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PHONOLOGICAL NEIGHBOURHOOD DENSITY IN RUSSIAN WORD PRODUCTION: EVIDENCE FROM CHILDREN AND ADULTS

Phonological neighbourhood density (PND) refers to the number of words which can be formed from a given word by substituting, adding or deleting one phoneme. Thus, word with many similar sounding neighbours has a dense neighbourhood, whereas a word with few neighbours or without neighbors has a sparse neighbourhood.

Previous studies have shown that dense and sparse neighbourhoods influence word production in different ways. Research in English-speaking adults demonstrated that words with dense neighbourhood are produced faster than words with sparse neighbourhood, facilitating lexical access. At the same time, sparse neighbourhood inhibits word production. Interestingly, studies in Spanish adults showed the reverse effect: dense neighbourhood inhibits word production whereas sparse neighbourhood facilitates it. This cross-linguistic difference in the PND pattern was explained in terms of morphological complexity of Spanish in comparison to English.

Although there are numerous studies of the PND effect in adults, some questions remain unknown. For example, how does PND influence word production in morphologically more complex language than Spanish? Or, how does the PND pattern develop in children? The present paper aims to explore these questions.

Keywords: phonological neighbourhood density, word production, picture naming, Russian adults, Russian children.

JEL Classification: Z.

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Introduction

Phonological development is a fundamental aspect of children's language acquisition. It is well established that phonological processing in early childhood is a significant predictor of language and vocabulary development and related disorders (Bishop, 2007; Tsao et al., 2004). Numerous studies in the past decades have shown that a phonological processing deficit affects children with Specific Language Impairment (Bishop & Adams, 1990; Montgomery, 1995; Gathercole & Baddeley, 1990; Ramus et al., 2013), developmental dyslexia (Dodd & Gillon, 2001; Ho et al., 2000; Kornev et al., 2010; Ramus et al., 2003), and Autism Spectrum Disorders (Ference & Curtin, 2013; Kuhl et al., 2013).

One of the significant phonological properties related to both lexical processing and vocabulary organization in children and adults is phonological neighbourhood density (PND) of a word. PND refers to the number of words that can be formed from a given word by substituting, adding or deleting one phoneme (Vitevitch & Luce, 1999). Thus, a word with many phonological neighbours, such as *bat* (*rat, mat, fat, pat…*), has a dense neighbourhood, whereas a word with few or without neighbors, like *squirrel,* is said to have a sparse neighbourhood. Importantly, it was reported that children acquire words with dense neighbourhood earlier and faster than words with sparse neighbourhood (Hansen, 2017), and even pseudoword learning depends on PND (van der Kleij et al., 2010). Overall, this evidence demonstrates a significant role of PND in word learning, vocabulary organization, and lexical access.

A different line of research has showed that PND influences word production and word comprehension in the opposite way, e.g. dense neighbourhood facilitates word production but inhibits word comprehension and vice versa (e.g., Garlock et al., 2001; Vitevitch & Sommers, 2003; Zeigler et al., 2003). The inhibiting effect of higher PND on word comprehension was detected in single-word shadowing task, identification of words in noise, auditory lexical decision, etc. (Luce & Pisoni, 1998; Vitevitch & Luce, 1998, 1999). These studies showed that words with sparse neighbourhood are perceived more accurately and faster than words with dense neighbourhood. Several psycholinguistic theories of speech perception suggest that similar sounding words are co-activated together with the target word (e.g., McClelland & Elman, 1986; Norris, 1994), and the activation of many phonological candidates inhibits the access to the appropriate word. Thus, sparse phonological neighbourhood facilitates word recognition in terms of accuracy and reaction time. In contrast to word comprehension, the existing studies on the influence of PND on word production clearly showed that words with dense neighbourhood tend to be accessed more easily than words with sparse neighbourhood both in typical (Harley & Brown, 1998; Vitevitch, 2002) and clinical

populations (Best, 1995; Gordon, 2002; Gordon & Dell, 2001). So, there is an opposite effect of PND on word production compared to word recognition.

