The Word Sound Structures Distribution as a Quantitative Measure for Speech Development

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Abstract: Studies in phonological development usually focus on the acquisition of separate segments and the quality of their realization, while much less is still known about the development of whole-word patterns. The analysis of the whole-word structure, or word shape, addresses word structure patterns (WSPs) that are mastered and constantly used by children in their speech. The aim of the current study was to analyze the distribution of syllable and WSPs in the corpus of Russian typically-developing children's discourse. The study was based on the corpus data (orthographically transcribed texts) of Russian-speaking monolingual children (n = 14; the mean age was ~68 months). The data included 28 fictional narratives and 14 conversational reasoning dialogues between a child and an experimenter. By means of specially designed software the PASTA, words were structurally analyzed and classified into 22 groups according to the basic types of syllable structure of a Russian word. Then, the percentage distribution of these structures was estimated. Statistical analysis revealed that the distribution of syllable types was quite similar between the children and adult speech data; in children, this measure did not depend on the discourse genre (narrative vs. conversational reasoning dialogue). The WSPs distribution, in contrary, discriminated children from adults and was significantly influenced by the discourse genre.

Keywords: Child language, word structure, phonology, narrative, conversation.

THEORETICAL BACKGROUND

Phonetic and syllabic structure of words considered one of the main characteristics of language and speech development [1]. Previous studies have suggested that phonotactic constraints may act as a filter for a lexical acquisition [2], i.e. a production of novel words might be influenced in children by the complexity of a whole-word structure and the length of a phoneme sequence. The phonological complexity of words depends on the length of the given word in sounds, the number and complexity of the syllables, and the presence of consonant clusters [3, 4, 5]. Since the syllable is the minimal unit of motor programming and speech production, acquisition of syllabic structures is one of the main constituents and indicators of articulatory base development [6, 7]. It is known that open syllables are the easiest to master [3, 6]. The earliest syllabic structures acquired by a child are V and CV[1]. Most of the early word shapes belong to an iterative type CVCV [6]. Already in the second year of life, children start using closed CVC syllables [3]. An early development of the whole-word structures have been studied in different languages, such as French [8], Brazilian [9], Polish [10], Finnish [11], Arab [12], Japanese [13], and Russian [14]. However, the data on further dynamics (starting with the third year of life) in a formation of the whole-word structures (both on lexical and on sub-lexical level) is still extremely scarce.

Following previous studies, an acquisition of the whole-word structures and mastering a pronunciation of the target speech sounds are in a competitive relationship due to the struggle for cognitive resources [15, 16, 17, 18, 19, 20, 21, 22, 23, 18]. Difficulties in acquiring new sounds often lead to temporary compensatory simplifications of syllable and/ or sound structure in words with the given sounds [14, 24, 25, 26, 27, 28, 2, 29, 30, 31, 32, 33, 34]. This might be also recognized as so-called trade-off effect, i.e. a simplification of some characteristics due to the high complexity of others (e.g., the omission of one consonant in a cluster in multisyllabic words but a correct pronunciation of the same cluster in mono- and disyllabic words). On the other hand, children with limitations in the articulatory base development tend to escape structurally complex words in spontaneous discourse.

According to W. Levelt and his followers, humans acquire not only a vocabulary but also so-called mental syllabary, i.e. a set of (high-frequency) syllables of a given language [35]. A child learns a novel word easier if its phonological structure is similar to acquired already words [36]. Most of these findings have been based on English-speaking children's data; however, the patterns of word structure are different across

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[1]Herein and after: V – vowel, C – consonant.

E-ISSN: 2311-1917/19

languages. In Russian, the syllable structure can be described in the formula C(0-4)-V-C(0-4); i.e. from 0 to 4 potential consonants before and after the vowel [37, 38].

