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VOCABULARY AND MORPHOLOGICAL PATTERNS IN HUNGARIAN CHILDREN WITH WILLIAMS SYNDROME: A PRELIMINARY REPORT*

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Abstract

Williams syndrome (WMS), a rare neurogenetic disorder, has been in the forefront of research in cognitive psychology for the last ten years. WMS is characterized by a distinctive cognitive profile: mild to moderate mental retardation with relatively and surprisingly good linguistic abilities, while performance on spatial tasks is extremely poor. Concentrating on the linguistic abilities of children and adolescents with WMS, studies of vocabulary development and grammatical development in 15 Hungarian WMS children are presented: children were tested on tasks testing vocabulary, regular and irregular morphological; measures of nonword repetition and digit span were also obtained. In contrast to previous observations, results on the vocabulary task do not show that uncommon words activated as easily for a WMS child as common ones. Results in a picture-naming task support that conforming to the normal pattern, uncommon words are harder to retrieve. Results on the production of accusative and plural forms confirmed for Hungarian as well that regardless of the frequency of the item, inflected forms of irregulars are harder to produce, and often overregularized in WMS, revealing a dissociation between the rules of grammar vs. the mental lexicon. Performance on rare words in the vocabulary task, and overall performance on the morphology task is associated to the capacity of phonological short-term memory: subjects with higher span perform better on both tasks. The specification of the close relation between the capacity of phonological short-term memory and their linguistic measures awaits further study.

1. Introduction

Williams syndrome (WMS) is a rare (1 in 25 000) genetically-based condition caused by micro-deletion of genes on the long arm of chromosome 7. Children

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with this syndrome are characterised by relatively preserved language abilities in contrast with serious deficits in other cognitive domains. They also have specific brain morphological differences compared to normal controls e.g., decreased overall brain and cerebral volumes, disproportionate volume reduction of the brainstem with relative preservation of cerebellar and temporo-limbic structures. WMS children have good social skills, they are sometimes called hypersociable because of their affective communicative style and their often indiscriminately positive approach to unfamiliar people. In contrast to their good language abilities they show serious deficits in spatial cognition and motor skill learning. Despite their visual-spatial organisation problems they show surprisingly excellent performance in face recognition, which might indicate a dissociation in the involvement of the dorsal and ventral brain streams responsible for visual processing. In the past decade WMS has attracted the attention of cognitive psychologists because it offers a population in which language and other cognitive domains are dissociated (for a survey see e.g., Bellugi et al. 2000).

In this paper we would like to focus on lexical and morphological development in WMS children from school age on.

Reviewing previous results concerning lexical development and lexical organisation in WMS people, we discuss some details of the different approaches, and in the second half of the paper we present data collected from Hungarian people with WMS.

Our Hungarian studies are relevant for several reasons. One of the central issues with regard to language is the proposed contrasts between a rule-based and an item-based system, or Grammar and Lexicon within the language faculty, which are associated with different brain areas and can be selectively impaired. Hungarian with its rich morphology and competing suffixation patterns provides a better ground to contrast rule based and item based processes than languages studied previously, with more possibilities to vary and control for frequency effects. Besides replicating studies adapted to a typologically different language, we are of course applying new methods in a complex approach of a longitudinal study, the Hungarian Williams Syndrome Research Project. In this project data are gathered from a single WMS subject pool on different aspects of language, spatial cognition, visual integration, implicit and explicit rule extraction, and memory.

1.1. Linguistic abilities of WMS people

After a late and difficult start of language development, people with WMS have remarkably fluent and grammatical speech by school age, with a conspicuously sophisticated and large vocabulary containing many infrequent and unusual words, and a constant urge to chat. Their linguistic skills are in sharp contrast with the general level of their cognitive abilities. The linguistic profile of WMS people is uneven too. Besides brilliant expressive language, we often find that language comprehension is much more limited, their speech is also often irrelevant and inappropriate, and some of their words and phrases may lack semantic content.

The cognitive and linguistic profiles of WMS people have received different accounts by different researchers and research groups. Ursula Bellugi and her colleagues emphasize the dissociation between language and cognition, pointing to the semantic abnormalities in WMS language (e.g., Bellugi et al. 2000). Another approach draws attention to the within-language dissociation of grammatical rules and lexical processes. WMS children are supposed to have a relatively intact grammar, combined with a much weaker lexical system. Therefore, overregularizations are characteristic of their performance. This view is based on Pinker and Prince's (Pinker 1991; Pinker–Prince 1994) hybrid model of language, and is taken up by Clahsen in connection with WMS (Clahsen–Almazan 1998). A third view is developed by Annette Karmiloff-Smith and her research group. Their central claim is that it is not only the representations or processes of language that are impaired in the first place, but as cognitive impairments are a result of a complex epigenetic process, language development in WMS takes a different course, so we might find deviant mechanisms even behind apparently normal perfomance (Karmiloff-Smith et al. 1997).

1.2. The mental lexicon of WMS people

People with WMS generally perform at a high level on standardized vocabulary tests, but several tasks show that their semantic organization is different from that of normal controls. Wang–Bellugi (1994) found in a semantic fluency task that people with WMS produce more infrequent words than normal controls. Another observation revealing unusual organization of the lexicon is that of Vicari et al. (1996a; 1996b): when subjects have to reproduce words from a word list, normal controls typically reproduce more high frequency words; in people with WMS no bias is shown towards frequent words in recall.

