

## GRAMMATICAL SENSITIVITY AND WORKING MEMORY IN CHILDREN WITH LANGUAGE IMPAIRMENT\*

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**Abstract:** Children with primary language impairment (LI) show a deficit in processing various grammatical structures, verb inflections, and syntactically complex sentences among other things (Clahsen–Hansen 1997; Leonard et al. 1997). Cross-linguistic research has shown that the pattern of performance is language-specific. We examined grammatical sensitivity to word order and agreement violations in 50 Hungarian-speaking children with and without LI. The findings suggest a strong association between sensitivity to grammatical violations and working memory capacity. Variations in working memory performance predicted grammatical sensitivity. Hungarian participants with LI exhibited a weakness in detecting both agreement and word order violations.

**Keywords:** grammatical sensitivity, verb agreement, word order, working memory, childhood language impairment

### 1. Introduction

Children with primary language impairment (LI) exhibit problems in various language areas but particularly show difficulty with the acquisition

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of morphosyntax. These children's language problems are not part of any other recognized syndrome or the consequence of intellectual disability, hearing impairment, neurological deficit, emotional disturbance, or environmental deprivation. Children with LI show grammatical deficits in marking verb inflections, in comprehending and producing complex sentence structures, and in detecting grammatical violations (e.g., Leonard et al. 1997; Norbury et al. 2002; van der Lely 1996).

There is no agreement among researchers regarding the background of these grammatical difficulties, whether they reflect a domain-specific or a domain-general problem. Some findings suggest that children with LI show a discrete grammatical deficit (van der Lely 2005), whereas an increasing number of studies indicate that children with LI show additional weaknesses in working memory (Marton-Schwartz 2003; Montgomery 2000), in procedural memory (Ullman-Pierpont 2005), in visuo-spatial memory (Marton 2008), in visual sustained attention (Finneran et al. 2009) among other things. These latter findings imply that the problem is domain general. One reason for this controversy in the literature is the heterogeneity of the children with LI. Both linguistic and cognitive findings indicate large individual variations within this population (Bortolini-Leonard 1996; Conti-Ramsden et al. 1997).

Many of the grammatical errors of these children resemble those of younger typically developing children. Based on this pattern, it has been suggested that the grammatical deficit reflects a maturational delay (Rice et al. 1995). Maybe this is the case in English, but language impaired children's errors in other languages might show different patterns. To provide further insight into the question of typical and atypical grammatical development and into the issue of domain specificity, we need to conduct cross-linguistic studies. Children's errors across languages reflect the structural characteristics of their language (Leonard 1998). In this paper we examine grammatical sensitivity to word order and agreement violations in Hungarian-speaking children with and without LI. We analyze the cognitive demands of word order and verb agreement in an on-line task within and across groups.

### **1.1. Grammatical sensitivity: accuracy in detecting word order and agreement violations**

Grammatical roles and meaning in a sentence are marked by different morphosyntactic forms, such as word order and agreement (McDon-

ald 2008). These distinct grammatical forms develop at different points in time. English-speaking children master the word order of their language earlier than specific forms of agreement (e.g., third person singular *-s*; Bates et al. 1984). Children may use word order information as a cue in interpreting sentences with complex morphology. Word order was the most important cue for English-speaking children at each age level (2-, 3-, 4-, 5-year) in a sentence interpretation task (*idem.*). Cross-linguistic research, however, suggested that this word order advantage is language-specific. Unlike English-speaking children, Japanese children acquire order and agreement cues simultaneously (Hakuta 1982). In other languages, the developmental pattern of word order and agreement acquisition differs even more from English.

Sentence comprehension data in Hungarian children showed that these children discriminate different suffixes before they acquire the cues of word order (MacWhinney et al. 1985). This contrast between English and Hungarian may be related to the differences in word order rules between the two languages and to the fact that the 3rd person singular is the only agreement marker in main lexical verbs in English. It is a critical difference between English and Hungarian that agreement in the main verb is a minor phenomenon in English. Hungarian has a more complex verb marking system than English because verb inflections have to agree with both the subject and the object. Hungarian verbs have two conjugations. If the sentence contains a definite direct object, then the definite conjugation is used; in all other cases the indefinite conjugation is applied.