The mean length of the word is 3-4 syllables and word length may vary from 2 to 18 phonemes. In this regard, acquisition and production of new words should be influenced by a) complexity of the whole-word structure and b) a length of phonemes sequence. This relation should manifest in speech production as a different distribution of a) words with less vs. more complex sounds and b) different structural patterns.

Most studies on the phonological development that have dealt with characteristics of syllabic structures have been based on a selective (mainly qualitative) analysis [39, 40]. This limitation might be caused by extremely time-consuming linguistic structural analysis and a lack of special software designed.

The current study aimed to analyze the whole-word structure and to estimate a distribution of different whole-word structures in Russian child speech corpus. One more point addressed in the current study is the impact of a discourse genre on the distribution of the whole-word structures. We presume that the distribution of a word structure is not a constant measure of language. On the contrary, this should be a dynamically changing measure which depends on language resources of an individual and on demands of current language activity. Finally, we aimed at a comparison of syllable and whole-word structure between the child *vs.* adult speech corpus data.

METHODOLOGY

Subjects and Data of the Study

For this cross-sectional quantitative study, we accessed *The Corpus of Russian Children's Language* compiled at St. Petersburg State Pediatric Medical University. The Corpus includes transcribed and morphologically annotated data of personal and fictional narrative speech, conversational reasoning dialogues between a child and an adult and spontaneous dialogues between children (144 114 word tokens in total). For this study, we selected 14 typically-developing 6-year-age Russian monolingual children (the mean age was 68 months) and analysed their fictional narratives (telling and retelling) and conversational reasoning dialogues.

In order to elicit *fictional narratives*, the subjects were assessed by means of the *Russian Assessment Instrument for Narratives – RAIN* [41, 42, 43] developed on the basis of several methodological sources, such as [44, 45, 46, 47, 48]. Each subject was assessed individually and was asked to tell and to retell a story according to different picture sequences (each of them consisted of 6 colored pictures, 10x10 cm in size); both tasks were followed by ten comprehension questions (these the corpus-data were not included into the analysis).

In order to elicit *conversational reasoning dialogues*, the 'nonsense-picture' method [49] was applied. During an individual assessment, an experimenter showed a child a picture with many unrealistic details (e.g. a cow sitting on a tree, a snowman standing on the Summer grass, etc.) and asked the child to evaluate its plausibility. While talking, the experimenter asked the child many provoking questions and made provoking statements (such as, *But why, actually, we cannot make a snowman in Summer? I think it must be great!*) and, thus, attempted to involve the child into a discussion.

For this study, we selected 28 narratives (2 286 word tokens) and 14 conversational reasoning dialogues (8 687 word tokens) transcribed orthographically.

In order to compare syllable and whole-word structure between the children *vs.* adult speech corpus data, we assessed *The Russian National Corpus* (http://ruscorpora.ru) developed at the Russian Academy of Sciences. Its *Sub-corpus of the Spoken Language* (sCSL) (http://dict.ruslang.ru/freq.php) (10 122 579 tokens in total) incorporates speech samples with different types and genres of private and public speech obtained from multiple regions and cities of Russia. For the current study, we analyzed the total list of 4 700 word lemmas from the *Frequency Dictionary of Russian* – FDR [50].

Measures Analyzed

The child speech data were analyzed as two entities (narratives and conversational reasoning dialogues). Analysis of the adult speech data was carried out separately in 1) the first 1 000 of the most frequent lemmas (max. frequency > 78 ipm) and 2) the rest of 3700 lemmas with the frequency between 10 and 78 ipm. For both data analysis, a specially designed software for text analysis – the PASTA [51] (see Figure **1**) – was used.