The above findings lead some researchers to accept two distinct systems, a computational symbol-manipulating rule system of grammar and an associative network of the mental lexicon within the language faculty (Pinker 1991; Pinker – Prince 1994; Marcus et al. 1995). They propose that these two distinct systems can be selectively impaired. Williams syndrome is an example of an intact rule system with an abnormally operating mental lexicon. In morphology this means that regularly inflected forms (e.g., *talk* → *talked*; purportedly generated by the rule system) are produced easily and correctly, but the retrieval of irregular forms (e.g., *go* → *went*; stored as a whole in the mental lexicon) is impaired, with signs of overgeneralization. This is the pattern of performance we find with WMS subjects. In Clahsen and Almazan's study (1998) English-speaking WMS children could inflect existing regular stems virtually as well as unimpaired controls, while their performance on irregulars was poor; they often overgeneralize the regular suffix both to existing regular forms and to novel words rhyming with existing irregulars. This dissociation is also reflected in their performance on inflecting derivational forms. The results are interpreted as selective impairment of the lexical module of language, as an inability to retrieve information from subnodes of lexical entries.

The range of contrasting views of the nature of linguistic impairment in WMS is further supplemented by Tyler et al.'s results (1997), who found in an online task that WMS people are subject to the same kinds of priming effects for both functionally related items and category coordinates as unimpaired controls. A possible interpretation given by the authors is that the organization of the WMS mental lexicon is normal, and semantic anomalies are due to the clinical subjects' inability to integrate information from the individual words into a context, i.e., the sentence.

Tapping the nature of semantic organization, Rossen et al. (1996) tested WMS subjects on three homonym tasks. In a free associations task, where subjects had to say the first word that came into their minds when hearing a homonym, WMS subjects, just as normal controls, responded mainly with words related to the primary (i.e., more frequent) associate of the homonym. In a similarity judgement task, though, WMS people judged words related to the primary and secondary associates to be equally similar to the target homonym, while normal subjects consistently judged words related to the primary associate more similar. In a definition task, WMS subjects gave definitions of the secondary associate significantly more frequently than normal controls. This may imply a looser semantic organization, where (a) in metalinguistic tasks WMS children show a more modular organization; and (b) they are less constrained by contingent associative knowledge.

1.3. Acquisition of the WMS lexicon

Some argue that despite the impressive vocabulary of adults with Williams syndrome, developmental processes of language acquisition are not only delayed, but follow an abnormal trajectory. Harris et al. (1997) contrasted early language development in children with WMS and Down syndrome (DS, a mental retardation of genetic etiology with serious linguistic impairments matching the general level of cognitive deficit; in this study, WMS mean age was 41 months, DS mean was age 39 months). They used the MacArthur Communicative Development Inventory, which relies on parental report to assess language development (see also Paterson et al. 1999). Results did not show any significant differences between the two groups in the number of words produced and comprehended, but the DS group produced significantly more gestures than the WMS group. The overall results showed that WMS children at this age were just as delayed in their language development as the DS group compared to normal children of the same age.

Another weird fact of early word learning in children with WMS is that inverting the normal course of events, naming precedes pointing. Mervis and Bertrand (in press) found in 6 children with WMS that pointing lagged behind naming with an average of 6 months. Besides less pointing, WMS children also produce less social referencing (Laing et al. 2000). An additional difference was that while in normal and DS children vocabulary spurt, fast mapping and exhaustive sorting of a pile of objects into different basic-level categories coincided, in five of the examined six WMS children vocabulary spurt leads exhaustive sorting and fast mapping, which occur together but only when vocabulary size is well over 500 words (Mervis–Bertrand, in press). These results suggest that WMS children do not apply fast mapping, at least not in the acquisition of their first 500 words, and that there has to be some other mechanism responsible for vocabulary growth in their case. The authors speculate that these mechanisms are a relatively good phonological short-term memory, and attention devoted to linguistic input at the expense of other stimuli which are in the focus of normal children‘s attention.

The late start and delayed language development do not seem to fully account for WMS language characteristics. Stevens and Karmiloff-Smith (1997) examined WMS children with respect to four lexical constraints shown to be operating in normal vocabulary acquisition between the ages 3 to 9. These four constraints were the fast mapping, mutual exclusivity, whole object and taxonomic constraints. Examining WMS children in two age groups, 3–4 years and 9–10 years, they found that just as normal children, WMS children apply the fast mapping constraint, i.e., they map a novel word onto an object which does not already have a name. Analogously, they rely on the mutual exclusivity constraint, stating that an object cannot have more that one name: WMS subjects mapped the novel word onto a part of the object when they already had a name for the object itself and the part was unfamiliar. Differences were found, however, between the WMS and normal groups in applying the whole object constraint, which stipulates that "a novel word heard in the presence of a novel object refers to the whole object rather than to its component parts or features such as colour, shape or texture" (Stevens–Karmiloff-Smith 1997, 747). WMS subjects made significantly fewer object responses than controls when they were presented with an unfamiliar object and a novel word, so it seems that WMS vocabulary acquisition is not constrained by the whole object constraint, which might be explained in part by their bias to process local features instead of global ones in a visual display. According to the fourth, taxonomic constraint, when the child hears a novel word "X" for an object, and is requested for another X, s/he will give an object from the same taxonomic category, not simply one with the same colour, texture or shape from another taxonomic or thematically related category. In normal children the trigger of the taxonomic constraint is hearing a novel name, instead of a simple deictic word like "it". WMS children gave equally few taxonomic responses both in the novel word and the no word ("it") condition. Individual variability among WMS subjects was great but taxonomic responses showed no correlation with vocabulary size, pointing to the fact that the taxonomic constraint cannot be responsible for WMS vocabulary size. So despite the large adult vocabulary size matching those of age-matched rather than mental-age-matched controls, we cannot conclude that the language faculty is intact in WMS, because some constraints on normal vocabulary acquisition do not seem to be operating in WMS.