Although the subject-verb-object word order that is typical for English is also common in Hungarian, Hungarian word order is more variable. Unlike English speakers, Hungarian speakers do not need to rely on word order to determine grammatical function because subjects and objects are distinguished by their case marking (Rounds 2001). Despite the variability, Hungarian word order is not free; it is governed by a number of principles. Previous research has examined how these morphosyntactic forms develop in Hungarian children (e.g., MacWhinney et al. 1985), but there are no data on the sensitivity to these form violations in children with LI.

Grammatical sensitivity shows gradual development with age. English-speaking younger children perform more poorly than their older peers in grammaticality judgment tests. Older children showed higher accuracy and faster detection time than the younger children. Despite the

group difference, both younger and older children showed better sensitivity to word order violations than to agreement violations. In contrast, adults showed equal sensitivity to both violation types (Wulfeck et al. 1991). Interestingly, adults with Broca's aphasia showed grammatical sensitivity similar to that of children. It has been suggested that in on-line grammatical tasks, sensitivity to grammatical violations (accuracy) reflects knowledge, whereas reaction time indicates processing (Wulfeck et al. 2004). In a grammaticality judgment task McDonald (2008) found that the most difficult structures for typically developing children between 6–11 years were the third person agreement and the regular past tense. Working memory played a significant role in grammaticality judgment beyond the effect of age. In contrast to the high working memory demands of verb marking, the maintenance of word order information in English seems to be less influenced by working memory variations.

## **1.2. Grammatical sensitivity in children with LI**

Language impaired children's difficulties with these grammatical forms have been studied from a number of theoretical perspectives. Clahsen and his colleagues tested the agreement account in German-speaking children with LI. They performed both cross-sectional and longitudinal studies. Children with LI showed difficulty with the production of subject–verb agreement. This was a consistent pattern across studies. These children performed more poorly than either the age-matched or the younger language-matched controls (Clahsen–Hansen 1997). In contrast to the deficit in subject–verb agreement, the authors reported correct word order use in most cases, except for verb-second. According to this rule, the finite verb is the second constituent of the sentence. It has been suggested that the problems with the verb-second rule might reflect an interaction with the agreement deficit in children with LI.

In a recent study, Hungarian-speaking children with LI performed more poorly than their vocabulary-matched younger peers in using verb inflections, tense and agreement (Lukács et al. 2009). The authors tested three theoretical models: the morphological richness hypothesis (Dromi et al. 1999), the extended optional infinitive account (Rice–Wexler 1996), and the agreement deficit hypothesis (Clahsen–Hansen 1997). Their findings suggest that the use of verb inflection in Hungarian-speaking language impaired children is highly influenced by these children's processing

capacity. According to the authors, none of the theoretical accounts provided a full explanation for the results, but the most compatible model was the morphological richness hypothesis.

In terms of a processing account, agreement constructions are highly demanding on working memory (McDonald 2008). Working memory correlates with structures involving verb morphology. Verb markings are typically more demanding than noun markings. Children with LI have more problems with verb learning than with nouns (Windfuhr et al. 2002).

The present study was designed to test the agreement deficit hypothesis and the processing capacity account in children with LI using an on-line grammaticality judgment experiment. Based on the literature reviewed above, the following hypotheses were formulated:

1. In contrast to the findings in English-speaking children (superior word order), Hungarian-speaking children will perform with similar accuracy in detecting word order violations and agreement violations (reflected by both accuracy and reaction time data).
2. Individuals with better working memory capacity detect more grammatical violations than individuals with lower working memory capacity (regardless of language status—LI or control).
3. Violations that occur at the end of sentences are more demanding on working memory than sentence-initial violations; therefore participants detect more violations at the beginning than at the end of sentences.
4. Participants with low working memory capacity will show longer reaction times in the grammatical judgment task than participants with high working memory capacity. Long reaction times will be associated with low working memory capacity.
5. Children with LI will perform with lower accuracy and with longer reaction times than their typically developing peers in the grammatical judgment task.