All the words were structurally analyzed and classified into 22 groups according to the basic types of

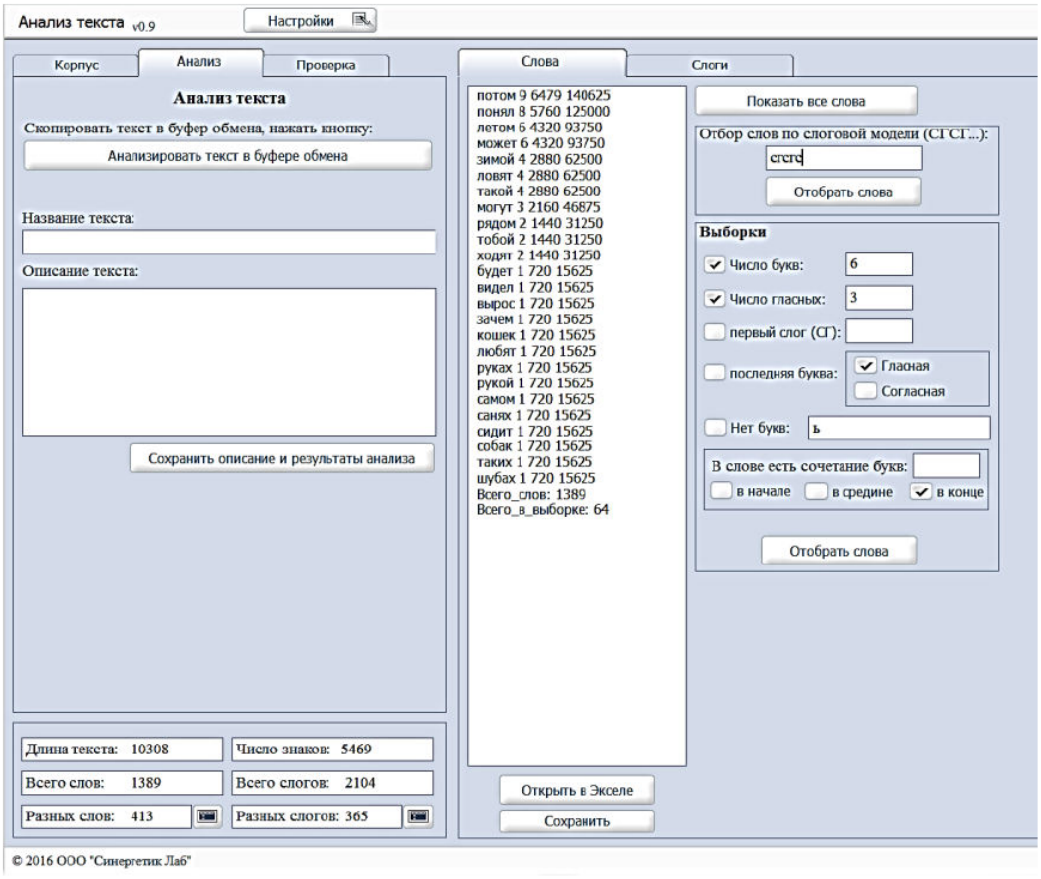

Figure 1: An example of a text analysed by means of the PASTA.

Russian word structure patterns (WSPs). It should be noted here that a huge amount of different WSPs exists in Russian. Structural typing depends on a) the type and the number of syllables, b) the number of clusters and their position in the word, and c) the total number of phonemes. Russian is a multi-syllable language that contains many words with clusters of 2-3 consonants and, thus, word structures vary from C or V to CCVCVCVCCVCV and even longer ones (for more details, see Kornev *et al.*, 2010). To simplify this multitude, some WSPs were merged to the main 22 structural types, from the simplest (such as C, V, CV, VC) to the most complex (12 phonemes with seven syllables) ones. Then, the percentage distribution of these structures was estimated and submitted for the statistical analysis.

