

Probing the Interaction of Dynamic Stability with Grammar: Evidence from Russian

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The goal of the current study is to investigate whether there is an interaction between speech motor stability induced by grammar and physiological stability patterns. We probe the possibility that in situations in which universal production constraints have been argued to emerge (reorganizations observed in forced rate-scaling tasks), the details of reorganization vary in a language-specific fashion, depending on phonotactic properties of the given language. This work aims to provide new insights into the relationship between physiological preferences in speech production and linguistic diversity: while the physiological foundations of spoken language may influence sound systems in the world's languages, we investigate how the powerful mechanism of learning allows languages to overcome these physiological givens in a non-deterministic fashion.

In the speech sciences forced-rate repetition has often been used to probe physiologically universal stability patterns in speech production (Goldstein et al 2007; Rochet-Capellan & Schwartz, 2007; Stetson, 1951). The premise has been that when overlearned, highly skilled behavior can no longer be maintained, the system will invariably converge onto basic, universally available stability patterns. Crucially, the patterns that have been observed to emerge in these situations can be related to linguistic structure. For instance, fast continuous repetition of a VC syllable leads to a spontaneous reorganization to CV, a universally preferred organizational pattern in the languages of the world (Stetson 1951). The (implicit) assumption in this work has been that under the same conditions, all speakers will converge onto these physiologically rooted stability patterns which exist outside and independently of grammar (Goldstein et al. 2006; MacNeilage & Davis 2000). Yet limitedly available cross-linguistic work suggests that the situation is more complex: there is some evidence that a language's prosodic organizational structure is at least partially maintained even in rate-scaling tasks designed to destabilize learned, language-specific patterns (Vatikiotis-Bateson & Kelso, 1993). There is, however, a dearth of cross-linguistic work that would allow us to better understand the interaction between presumably intrinsically stable, 'physiologically given' patterns and the learned patterns, specific to a given language. Such knowledge is, however, indispensable to better understand how languages may negotiate the tension between performance constraints and linguistic diversity.

We tackle this question using Russian, a language that features large range of phonotactically permissible consonant clusters. We build on previous research which reported for English speakers that an alternating consonant pattern (continuous repetitions of *cop top*) will, under rate pressure, reorganize to the simultaneous production of both constrictions in the same prosodic position (i.e., /t, k/ constrictions are produced on top of each other in every word onset position; Goldstein et al. (2007)). We will term this simultaneous production of two constrictions an intrusion cluster. The authors argued that a basically stable pattern, rhythmic synchrony, ubiquitous in natural systems, emerges in situations of breakdown and error. Neither /tk/ nor /kt/ are legal word onset clusters in English, so their emergence must reflect an extra-linguistic stability attractor. We exploit the phonotactic potential of Russian in order to probe the possibility that the stabilizing force of grammar may lead to a different result in cases in which a lexically stabilized pattern exists.

Using articulography (EMA) which allows us to track articulatory motion over time we recorded 10 native speakers of Russian. We elicited prosodically grouped two-syllable C₁aC C₂aC repetitions at a forced metronome rate, for instance *bag nag*. Two conditions were contrasted: consonant combinations triggering intrusion clusters with a corresponding lexical cluster in Russian in either order ('lexical condition', combinations: /b-l/, /t-k/, /g-l/, /d-v/), vs. those without a lexical correspondence cluster ('nonlexical condition', combinations: /b-n/, /k-m/, /d-b/, /g-b/). For instance, *tap cap* alternations may lead to intrusion cluster /tk/ or /kt/, both phonotactically legal word-initial clusters in Russian. In contrast *bag nag* alternations may trigger the intrusion cluster /bn-/ or /nb-, neither has a lexical correspondence in Russian (Figure 1). Presentation order (*bag nag* vs. *nag bag*) was balanced across trials, each order being presented twice during the experiment. We also collected

in the same experimental session lexical C₁C₂V cluster productions in a regular sentence reading task. The goal of our analysis was to determine whether the frequency of intrusions varied as a function of the existence of a lexical correspondence cluster, and whether the timing pattern of the intrusion clusters reflected the timing differences among corresponding lexical clusters. Intrusion clusters were identified to occur if a peak-picking algorithm identified two constrictions within the same prosodic position. The order of the intrusion cluster was determined on the basis of the temporal order of the peak constrictions (Figure 1). Peak lag was calculated as the absolute time lag between the two constrictions, normalized to metronome speed.

Globally the results replicate those of Goldstein et al. (2007) for Russian in that the task triggered intrusion clusters. 8.4% of tokens had two constrictions in the same prosodic position (N=1562). Lexicality had no significant influence on the frequency of occurrence of intrusion clusters (lexical condition: 801, nonlexical condition: 761 intrusion clusters). Neither had lexicality a significant influence on the timing of the peak lags overall. This seems to confirm the hypothesis that in these types of tasks, an extra-linguistically stable attractor comes to dominate the production patterns. A further analysis investigated whether there was a preference for sonorant-obstruent (SO) or obstruent-sonorant (OS) clusters to emerge and whether there was a difference in timing reflecting differences between lexical clusters. First, there were about twice as many OS intrusion clusters (n=454) compared to SO (n=207) clusters. This agrees with the frequency of occurrence of the lexical clusters in Russian with OS being more frequent than SO clusters. Also for timing of the intrusion clusters we found a significant effect for Order (SO vs. OS), plus a significant interaction with Lexicality. While for both lexicality conditions OS clusters had greater peak lags compared to SO clusters, the interaction identified this difference to be significantly more pronounced in the lexical condition. Importantly, this relative difference in OS vs. SO timing for intrusion clusters corresponds to the relative difference found in the corresponding lexical clusters produced by the same speakers. In sum, basic timing asymmetries (SO vs. OS) emerged independently of the lexicality condition, yet the existence of a lexical correspondence cluster significantly enhanced this basic asymmetry. We conjecture that the basic OS-SO timing asymmetry may be rooted in the jaw cycle, which is to be confirmed by further analyses. We interpret our results as showing how grammars may capitalize on physiologically 'given' patterns (SO vs. OS timing), yet at the same time, learned patterns may prevail in situations in which universal stability patterns have been suggested to emerge uniformly.

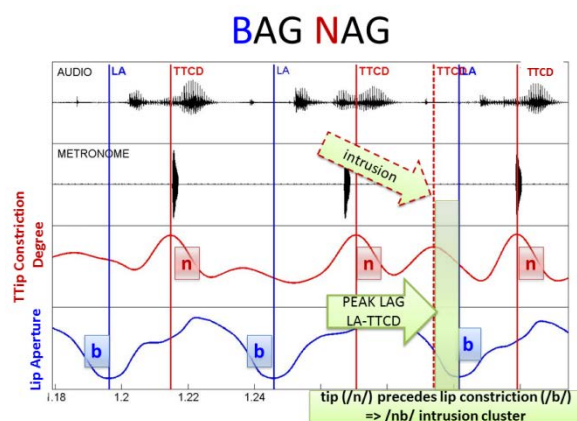


Figure 1. Illustration of a /nb/ intrusion cluster emerging in /bag nag/ alternations. The panels show from top to bottom: Audio recording, metronome beat, tongue tip constriction degree (TTC), lip aperture (LA). Vertical lines are algorithmically identified constriction peaks. Peak lag was calculated as the temporal difference between two constrictions occurring in the same prosodic position.

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