Chapter 7
General discussion
Does moderate to severe congenital hearing impairment (CHI) affect the use of morphosyntactic knowledge in spoken language production, written language production, visual sentence recognition, and auditory sentence recognition in adults? This was the main question in the series of studies that are described in this thesis. In this final chapter, the main findings of the studies are discussed, as well as how these findings contribute to the research field. Furthermore, possible directions for future research and clinical implications are considered.

The effect of moderate to severe CHI on language production in adults

The data of the subsequent studies in this thesis showed that adults with moderate to severe CHI had selective difficulties with the deployment of particular aspects of morphosyntax in spoken language production (chapter 2 and 5). These difficulties were not attributed to current limitations in auditory perception, but to perceptual limitations during language acquisition (chapter 5). In written language production, no significant problems with the deployment of morphosyntax were observed on a group level (chapter 3). However, within the group of adults with moderate to severe CHI, the outcomes of morphosyntactic correctness were associated with the degree of hearing impairment during childhood, both in the written and spoken modality (chapter 2 and 3). This gradual effect of CHI on linguistic outcomes is in line with the inconsistent access account (Moeller & Tomblin, 2015), which predicts that more limited access to linguistic input during language acquisition results in more pronounced effects on linguistic abilities. Despite the absence of a group difference in the morphosyntactic correctness of written language production, this association suggests that consequences of CHI on written language production may be expected in adults who have a more severe degree of CHI (chapter 3).

The relationship between error patterns and hearing loss during language acquisition

The role of auditory perception in the acquisition of morphosyntax was not only reflected in the association between linguistic outcomes and the degree of the participants’ congenital hearing loss, but also in the specific error patterns in the spoken language production of adults with CHI: most observed errors were (at least partly) accounted for by perceptual salience. In chapter 2, the errors were discussed in view of the position of the various Dutch morphological markers on a perceptual salience continuum. Morphological markers that were positioned at the least salient side of the continuum, and thus characterized as being relatively hard to perceive acoustically, appeared to be specifically vulnerable when acquired with impaired hearing. Low perceptual salience explained errors in the use of inflectional suffixes in Dutch present tense verb conjugation, and in the use of the Dutch definite articles de and het (the). Within the paradigm of verb conjugation in the present tense, most errors concerned the least salient inflectional marker (2nd/3rd singular suffix -t’). Likewise, within error categories for which no significant group differences were found, specific patterns could be explained by
the relative perceptual salience of the corresponding morphological markers. Errors in noun plural marking mostly concerned the use of the least salient noun plural suffix ‘-s’, while less errors occurred in the use of the more salient noun plural suffix ‘-en’. For the use of determiners, errors in gender agreement between a singular noun and the definite articles *de* and *het* were observed in both directions: the common gender article *de* was (incorrectly) combined with neuter nouns, while the neuter article *het* was (incorrectly) combined with common nouns. In the course of Dutch language acquisition, either as a first or a second language, a stage in which the common article *de* is overgeneralized to neuter nouns, is normal, due to the higher frequency of *de* in the input (Orgassa & Weerman, 2008). Thus, the bidirectional pattern in article substitutions that was observed in the spoken output of adults with moderate to severe CHI suggests that the acquisition of grammatical gender in individuals with moderate to severe CHI, was influenced by another factor than frequency differences in the input. Because Dutch definite articles are generally unstressed and are situated close to each other on the perceptual salience continuum, the uptake of determiners preceding a noun could be inconsistent due to the hearing loss. Inconsistencies in the uptake are then likely to account for the bidirectional pattern in the determiner substitutions. Thus, perceptual salience seems a key factor underlying the observed performance errors in the spoken language production of adults with moderate to severe CHI.

