 of the TD children in their finite verb production. By age 7, they have yet to move beyond this P2.5.

Figure 4. Mean raw scores on finite verb production per age group and SD for the CI children and HA children. Reference scores of hearing children are plotted in each graph, with the dotted line indicating the lower boundary of the 95% confidence-interval (P2.5).



Here, too, raw scores have been standardized by transforming them into z-scores for each age group. The results are depicted in Figure 5.

Group comparisons between CI and HA children show that there is no significant difference between both hearing-impaired groups in regard to finite verb production (see Table 6).This is probably due to the large variation in outcomes among children for both groups. The standardized results show that at age 4, more than 50% of the CI children perform as well as their TD peers. As for the HA children, a percentage of them reach a performance level that is comparable to that of their TD peers. However, at all ages, most HA children score within the lower boundary of the normal distribution (between the z-scores of -1.96 and -1). This implies that the CI children are slightly better performers than their HA peers (e.g. at age 7 median CI = 0.11, HA: -1.73).

Figure 5. Box plots represent the standardized finite verb production scores for the CI and HA children per age group. The reference data from hearing children are indicated by horizontal lines. The area within one SD from the mean is indicated by a dotted line (z-scores -1 – 1). The 95% confidence interval is indicated by a solid line (z-scores -1.96 – 1.96).

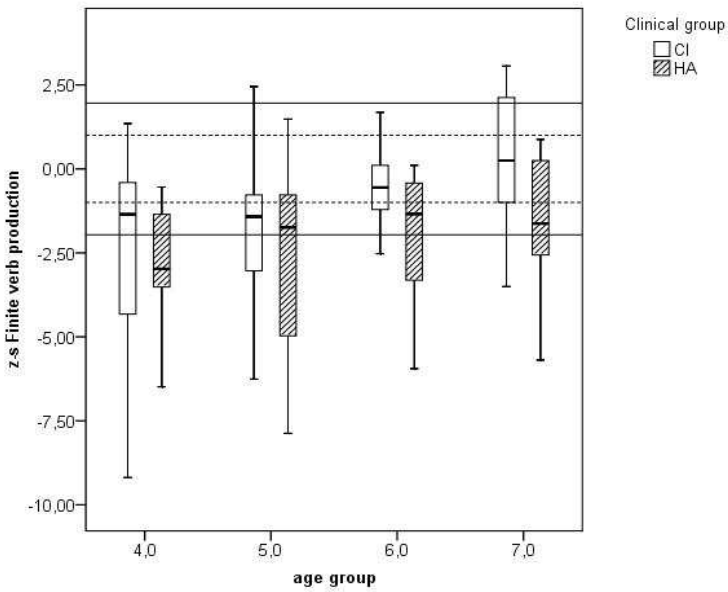


Table 6. Statistical results for the group comparison between CI and HA children on finite verb production.

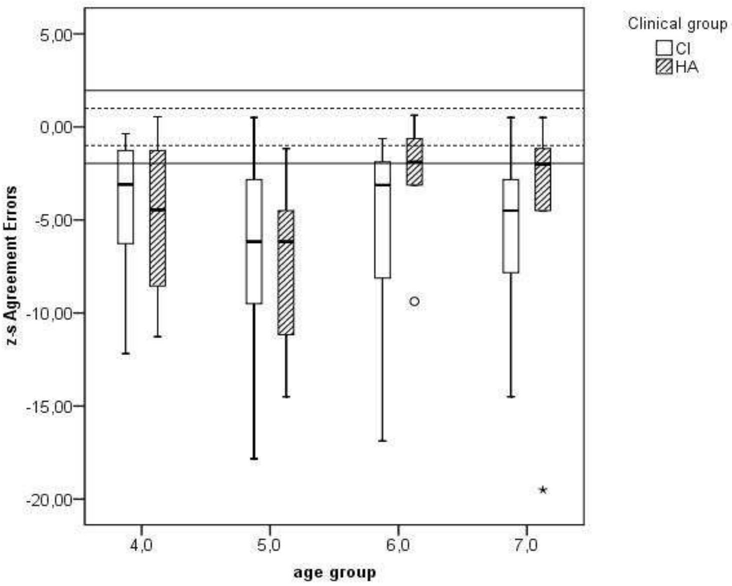
	statistical results
4 yrs	U=59.0, p=.37
5 yrs	F(1,21)=.415, p=.527
6 yrs	F(1,14)=2.984, p=.106
7 yrs	F(1,13)=2.340, p=.150