1.4. Evidence of lexical impairment from syntax

Despite the fact that language is a strength in WMS, we find that within-language dissociations exist. Even the idea of an intact "grammar" module was challenged by Karmiloff-Smith and collegues, who showed in several experiments that syntactic processing is in fact impaired in WMS. Most of these results, though, point to the previous observation that WMS people have difficulties retrieving information from the lexicon. In one of their studies Karmiloff-Smith et al. (1998) examined linguistic performance in an online and an offline task. The online task was word monitoring (subjects listen to sentences and press a key when they hear a target word), examining the participants' ability of using syntactic information in interpreting a sentence, measuring their sensitivity to three different types of syntactic violation: phrase structure violations (e.g., *Susan seems much happier. I expect *special the* PILLS she got from the doctor...), subcategorization violations (e.g., *The burglar was terrified. He continued *to struggle the* DOG but he couldn't break free.) and auxiliary violations (It could have been very embarrassing. We did not realize he *might expecting* SPEECHES at the...). WMS reaction times were quite similar to those of normal controls, but while normal control subjects showed a grammaticality effect in all three conditions, WMS failed to display such an effect in the subcategorization condition, while being just as sensitive to phrase structure and auxiliary violations as normal controls. The authors, admitting that it is possible that WMS people are insensitive to lexically specified syntactic constraints, favor an interpretation in which WMS people are sensitive to such information, but its integration into the representation of a sentence is very slow. The offline task showed indeed an impairment of syntactic processing in WMS. Subjects had to choose, from among different pictures, the one matching the sentence they heard. Controls performed at a ceiling level, while WMS subjects comitted errors, on average, in 24% of the items, and 81% of their errors was choosing a syntactic distractor (they reversed the roles in the sentence) and only 19% of the times did they choose a lexical distractor. If, as recent lexicalist grammars would argue, all three types of constraints violated in the online task are lexically represented, then variation of performance in the three conditions cannot be attributed to representational differences but to the relative ease of integrating these kinds of information into the sentence during processing.

In another experiment, evidence from another language is presented supposedly showing that morphosyntactic rules are not intact in Williams syndrome. French-speaking people with Williams syndrome were tested on a gender agreement task: while their performance on repeating the nonce terms was better than those of normal controls, WMS subjects made far more errors in assigning correct grammatical gender based on largely probabilistic constraints. Although several explanations are possible, each has to take into account the fact that although gender agreement in French is a morphosyntactic rule, it draws on idiosyncratic lexical information about a word. Thus failures of correct agreement do not necessarily reflect morphosyntactic deficits, but might be explained by deficits in retrieving lexical information.

1.5. Working memory and language acquisition

As mentioned above, one of the possible engines of vocabulary acquisition in WMS children is the capacity of phonological short-term memory. Research in the last decade has shown that it is a mechanism operating in language acquisition in normal children as well. The phonological loop component of working memory is specialised for the retention of verbal information over short periods of time; it comprises both a phonological store and a rehearsal process which has the function to maintain decaying information. According to Baddeley and colleagues, the real function of the phonological loop is not to remember familiar words but to help learn new words (Baddeley–Gathercole–Papagno 1998). From this point of view the rate of vocabulary development is influenced by working memory capacity. In agreement with this conception, in childhood large individual differences are found in phonological loop capacity (Gathercole–Adams 1993). Many studies have found strong correlation between STM performance and vocabulary knowledge (Gathercole–Adams 1993; 1994; Gathercole et al. 1997).

Although correlation does not mean causation, it is possible that good vocabulary knowledge supports accurate repetition in STM tasks. However, the result of Gathercole et al. (1992) is inconsistent with this later assumption, as they found no correlation between vocabulary knowledge and STM performance 1 year later in children, but found strong correlation between earlier STM performance and vocabulary knowledge 1 year later (Gathercole–Willis–Emslie–Baddeley 1992). This result further supports the view that phonological loop capacity influences the learning of new words. Another branch of research has found connections between individual differences in working memory span and the acquisition of foreign language vocabulary (Service 1992). The measure of verbal short term memory in 10-year-old children was a very strong predictor of foreign language learning when it was tested 2 years later (Cheung 1996; Service 1992; Service–Kohonen 1995). In addition to this, polyglots have significantly higher verbal working memory span than nonpolyglot adults (Papagno–Vallar 1995).

The role of phonological loop in language learning is also revealed by cases of brain damage. Patients with verbal working memory deficit usually show a specific impairment in long-term learning of unfamiliar phonological material (Papagno et al. 1991). These patients are unable to learn auditorily presented word-nonword pairs, despite showing normal performance in learning tasks that do not require phonological working memory contribution (Trojano–Grossi 1995). Other neuropsychological evidence come from studies of children with specific language impairment (SLI). SLI children usually lag behind their age in terms of vocabulary development (Bishop 1992). They show poor performance on both digit span and nonword repetition tasks and recall much fewer phonologically novel names than control children (Taylor–Lean–Schwartz 1989).

There is also an increasing amount of data concerning the association between working memory and language development in genetic syndromes associated with some mental handicap (Jarrold et al. 1998). Wang and Bellugi (1994) compared digit span in individuals with Williams and Down syndrome, using groups matched on overall IQ. Williams syndrome children had a mean digit span of 4.6, whereas the mean span of the Down syndrome group was only 2.9. Until now no research has directly explored the relationship between phonological loop capacity and vocabulary knowledge in these groups, although it seems possible that phonological short-term memory may mediate normal levels of vocabulary learning. This was one of the main concerns of our study. Our three aims were to explore (a) lexical acquisition and phonological short-term memory, (b) frequency effects in morphological overgeneralization, (c) relationships between phonological short-term memory and morphological performance.