Besides perceptual salience, the relatively high grammatical complexity to use Dutch pronominal adverbs was discussed as an additional factor accounting for the substantial occurrence of adverb errors in the spoken language production of adults with moderate to severe CHI. In adult learners of Dutch as a second language, difficulties with gender agreement between determiners and nouns, with the use of the Dutch adverb *er*, and with pronominal adverbs are also often observed. From second language research, it is suggested that language learners need a certain threshold in the uptake of language within an age-related timeframe to acquire specific aspects of a language successfully (e.g., Sorace, 2005). Hence, because congenital hearing impairment affects the amount of uptake of the linguistic input and may thereby lead to a less efficient use of the timeframe that is critical for successful acquisition of specific aspects, long-term effects of CHI on language production may resemble the difficulties that are observed in adult learners of Dutch as an additional language. The observed errors in our data support this prediction.

Discussion of our findings in view of the vulnerable marker hypothesis

The findings with regard to the morphosyntactic correctness of spoken and written language production of adults with moderate to severe CHI were interpreted within the framework of the vulnerable marker hypothesis (Bishop, 1994). This hypothesis states that problems in the expression of morphosyntactic markers that are vulnerable in the process of language acquisition surface when communication demands challenge the language production system, while they do not appear in conditions that are less taxing. In line with the vulnerable
marker hypothesis, the adults with CHI in our studies show specific vulnerabilities in their language production that can be related to the conditions under which their language was acquired. The errors in the spoken language production of the CHI adults are not random, but seem to be associated with hearing loss during language acquisition. This indicates that CHI has affected specific parts of their language. Thus, our data identify the markers of Dutch that are vulnerable when acquired with impaired hearing. The vulnerable marker hypothesis also applies to the conditions in which performance problems surface: the occurrence of errors seems to depend on the amount of strain the language production system is under. Within each modality, the level of strain is related to the task demands (e.g., a task to elicit language in expository discourse has relatively high demands because participants have to tap into their cognitive and linguistic resources) and may vary depending on the linguistic context (e.g., earlier research suggests that errors in spoken language production are more likely to occur in longer, complex utterances than in short, simple utterances (Bishop, 1994; Franck et al., 2002). The influence of variance in the level of cognitive strain is reflected in the participants’ variability in performance, i.e., morphosyntactic structure errors are made in one utterance, while the same structure is produced correctly in errors another utterance. Between modalities, constraints that are specific for each modality seem to influence the chance of performance errors occurring. In the task we used to elicit written language, production was less time constrained than in the spoken modality. Moreover, while writing, explicit linguistic knowledge could be consulted during recurring cycles of revision, while this was not possible when producing spoken language. Thus, the task we used to elicit spoken language may have taxed the participants’ capacities to a greater extent than the language production task in the written modality. Modality-specific constraints are thus likely to explain the differences in the outcomes of group comparisons between the two modalities.

**Interpretation of the results on language production**

In line with the framework of the vulnerable marker hypothesis, the variability in the performance of adults with moderate to severe CHI in their language production (chapters 2, 3, and 5) suggests that the adults are not impaired in their knowledge of the morphosyntactic paradigms in which they show difficulties. When the demands of the communicative context allow for it, the adults are able to correctly deploy their knowledge in the process of language production. Acquiring an oral language with impaired hearing thus rather seems to induce an increased vulnerability in the implementation of the acquired knowledge than an impairment in the knowledge itself. We proffer that the increased vulnerability in the use of linguistic knowledge is a possible result of a lower level of ‘consolidation’ of morphosyntactic knowledge. If knowledge is firmly established within the language of an individual, conditions that put considerable strain on the capacity of the language production system will be less likely to induce a problem in the deployment of that knowledge. Given the association we found between the degree of hearing loss during language acquisition and the adults’ morphosyntactic performance in writing and
in speech, the gradual effect of inconsistent access to linguistic input seems to be reflected in the level of consolidation of the morphosyntactic knowledge.

**The effect of moderate to severe CHI on language recognition in adults**

As we found a long-term effect of moderate to severe CHI on the deployment of morphosyntactic knowledge in spoken language production, we examined whether consequences of CHI could also be found in the use of this knowledge in the domain of language reception. This topic was addressed by examining sentence recognition in the visual modality (chapter 5), thus without confounding of differences in auditory abilities, and in the auditory modality (chapter 6). Two approaches were used: the distortion-sensitivity approach (DSA) was applied to assess the specific contribution of a selection of morphosyntactic cues to sentence recognition performance (chapter 5 and 6), while regression analysis was performed to examine the differential contribution of bottom-up auditory abilities and top-down linguistic abilities to sentence recognition (chapter 6).