Errors\omission of verbal agreement

For the TD children, as early as at age 4 the mean occurrence of verbal agreement omission (bound and unbound morphology in obligatory contexts) is less than one. This indicates that in hearing children between 4 and 7 years of age, the accuracy in agreement marking is high.

As regards the hearing-impaired populations, the standardized scores of both CI and HA children as depicted in Figure 6 show that the majority of the children do not perform within the normal range at any age.

Figure 6. Box plots represent the standardized agreement error scores for the CI and HA children per age group. The reference data from hearing children are depicted by horizontal lines. The area within one SD from the mean is indicated by a dotted line (z-scores -1 – 1). The 95% confidence interval is indicated by a solid line (z-scores -1.96 – 1.96).



No significant differences were found between the CI and HA children at any age (see Table 7). Once again, a considerable variation can be observed within each age group for both the CI and HA children. For more than two thirds of the CI children, the number of agreement errors made was not within the normal range. Significantly, the data reveal that there was no clear improvement over the years. The HA children also show difficulties in verbal agreement production. At the ages of 4 and 5, more than 70% of the children fell outside the normal range. At the ages of 6 and 7, this percentage dropped, with more than 20% performing outside the normal range.

Table 7. Statistical results for the group comparison between CI and HA children for errors/omission of verbal agreement.

	Statistical results
4 yrs	F(1,23)=.143, p=.709
5 yrs	F(1,21)=.466, p=.502
6 yrs	F(1,14)=1.278, p=.277
7 yrs	F(1,13)=.075, p=.789

Perceptual prominence

To analyze the influence of perceptual prominence on the acquisition of verbal morphology, we compared the percentages of finite verb production in obligatory contexts with those of target-like bound verb morphemes for the total number of finite verbs in both CI and HA populations. Table 2 of the Appendix provides information about the number of obligatory contexts and the total number of finite verbs used in the analysis.

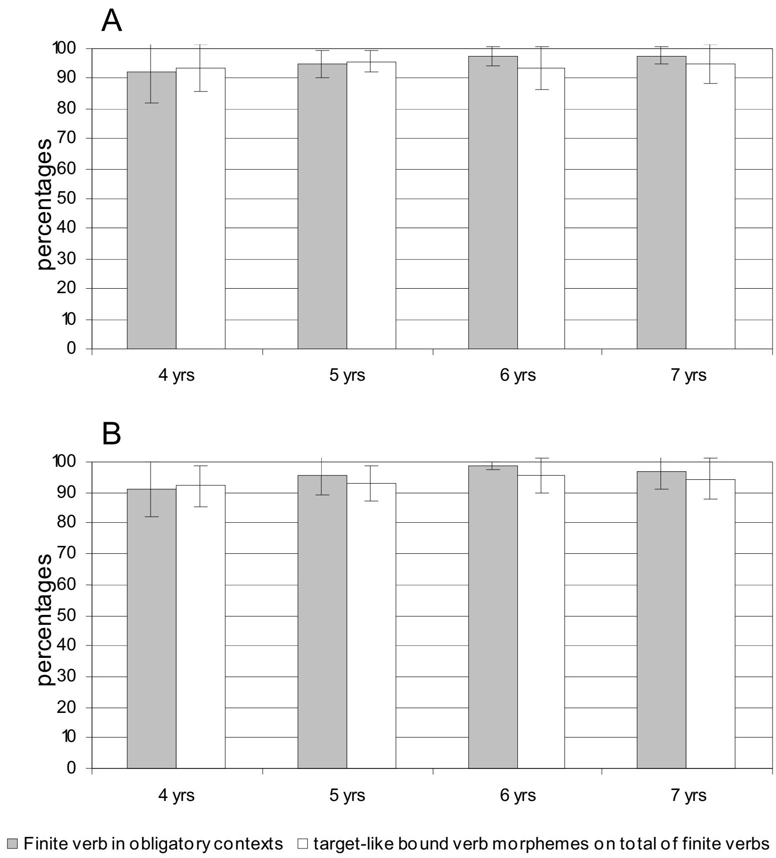
The results in Figure 7 indicate that over the years, CI and HA children produce slightly higher percentages of finite verbs in obligatory contexts. In contrast, both groups of children fail to show the same increase in the target-like production of bound verb morphemes over the years. This means that as children grow older, they tend to produce more verbs, yet at the same time, they do not necessarily mark these verbs correctly with respect to subject-verb agreement.

