EVOLUTION OF SYNTACTIC COMPLEXITY AND AVOIDANCE STRATEGIES IN CHILDREN AND ADOLESCENTS WITH MILD-TO-MODERATE HEARING LOSS

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1. Introduction

Studies that have examined the evolution of syntax in typical development, after the so-called critical period for language acquisition (age 6-7), have underlined the fact that language performance in this period is characterized by an increase in the complexity of the utterances, in particular with higher MLUs and higher rates of embedding (Hass & Wepman, 1974; Leadholm & Miller, 1992; Tuller et al., 2006; Hamann et al., 2007). No new syntactic structures appear at this age. When concentrating on atypical language development, studies have consistently shown less frequent use of embedding in children and adolescents with different pathologies (SLI: van der Lely, 1998 and Hamann et al., 2007; epilepsy: Monjauze, 2007; profound hearing loss: Audollent & Tuller, 2003; focal brain injury: Reilly et al., 2004). However, no such investigation has been made on language development in older children and adolescents with mild-to-moderate hearing loss. This congenital and bilateral hearing loss corresponds to an average hearing loss in the range of 21 to 70 decibels. It is much more frequent than more severe hearing loss in children and it’s detected relatively late (around age 5). These children have therefore several crucial years of degraded language input. Studies on language development in this population have shown significant and persistent language impairment, especially in morphosyntax, in children and adolescents, even if there is considerable inter-subject variability (see Delage & Tuller, 2007 and Delage, 2008 for literature reviews). We undertook a longitudinal study of this population in order to explore the nature and the evolution of the effects of limited hearing loss on language acquisition: Are they merely temporary or are there long-lasting effects on language? And secondly, how can we explain these eventual long-lasting effects? Could the implication of performance systems provide a share of the explanation? We propose to explore these questions by focusing on the development of syntactic complexity in this population.
It has been proposed that constructions that emerge slower/later in typical acquisition and generally cause difficulties in atypical acquisition can be characterized by a higher degree of computational complexity (Tuller et al., 2006; Hamann et al., 2007, Jakubowicz & Tuller, 2008). Computational complexity can be characterized by three main factors:

1) The number of syntactic operations: with the number of merges and presence or absence of movement (as defined by the formal Derivational Complexity Metric proposed by Jakubowicz, 2005; Jakubowicz & Tuller, 2008);

2) The nature of syntactic operations: merge versus movement, distance of dependency relations and/or the nature of the intervener in such relations (Gibson, 1998; Jakubowicz, 2005; Friedman et al., 2009);

3) The depth of embedding: indeed, we have argued in previous work that deeply embedding constituents increases the cost of the syntactic computation (Tuller et al., 2006; Hamann et al., 2007; Delage et al., 2008; Jakubowicz & Tuller, 2008).

We have proposed in previous work\(^1\) that embedded clauses in French can be classified according to their degree of computational complexity by using the above factors. Adverbial clauses are less complex than complement or relative clauses, since they are merged to CP or IP (versus VP or DP), and thus are less deeply embedded. Non-finite embedded clauses are less complex than finite embedded clauses because the latter involve dependencies at several levels: subject agreement, complementizer-tense agreement, mood and tense dependencies and finally, presence of a lexical subject and a complementizer. As predicted, these differences in terms of degree of complexity do in fact coincide with the chronology of normal L1 acquisition. Thus, adverbial clauses and non-finite embedded clauses appear earlier than other embedded clauses (Clark, 1985; De Cat, 2002; Hamann et al., 2007).