**The use of specific linguistic cues in sentence recognition**

Before using the DSA in our studies with adults with moderate to severe CHI, its applicability for assessing the use of various linguistic cues in sentence recognition in adverse conditions was demonstrated in two groups of adults with an evident difference in linguistic proficiency, i.e., in native and non-native users of Dutch (chapter 4). Auditory sentence recognition performance was assessed, as well as the adults’ abilities to recognize masked text stimuli that were either correct Dutch sentences or sentences distorted in their lexical, syntactic, or semantic content. The data showed that the reduced performance of non-native participants on the Text Reception Threshold (TRT) task with correct Dutch sentences, compared to the performance of native participants, could be attributed to the non-native participants’ poorer abilities to exploit lexical and syntactic cues. Because sentence recognition performance was affected by non-nativeness in both the auditory and visual modality, we assumed that the same linguistic aspects that influence the TRT also contribute to the performance in the auditory modality. Thus, these differentiated results on the use of specific linguistic cues in the two groups showed the potential of the DSA for further research into the use of other specific linguistic cues when recognizing sentences in adverse conditions.

In contrast with the groups that were assessed in chapter 4, differences in linguistic proficiency between adults with moderate to severe CHI and adults who acquired their language while hearing normally were more subtle. As the data in chapter 2 and 5 showed, morphosyntactic correctness of spoken language production was an aspect of proficiency in which a long-term consequence of auditory limitations during language acquisition could be objectively assessed. As explained earlier, the adults’ selective difficulties with morphosyntax in language production were assumed not to result from impaired morphosyntactic knowledge, but from an increased
sensitivity to loss when the language production system is strained. Using the DSA in the visual and auditory modality, the studies in chapter 5 and 6 examined whether hearing loss during language acquisition had affected the exploitation of specific morphosyntactic cues in the process of sentence recognition. In both modalities, distortion of the morphosyntactic cues yielded a decrease in the participants’ performance, indicating that the cues were actually used in the tasks under assessment. However, as the adults with CHI did not differ from the NH and AHI adults in their sensitivity to the distortions, our data indicated that, when processing short sentences in adverse conditions, the CHI adults’ exploitation of these specifically examined morphosyntactic cues, had not been affected by their auditory limitations during language acquisition.

In the studies of this thesis, language recognition was assessed with a sentence recall task. This type of task is generally used to assess hearing-impaired individuals’ speech recognition abilities in clinical practice (Nilsson et al., 1994; Plomp & Mimpen, 1979). A better insight into the influence of CHI-induced differences in linguistic proficiency on the outcomes of this task was therefore of additional value to the clinic. The question arises why the CHI adults’ vulnerability in the correct deployment of specific morphosyntactic markers in language production was not directly reflected in the exploitation of this knowledge in the sentence recall task. Differences between the processes used in language production and language recognition are likely to explain this. In the sentence recall task, the correct response was partially given, so linguistic knowledge was used only to complete missing information. In the language production task, in contrast, produced utterances depended completely on the participants’ active deployment of linguistic knowledge. Therefore, recalling sentences is probably a task that is not sensitive enough to assess possible differences between the adults with CHI and the reference groups in their use of the morphosyntactic cues under study. Assessment of adults with CHI with a self-paced reading or listening task (Marinis, 2003; Vasić & Blom, 2011) could be a more sensitive method to study this issue.