## 2. Methods

### 2.1. Participants

Fifty children participated in this study (see participant profiles in Table 1). All children with LI ( $n = 25$ ) had been diagnosed by a speech-language pathologist as having receptive and expressive language deficits.

They all received speech–language services at the time of testing. These children performed about 1.5–2 years below age average on word recall and in sentence comprehension. Every participant showed a normal range of non-verbal IQ on the SON-R test (Snijders et al. 1989). Children with reported attention control difficulties and with articulation problems were excluded from this study.

The control group consisted of age-matched children with typical language development (TLD,  $n = 25$ ). These children’s academic performance was age appropriate, according to reports from parents and classroom teachers. All participants with TLD scored within the normal range in non-verbal intelligence (SON-R test; Snijders et al. 1989). None of these children had ever received any special services. All participants were monolingual Hungarian speakers. None of the children had a history of frank neurological impairment or psychological disturbance.

*Table 1*  
Participant profiles

	Children with LI ( $n = 25$ )	Children with TLD ( $n = 25$ )
Gender: female/male	8/17	8/17
Age: mean (SD)	9.9 (0.82)	9.8 (0.79)
Non-verbal IQ: mean (SD)	108.3 (11.72)	117.16 (9.22)
Verbal working memory and listening		
span: mean (SD)	55.27 (17.87)	93.18 (7.98)
Word recall: mean (SD)	65.37 (17.38)	91.68 (8.28)
Sentence comprehension: mean percent (SD)	71.57 (16.74)	92.49 (6.78)
Phonological working memory and nonword repetition: mean (SD)	23.16 (11.9)	40.92 (2.87)

## 2.2. Stimuli

### 2.2.1. Grammaticality judgment task

The task included 80 sentences matched for length and sentence structure. The syntactic structure was simple in each sentence, the length varied between 7–9 words. Half of the sentences included verbs with a definite conjugation, whereas the other half of the sentences contained verbs with an indefinite conjugation. There were 24 grammatically correct sentences and 56 ungrammatical sentences. Half of the ungrammatical sentences

included an agreement error in definiteness, the other half contained a word order error. Both types of violations occurred either at the beginning of the sentence or at the end. Thus, the experimental design included 2 types of violation (agreement, word order), 2 positions (sentence initial, final), and 2 groups (LI, TLD). The dependent variables were percentage of accuracy and reaction time.

*Table 2*  
Sample ungrammatical sentences (the errors are typed in italics)

Type of error	Position: initial	Position: final
Agreement	<i>Elfúj</i> a gyertyákat a gyerek a tortán. The child blows the candles on the cake.	Az állomáson a vonatra sok ember <i>várja</i> . Many people are waiting for the train at the station.
Agreement	<i>Megfognak</i> egy kisfiút a gyerekek az udvaron. The children catch a little boy in the yard.	A gyerekek az órán az új szöveget <i>olvasnak</i> . The children read the new text in class.
Word order	<i>Az segítenek</i> eltévedt fiúnak az állatok az erdőben. The animals help the lost boy in the forest.	Jól vezeti az ezüst az áramot <i>elektromos</i> . Silver conducts electricity well.
Word order	<i>A fiúnak szomszéd</i> adom a régi lemezeket. I give the old disks to the neighbor boy.	A varázsló a kezébe ad <i>csodakulcsot egy</i> . The wizard puts a magic key into his hand.

### 2.2.2. Working memory: Listening span task

The stimuli were 45 sentences and 45 questions targeting sentence content to measure participants' working memory capacity. Children were asked to listen to the sentences (one at a time), to memorize the sentence-final word, to answer a question following presentation, and finally to repeat the sentence-final word. This task was created to examine the effect of sentence length and morphological complexity on working memory performance, and the stimuli and procedures for this task were published in Marton et al. (2006). In the present study, we used the data from this task to investigate the relationship between working memory and sensitivity to grammatical violations. The task was used to divide the 50 participants into 2 groups: children with high working memory capacity and

children with low working memory capacity, regardless of their language status (LI or TLD).