However, none of the age groups showed significant differences between the two types of verbal morphology measures for either the CI or HA children (see Table 8 for statistical results).

Table 8. Statistical results for the comparison between production of finite verbs in obligatory contexts and target-like production of bound verb morphemes.

	CI-children	*HA-children*
4 yrs	U=106.0, p=.81	U=48.5, p=.91
5 yrs	U=88.5, p=.67	U=28.0, p=.30
6 yrs	U=33.5, p=.22	U=11.5, p=.31
7 yrs	U=28.0, p=.30	U=14.0, p=.59

Figure 7. Mean percentages and standard deviations per age group for the production of finite verbs in obligatory contexts and target-like production of bound verb morphemes on total number of finite verbs produced. (In Panel A for the CI children and in Panel B for the HA children).



Age at implantation and hearing age

The variation between the CI children on MLU and target-like production of bound verb morphemes is not significantly related to the age at which the children received their implants or the duration of their aural language experience (respectively $F(2,45)=1.995$, $p=.148$ and $F(2,45)=.457$, $p=.636$).

For finite verb production, however, the regression function in which both factors have been entered together is significant ($F(2,45)=8.323$, $p=.001$) and accounts for 27% of the variance. In this regression function, only hearing age is a significant predictor whereas age at implantation is not (see Table 9). This indicates that the CI children need a similar length of aural language experience to reach age-appropriate scores on finite verb production, regardless of their age at implantation.

Table 9. Regression analyses for the three verbal measures under investigation with age at implantation and hearing age entered together as factors.

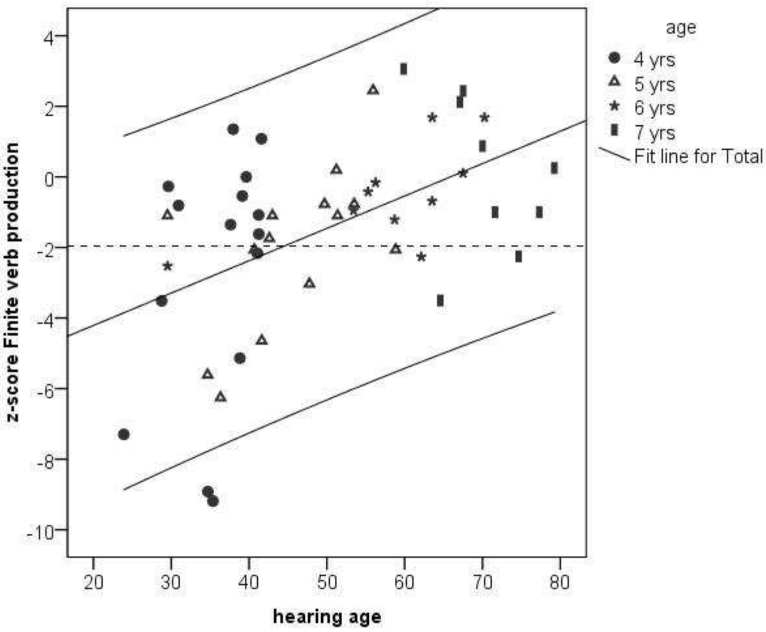
	MLU		*finite verb production*		*% subject-verb agreement errors*	
	β	p	β	p	β	p
age at implantation	-.123	.444	.165	.265	.123	.464
hearing age	.207	.208	.421	.005*	-.032	.846