With respect to relative clauses, different types of these subordinate clauses can also be classified according to their degree of syntactic complexity. Thus, relative clauses are more complex than other embedded clauses because they imply wh-movement. And, what we have called genuine relatives (Delage et al., 2008; Delage, 2008) differ from “pseudo”-relatives in depth of embedding. Indeed, genuine relatives involve a depth embedding characterized by a subordinate clause inside a DP, which is itself inside an IP. On the other hand, pseudo-relatives involve shallower embedding. For example, 0-level relatives (as in (1)), which are not embedded within a matrix clause, involve no embedding within IP. Absence of embedding within IP also characterizes dislocated relatives (2). To summarize, whereas genuine relatives involve embedding of a CP inside a DP (which is itself inside an IP), none of the constructions classified as pseudo-relatives (0-level

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\(^1\) See Tuller et al. (2006), Hamann et al. (2007), Delage (2008), Delage et al. (2008) and Jakubowicz & Tuller (2008).
relatives, dislocated relatives, clefts and presentational relatives) contain subordinate clauses embedded in this way. We therefore conclude that pseudo-relatives are less complex than genuine relatives.

(1) Little brother who is crying. [DP [CP ... ]]
(2) The man who was ill, he’s dead. [IP [DP [CP ... ]]] [IP ... ]

If we turn now to production of errors in spontaneous language, and if we are on the right track regarding the notion of computational complexity, it follows that errors are more likely to occur in the most complex structures\(^2\). In general, these errors result in simplification of the structure in question. In other words, errors in complex structures frequently entail avoidance of computational complexity. For example, a child who omits an accusative clitic in an illegitimate context avoids computational complexity, but produces an ungrammatical utterance. Thus, we can imagine that more errors ought to occur in complex utterances and, that, among the different types of embedded clauses, more errors could be found in the most complex ones (in relative clauses for instance).

Avoidance of computational complexity could also result in the use of over-all simpler structures, which increases the chances of production of an error-free utterance. Thus, young typically-developing children and atypically-developing subjects could use fewer embedded clauses compared to matrix clauses, fewer finite embedded clauses compared to non-finite, and fewer genuine relatives compared to pseudo-relatives\(^3\). Hamann et al. (2007) also found (in children and adolescents with SLI) other mechanisms used to avoid subordination: juxtaposition of two matrix clauses within the same prosodic contour in order to avoid the production of a relative clause, as in (3), self-interruption of a subordinate clause, which is abandoned (4), or even the grammatical omission of the complementizer (5).

(3) J’ai vu son copain il est sympa. [I saw his friend he’s nice]
(4) Je pense qu’il… [I think that he…] / Elle pleurait parce que… [She cried because…]
(5) Je pense on va jouer. [I think (that) we will play]

To summarize, given what we know about how typically-developing children avoid computational complexity, our expectation is that the following will also hold for children and adolescents with mild-to-moderate hearing loss:

✓ Frequency of the various types of embedded clauses should follow the degree of syntactic complexity of the structures observed.

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\(^2\) See for example Franck et al. (2004) and Hamann et al. (2007) for children with SLI, or Audollent & Tuller (2003) for young adults with SLI and profound hearing loss.

\(^3\) These patterns have been observed in typically-developing children and in participants with SLI (Tuller et al., 2006; Hamann et al., 2007; Delage et al., 2008).
Avoidance of syntactic complexity will be higher in deaf participants than in controls and will affect the most complex structures.

Production of errors will increase in relation to the degree of computational complexity, as the use of complex structures increases the risk of errors.

And finally, longitudinal results between childhood and adolescence, as performance systems are still maturing, should show an increase in the frequency of complex structures, a reduction of their ungrammaticality and also a reduction in the use of avoidance mechanisms.

2. Method

In this study, we focused on the evolution of syntactic complexity and the use of avoidance strategies in a population of children and adolescents with mild-to-moderate hearing loss (MMHL). To explore both age differences and evolution of language performance, we analyzed spontaneous language samples (approximately 60 utterances per subject, using CLAN, MacWhinney 2000) in two groups of participants with MMHL which were tested at two times. At the first testing time, the MMHL group included 32 participants aged 6;1 to 11,11, subdivided into two age groups: 16 Younger MMHL aged 6 to 9 and 16 Older MMHL aged 9 to 11 (see Table 1). These participants were evaluated at a second testing time, about two years later (M = 23 months, SD = 8 months). At this time, Younger MMHL had a mean age of 9;8 years (7;11-11;3) and Older MMHL were 12;6 years (11;4-13;11). These deaf participants were compared to 36 subjects benefiting from typical development (TD): 12 TD 6-year-olds, 12 TD 8-year-olds and 12 TD 11-year-olds. Table 1 summarizes the characteristics of all of the groups, and provides basic measures of their spontaneous language (MLU and rate of embedding—number of subordinate clauses over the total number of verbal utterances):