### 2.3. Procedures

All stimuli were created using e-Prime software (version 2.0). Children were tested individually in their schools. Stimuli were presented using a PC notebook through headphones. Children listened to auditorily presented single sentences and responded by pressing the appropriate key on the notebook following each sentence. Practice trials with different stimuli were provided for both tasks. There was no limitation in the number of practice trials. Children were able to practice until they fully understood the tasks. Testing and data analysis were performed by different investigators. Percentage of accuracy was calculated for the grammaticality judgment task. The number of correctly recalled words was used for the analysis of working memory performance.

## 3. Results

We performed both non-parametric and parametric analyses to test our hypotheses because some of the assumptions of parametric statistics, such as normal distribution, were not met. The correlation analyses included Pearson (parametric) and Spearman's rho and Kendall's tau-b (non-parametric) analyses; the between subjects analyses included ANOVAs (parametric) and the Mann-Whitney U test (non-parametric), and the within group analyses consisted of repeated measures ANOVAs (parametric) and the Wilcoxon Signed-Rank test (non-parametric). There was no difference between the parametric and non-parametric results, therefore we report the data from the parametric tests only.

The first hypothesis of this study—that Hungarian-speaking children would perform with similar accuracy in detecting word order violations and agreement violations—was tested within groups across positions. Repeated measures ANOVA results showed no difference in grammatical sensitivity between verb agreement violation detection and word order violation detection accuracy in children with TLD:  $F(1, 24) = 0.78$ ,  $p = 0.39$ ; in initial position:  $F(1, 24) = 0.2$ ,  $p = 0.65$ ; in final position:  $F(1, 24) = 1.87$ ,  $p = 0.19$ . The overall reaction time data between violation detection types were similar, too:  $F(1, 24) = 0.1$ ,  $p = 0.76$ . There



was, however, a small difference when we analyzed the data in initial and in final positions:  $F(1, 24) = 4.14$ ,  $p = 0.054$ ;  $F(1, 24) = 4.94$ ,  $p < 0.05$  (see Table 3 for basic descriptive statistics). Although detection accuracy did not differ between the two types of grammatical violations, children detected word order errors faster than agreement errors.

Table 3

Basic descriptive statistics of sensitivity to grammatical violations

Sensitivity to	Children with LI		Children with TLD	
	Mean	SD	Mean	SD
Agreement violation (accuracy)	0.66	0.05	0.91	0.01
Agreement violation (RT)	1204.88	88.35	824.29	59.61
Word order violation (accuracy)	0.64	0.04	0.92	0.02
Word order violation (RT)	1246.18	74.09	814.8	65.07

In contrast to the control group, children with LI detected more word order violations than agreement violations, however, only in sentence-final position:  $F(1, 24) = 15.25$ ,  $p < 0.001$ ; in initial position:  $F(1, 24) = 0.45$ ,  $p = 0.51$ . The reaction time data did not differ across violation types: in initial position:  $F(1, 24) = 0.25$ ,  $p = 0.62$ ; in final position:  $F(1, 24) = 0.002$ ,  $p = 0.97$ .

The second hypothesis of this study was that children with high working memory capacity would detect more grammatical violations than children with low working memory capacity. This hypothesis was tested in three steps. First, we examined the relationship between grammatical violation detection and working memory performance within groups using the Pearson 1 tailed analysis. We used the number of correctly recalled words from the working memory task for this analysis. In the control group, overall accuracy of detecting agreement violations was highly correlated with working memory performance:  $r(25) = 0.48$ ,  $p < 0.01$ . This relationship between sensitivity to agreement violations and working memory differed across sentence positions. Sentence-initial agreement violations did not show correlation with working memory ( $r(25) = 0.06$ ,  $p > 0.05$ ), but the sentence-final agreement violations showed a high correlation with working memory:  $r(25) = 0.62$ ,  $p < 0.01$ . Sensitivity to word order violation was not related to working memory performance:  $r(25) = 0.2$ ,  $p > 0.05$  in the typically developing participants.