However, evidence from inhibition and facilitation effects in word production and comprehension comes primarily from studies conducted in English. Research in other languages showed contradictory results. The same effects as in English were found for French adults in auditory (Dufour & Frauenfelder, 2010) as well as in visual domains (Zeigler & Muneaux, 2007; Zeigler et al., 2003). Note that the mentioned studies in visual domain calculated the phonological neighbourhood as a number of words resulting only from a single phoneme substitution, whereas works in auditory domain include words that can be generated by substitution, deletion or addition one phoneme. The opposite PND effect was observed for Spanish adults (Vitevitch & Sommers, 2003; Vitevitch & Stamer, 2006): words from dense neighbourhood are perceived faster and more accurately than those from sparse neighbourhood. By contrast, dense neighbourhood impedes word production in Spanish. This data was explained in terms of inflectional system of Spanish, which is more complex than in English. Presumably, two similar sounding words in Spanish might also be more morphologically and semantically similar to each other than two words in English (Vitevitch & Stamer, 2006). For example, the Spanish nouns *niño* (a male child) and *niña* (a female child) are phonological neighbours, but at the same time they are morphologically and semantically similar, which gives rise to the competition at the phonological as well as morphological and semantic levels, thus, putting additional inhibition on lexical access (Vitevitch & Stamer, 2006).

Similarly to the contradictory findings reported for adult population, the influence of PND on children's word production and comprehension remains unclear. Research in English-speaking children demonstrated the same results as in adults: there is more successful word production when target words are from dense neighbourhood (German & Newman, 2004; Newman & German, 2002), and faster word comprehension when target words are from sparse neighbourhood (Garlock et al., 2001; Metsala, 1997). However, existing studies in children have serious limitations. Firstly, most of the research was conducted in offline paradigms employing, for example, classification tasks and was based on retrospective data or parental reports (German & Newman, 2004; Strokel, 2002, 2004). Secondly, these works aimed to examine the role of PND in learning of new words or pseudowords and lexicon development both in typical and clinical children's populations (Hansen, 2017; Hoover et al., 2010; van der Kleij et al., 2010) rather than to focus on how familiar words are processed during speech production and comprehension. Finally, the absolute majority of experiments have been conducted in English-speaking children, except for a single study carried out in German (Zaba & Schmidt, 2011). At the same time, findings reported for adult speakers of different languages suggest that the precise nature of the influence of PND on word production and

comprehension depends on language morphological complexity (English vs. Spanish; e.g., Vitevitch & Stamer, 2006). Therefore, the research on the influence of PND on word production in children would greatly benefit from a more detailed study applying online techniques in a language with higher morphological complexity compared to English.

The major purpose of the present research is to investigate the influence of PND on word production in 4-6-year-old Russian children and Russian adults in the same experimental online paradigm and with the same stimuli.

Method

Participants

Children: A total of 25 native Russian-speaking children (10 males, 15 females) within the age range from 4 to 6 years old (M = 4.9 years) participated in the present study. Exclusion criteria were previous history of hearing / vision problems, neurological or psychiatric disorders. The parent or primary caregiver of children gave the written informed assent and consent respectively for their children participation in the experiments. The data was collected in the kindergarten INESNEK in Moscow, Russia.

Adults: A total of 20 native Russian-speaking adults (13 males, 7 females) within the age range from 19 to 36 years old (M = 25.2 years) participated in the present study. Exclusion criteria were the same as in study with children. All participants signed the written consent form in Russian. The data were collected at the Center for Language and Brain HSE in Moscow, Russia.

Materials

Thirty child-friendly color pictures, half of which illustrated words with dense neighbourhoods and half of which illustrated words with sparse neighbourhoods, were used in the present experiment. Words familiar to four to six years old children were selected according to norms for the Russian language reported by Akinina et al. (2015). Neighbourhood density count as well as sparse and dense neighbourhoods for Russian words were determined by Stimulstat database (Alexeeva et al., 2016). The words with dense neighbourhoods had a significantly more neighbours (M = 5.2 words) than words with sparse neighbourhoods (M = 0.4 words), $t(17.1) = 11.4$, $p \leq 0.001$.

