Quantitative Account of Syntactically Conditioned Word-Initial Voicing In Maloe Karachkino Chuvash

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Background: Recent research has interrogated the diagnostic criteria for distinct levels of phonological structure [1, 2]. This study shifts the perspective by investigating how syntactic processing shapes phonological output. Through a quantitative analysis of variable word-initial voicing in the Maloe Karachkino dialect of Chuvash, we argue that the gradient application of this process directly reflects the online syntactic integration of words and the chunked lexical retrieval of high-frequency items. Thus, we propose that phonetic variation at word boundaries serves as a measurable cue to underlying speech production mechanisms.

In Chuvash, obstruents undergo voicing before a vowel when preceded by a vowel or a sonorant. With some exceptions this process is obligatory within words [3]. Crucially, voicing is also permitted under the same phonological conditions at word boundaries, yielding structures such as *petʲə-n børʧ-ë* (Petya-GEN house-P_3) 'Petya's house', where the corresponding standalone form of the second noun is *pørʧë*. By contrast, voicing never occurs in word-final position, as shown by *torat* / **torad iltʧë* (branch took) 'he took a branch'. In all documented instances, word-initial voicing is non-obligatory and exhibits high variation in natural speech.

Method: The study employs original audio data drawn from the Corpus of spoken Maloe Karachkino Chuvash [4]. The analysis was conducted using Praat [5] and the Parselmouth [6] package for Python. The manual annotation identified over 2,500 word boundaries that satisfied the phonological context described above. For each boundary, the following parameters were manually annotated in Praat: (1) syntactic relation between the words at the boundary (25 distinct categories such as "AMOD N" — "adjective + noun", including the "NC" for non-constituents); (2) the consonant at the boundary; (3) its perceived voicing; (4) a vowel or a sonorant preceding it. If present, a release burst visible on the spectrogram was marked on a corresponding point tier.

The same annotation protocol was applied to (1) consonants that undergo regular voicing within words, and (2) consonants that remain consistently voiceless in positions where the factors promiting voicing are inactive.

Subsequently, the annotated TextGrid files and their corresponding audio files were processed using a Python script leveraging the Parselmouth library. The script extracted the following acoustic measurements which have been identified in the literature as potential acoustic cues of voicing [7–12]: (1) duration of the consonant; (2) a list of pitch values (in Hertz) for the target consonant; (3) a list of intensity values (in decibels) for the target consonant; (4) formant frequency information (in Hertz) for the 0.05-second interval following the consonant.

The data for regularly voiced and voiceless consonants were used to train a logistic regression model. The trained model was then applied to the data for variable-voicing at word boundaries to quantify the probability of voicing. The results were used to calculate the likelihood of voicing within specific syntactic constructions.

To analyze data on syntactic contexts that are less frequent in the corpus, a supplementary experiment involving the reading of an artificially constructed text was conducted with four native Chuvash speakers.

Results: Voicing is inhibited in the absence of a syntactic dependency between words. Conversely, it is favored in contexts of tight syntactic cohesion: objects voice more than subjects, canonically placed dependents more than displaced ones, and complement clauses more than adverbial ones. A lexical

effect is also observed: closed-class lexemes like postpositions and numerals show a higher propensity to voice or trigger voicing.

Discussion: The results of this study establish a link between word processing in context and its phonetic realization. The gradient probability of voicing at word boundaries quantitatively reflects syntactic integration, while its prevalence with high-frequency phrases indicates their holistic storage and processing as chunks.

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