In order to answer the main research questions, we analysed the distribution of 1) different WSPs and 2) different syllables in narratives and conversational reasoning dialogues separately. The analysis of the child speech data was carried out twice: first, we analysed the total amount of word tokens; then, we analysed a list of different lemmas generated by the CLAN [52] tools. This dual analysis was necessary due to the morphosyntactic features of Russian as a morphologically rich and highly inflected language. While in such languages as English a word has only a few inflectional forms which fall into even less amount of phonetical structures (e.g. *a dream – dreams*), in Russian, it has many more inflectional forms; e.g. 'a dream/dreams' in Russian might have such forms as *son*:SG-NOM/ACC, *sna*:SG-GEN, *snu*:SG-DAT, *snom*:SG-INS, *sne*:SG-LOC, *sny*:PL-NOM/ACC, *snov*:PL-GEN, *snam*:PL-DAT, *snami*:PL-INS, *snakx*:PL-LOC[2]. A declination paradigm of such a simple word includes four different structural word types: CVC (*son*), CCV (*sna, snu, sne, sny*), CCVC (*snom, snov, snam, snakx*), and CCVCV (*snami*). More complex words (4-, 5-, 6-syllabic, etc.) would include even more complex inflectional (and, consequently, phonetical) structures.

As for adult speech, only a list of different lemmas was available for the analysis.

[2]Following the internationally agreed *Leipzig Glossing Rules*, SG – singular, PL – plural, NOM – nominative case, GEN – genitive case, DAT – dative case, ACC – accusative case, INSTR – instrumental case, LOC – locative case [53].

RESULTS

Syllable Types in the Narratives *vs.* Conversational Reasoning Dialogues

Results of the analysis of the distribution of different syllable types unambiguously demonstrated that this measure was constantly the same in the analyzed children speech regardless of the genre (Figure **2**).

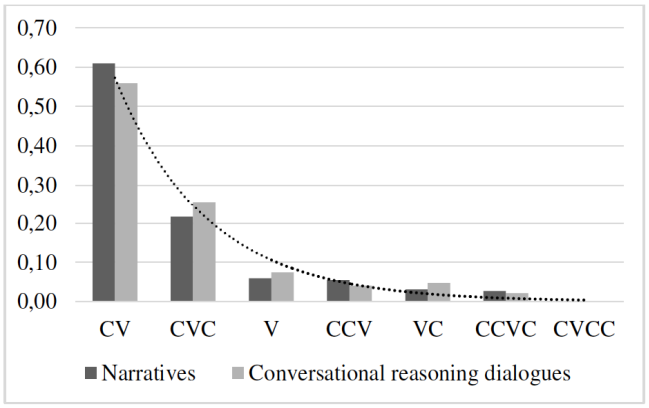

Figure 2: The distribution of different syllable types in the narratives *vs.* conversational reasoning dialogues.

In both narratives (story-telling and retelling) and conversational reasoning dialogues, the simplest syllable types (CV and CVC) were dominant, while other structures were much rarer.

Syllable Types in Child *vs.* Adult Speech Data

The obtained results (the percentage of the distribution of the main syllable types) was compared with the results of an identical analysis in Modern Russian [37]. The exponential curve was very similar to that obtained in the children speech data (Figure **3**).

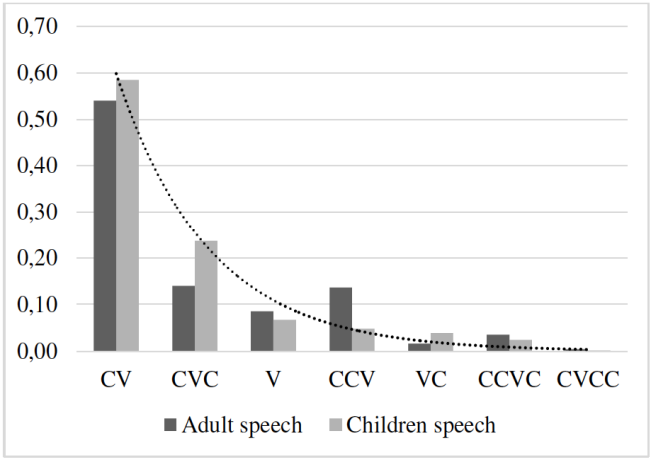

Figure 3: The distribution of different syllable types in child vs. adult speech data (the adult speech data have been analysed by Bondarko, 1998).