Procedure

In a word production experiment, we use a classical naming task in which participants are shown a display with a picture and are asked to name it. All participants (children and adults) were sitting with instructor in a quiet room and are shown pictures presented with using the special AutoRAT tablet application created at the Center for Language and Brain, HSE (Ivanova et al., 2016). Pictures corresponded to words with dense neighbourhoods were presented in random order with pictures corresponded to words with sparse neighbourhoods. Speed and accuracy of answers were recorded on high quality audiotape. No picture was shown more than once. Reaction time (RT) in picture naming was measured.

Results

Children

The statistical analysis of experimental data showed that there is no significant difference in RT between pictures corresponded to words with dense versus sparse phonological neighbourhoods (Table 1).

	Reaction time		
	Estimate	***Standard error***	***p***
Fixed Parts			
(Intercept)	7.264	0.052	<.001
Density	-0.123	0.063	.065
Random Parts			
σ^2		0.081	
$\tau_{00,\,ID}$		0.016	
$\tau_{00,\,words}$		0.016	
N_{ID}		23	
N_{words}		21	
Observations		418	
R^2 / Ω_0^2		.032 / .306	

Table 1. The PND effect in word production (RT) in Russian children

At the same time, we found an interesting tendency of the PND effect in word production: words with dense neighbourhood tended to be produced on average 210 ms slower than words with sparse neighbourhood by 4-6-year-old Russian children (Fig. 1).

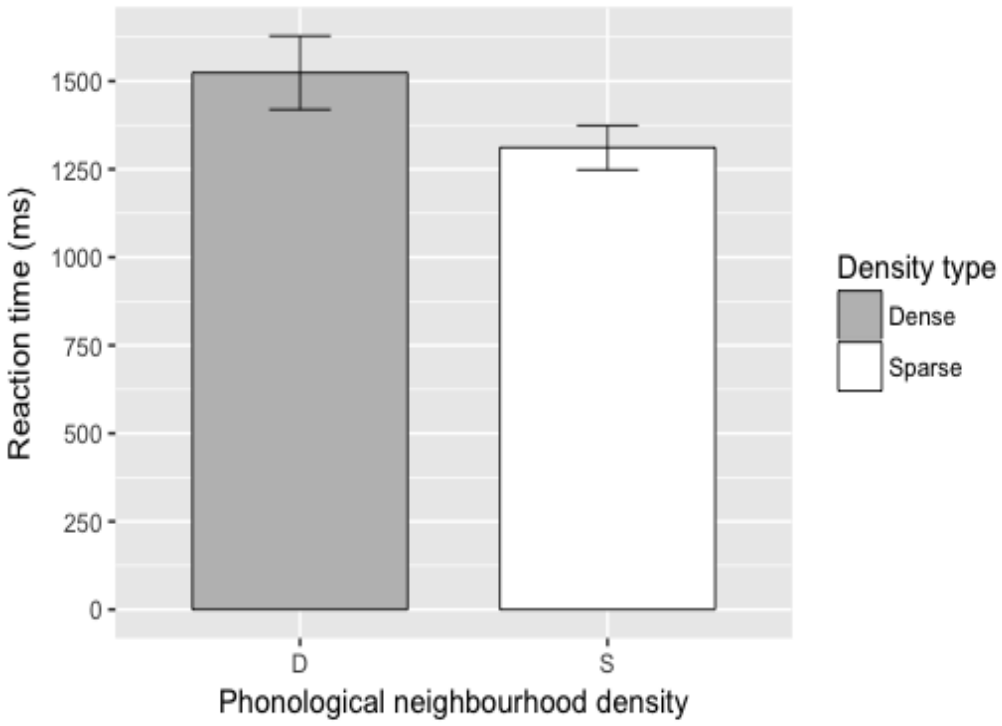

Figure 1. The PND effect in Russian children

Adults

The statistical analysis of experimental data showed that there is a significant difference in RT for pictures corresponded to words with dense neighbourhood in comparison to words with sparse neighbourhood (Table 2).