2. Lexical development

Our study focuses on the frequency sensitivity of active WMS vocabulary, and the relationship of lexical development with verbal short term memory. To address this issue, measures of verbal short term memory, digit span and nonword span were taken, and an oral picture naming vocabulary task was administered.

2.1. Methods

2.1.1. Participants

The group tested in this study consisted of 15 children and young adults with Williams syndrome; their mean age was 13.2 years (ranging from 5.9 to 19.6 years at the time of assessment). Subjects were recruited through the Hungarian Williams Syndrome Association, and most of them were assessed in a summer holiday camp for WMS children and their families. Children were tested individually; all of them were assessed on the vocabulary task, the digit span and nonword repetition tests, and 14 subjects' results are included in the morphology task.

2.1.2. Verbal short term memory

Two measures of verbal short-term memory were taken, digit span and nonword repetition test. In the *digit span task*, subjects hear digit sequences of increasing length and attempt to repeat them immediately. Digits are taken from those between 1–9, and none of them are repeated within one sequence. The score is the amount of digits in the longest sequence correctly repeated; there were two token series with each length. The subject was given the score if s/he could repeat either of them; if the subject failed both trials of one length, testing terminated. In the nonword repetition test, subjects hear single unfamiliar phonological strings of increasing syllable number, and attempt to repeat them immediately. We constructed 36 nonwords of varying length (1–9 syllables, 4 items for each length). The phoneme sequences in each nonword conform to the phonotactic rules of Hungarian. Nonwords were read out by an experimenter trained on the items. The score in this task is the number of syllables in the longest nonwords correctly repeated; the subject was given the score if s/he could correctly repeat at least 50% (2) of the items, testing terminated when subjects failed all items of a given length.

2.1.3. Picture naming

2.1.3.1. Materials

Pictures in the naming task were black and white line drawings (Székely–Bates 2000; Bates et al. 2000; Druks–Masterson to appear; Masterson–Druks 1998), printed on cardboard paper.[1] Stimuli came in three categories: the NOUNS group had 30 line drawings of objects or animals and plants, the VERBS group consisted of 30 pictures displaying actions, and the COMPOUNDS group consisted of 20 items (for technical reasons) showing objects and creatures again, with the proviso that their name could only be a compound word. Half of the names of the items in each category were frequent words, half were rare, according to norms in the frequency dictionary of Hungarian (Füredi–Kelemen 1989). Examples are given in Table 1.

[1] The reason for designing our own vocabulary test instead of using a standardized one was that there were no tests in Hungary that would have fit our specific questions.

Table 1
Examples of stimuli from the vocabulary task

	NOUNS	VERBS	COMPOUNDS
Frequent	macska 'cat'	táncol 'dance'	babakocsi 'pram'
Rare	piramis 'pyramid'	térdepel 'kneel'	karmester 'conductor'

2.1.3.2. Procedure

Participants were tested individually. They were given the pictures one by one by the experimenter, and were asked to name it in questions like "What is this?" in the case of NOUNS and COMPOUNDS, and "What is he/she/it doing?" in the case of actions. Responses were tape-recorded for later assessment; there was no time limit on the response of the subject. The independent variables were the category and the frequency of the word, the dependent variable was the correctness of the response. A response was coded as correct if it corresponded to the dominant response of normal subjects to the picture (established by Székely–Bates 2000; Bates et al. 2000) or were synonymous with it in the NOUNS and VERBS groups; in the case of compounds, only responses that were compounds were accepted.

2.1.3.3. Results

Figure 1 shows the mean percentages of correct answers in the three lexical classes (overleaf).

Table 2 summarizes various analyses of variance performed on the data. A two-way within subject design with WORD CLASS and FREQUENCY as factors showed that although compounds seem to be harder to retrieve in this naming situation, the difference is not significant. Frequency, on the other hand, had a strong main effect. In average, subjects mobilized 36 frequent words (90% correct, out of 40 (15+15+10)), and 26.41 rare words (65% correct). This factor had a significant effect both in nouns and in verbs, while it had no significant impact on compounds. Age had no significant effect; although our sample was too small and unevenly distributed with respect to age, there was an observable increase from 67% mean word mobilization to 83% comparing children up to 10 years (n=4), and children over 10 years (10). ($F=3.75$, $p < 0.10$).

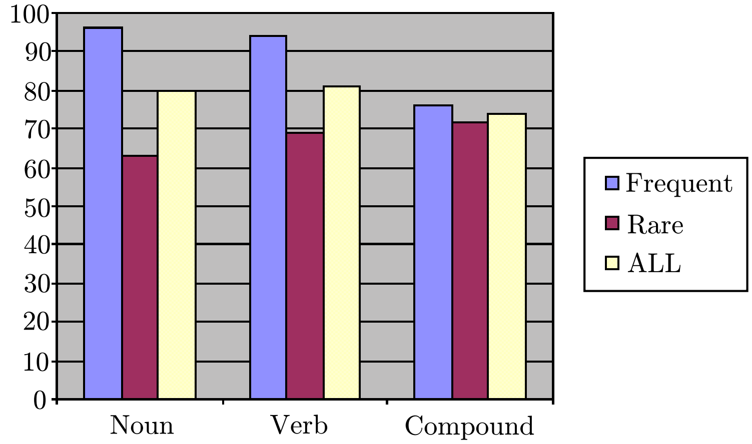

Fig. 1
Mean percentages of correctly named pictures

Table 2
Summaries of analyses of variance over percent of words correct in WMS children

EFFECT	F	Df	P
Word Class	2.53	2,24	n.s.
Frequency	9.56	1,12	0.01
F × Wclass	3.87	1,12	0.05
Nouns,Frequency	31.63	1,12	0.0001
Verbs,Frequency	25.79	1,12	0.0002
Compounds,Freq.	<1	1,12	n.s.

