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Prevoicing and prenasalization in Russian initial plosives

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ABSTRACT

This study investigated the production of prevoiced initial plosives in Russian, including examining (i) how closure voicing varies depending on consonantal place, vocal context and speaker gender and (ii) whether Russian speakers rely on prenasalization to produce vocal fold vibration in initial closures, which is one of the mechanisms of reducing supraglottal pressure during oral occlusion. The study analyzed acoustic and airflow data from large samples of speakers and stimulus items, which made it possible to examine group-level patterns. Results for prevoicing duration revealed an effect of consonantal posteriority and adjacent vowel height. Shorter durations were seen in velars than bilabials or dentals and in tokens with high vowels (especially in male speech). Prevoiced tokens also showed higher levels of nasal flow than voiceless plosives during the initial part of closure. Nasal flow levels were lower in bilabials than dentals or velars and were not affected by vowel context. Speaker gender influenced voiceless tokens only. Towards the end of closure, voiced and voiceless tokens demonstrated comparable nasal flow levels. These results provide new insights into prevoicing in Russian and the link between prevoicing and prenasalization.

1. Introduction

The current study examined the production of voicing in initial voiced stops in Russian, a language with robust closure voicing (Ringen & Kulikov, 2012). On the basis of acoustic and airflow data, it investigated how voicing is affected by consonantal place of articulation, vocalic context and speaker gender and whether speakers of Russian maintain vocal fold vibration in initial voiced closures by means of prenasalization, which is a mechanism that enables continuous airflow through the larynx even in the presence of a complete oral occlusion (among others, Ohala & Riordan, 1979; Solé, 2018).

1.1. Prevoicing. General overview

The term 'prevoicing', also known as 'voicing lead' or 'negative Voice Onset Time (VOT)', refers to the presence of vocal fold vibration during the closure stage of plosives. Prevoicing contrasts with 'voicing lag' or 'positive VOT' when vocal fold vibration is absent prior to the release (Abramson & Whalen, 2017; Lisker & Abramson, 1964). Prevoiced closures occur in a variety of languages, including Dutch, Norwegian, French, Spanish, and Russian (Caramazza & Yeni-Komshian, 1974; Helgason & Ringen, 2008; Lisker & Abramson, 1964; Ringen & Kulikov, 2012; Ringen & van Dommelen, 2013; Solé, 2011, 2015, 2018; van Alphen & Smits, 2004). Although not as common as short voicing lag, prevoicing can also be seen in both British and American English (Davidson, 2016; Docherty, 1992; Lisker & Abramson, 1964) where it is especially common in hyperarticulated tokens (Schertz, 2013) and in the speech of African Americans (Ryalls, Zipprer, & Baldauff, 1997).

Robustness of prevoicing differs across languages. Previous studies report mean rates of prevoiced closures of around 37% for Norwegian (Ringen & van Dommelen, 2013), 42% for Canadian French (Caramazza & Yeni-Komshian, 1974), 75% for Dutch (van Alphen & Smits, 2004), 86% for Spanish (Solé, 2015, 2018), and 97% or above for Continental French (Solé, 2011, 2018) and Russian (Ringen & Kulikov, 2012). Average durations are often found to be between 70 ms and 115 ms (e.g., 75 ms for Norwegian in Ringen & van Dommelen, 2013; 104 ms to 113 ms for Dutch in van Alphen & Smits, 2004; 70 ms to 78 ms for Russian in Ringen & Kulikov, 2012). Individual tokens can show substantially longer durations (e.g., up to 235 ms in Spanish in Lisker & Abramson, 1964; up to 160 ms in Russian in Ringen & Kulikov, 2012).

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1.2. Aerodynamics of prevoicing. Factors affecting prevoicing duration

Production of prevoicing requires continuous flow of air through the larynx, which is achieved by keeping the subglottal pressure higher than supraglottal pressure. As air accumulates in the cavity above the larynx, subglottal and supraglottal pressures equalize and airflow ceases. Without expansion of the supraglottal cavity, closure voicing can be maintained for no more than 15 ms (Ohala, 1983; Ohala & Riordan, 1979). This dependence of voicing on vocal tract geometry is known as the 'aerodynamic voicing constraint (AVC)' (Ohala, 1983, 1997). The AVC explains why prevoicing duration is sensitive to factors such as consonantal place of articulation. Namely, posterior plosives are produced with a smaller volume of space behind the oral occlusion, which limits the surface area that can respond to the rising pressure (Ohala, 1983, 1997; Ohala & Riordan, 1979). As a result, longer prevoicing durations are usually observed in labials and dentals/alveolars than velars (e.g., Helgason & Ringen, 2008; van Alphen & Smits, 2004; for related positive VOT findings, see Cho & Ladefoged, 1999). For similar reasons, production of voicing may also be affected by vocalic context, since tongue movement in anticipation of the following vowel changes the size of the area involved in responding to rising air pressure (see Ohala & Riordan, 1979; Pape, Mooshammer, Hoole, & Fuchs, 2006). Higher vowels are also known to show greater vocal fold tension, which is another factor that can inhibit vocal fold vibration (see Koenig, Fuchs, & Lucero, 2011). At the same time, as most previous prevoicing studies only reported the data averaged across different vowel types (e.g., Helgason & Ringen, 2008; Ringen & Kulikov, 2012), the exact effect of vowel quality on negative VOT remains to be investigated.