In Figure 8, we plotted the finite verb z-scores for each child against the hearing age of the child. This figure shows the regression line as well as the 95% confidence interval. The horizontal dotted line indicates the P2.5 of hearing children. CI children scoring below the P2.5 can be considered deviant from the TD population.

From this Figure, it can be seen that the regression line intersects the P2.5 at approximately 44 months of age. This indicates that 4 to 7-year-old CI children need approximately 44 months of aural language experience to produce a percentage of finite verbs that is within the normal range.

From Figure 8, it can also be observed that the number of finite verbs produced by about 56% of all CI children (across age groups) is within the normal range. Obviously, this percentage is not consistent across age groups, but increases over time: it is as low as 40% for the 4-year-olds, but reaches 78% for the 7-year-olds.

Figure 8. Scores obtained by CI children in finite verb production as a function of hearing age. The regression of age onto finite verb z-scores as well as the 95% confidence interval are indicated by the solid lines. The dotted line presents the P2.5 of the TD children, the reference population.



6. Discussion

Do CI children out-perform their HA peers?

The first aim of our study was to compare the language outcomes of cochlear-implanted children with those of hearing-impaired children wearing classical hearing aids. We hypothesized similar production patterns for CI and HA children with respect to their verbal morphology, as these children compare in perceptual abilities, having similar aided hearing thresholds. This hypothesis is only partially supported by our results. No significant differences were found between CI and HA children at any age on MLU, finite verb production and verbal agreement errors.

However, the increase in finite verb production between the ages of 4 and 7 is steeper for the CI children than for the HA children. At the age of 6, the CI children perform comparably with the mean of their TD peers. The HA children, however, have verbal production scores that are similar to those found in the weaker TD children at age 6 and 7.

Importantly, the lower production of finite verbs for the HA children is not due to a relatively high rate of finite verb omission. Our results show that CI and HA children decrease their finite verb production in obligatory contexts at the same rate (see Table 2 of the Appendix). For the HA children, the low production of finite verbs points towards an overuse of elliptical utterances. Such an overuse of ellipses has been reported frequently in young, normally developing children. The use of ellipses avoids computational overload and is typical for speakers with processing limitations (Kolk, 2001). When adopting the working memory model of Baddeley et al. (1998, see also Baddeley, 2003), processing limitations could explain the low production of finite verbs for the HA children. In this working memory model, phonological material is retained in the phonological loop. This retention enables the permanent storage of the phonological material (e.g. words). The efficiency of the phonological loop, and ultimately of permanent storage, is dependent on the acoustic and phonological representations. Acoustically salient material and strong phonological representations facilitate permanent storage of the phonological material (Baddeley, 2003). It is possible that the HA children build phonological representations more slowly as compared to CI children. Incomplete functioning of the working memory results in protracted language development, because more input is required for adequate processing and incorporation in the child's language system (Leonard, Ellis Weismer, Miller, Francis, Tomblin & Kail, 2007).

It could well be the case that the CI children in this study were able to improve their perception abilities to a level at which the phonological representations allowed more efficient storage of phonological material compared to children wearing a HA. However, the fact that the CI children still produce subject-verb agreement errors to a similar extent as their HA peers implies that within the CI group, perception abilities are not yet optimal. Similar problems with respect to the target-like use of verbal morphology have also been reported by Brown (1984), Norbury et al. (2001) and Hansson et al. (2007).

Do CI children catch up with their TD hearing peers?