There were interesting age effects between Rare and Frequent words, as well as between word classes. To summarize it simply, the most remarkable age effects were observed in frequent compound words ($F=8.68$, $p < 0.001$), and this was responsible for the significant age effect in all frequent words, while in rare words, surprisingly, there was no age effect. Figures 2A and 2B summarize these differences. If we compare the upper and lower charts, it is apparent that while the effects are not significant (see Table 3), in rare words there seems to be an age related increase in nouns and verbs, while in more common items, age seems to be related to the more difficult compounds. (See Table 4 for a summary.) Our preliminary results suggest that there are characteristic frequency dependent effects in WMS children, and they seem to be related to grammatical complexity (reflected in compounds). The details of this relationship have to be worked out with more specific vocabulary studies.

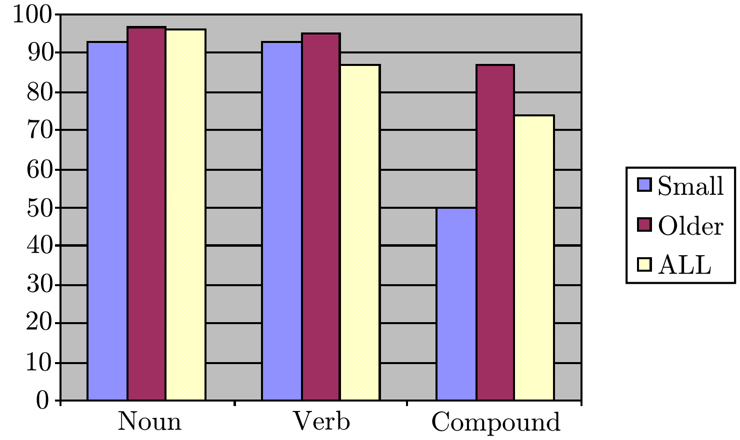

Fig. 2A
Correct word naming in frequent words as a function of age

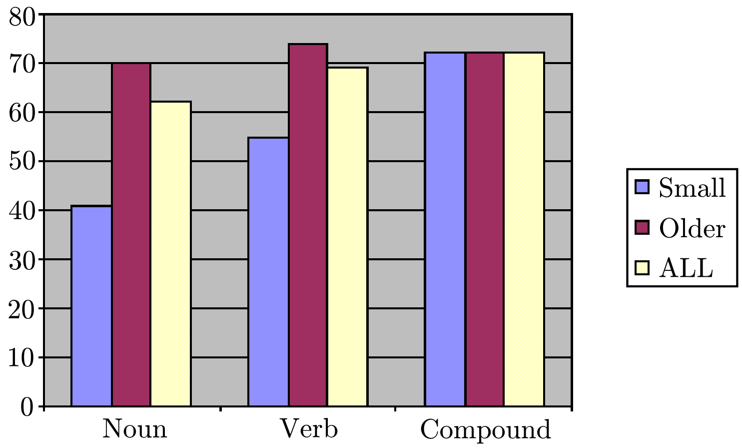

Fig. 2B
Correct word naming in rare words as a function of age

Table 3

Summaries of analyses of variance on the effects of age on percent of words correct

EFFECT	F	Df	P
FREQUENT WORDS			
Age	9.44	1,12	0.01
Word Class	14.87	2,12	0.0001
Word Class × Age	6.42	2,24	0.01
RARE WORDS			
Age	1.31	1,12	n.s.
Word Class	<1	2,12	n.s.
Word Class × Age	<1	2,24	n.s

Table 4

Summaries of age effects on percent of words correct

EFFECT	F	Df	P
FREQUENT WORDS			
Nouns	1.19	1,12	n.s.
Verbs	<1	1,12	n.s
Compounds	8.68	1,12	0.01
RARE WORDS			
Nouns	4.60	1,12	0.06
Verbs	2.16	1,12	n.s.
Compounds	<1	1,12	n.s

2.2. Data from unimpaired children

Data from a control group of 7-year-old average children (n=21) is available on vocabulary measures. Figure 3 shows their results contrasted to WMS children over different lexical tasks.