In both children and adult speech, the CV syllables were the most frequent, followed by the CVC and CCV syllables. The CVCC syllables were used in the adult but not the children speech.

This result corresponds to the *Principle of Least Effort* [54, 55, 56, 57] which states that humans tend to save their resources and to escape effortful activities when speaking/writing and, thus, try to convey maximum information by means of the simplest verbal constructions.

A Distribution of Different WSPs

In contrary to syllable types, the WSPs distribution estimated in the *list of word tokens* demonstrated many significant distinctions between narrative and conversational speech data; the differences were extremely dramatic if to compare conversations with *story-telling* (Figure **4**).

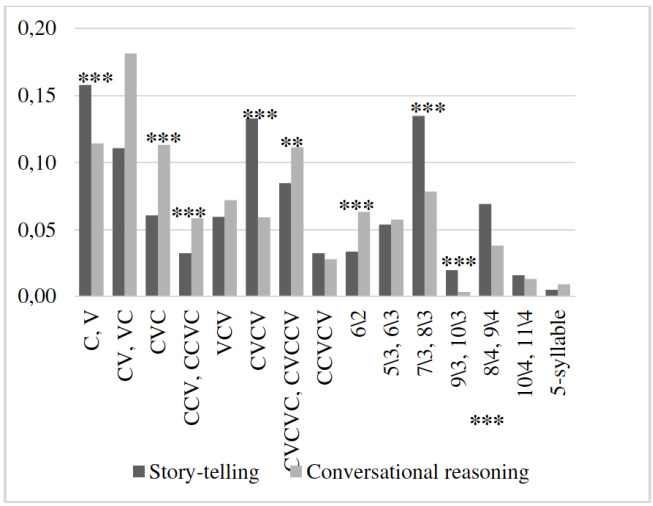

Figure 4: The distribution of WSPs in story-telling vs. conversational reasoning. Herein and after: 6\2 – 2-syllable WPS containing six sounds; 5\3 – 3-syllable WPS containing five sounds; 6\3 – 3-syllable WPS containing six sounds; 7\3 – 3-syllable WPS containing seven sounds; 8\3 – 3-syllable WPS containing eight sounds; 9\3 – 3-syllable WPS containing nine sounds; 10\3 – 3-syllable WPS containing ten sounds; 8\4 – 4-syllable WPS containing eight sounds; 9\4 – 4-syllable WPS containing nine sounds; 10\4 – 4-syllable WPS containing ten sounds; 11\4 – 4-syllable WPS containing 11 sounds. ** $p \leq 0.01$; *** $p \leq 0.001$.

As can be seen on the plot of Figure **3**, the frequency of most types of WSPs significantly differs between the story-telling and the conversational reasoning. The possible interpretation of these results is a dynamical change of the WSPs repertoire produced by the same children governed by requirements of different discourse genres. The main feature of these changes is their link to the WSP

complexity. In the conversational reasoning discourse, the range of WSPs was less complex compared to the story-telling.

The same analysis was carried out in the *list of different lemmas* obtained from the lemmatized word tokens. A comparison between the distribution of WSPs in the story-telling texts and in the conversational reasoning texts revealed many fewer significant distinctions compared to the word tokens analysis (Figure **5**).