As can be observed from the data in Figure 2, the TD children already reach a plateau in finite verb production at the age of 4. CI children also reach such a plateau, but not before the age of 6. This indicates that CI children have a delay in verbal morphology development spanning approximately 2 years, but that they are also able to catch up with their TD hearing peers by the age of 6.

A similar observation is valid for general language development measured by means of MLU in words. From age 6, the MLU of TD children begins to level off. Here, also, CI children show an increase in MLU over the years and approach the mean MLU of the TD children at the age of 7, indicating that by this age, they have caught up with their hearing peers with respect to utterance length.

Can age at implantation or hearing age predict morphology development?

Variation in outcomes is observed between CI children for all the language measures under investigation. The variation in outcomes on MLU and the percentage of subject-verb agreement errors is not explained by age at implantation or hearing age. The outcomes on finite verb production can be partially predicted by hearing age but not by age at implantation.

When comparing outcomes in CI children with the same chronological age, the children's age at implantation is inherently confounded with auditory experience. Children who are implanted earlier in life will also benefit from longer aural language experience. Such a benefit has been reported by Spencer et al. (1998) who show that auditory speech experience correlates with morphology production in a population of 9-year-old CI children when controlled for chronological age. This study confirms that aural language experience may be a crucial variable, instead of chronological age and age at implantation alone. It suggests that CI children are likely to catch up with their hearing peers provided they have had a similar duration of aural language experience.

For the language measures under investigation, TD children show a plateau-effect at some point in their language development. Most CI children will eventually reach this plateau, albeit with a delay. Once the plateau has been reached, language outcomes are steady and age at implantation and/or the hearing age no longer seems to play a role. For MLU, this can be illustrated by the absence of significant correlations between both factors and the children's utterance length. At age 4, most of the CI children perform within the 95% confidence interval, making linear growth minimal (see Figure 2 and 3). In a similar vein, Geers et al. (2003) and Geers (2004) did not find significant correlations between age at implantation and language outcomes for the 8 and 9-year-old CI children participating in their study. Most of these children compared to their TD peers in terms of general language outcomes.

It is important to notice, however, that the congenitally deaf children participating in this study had an initial delay that is proportionally related to the number of months they spent with little to no access to spoken language (i.e. from birth to the moment of activation of the implant). This means that children that reach the plateau level for MLU could only have done so by having faster than normal language learning rates.

Does perceptual prominence play an important role in verb morphology development?

With respect to perceptual prominence, we expected to find a larger error rate for bound verb morphemes alone as compared to omissions of the entire verb form (verb stem + bound morpheme) for CI and HA children. The underlying idea behind this expectation was that complex lexical items such as inflected verbs are perceptually more salient than the bound verb morphemes by themselves. Our findings show that these expectations were not met: CI and HA children did not omit significantly more target-like bound verb morphemes as compared to inflected verb forms in obligatory contexts. In terms of acquisition, this equates to stating that CI and HA children are able to acquire both types of morphology.

We also formulated the alternative hypothesis that the similar use of both types of morphology could reflect the acquisition of grammatical features such as tense and/or agreement. Under this hypothesis, when grammatical tense and agreement remain underspecified, both bound verb morphemes and inflected verbs are expected to be omitted. However, our data indicate that both hearing-impaired populations participating in this study *do* produce inflected verbs within a normal range. As these inflected verbs must be specified for tense and agreement features, the observed findings can therefore not result from mere grammatical underspecification.

However, the agreement markers on the inflected verbs are not always used in a target-like manner. In many cases, person/number features of the subject and the verb do not agree. These problems with subject-verb agreement marking persist up to the age of 7. The number of errors is not related to the children's age at implantation nor to the hearing age. Importantly, subject-verb agreement errors are already uncommon in TD children from age 4.