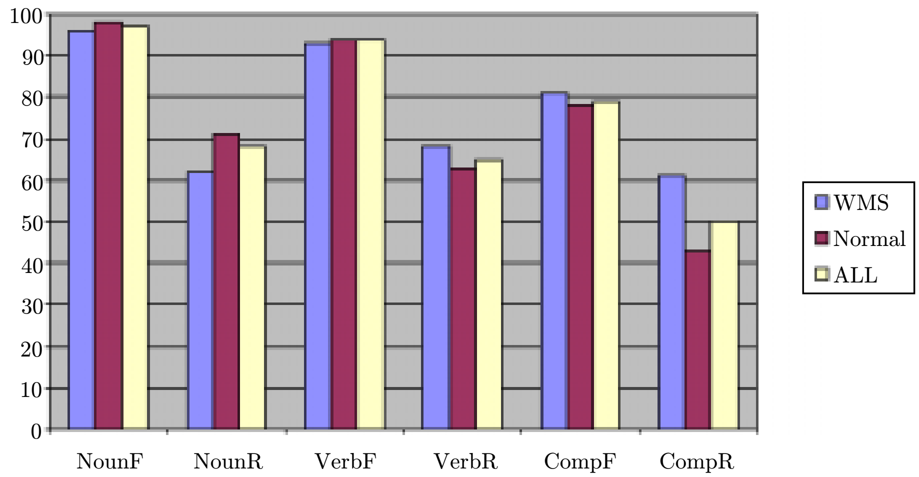

Fig. 3

Comparison of WMS and 7-year-old average children in the lexical tasks

In the overall analysis of variance comparing the two groups there were no across-the-board differences, the two means being 77 and 74 percent for WMS and normal children, respectively ($F < 1$, n.s.). At the same time, there was a strong Word class effect ($F_{2,66}=46.21$, $p < 0.0001$), accompanied by a strong Group x Word Class interaction ($F= 9.47$, $p < 0.0002$). Frequency had by far the largest effect ($F_{1,33}= 184.80$, $p < 0.00001$). Frequency had no interaction with Group ($F_{1,33}= 1.19$, n.s.) corresponding to our impression that frequency is an independent factor both in WMS children and in normals. Essentially, compounds are harder, and frequency has an impact on performance in both groups. However, WMS children seem to perform better on rare compound words compared to normal controls ($F_{1,33}=7.71$, $p < 0.001$), while in frequent compounds there is no such difference. Table 5 summarizes the significant differences within the normal group. Comparing Tables 2 and 5, it is apparent that in WMS children there is an interaction between word class and frequency (because frequency effects are attenuated in compounds), while in normal children compounds are clearly more difficult, and frequency effects are observable in all word classes.

Table 5

Analysis of variance over percent of words correct in normal 7-year-old children

EFFECT	F	Df	P
Word Class	54.73	2,40	0.00001
Frequency	320.62	1,20	0.00001
F × Word Class	1.62	2,40	n.s

2.3. Relationships to measures of short term retention

In our study two general (possible) measures of verbal memory were used: number span and non-word repetition. Interestingly enough, in our WMS sample the cruder measure of number span proved to be a better predictor of vocabulary level than the theoretically more promising non-word repetition. We shall be trying to cross-tabulate this data with measures of non-verbal retention in later analyses; for the moment only some rough comparisons shall be presented. We compared lexical performance of children below and above the median on both measures of verbal short-term memory. In the case of number span this meant groups with a span of 3 and below versus groups of 4 and more, with 8 and 6 members, respectively. In the case of non-word repetition the cutpoint was 4, with 7 and 8 children in the two groups. As Figure 4 shows, higher number span was associated with knowing more rare words.

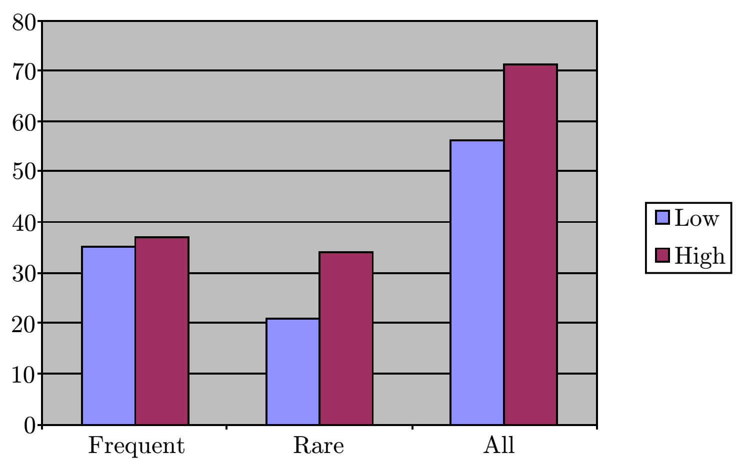

Fig. 4

Effects of number span on lexical knowledge

The summary of a series of comparisons shown in Table 6 indicates that the effect of non-word repetition was only significant in the case of rare nouns. However, with digit span, a higher performance was associated with knowing more rare words both for nouns and for compounds. Further studies will decide whether this is related to the overall level of intelligence, or whether the high verbal subgroups also have better overall memory functions. Some preliminary multivariate analyses are presented below to indicate the direction our research might take.

Table 6

A summary of comparions of vocabulary with number span and non-word repetition

INDICATOR	NUMBER SPAN EFFECT	NONWORD EFFECT
NounF	1.62, n.s.	<1, n.s.
NounR	7.30, 0.02	4.65, 0.05
VerbF	9.32, 0.01	<1, n.s
VerbR	3.64, 0.10	<1, n.s
CompF	<1 n.s.	2.26, b.s.
CompR	6.25, 0.05	<1, n.s
Frequent	1.35, n.s.	1.57, n.s.
Rare	13.13, 0.005	<1, n.s
All words	10.58, 0.005	<1, n.s

2.3.1. Predictors of word knowledge

Stepwise regression analyses taking different summary indices of lexical knowledge as dependent variables showed that for rare words digit span was the strongest predictor while for frequent words, age. Table 7 summarizes these equations. In all of the analyses age, digit span, and nonword repetition were taken as predictors. Although nonword repetition performance is a weaker predictor ($\beta = 0{,}39$) than digit span, its correlation with rare words is moderate even if age effect was partialed out ($r = 0{,}5$, $p < 0.07$).