	Reaction time		
	Estimate	*Standard error*	*p*
Fixed Parts			
(Intercept)	6.910	0.040	<.001
Density	-0.150	0.047	.004*
Random Parts			
σ^2		0.031	
$\tau_{00,\ words}$		0.013	
$\tau_{00,\ ID}$		0.009	
N_{words}		26	
N_{ID}		20	
Observations		491	
R^2 / Ω_0^2		.096 / .472	

Table 2. The PND effect in word production (RT) in Russian adults

Interestingly, the PND effect in Russian word production in adults is the same as in Spanish adults: words with dense neighbourhood are extracted from memory to about 150 ms slower than words with sparse neighbourhood (Fig. 2) whereas in English dense neighbourhood facilitates word production.

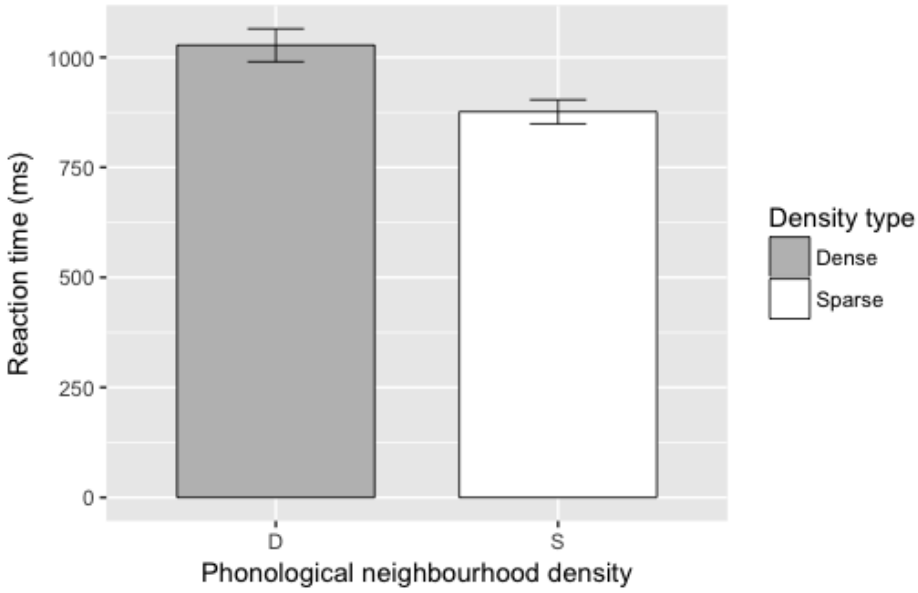

Figure 2. The PND effect in Russian adults

Discussion

The present study aimed to investigate the influence of PND on word production in Russian children and adults. In fact, this study is the first, assessing the PND effect in Russian word production in developmental prospective with using the same experimental materials for both children and adults.

The results of our experiments clearly showed that words with dense neighbourhood tended to be produced on average 210 ms slower than words with sparse neighbourhood by 4-6-year-old Russian children (there is no statistically significant difference between the two conditions). At the same time, the PND effect in Russian word production in adults is the following: words with dense neighbourhood are produced to about 150 ms slower than words with sparse neighbourhood (there is statistically significant difference between the two conditions). Thus, Russian children have tendency to develop the PND effect as have Russian adults.

The existing studies in English have demonstrated that dense phonological neighbourhood facilitates word production whereas data in Spanish showed the opposite effect: dense neighbourhood inhibits word production. This dissociation was explained in terms of morphological complexity of language (Vitevitch & Stammer, 2006). In languages with rich inflectional system dense neighbourhood inhibits word production because of additional competition in morphological and semantic levels. In our study, evidence from Russian supported this theory: Russian has a more complex morphological system than Spanish, and in Russian word production dense neighbourhood inhibits word production similarly to Spanish.

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