Both perceptual prominence and tense/agreement underspecification have thus been shown not to be viable. In our view, the observed findings could relate to reduced auditory speech input, causing a delay in hearing-impaired children with respect to the storage of verb morphemes in the paradigm. A substantial amount of research indicates that hearing-impaired people have difficulties perceiving speech in noisy backgrounds (e.g. Lorenzi et al, 2006). As most of the day-to-day speech is typically produced in difficult listening situations, it is not unlikely that in CI and HA children, these morphemes are often missed in continuous speech. Translating this perception deficit in terms of acquisition, one may take the number of stored exemplars of inflected verbs in hearing-impaired children to be too low for adequate morphological analysis. As we know from the literature, the acquisition of verbal morphology starts when the number of stored exemplars (i.e. inflected verbs) exceeds a particular level (the Critical Mass Hypothesis, Marchman & Bates, 1994). Analysis of these exemplars enables a child to discover the verbal morphological paradigm of the native language when a critical mass is reached (see also Locke, 1997). In hearing-impaired children, the absence of such a critical mass therefore results in failure to initiate the morphological acquisition process.

Implications and future research

In the present study, CI and HA children are tested up to the age of 7. Not all children perform within the normal range by this age. Due to this age limit, it is not clear whether the observed delay persists into the older ages, or whether CI and HA children will be able to catch up with their hearing peers with respect to the target-like use of verbal morphology after the age of 7. If so, this would indicate that the use of verbal morphology in these populations is delayed rather than impaired.

It should also be mentioned that although some late-implanted children are able to catch up with their TD peers, it does not imply that age at implantation is of little concern. Earlier age-appropriate language skills could enhance learning on other cognitive domains (i.e. theory of mind) and pragmatic skills. Future research investigating language outcomes should therefore also include cognitive and pragmatic measures.

7. Conclusion

The aim of the present study was to investigate the verbal morphological production of 4 to 7-year-old CI children. The results were compared to those of age-matched, moderately severe hearing-impaired children with classical Hearing Aids (HA). In both populations, production of verbal morphology was investigated quantitatively by counting the number of inflected verbs produced, and qualitatively by analyzing the target-like use of unbound and bound verb morphology in obligatory contexts. The use of standardized language testing allowed us to compare the results of both hearing-impaired populations with the results of age-matched Typically Developing (TD) peers. With respect to the qualitative measure of verbal morphology, we analyzed the results in the light of the Perceptual Prominence Hypothesis (Svirsky et al., 2002). The results of all language measures for the CI children were analyzed as a function of age at implantation and hearing age.

The CI and HA children participating in this study compared to one another in aided hearing thresholds (between 28 – 33dBHL). This allowed us to investigate the influence of aided hearing on language outcomes in terms of the type of device used. No significant differences were found between the CI and the HA group with respect to the number of finite verbs produced, the number of subject-verb agreement errors and the MLU in a representative speech sample. However, over the years, CI children showed a steeper increase in finite verb production than HA children. This has been attributed to speech processing differences between CIs and HAs. As a result, HA children build phonological representations more slowly as compared to their CI peers. This results in incomplete functioning of the working memory and, as a consequence, delayed language development.

At the age of 4, a subgroup of the CI children performs within the normal range on MLU and finite verb production. This subgroup increases with increasing age. The results of these measures are not predicted by age at implantation. For finite verb production, 27% of the variance was predicted by the child's aural language experience only. Thus, it seems that for these CI children, a similar amount of time is needed to reach the performance plateau of the TD children on these measures. However, as aural language experience is proportionally related to the time that CI children have spent with little to no access to spoken language, early-implanted children are likely to reach the plateau earlier as compared to later-implanted children.

CI and HA children show persistent problems in the target-like use of bound verb morphology. This is not explained by the perceptual prominence in the spoken language input or the underspecification of grammatical tense and agreement. Instead, we propose that the delayed acquisition of verb morphology results from the reduced auditory speech input offered by the CI. Hearing-impaired people experience difficulties in speech recognition in noisy surroundings (Lorenzi et al., 2006). As everyday speech is mainly produced in such difficult listening situations, we argue that CI and HA children often miss verb morphemes in continuous speech, and that this may explain their delayed acquisition process.