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Sex</th>
<th>Age</th>
<th>MLU</th>
<th>Rate of embedding</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMHL</td>
<td></td>
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<tr>
<td>Younger MMHL</td>
<td>16</td>
<td>12m/4f</td>
<td>6 to 9</td>
<td>5.6</td>
<td>21% (12,4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(M = 7;9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Older MMHL</td>
<td>16</td>
<td>7m/9gf</td>
<td>9 to 11</td>
<td>6.5</td>
<td>30% (14,4)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(M = 10;8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TD-6</td>
<td>12</td>
<td>6m/6f</td>
<td>M = 6;4</td>
<td>7.0</td>
<td>32% (11,4)</td>
</tr>
<tr>
<td>TD-8</td>
<td>12</td>
<td>6m/6f</td>
<td>M = 8;2</td>
<td>7.6</td>
<td>36% (11,6)</td>
</tr>
<tr>
<td>TD-11</td>
<td>12</td>
<td>6m/6f</td>
<td>M = 11;4</td>
<td>7.9</td>
<td>41% (10)</td>
</tr>
</tbody>
</table>

| MMHL versus Older MMHL: | p<.05 | ns |
| TD-6 versus TD-8: |       |    |
| TD-8 versus TD-11: |       |    |

**Table 1:** General characteristics of groups with mild-to-moderate hearing loss (MMHL) and groups with typical development (TD)
3. Results

3.1. First testing time (T1)

As was shown in Table 1, the younger MMHL children had lower scores than the older ones for MLU and for rate of embedding. And these scores in both of these groups were lower than scores of TD subjects of the same age. Moreover, frequency of the various types of embedded clauses that were produced followed their degree of syntactic complexity. Thus, among the subordinate clauses, both MMHL groups produced significantly fewer relative clauses than TD children. Recall that we argue that relatives are the most complex embedded clauses, as they imply movement. And among the relative clauses, both MMHL groups produced fewer genuine relatives than TD children of the same age (see graph 1). We have argued that genuine relatives are the most complex relative clauses as they are more deeply embedded than CPs in pseudo-relatives. Notice that 41% of children with MMHL produced no genuine relatives at all; only 19% of TD subjects fell into this category.

[Graph 1: Proportion of genuine relatives]

Comparison of the two age groups showed that younger MMHL were more sensitive than older to differences in the degree of syntactic complexity. Indeed, younger MMHL produced significantly fewer subordinate clauses embedded in subordinate clauses (=’deeply embedded subordinates’) than older MMHL. Younger MMHL also produced many more 0-level relatives than older MMHL and than controls. Finally, they produced more non-finite embedded clauses than older MMHL and than TD subjects, even if these last differences were not significant. These results are presented in Table 2.

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4 Mean number of relative clauses produced by child: 2.9 for Younger MMHL vs. 5.3 for TD 6-8 (N = 24) : p <.01 ; 4 for Older MMHL vs. 6 for TD 8-11 (N = 24) : p <.05.
5 Difference is significant only for Older MMHL vs. TD 8-11: p <.05.
Table 2: Proportions of deeply embedded subordinates, 0-level relatives and non-finite embedded clauses in MMHL groups and in TD groups