Table 7

Stepwise regressions solutions for different vocabulary measures

DEPENDENT VARIABLE	REGRESSION COEFFICIENT	EQUATION	FIRST R	SECOND R IMPROVEMENT
All words	0.79	33.88 + 1.14 age + 3.83 span	Span 0.66 F=9.06	Age 0.13 F=5-79
Rare	0.65	1.82 + 4.2 span	Span 0.65 F=8.59	—
Frequent	0.75	29.18 + 0.51 age	Age 0.75 F=15.26	—

2.4. Multivariate comparison of relationships in normal and WMS children

We also made some pilot multivariate comparisons to see if the internal relationships between different subgroups within vocabulary are the same in normal and WMS children. In 7-year-old normal children the correlation matrix shown in Table 8 was obtained. Table 9 shows the same matrix for WMS subjects. It is apparent that in WMS children, vocabulary measures have a denser correlation structure. The bold numbers in Table 9 indicate those correlations which seem to be higher in the WMS group compared to isomorphic ones in normal children.

Table 8

Correlation matrix of lexical measures in normal 7 year olds

	nounf	**nounr**	**verbf**	**verbr**	**compf**	**compr**
nounf	1.0000					
nounr	−0.0000	1.0000				
verbf	0.2089	−0.0536	1.0000			
verbr	0.1506	0.3434	0.0959	1.0000		
compf	−0.1044	0.3192	−0.1181	0.2271	1.0000	
compr	0.1105	−0.0154	−0.0391	0.2594	0.4863	1.0000

Table 9

Correlation matrix of lexical measures in WMS children

	nounf	**nounr**	**verbf**	**verbr**	**compf**	**compr**
nounf	1.0000					
nounr	0.2815	1.0000				
verbf	0.1338	**0.7235**	1.0000			
verbr	0.0919	**0.7852**	**0.6529**	1.0000		
compf	0.1571	**0.7712**	0.4758	**0.7942**	1.0000	
compr	0.3822	**0.8419**	**0.7795**	**0.6934**	0.6850	1.0000

Preliminary factor analyses support this impression: as Table 10 shows, while there are 3 unrotated factors in normal children (the two stronger ones shown in the table), in WMS children we find only one, with a much higher proportion of variance explained.

Table 10

Unrotated factor loadings for principal components of the memory indices in the two groups

	NORMAL 7-YEAR-OLDS		WMS CHILDREN
VARIABLES	RARE	FREQUENT	VOCABULARY
NounFrequent	0.089	0.758	0.316
NounRare	0.565	−0.039	0.940
VerbFrequent	−0.080	0.728	0.813
VerbRare	0.661	0.348	0.878
CompFrequent	0.786	−0.290	0.839
CompRare	0.668	0.016	0.920
Variance explained	1.835	1.312	3.966

In line with these impressions, after rotation, in WMS children the single overwhelming lexical factor remained the one with rare nouns having the highest loading (0.940), while in normal children the three rotated factors were Compounds, with the two compound words having a loading of 0.735 and 0.924, Rare words with rare nouns having the highest loading (0.906) and Frequent words with frequent nouns loading 0.773, and frequent verbs with a loading of 0.719.

3. Morphological development

The issue of the effect of frequency and short term memory span was raised again in a morphology task tapping affixation patterns in WMS children. This task contrasted regular versus irregular inflectional forms on the one hand, and frequent versus infrequent items on the other.

3.1. Materials

32 picture pairs were used in this experiment, those of Pléh et al. (1994), complemented by new picture pairs to adjust the test to our question concerning frequency effects in regular and irregular suffixation. The first picture of each pair shows an object, the second one is supposed to elicit either its accusative or plural form. The test had 4 items is each of the 3 regular and 4 irregular classes, 2 frequent and 2 rare, based on Füredi–Kelemen (1989).

Table 11

Examples of stimuli used in the morphology task

	EXAMPLE	
STEM CLASS	FREQUENT	RARE
1. Epenthetic n=104	majom–majmok 'monkey–monkey acc.'	bagoly–baglyot 'owl–owl acc.'
2. Lowering n=71	hal–halak 'fish–fish pl.'	sál–sálak 'scarf–scarf acc.'
3. Shortening n=222	kenyér–kenyerek 'bread–bread pl.'	bogár–bogarak 'beetle–beetle pl.'
4. *v*-inserting	kő–követ 'stone–stone acc.'	távcső–távcsövet 'telescope–telescope acc.'
5. 'Low V'-final	kutya–kutyát 'dog–dog acc.'	teve–tevék 'camel–camel pl.'
6. C-final	asztal–asztalok 'table–table pl.'	pingvin–pingvinek 'penguin–penguin pl.'
7. 'Nonlow V'-final	cipő–cipőt 'shoe–shoe acc.'	hattyú–hattyút 'swan–swan acc.'

3.2. Procedure

This task was carried out on the same subject pool as the vocabulary task. Participants were tested individually again. They were given the pictures one by one by the experimenter, the one depicting an individual object shown first from each pair. After providing the name for the object, they were shown the second picture from the pair, and were asked questions prompting either a plural ("What are these?") or an accusative ("What is the boy eating?") forms. Responses were tape-recorded; there was no time limit on the response of the subject. The independent variables were the stem type and the frequency of the word, the dependent variable was the correctness of the response. A response was coded as correct if it was properly inflected; it was considered incorrect if it was overregularized or unmarked.

3.3. Results

Figure 5 shows that, in accordance with previous observations, WMS children seem to overgeneralize exceptional items (see previous research on the issue in Hungarian: Lukács–Pléh 1999; Lukács to appear).