Prevoicing can also be affected by speaker gender. Longer durations and/or higher rates of prevoiced closures have been reported for male speakers, presumably because it is easier to produce and maintain voicing for males due to larger vocal tracts (Helgason & Ringen, 2008; Ryalls et al., 1997; Swartz, 1992; van Alphen & Smits, 2004). However, the exact role of speaker gender is also not entirely clear. For example, Ringen and van Dommelen (2013) reported that prevoicing was longer and more frequent in female speakers in Norwegian, whereas Ringen & Kulikov (2012) did not find a significant effect of gender on VOT in Russian. Thus, robustness of negative VOT cannot always be predicted from purely physiological differences.

1.3. Overcoming the AVC. Prenasalization

The AVC poses a special problem for prevoicing languages where closure voicing can last well in excess of 100 ms in both anterior and posterior plosives. To facilitate production of prevoiced closures, speakers can use passive or active mechanisms that increase the area involved in responding to changing air pressure. Passive mechanisms entail reduced muscle activity, such as laxing of pharyngeal walls (the cheeks, the lips) or relaxing the levator veli palatini to allow passive lowering of the velum. Active mechanisms rely on increased muscular activity, such as lowering the mandible or the larynx, contracting the levator palati to elevate the velum, using the palatoglossus and palatopharyngeus muscles to actively lower the velum, and depressing or advancing the tongue (among others, Bell-Berti, 1975; Catford, 1977; Gandour & Maddieson, 1976; Müller & Brown, 1980; Ohala & Riordan, 1979; Perkell, 1969; Rothenberg, 1968; Svirsky et al., 1997; Warren, 1976; Westbury, 1983; Westbury & Keating, 1986). According to Ohala and Riordan (1979), passive enlargement (without involving the velum) can provide enough volume for approximately 60 to 70 ms of voicing, with slightly longer durations of around 80 ms expected for bilabials and shorter durations of around 50 ms anticipated for velars. A more conservative estimate for such expansion is given in Rothenberg (1968) who calculated a likely duration of vocal fold vibration of around 30 ms. Considering that voiced closures can be well in excess of 100 ms, speakers have to use either additional or different enlargement mechanisms. The focus of the current investigation is on expansion by means of nasal venting, which involves keeping the velum partially lowered during closure to allow escape of the air through the velopharyngeal port, such that prevoiced plosives are produced as prenasalized stops (among others, Solé, 2018).

The possibility of nasal flow for oral obstruents has long been noted in the literature (e.g., Rothenberg, 1968; Yanagihara & Hyde, 1966). However, earlier studies often argued that there are only two modes of muscular activity for the velum (raised versus lowered) and that any intermediate positions are unintended (e.g., Moll & Shriner, 1967). Presence of nasal airflow in oral sounds was therefore attributed to minor adjustments to the position of the velum during speech, which can lead to ejection of air from the nasal cavity while the velopharyngeal port is completely closed (Lubker & Moll, 1965; Thompson & Hixon, 1979).

In more recent years, research has largely focused on clinical aspects of nasal venting, such as comparing nasal flows in speakers with and without an orofacial cleft (e.g., Dalston, Warren, & Smith, 1990). Only a few recent articulatory or acoustic studies have examined the interaction between nasality and voicing in speakers without velopharyngeal impairments (e.g., Kong, Syrika, & Edwards, 2012; Kuehn & Moon, 1998; Solé, 2011, 2015, 2018; Solé & Sprouse, 2011). The articulatory findings in Kuehn and Moon (1998) showed that voiceless plosives were produced with a tighter velopharyngeal port closing than their voiced counterparts, which indicates that the velum can in fact be controlled with precision and that voicing interacts with velar position.

Articulatory and acoustic results in Solé (2011, 2015, 2018) and Solé & Sprouse (2011) demonstrated that the velopharyngeal closing was not complete during the production of 62% of Spanish, 54% of French and under 10% of English voiced plosives (labial and alveolar). In comparison, voiceless plosives did not show evidence of nasal venting during closure. There was also an effect of consonantal place of articulation for Spanish, with more prenasalization seen for alveolars than labials. For all 3 languages, if there was a prior exhalation, closure of the velopharyngeal port was delayed until after the onset of vocal fold vibration. Without prior nasal flow, there was a brief nasal burst concurrently with the start of prevoicing. In most tokens, nasal airflow ceased before the end of closure. This description matches the findings for prenasalized plosives in languages with phonemic prenasalization that are also produced with initial nasal flow, followed by complete closing of