Performance in children with LI also showed a strong relationship between sensitivity to agreement violations and working memory:  $r(25) = 0.68$ ,  $p < 0.01$ ; in sentence-initial position:  $r(25) = 0.64$ ,  $p < 0.01$ ; in sentence-final position:  $r(25) = 0.62$ ,  $p < 0.01$ . In contrast to the children with TLD, children with LI showed strong correlations between working memory and sensitivity to word order violations:  $r(25) = 0.62$ ,  $p < 0.01$ ; in sentence-initial position:  $r(25) = 0.62$ ,  $p < 0.01$ ; in sentence-final position:  $r(25) = 0.49$ ,  $p < 0.01$ . Thus, the detection of word order violations was highly correlated with working memory performance in the children with LI, but not in the children with TLD.

Next, we combined the number of correctly recalled words in the listening span task from the two groups (LI, TLD). We determined the median and divided the children into high and low working memory groups, regardless of their language status. Values above the median were considered as high working memory scores, whereas values below the median were considered as low working memory scores. In the LI group, 22 children showed low working memory capacity and three children showed high working memory capacity; in the control group 22 children showed high working memory capacity and three children had low working memory capacity. Working memory performance clearly distinguished the groups. We performed a between groups analysis using ANOVA to determine whether children with high working memory capacity detect more grammatical violations than children with low working memory capacity. There was a significant group difference for sensitivity to agreement violations:  $F(1, 47) = 27.01$ ,  $p < 0.01$ ; in sentence-initial position:  $F(1, 48) = 17.21$ ,  $p < 0.01$ ; in sentence-final position:  $F(1, 46) = 35.27$ ,  $p < 0.01$ . A similar pattern was observed for sensitivity to word order violations:  $F(1, 47) = 36.59$ ,  $p < 0.01$ ; in sentence-initial position:  $F(1, 48) = 23.88$ ,  $p < 0.01$ ; in sentence-final position:  $F(1, 46) = 43$ ,  $p < 0.01$  (see Figure 1). Children with high working memory capacity outperformed children with low working memory capacity in the grammaticality judgment task under each condition. Children with high working memory capacity performed the task more accurately and faster than children with low working memory capacity.

According to the third hypothesis of this study, detection of sentence-final grammatical violations is more demanding on working memory than the detection of sentence-initial grammatical violations, therefore participants would be expected to detect more errors in sentence-initial position than in sentence-final position. A within subjects analysis (re-

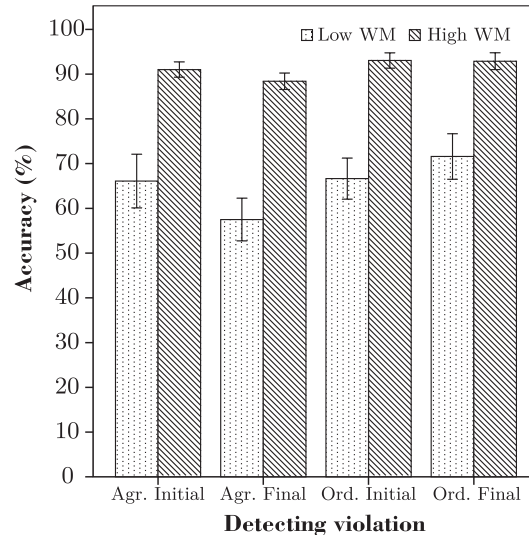


Fig. 1

Sensitivity to grammatical violations in children with high working memory capacity and in children with low working memory capacity (the error bars represent  $\pm 1$  standard error)

peated measures ANOVA) was performed for position type (initial and final) for children with low working memory capacity and for children with high working memory capacity. Children with low working memory performance detected more agreement violations at the beginning of the sentences than at the end of the sentences:  $F(1, 49) = 6.35$ ,  $p < 0.05$ . There was no difference in sensitivity to word order violations across positions in children with low working memory capacity:  $F(1, 49) = 1.29$ ,  $p = 0.27$ . Children with high working memory capacity performed equally well at the beginning and at the end of the sentences. Detection of agreement violations across positions:  $F(1, 49) = 2.16$ ,  $p = 0.16$ ; the means for detecting word order violations were the same for sentence-initial errors than for sentence-final errors (mean: 0.93; st. error: 0.02 for both positions). Thus, sentence position had no impact on performance accuracy in children with high working memory capacity, but did affect children with low working memory capacity in detecting agreement violations.