<table>
<thead>
<tr>
<th></th>
<th>Younger MMHL</th>
<th>Older MMHL</th>
<th>TD-6</th>
<th>TD-8</th>
<th>TD-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of deeply embedded subordinates</td>
<td>1,1%</td>
<td>3%</td>
<td>3,1%</td>
<td>3,6%</td>
<td>3,5%</td>
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<tr>
<td></td>
<td>Younger MMHL &lt; Older MMHL: p &lt; .05</td>
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<tr>
<td></td>
<td>Younger MMHL &lt; TD-6: p &lt; .05</td>
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<td></td>
</tr>
<tr>
<td>Rate of 0-level relatives</td>
<td>24%</td>
<td>7%</td>
<td>7,3%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Younger MMHL &gt; Older MMHL: p &lt; .05</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of non-finite embedded clauses</td>
<td>49,4%</td>
<td>38,2%</td>
<td>33%</td>
<td>33%</td>
<td>32,5%</td>
</tr>
</tbody>
</table>

Turning to the use of avoidance mechanisms, we found that out of all potential embedded clauses, a large number of those produced by deaf children did not surface as embedded clauses, especially in the younger MMHL who had a rate of failed attempts at embedding of 22,3% versus 11% in Older MMHL versus only 2-3 % in typically-developing children (whatever their age). We observed two predominant strategies: self-interruption of a subordinate clause (54% of total attempts), and avoidance of a relative clause by using juxtaposition of simple clauses (36% of total attempts).

As expected, production of morphosyntactic errors correlated with the degree of computational complexity: 21% of complex utterances produced by participants with MMHL (Younger and Older mixed) were erroneous (versus 3% of those produced by TD subjects, p < .001). And among the different types of subordinate clauses, relative clauses, the most complex embedded clauses, were also the most erroneous embedded clauses: 37% of the relative clauses produced by MMHL participants were in an erroneous utterance, versus 19% of their finite complement clauses, 20% of their adverbial clauses and 13% of their non-finite complement clauses. This tendency is not observed in TD children, who produced few errors.

### 3.2. Second testing time (T2)

Comparing the first and the second testing time, language samples from both MMHL groups increased in syntactic complexity of relative clauses: with respective rates of 41 and 43%, their relative clauses became as complex as those in the TD-8 group (also 43%). Nevertheless, this measure is the only one that progressed between T1 and T2 in the group of older MMHL. Indeed, whereas the younger MMHL significantly improved their performance on several measures, notably for MLU and for rate of embedding (see Graphs 2 & 3), older MMHL did not.

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6 Differences were significant: Younger MMHL > TD 6-8: p < .01; Older MMHL > TD 8-11: p < .01.
Younger MMHL also produced fewer non-finite embedded clauses, the simplest embedded clauses, at T2, and fewer 0-level relatives, which involve no embedding in an IP. On the other hand, the group of older MMHL stagnated, continuing to produce high proportions of these compared to TD groups; their performance at T2 remained lower than that of TD-11 (see Graphs 4 & 5).

Lastly, it’s interesting to note that, at T2, failed attempts at embedding decreased significantly in Younger MMHL but not in Older (Graph 6). In other words, the Younger MMHL not only displayed an increase in the frequency of more complex structures, they also showed a decrease in the use of avoidance strategies. Concerning production of morphosyntactic errors, rate of errors remained very high in both groups and did not show any improvement, as illustrated in Graph 7.
4. Discussion

Our results confirm our main predictions: 1) Participants with MMHL tended to avoid the most complex constructions, especially finite embedded clauses and genuine relatives. 2) This phenomenon showed an age effect, the younger having poorer results than older MMHL, at the first testing time, on measures of syntactic complexity. 3) Failed attempts at embedding were much more frequent in MMHL groups, compared to TD groups. 4) Finally, production of errors correlated with the degree of computational complexity.