The contribution of auditory and linguistic abilities to sentence recognition

In chapter 6, regression analysis was performed to examine the differential contributions of a measure of bottom-up auditory abilities and a measure of linguistic abilities to the auditory and visual sentence recognition performance of adults in each group. The results showed that CHI-induced differences in linguistic abilities, as assessed by analyzing the morphosyntactic correctness of spoken language production, explained part of the variance in sentence recognition performance within the CHI group. This finding implies that acquiring a language in the context of moderate to severe CHI does affect the processes that are used in the recognition of short sentences in adverse conditions in both modalities (chapter 6). Thus far, it is unclear which specific sub processes of language recognition that are somehow related to the measured ability in spoken language production, are affected by CHI. As the language production data suggest that CHI has impacted the level of consolidation of specific
morphosyntactic knowledge in the participants’ language, linguistic abilities that are used in sentence recognition and that depend on this level of consolidation could be affected in a similar way. Furthermore, CHI could have an impact on other linguistic and more general cognitive resources that are used in sentence recognition. If CHI has induced an impediment in the use of more general cognitive resources like memory capacity and other executive functions (Kronenberger et al., 2013), this would also affect sentence recognition performance.

**Methodological considerations and suggestions for further research**

All studies in this thesis were designed to explore possible long-term consequences of moderate to severe CHI on various aspects of language production and language reception. The choice of research methodologies was based on previous studies in other populations and adapted for use in a population of adults with CHI. Due to the explorative character of the studies, the outcomes should be interpreted with some caution.

The type of research as conducted in this thesis is generally based on relatively small numbers of participants. Despite the small sample sizes, the outcomes of the analysis of morphosyntactic correctness of the spoken language production of the 20 adults with moderate to severe CHI in chapter 2, were replicated in a study sample of 21 different adults with moderate to severe CHI in chapter 5. The replication of the findings in another study population strengthens the conclusions we drew regarding the aspects of Dutch morphosyntax that are at risk when acquired with impaired hearing. For the outcome measures of the other research topics, i.e., for written language production, visual sentence recognition, and auditory sentence recognition, no significant differences in performance between the groups under study were found. The relatively small sample sizes could account for this finding and it is unclear whether it would hold in a study including more participants.

The studies in this thesis evoke additional research questions, sketching the outlines of possible future studies. First, further analysis into the type of errors in which adults with CHI distinguish themselves from adults who acquired their language while hearing normally could be valuable. As stated in chapter 3, we consider it possible that the error types we used to categorize the observed errors were too general, thereby possibly concealing more differences in morphosyntactic correctness between the CHI adults and the reference group. Second, the use of specific morphosyntactic cues in sentence recognition could be more adequately assessed using a task with an outcome measure that is more sensitive to possible differences in processing. As stated earlier, a self-paced reading or listening task (Marinis, 2003; Vasić & Blom, 2011) could be an appropriate alternative for the sentence recall task used in the studies of this thesis. Third, the contributions of bottom-up auditory abilities and top-down linguistic abilities to auditory speech recognition were examined with a task using short Dutch sentences that were relatively simple in their linguistic structure, i.e., containing a main clause and no more
than one dependent clause. Utterances used in daily communication are generally longer and often contain several dependent clauses, varying in their level of embedding. It is therefore likely that the outcomes of our study in chapter 6 underestimate the effect of moderate to severe CHI on the adults’ speech comprehension abilities in daily life. Available cognitive resources are called upon to a larger extent when understanding continuous speech than when repeating sentences. Therefore, assessing language reception with tests for ongoing speech comprehension is expected to yield a more representative representation of an individual's speech comprehension abilities in daily life (Best et al., 2016). Last, future research into the consequences of CHI on the use of top-down resources in language recognition should include an assessment of more general cognitive abilities. It is well known that inter-individual variance in the use of cognitive resources influences language recognition and that hearing impairment affects various aspects of this top-down processing (Arlinger et al., 2009). However, it is yet unclear how the acquisition of linguistic and non-linguistic cognitive abilities with impaired hearing specifically affects sub processes used in language recognition. To examine this, a comparison could be made between the performance of adults with AHI and adults with CHI on various cognitive tasks and on a measure for the effort deployed during speech recognition. The use of pupil dilation as a measure of listening effort suggests that top-down processing (also referred to as processing load) increases when speech intelligibility decreases (Zekveld et al., 2011). In addition, interindividual differences in cognitive abilities are related to the processing load evoked by speech perception (Koelewijn et al., 2012). We suggest that the impact of CHI on the acquisition of linguistic and non-linguistic cognitive abilities could be reflected in their processing load during speech recognition, as well as in the relations between this measure and more general cognitive abilities.