The fourth hypothesis of this study was that the reaction time data from the grammatical sensitivity task will be associated with working memory capacity. It was hypothesized that children with low working memory capacity need longer time to detect grammatical violations than

children with high working memory capacity. First we performed correlation analyses to examine the relationship between the speed of detecting grammatical violations and working memory capacity using the Pearson correlation coefficient. There was a correlation between the above variables with each violation type, in each position. The following relationships were identified: detecting agreement violations in sentence-initial position and working memory capacity:  $r(50) = -0.36$ ,  $p < 0.01$ ; reaction time for detecting agreement violations in sentence-final position and working memory:  $r(50) = -0.27$ ,  $p < 0.05$ ; reaction time for detecting word order violations in sentence-initial position working memory:  $r(50) = -0.33$ ,  $p < 0.01$ ; reaction time for detecting word order violations in sentence-final position working memory:  $r(50) = -0.3$ ,  $p < 0.05$ . Thus, the lower the child's working memory performance, the longer the reaction time in the grammaticality judgment task.

Our second analysis to test hypothesis 4 included a between groups comparison using ANOVA for reaction time between children with high and low working memory capacity (see Figure 2). Children with high working memory capacity detected both types of violations in both positions faster than children with low working memory capacity: reaction time to agreement violations in sentence-initial position:  $F(1, 46) = 20.42$ ,  $p < 0.001$ ; reaction time to agreement violations in sentence-final position:  $F(1, 46) = 8.67$ ,  $p < 0.01$ ; reaction time to word order violations in sentence-initial position:  $F(1, 47) = 12.28$ ,  $p < 0.01$ ; reaction time to word order violations in final position:  $F(1, 47) = 13.02$ ,  $p < 0.01$ .

Finally, we hypothesized that children with LI perform with lower accuracy and longer reaction times than their TLD peers in the grammaticality judgment task. There was a significant group difference for each violation type in each sentence position based on a MANOVA analysis (see Table 4). The children with TLD performed with higher accuracy and with faster speed than the children with LI (see Figures 3 and 4).

Table 4

Accuracy and reaction time differences between groups (LI, TLD; MANOVA)

Source	Accuracy			Reaction Time		
	df	<i>F</i>	<i>p</i>	df	<i>F</i>	<i>p</i>
Agreement: initial	1	19.87	.001	1	14.57	.001
Agreement: final	1	39.41	.001	1	8.61	.005
Word order: initial	1	20.81	.001	1	8.15	.007
Word order: final	1	13.93	.001	1	13.43	.001

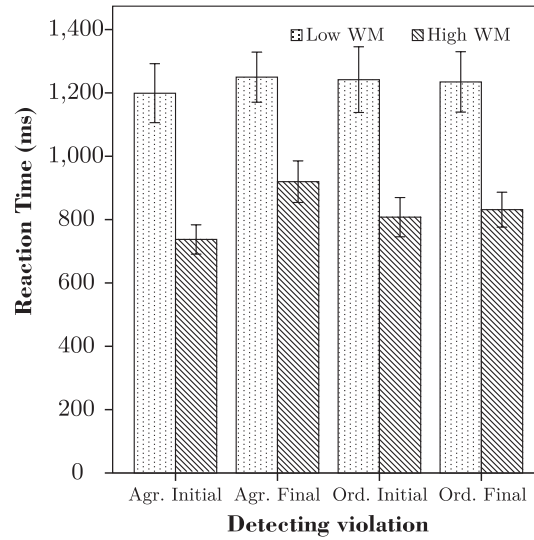


Fig. 2

Reaction time differences between children with high working memory capacity and in children with low working memory capacity (error bars:  $\pm 1$  standard error).