One of our more interesting results concerns the evolution of language performance in the two age groups between T1 and T2. At T2, we observed a clear progression in younger MMHL, which is characterized by an increase in the use of complex structures and a reduction in the use of avoidance mechanisms. In fact, the younger MMHL caught up with older MMHL, but their final performance remained lower than that of control subjects of the same age. How can we explain this progression of younger MMHL and the stagnation of older MMHL? We propose a hypothesis which is based on maturation of language performance systems, and especially of working memory capacities. Why could maturation of working memory capacities be limited in subjects with MMHL? Firstly, it seems reasonable to assume that hearing loss, particularly if it’s detected late, entails a greater burden on attention because more resources are devoted to attending to auditory (and probably visual) input. As these resources must be actively engaged by deaf children in order to identify spoken messages, they would be less available for other types of processing, such as working memory. It may therefore be the case that working memory cannot mature normally or not as rapidly as in normally-hearing children. According to this reasoning, insufficient availability of resources essential to maturation of working memory capacities would result in an immaturity of this performance system, which could in turn have long-term effects on language performance. Support for this scenario comes from the fact that it is well known that working memory capacities are impaired in children with more severe hearing loss (see Alegria et al., 1999, or Burkholder & Pisoni, 2003). We are suggesting that this might also be the case for children with MMHL.

With respect to links between working memory capacities and language performance, several studies have mentioned a reciprocal relationship. There is evidence that language development contributes to maturation of working memory (Gupta & MacWhinney, 1997; Adams & Gathercole, 2000; Baddeley 2003; Zébib, 2009). Moreover, Jakubowicz (2005, 2005; Jakubowicz & Tuller, 2008), following Chomsky (2005), proposed that both typical and atypical language development

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7 We also found this pattern of progression in younger MMHL and stagnation in older MMHL in other types of tasks, notably in an elicited production probe of pronominal clitics (Delage, 2008).
are affected by developmental constraints, such as working memory capacities which are sensitive to the computational complexity of the derivation. This capacity is limited in younger children and thus results in the use of structures involving less computation. This limitation disappears with normal maturation of working memory capacities. Normal maturation of working memory crucially entails rapid maturation in young children and slower development at the end of childhood (see for example Huizinga et al., 2006).

If individuals with MMHL may indeed be impaired in working memory, it follows that they may experience difficulties computing more complex syntactic constructions, which require more working memory resources. While this hypothesis clearly requires targeted evaluation of working memory capacities in this population, one result did emerge from our study which appears to lend it support. One of the standardized tests taken by the participants with MMHL was a word repetition task, a type of task which reflects in part phonological working memory (and particularly since unknown words in this task are arguably treated as non-words). It was found that the younger MMHL, for whom working memory capacities are rapidly maturing, significantly improved their word repetition scores between T1 and T2, as expected. The older MMHL, on the other hand, for whom maturation of working memory has considerably slowed down, did not improve on word repetition (Delage, 2008).

5. Conclusion

Two main results emerge from this study on language evolution of children and adolescents with MMHL. The first point we want to underline concerns the observed avoidance of the computationally most complex embedded clauses. Indeed, participants with MMHL tended to avoid finite embedded clauses and genuine relatives. Moreover, they produced failed attempts at embedding much more frequently than controls. Finally, when they produced complex utterances, they produced a great number of errors, especially in the most complex embedded clauses, i.e. in relative clauses. Support is therefore provided for the hypothesis that language acquisition with congenital, limited hearing loss has persistent effects on language acquisition, and that these effects result in less frequent use of complex structures and in higher error rates in complex structures, compared to typically-developing children.

The second point we would like to emphasize is that the longitudinal results of this study showed that the younger MMHL made real progress (their language increased in complexity between the first and the second testing time), but the older MMHL appeared to stagnate. We have suggested that this difference is due to the fact that the performance systems, including working memory, are still maturing in childhood, but that they slow down at the end of childhood. Because of
hearing loss and its presumed effect on the maturation of working memory, children with MMHL have not reached normal levels of maturation at the end of childhood. The result of this immaturity of working memory capacity, we are arguing, is the observed stagnation of linguistic performance in older subjects.

References