**Implications for clinical practice**

From a clinical point of view, the studies in this thesis yield valuable and relevant results as they indicate that the effects of moderate to severe CHI on language production and language recognition in adults are subtle, specific, and persistent. In addition, the data show that selective weaknesses in the deployment of morphosyntax in spoken language production, surface depending on the cognitive demands of the communication situation. For the clinical practice, this implies that outcomes of tests assessing language production in individuals with CHI should be interpreted within the context of the specific demands of the task. When the cognitive demands of a language production task do not strain the capacity system of the assessed individual, the outcomes of the test may underestimate possible consequences of CHI on their linguistic abilities. Therefore, the findings of the studies in this thesis show the importance of using cognitively challenging tests in the clinical evaluation of language production abilities of people with CHI.
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For professionals working in health care with adults who are hard of hearing, the outcomes of this thesis are relevant as they identify aspects of communication in which adults with congenital hearing impairment (CHI) may differ from adults with acquired hearing impairment (AHI). The consequences of CHI affect auditory speech recognition performance and thus the expected benefit of auditory rehabilitation. This aspect should therefore be taken into account in clinical practice. The expected benefit of auditory rehabilitation is generally based on the degree of hearing impairment of the patient, combined with general knowledge of how a hearing device is expected to support bottom-up auditory processing of the acoustical signal. However, if a patient acquired their oral language with impaired hearing, the result of auditory rehabilitation may not be as expected, due to a smaller contribution of top-down processing to language recognition performance. Thus, analysis of morphosyntactic correctness of the spoken language production of a patient with CHI could be of additional value to a professional to yield insight in the degree to which CHI has affected the acquisition of language.

Within the context of current hearing health care, the conditions in which children with congenital hearing impairment are growing up now, differ in certain aspects from the conditions in which the CHI participants of the studies in this thesis were raised. Over the last decades, innovations were introduced that assure early identification of hearing impairment in young children, allowing auditory rehabilitation to start at an early age. Furthermore, the hearing aids and cochlear implants that are currently used, are technically superior to the devices that were used when the participants of the studies in this thesis were children. Hence, one could ask whether our findings still apply to the current generation of children that are diagnosed with CHI. Tomblin et al. (2015) showed that, in a large group of children who were nearly all diagnosed with mild to severe hearing impairment subsequent to newborn screening, and who were rehabilitated with state-of-the-art hearing aids, inconsistent access to linguistic input due to hearing impairment has a gradual effect on linguistic outcomes. Despite the early rehabilitation and positive effect of state-of-the-art hearing devices on the bottom-up auditory abilities of children, the acquisition of language is thus still at risk. Diagnostics and rehabilitation in children with CHI should therefore not only increase their bottom-up auditory processing abilities, but should also strengthen the acquisition and consolidation of linguistic resources that are used in both language production and language reception. Hence, we stress the importance of fine-grained linguistic diagnostics in children with CHI during the course of language development, followed by speech and language therapy with a focus on the language-specific aspects that are vulnerable when acquired with impaired hearing. Though more research is needed to determine which therapy techniques are most effective in morphosyntax intervention (Proctor-Williams, 2009), morphological training is shown to improve the morphological knowledge and language production abilities of children with severe to profound CHI (Bennett et al., 2014; Bow et al., 2004). Speech and language therapy with an extra focus on advancing the acquisition and consolidation of specific morphosyntactic
knowledge in children with moderate to severe CHI thus may prevent long-term consequences of CHI as observed in the studies of this thesis.