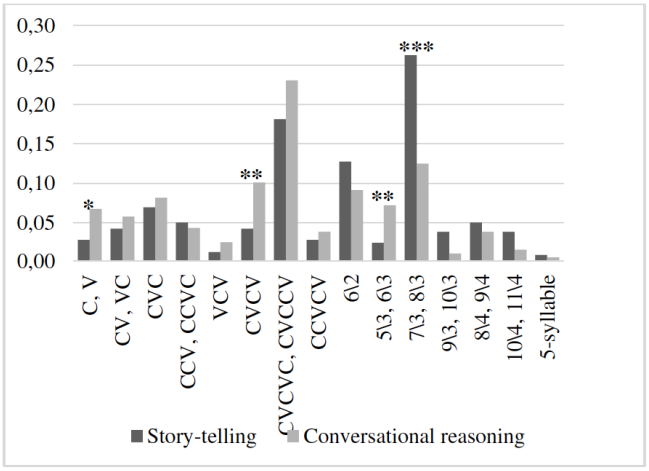

Figure 5: The distribution of WSPs in the lists of the different lemmas produced in story-telling vs. conversational reasoning. * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

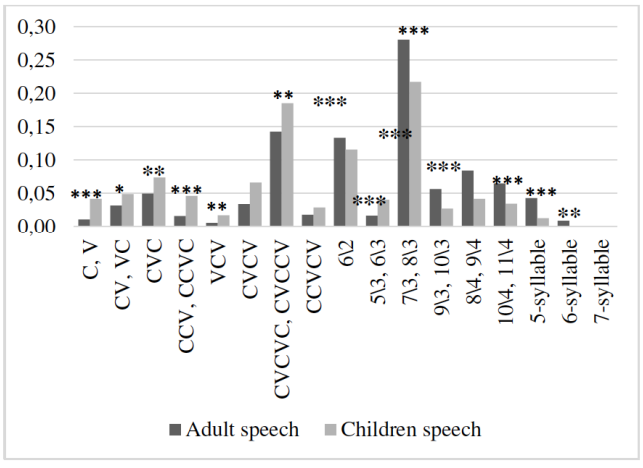

Figure 6: The distribution of WSPs in the list of different lemmas in children vs. adult speech. * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

From six different types of WSPs (C, V; CV, VC; CVC, CCV, and 7/3) which differentiated the story-telling discourse from the conversational one in the list of word tokens, only two WSPs (CV, VC, and 7/3) replicated this effect in the list of different lemmas.

While the word tokens list illustrates the so-called 'linguistic performance', i.e. an ability to select proper morphological forms to construct an utterance in flow of conversation, the list of lemmas refers rather to the 'linguistic competence', i.e. semantic knowledge and vocabulary structure. A comparative analysis of the distribution of different WSPs in the list of lemmas in the child vs. adult speech revealed great distinctions (Figure **6**).

The 6-year-age children still tended to use a lot of short words and many fewer long words in their conversation in comparison to adult speech.

CONCLUSIONS

Our results confirmed that linguistic characteristics of children spoken discourse are not constant but rather stochastic patterns. But it should be noted that the variability of speech activity was attributed only to syllable and whole-word structure but not to the syllable repertoire. It was evidenced that the distribution of *syllable types* in the children speech data did not depend on the discourse genre (narrative vs. conversational reasoning dialogue) and this distribution was quite similar to the same measure of adult speech [37] data. However, the *WSPs distribution* discriminated children from adults and was significantly influenced by the discourse genre. Presumably, children tried to convey maximum information by means of the simplest verbal constructions, in a correspondence to the *Principle of Least Effort* [54, 55 56, 57], i.e. they tended to save their resources and to escape effortful activities. The content and language form plans are competing with each other for spare resources in the utterance programming. It is reasonable to suppose that the production of the same word requires different efforts on the part of adults and on the part children.

In this study, we assessed the syllable and whole-word structure in a few of discourse genres (narrative and conversational reasoning dialogues), therefore, we cannot derive conclusions about the whole production of children language. Nevertheless, the new methodological approach and the special software [removed for review] confirmed to be a promising tool for further analysis of Russian speech data.

ACKNOWLEDGEMENTS

The study was carried out with the financial support from the Russian Science Foundation, grant No. 18-18-00114.

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Received on 02-12-2019 Accepted on 11-12-2019 Published on 17-12-2019

DOI: https://doi.org/10.12970/2311-1917.2019.07.03