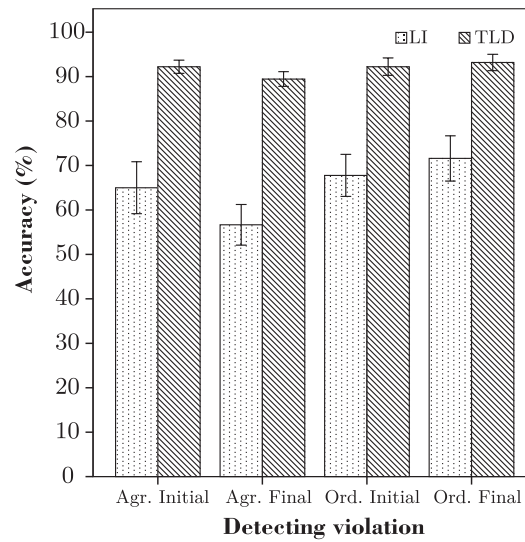
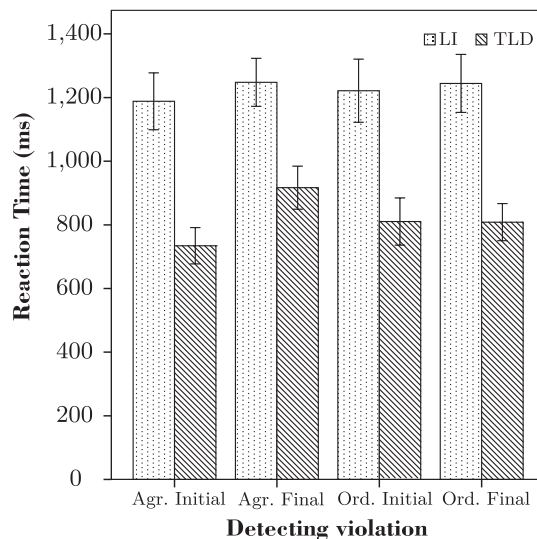


Fig. 3

Sensitivity to grammatical violations in children with LI and TLD (error bars:  $\pm 1$  standard error)



*Fig. 4*

Reaction time differences between children with LI and TLD  
(error bars:  $\pm 1$  standard error)

Given the high impact of working memory capacity on grammatical sensitivity, our last analysis involved a MANCOVA, where we compared grammatical sensitivity between children with LI and children with TLD and entered working memory as a covariate. The results of this analysis showed that if working memory is used as a covariate, then the differences in grammatical sensitivity between children with LI and TLD disappear: detection of agreement violations in sentence-initial position:  $F(1, 49) = 0.22$ ,  $p = 0.64$ ; detection of agreement violations in sentence-final position:  $F(1, 49) = 3.33$ ,  $p = 0.08$ ; detection of word order violations in sentence-initial position:  $F(1, 49) = 0.5$ ,  $p = 0.48$ ; detection of word order violations in sentence-final position:  $F(1, 49) = 0.3$ ,  $p = 0.59$ .

#### 4. Discussion

The aim of the present study was to examine on-line grammatical sensitivity in Hungarian-speaking children with LI with regards to two theoretical accounts: the agreement deficit account (Clahsen–Hansen 1997) and the processing capacity limitation account. Similarly to Wulfeck–Bates (1991), we measured grammatical sensitivity to agreement violations and

to word order violations. We chose these grammatical forms for two reasons. First, the developmental order and difficulty level of detecting verb agreement violations and word order violations differ across languages. Most of the previous studies were conducted with English-speaking individuals (e.g., McDonald 2008; Wulfeck–Bates 1991). Second, the agreement deficit account predicts that children with LI will have difficulty in detecting agreement violations, but not word order violations (or to a significantly smaller extent).

The present study revealed that typically developing Hungarian-speaking school-age children perform similarly in detecting verb agreement and word order violations. These children performed with high accuracy and short processing time. The data of the children with LI were less consistent. These children detected a similar amount of agreement violations and word order violations if the errors occurred in the sentence-initial position. In the sentence-final position, however, children with LI detected more word order violations than agreement violations. The reaction time data were similar for the two types of error detection, regardless of sentence position. These results provide only partial support for the agreement deficit account.