**Recommendations for linguistic diagnostics in children with CHI**

Assessment of the linguistic abilities of children with moderate to severe CHI needs to be sensitive and specific enough to detect deviations in the acquisition of morphosyntactic aspects that are specifically at risk when acquired with impaired hearing. As our data show, vulnerabilities in morphosyntactic attainment may surface depending on the demands of the task and on the scope of abilities that are assessed by the task. Therefore, the sensitivity and specificity of language tests should be evaluated from this perspective. In addition, a standardized norm-referenced score, used to evaluate the outcome of an individual child on a language test, should be interpreted with caution. Generally, a child’s test score is defined as reflecting normal development if the child performs within the normal variance of a reference group of peers. However, linguistic outcomes should be evaluated in view of other aspects of the cognitive development of a child to identify possible discrepancies. As Tomblin et al. (2015) showed, the sole reliance on norm-referenced scores may underestimate the real effect of CHI on linguistic abilities. A child’s performance on a test may be within the normal range of a norm group, though when comparing the score to that of a norm group of peers that are equal in their socio economic status, a significant delay may become apparent (Tomblin et al., 2015). Thus, assessing the possible effect of CHI on linguistic abilities with standardized tests has its limitations. Given these limitations, the added value of analysis of language production with a focus on morphosyntax should be emphasized. Specific vulnerabilities that are not identified when using a standardized test may be revealed when a sample of spontaneous language is analyzed (Hadley, 1998).

**Recommendations for speech and language therapy in children with CHI**

Based on the findings of the studies in chapters 2 and 5, and in line with other research (e.g., Hammer & Coene, 2016; Tomblin et al., 2015), we recommend an additional focus within speech and language therapy in children with CHI who acquire Dutch on the following aspects (examples of utterances containing an error are marked with an asterisk):
• Noun gender agreement between determiner and noun (de/het (the), deze/dit (this))
  * De bal moet dus binnen het rechthoek zijn.
    De bal moet dus binnen de rechthoek zijn.
    The ball must be within xxx [substitution of common definite article de for neuter definite article het] rectangle.

• Obligatory use of determiners in front of particular types of nouns and in particular syntactic positions
  * De service moet in servicevak.
    De service moet in het servicevak.
    The service has to go into [ø] [neuter definite article het] service box.

• Verb conjugation using inflectional suffixes
  * Maar als je in een peloton fiets, (…).
    Maar als je in een peloton fietst, (…).
    But when you ride [omission of 3rd person singular suffix ‘-t’] in the peloton, (…).

• Markers for pluralisation of nouns
  * En twee tegenstander proberen een doelpunt te maken.
    En twee tegenstanders proberen een doelpunt te maken.
    And two opponent [omission of noun plural marker ‘-s’] try to score.

• Use of Dutch pronominal adverbs, with specific attention to the correct use of their prepositional part
  * Daar kan je redelijk mooi de roeihaal simuleren.
    Daarmee kan je redelijk mooi de roeihaal simuleren.
    There - [ø] [omission of the prepositional part of a pronominal adverb ‘with’], you can simulate the rowing stroke quite nicely.

• Use of ‘er’ in its repletive function, i.e., as an indicator for an indefinite subject or as the subject of a passive verb
  * En je zorgt dat het bij jou geen doelpunten in het doel vallen.
    En je zorgt dat er bij jou geen doelpunten in het doel vallen.
    And you make sure that xxx [substitution of repletive er] are no goals scored in the goal.
General conclusion

‘Perception is of definite and probable things’ (James, 1890) was quoted at the beginning of this thesis. While bottom-up auditory processing feeds the definite part of perception, top-down use of linguistic knowledge, among other cognitive resources, determines the most probable interpretation of the signal. Our findings indicate that adults with moderate to severe CHI are impeded in both building blocks of their perception, due to disturbed processing caused by their current hearing loss and due to the effect of their hearing loss on the acquisition of language and other cognitive resources. In addition, moderate to severe CHI appears to induce vulnerabilities in the deployment of specific morphosyntactic knowledge in language production. The data of this thesis thus show where language and hearing meet: the aspects of language production in which the impact of hearing loss on language acquisition was apparent, were identified. Additionally, general indications of a subsequent effect of CHI-induced impediments in linguistic abilities on language recognition abilities were found. Despite this, the question how the consequences of acquiring linguistic resources with impaired hearing affect the production and recognition of language in adults is yet unanswered. Further research within a psycholinguistic framework, including assessment of cognitive abilities, is needed to identify the specific processes in language production and language reception that are affected by CHI.