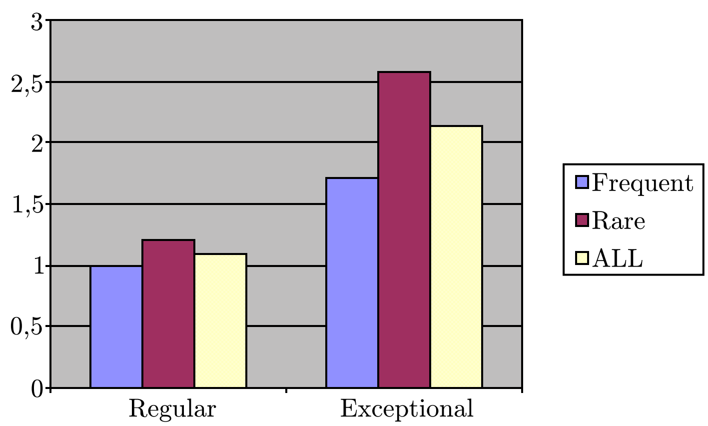

Fig. 5

Overall differences in errors between regular and exceptional nominal stem classes

In a two way analysis of variance, regularity had a significant main effect ($F_{1,13} = 5.46$, $p < 0.05$), while the frequency effect was not significant ($F_{1,13} = 2.13$, n.s.). Table 12 summarizes the results of the analyses performed over the different subtypes of regulars; Table 13 summarizes results on irregulars.

Table 12

Summary of item frequency related differences in regulars

STEM TYPE	FREQUENT	RARE	F	p
Low V	0.46	0.30	<1	n.s.
Nonlow V	0.23	0.08	<1	n.s.
Consonant	0.23	0.61	4.45	0.06.

Table 13

Summary of item frequency related differences in exceptionals

STEM TYPE	FREQUENT	RARE	F	p
Shortening	0.69	0.61	<1	n.s.
Epenthetic	0.60	1.00	<1	n.s.
Lowering	0.15	0.31	1.34	n.s.
v-inserting	0.53	0.84	5,21	0.05

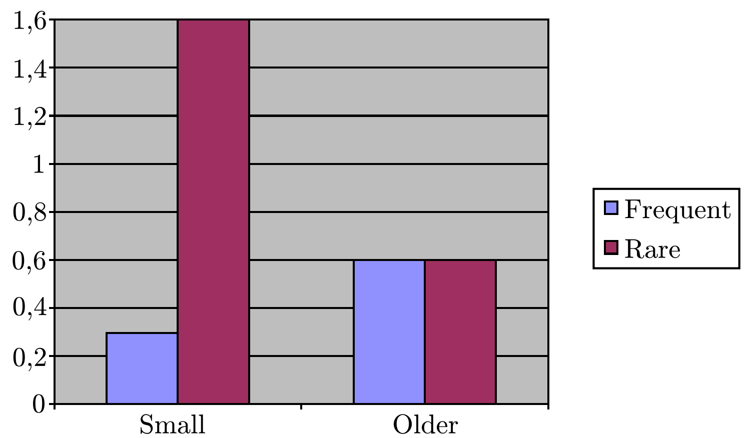

Fig. 6

Overgeneralizations in v-stems as a function of frequency and age

Thus, interestingly enough, overgeneralizations also appear with one regular class, namely, in consonant-final stems. In irregulars, however, beside the general effect of regularity there is a clear item effect in v-inserting stems. However, as Figure 6 shows, this is also related to age: younger WMS children (under 10 years) are especially sensitive to overgeneralizations here. Some interesting relationships hold between short-term memory measures and morphologiocal performance. Table 14 shows that low-span children made more morphological errors both on regulars and irregulars. This implies that working memory capacity is related to grammatical proficiency as well.

Table 14

Effects of digit span differences on morphological errors

STEM TYPE	LOW SPAN	HIGH SPAN	F	p
Regular	2,75	0,40	5,72	0,05.
Exceptional	6,25	1,60	6,61	0,05
All	9,0	2	8,83	0,01

4. Discussion

Results of the three tasks point to the importance of the role of phonological short term-memory both in vocabulary acquisition and in grammatical development. Regarding the three issues raised in designing the experiments, our results gave the following answers. Vocabulary size is related to the capacity of verbal short-term memory: higher working memory span predicts larger vocabulary. This is especially true for rare words. This implies that regarding one of the debated issues in the WMS literature, there is a frequency sensitivity in WMS vocabulary. We might postulate that this frequency sensitivity is mediated by working memory: children with higher working memory span learn less frequent words more easily. This complies with the observation that WMS people often produce unusual and sophisticated words without knowing their meaning: these might be stored as a pure phonological string. The less expressed effect of working memory with frequent words might be due to a ceiling effect and thus little variance of result. Our future studies using a nonword learning paradigm might clarify this relationship.

In the morphology task we obtained the usual superiority of regulars over irregulars. Within this general pattern, moderate frequency sensitivity was observed in some stem types (one regular and one exceptional). More interestingly, however, performance on the morphology task was also related to working memory span. It is too early to draw conclusions but this may suggest that grammatical proficiency bears some intricate relation to working memory: this might take the form of performance limitations or lack of grammatical competence. This is to be clarified using online processing tasks.

As a general implication of our results, we might suggest that some of the non-homogeneity of WMS children on cognitive and behavioral measures (emphasized by Jarrold et al. 1998; Bellugi et al. 2000) might reduce, at least in linguistic aspects, to differences in verbal working memory capacity. This suggestion is supported for example by the fact that working memory differences remain after age effects are controlled, and in some measures performance is more dependent on memory than on age. Our further studies broadening the age-range within our sample might help to articulate this suggestion.

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