The difference in accuracy for detecting agreement and word order violations in sentence-final position in children with LI suggested that sensitivity to agreement violations is associated with working memory. Sentence-final items are typically more demanding on working memory than sentence-initial ones. Our correlation data from the typically developing children confirmed this suggestion. Detection of sentence-initial agreement violations did not correlate with working memory, whereas the detection of sentence-final agreement violations showed a strong relationship with working memory. Sensitivity to word order violations did not show a relationship with working memory in the children with TLD. This finding is in agreement with the results of McDonald (2008). The author suggests that in English, word order rules are acquired earlier than agreement rules and that the former ones are more resilient than the latter ones. Agreement development is highly affected by working memory capacity.

A different pattern was observed for the children with LI in the present study. Working memory was strongly related to both error types in both positions. Thus, both the detection of word order errors and sensitivity to agreement errors were associated with working memory capacity, even in sentence-initial positions. These findings suggest that

the detection of any type of grammatical violation is highly demanding on working memory in children with LI. This finding supports the processing capacity account. These results suggest that working memory has a high impact on performance accuracy in the grammaticality judgment task, and that children with LI show difficulty in this task.

To further examine this relationship, we divided the participants of the present study into two groups based on their working memory performance: low working memory group and high working memory group. All but three of the children with LI fell in the low working memory group and all but three of the children with TLD fell in the high working memory group. Thus, the groups based on working memory performance overlapped to a great extent with the groups based on language status (LI and TLD). The comparison of grammatical sensitivity between the two working memory groups revealed that children with high working memory capacity perform superior to children with low working memory capacity with each error type in each sentence position. Participants in the former group performed more accurately and with greater processing speed than the children in the latter group. Moreover, the sentence position of the errors had no effect on performance accuracy in the children with high working memory capacity, but it did have an impact on performance accuracy in children with low working memory capacity.

In addition to the accuracy data, working memory performance was strongly associated with the reaction time measures. Children with low working memory performance showed slower processing speed in the grammaticality judgment task, whereas children with high working memory performance detected the errors faster.

A comparison between children with LI and TLD indicated that children with LI perform with lower accuracy and longer processing speed than the children with TLD in detecting grammatical violations. This finding was not unexpected. Previous research involving children with LI evidenced a deficit with verb inflections and in sentence processing (e.g., Clahsen–Hansen 1997; Leonard et al. 1997). The surprising result was that this group difference was fully predictable from the children's working memory capacity. All group differences between the LI and the TLD participants disappeared when working memory was entered as a covariate in the analysis.

The findings suggest that sensitivity to grammatical violations is highly influenced by the working memory demands of the task. Children with LI perform poorly in detecting agreement violations because



they are demanding on working memory. In contrast to English-speaking children, Hungarian children with LI showed problems in detecting word order violations as well. In Hungarian, many word order variations are permitted, therefore it is difficult for the children with LI to identify word order violations, particularly when they occur in sentence-final position. Detecting a rule violation in sentence-final position is highly demanding on working memory.

Although the data of the present study very consistently showed a strong interaction between sensitivity to grammatical violations and working memory, there were some limitations in the experiments. Measures of sensitivity to grammatical violations were limited to agreement and word order. Performance on the grammaticality judgment task was analyzed in relation to working memory, but attentional capacity might have influenced the results as well. Inclusion of other grammatical forms and more cognitive functions in future studies will broaden our understanding of the relationship between language and cognition in children with LI.

In summary, the present findings suggest a strong association between sensitivity to grammatical violations and working memory capacity. Children with high working memory capacity detect more grammatical violations and perform the task faster than children with low working memory capacity. Most children with language impairment show a limitation in working memory performance. Accuracy and processing speed of detecting different grammatical violations is language-specific. In contrast to English-speaking children, Hungarian participants with LI exhibited a weakness in detecting both types of grammatical violations (agreement and word order). The findings are more compatible with the processing capacity limitation account than with the agreement deficit account. The results do not support a domain-specific grammatical deficit, but a domain-general cognitive-linguistic problem instead. Further research is needed to determine more specifically the nature of the processing limitation of children with LI.

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