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PERCEPTION OF NATIVE CONSONANT CLUSTERS WITH NON-NATIVE PHONETIC PATTERNS

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ABSTRACT

This study examines the role of native phonetic patterns in perception of word-initial consonant clusters. Specifically, we ask how phonotactically native CC clusters produced with atypical inter-consonant timing patterns are perceived by native speakers of Georgian and French. Georgian permits more varied onset clusters than French, produced with a longer inter-consonant lag than in French. A Georgian native speaker and a French native speaker produced CCV and CVCV stimuli with their own native phonetic patterns. Listeners heard the stimuli in CCV-CVCV pairs, and determined whether the two sequences were the same or different. The results show that French listeners confused Georgian CCV with Georgian CVCV even when the clusters are legal in French. Furthermore, some Georgian listeners confused French CCV with French CVCV. These results suggest perception of foreign consonant clusters is guided not only by native phonotactics, but also by preferred inter-consonant timing patterns of the listeners' native language.

Keywords: onset CC cluster, non-native perception, inter-consonantal timing lag, transitional vowel

1. INTRODUCTION

The perception of non-native consonant clusters has been investigated extensively with a primary focus on the role of native phonotactics. Phonotactically illicit clusters are perceptually assimilated to their licit counterparts, making the discrimination between the two very difficult (e.g., [5, 7]). However, recent findings suggest that such perceptual assimilations are not exclusively driven by the listeners' phonological knowledge. Rather, listeners' behaviors seem to be influenced by the phonetic properties of the stimuli as well as by the preferred phonetic settings of the listeners' native language (e.g., [5, 8, 9]). This study aims to investigate the role of phonetic patterns of both the stimuli and the listeners' native language in consonant cluster perception. Focusing on onset CC clusters of Georgian and French, and a well-documented perceptual "repair" strategy involving "illusory vowels", we examine how the perception of onset CC clusters can change due to phonetic as well as prosodic differences between the languages of the stimuli and the listeners. Specifically, we ask whether native listeners of French and Georgian can distinguish $C_1C_2V_2$ sequences, including CC clusters with atypical phonetic patterns, from their $C_1V_1C_2V_2$ counterparts.

The following dissimilarities between French and Georgian are expected to influence how listeners of one language will behave when confronted with the consonant clusters produced by a speaker of the other language. First, in terms of phonotactics, Georgian permits more varied onset CC clusters than French. Second, the two languages differ in their articulatory timing between the consonants of a cluster: Georgian has a longer inter-consonant timing lag than French [2, 10]. This longer lag often results in a transitional vowel (a vocalic transition between the two consonants of a cluster) in Georgian native speakers' production [3]. Third, Georgian and French differ in their prominence pattern: For disyllabic words, Georgian shows initial prominence ('CVCV) whereas French typically has final prominence (CV'CV) [4].

For French listeners, not all Georgian onset CC clusters are licit in their native language. If the listeners' native phonotactics affect their perception of non-native clusters as in [7], French listeners are predicted to have difficulty discriminating Georgian CCV and 'CVCV only when the CC is not licit in French. The perceptual "repair" is not expected when CC is licit in both languages, even if it has atypical timing patterns. On the other hand, if phonetic implementation of consonant clusters can influence the perceptual patterns, French listeners can possibly assimilate Georgian CCV sequences to French CV'CV. This is because Georgian CC clusters typically have a long inter-consonant lag often accompanied by a transitional vowel, and V_1 in French $C_1V_1'C_2V_2$ does not bear prominence. In this case, French listeners will have difficulty discriminating Georgian CCV and 'CVCV sequences, as both will be assimilated to French CV'CV, regardless of the nativeness of the CC clusters.

For Georgian listeners, onset clusters produced by a native French speaker are phonotactically licit but phonetically atypical. Also, the unstressed V_1 in French disyllabic $C_1V_1'C_2V_2$ can be more similar to the transitional vowel in Georgian CCV than to the V_1 in Georgian $'C_1V_1C_2V_2$ in terms of its duration and

vowel quality. French /ø/, when unstressed, can be qualitatively similar to the Georgian transitional vowel. Thus, we predict Georgian listeners will have difficulty discriminating French CCV and Cø'CV sequences, as both will be assimilated to Georgian CCV.

2. METHODS

2.1. Participants

Participants were 43 native speakers of French and 34 native speakers of Georgian. French participants were recruited and tested at Université Paris Diderot, France, and Georgian participants at Tbilisi State University, Georgia.

The participants were not monolingual speakers. Most of the Georgian participants reported speaking Russian and/or English as their second languages. The French participants had studied English in school. Nonetheless, we tried to control for the language experience of the participants by excluding French participants who knew any cluster-heavy languages (e.g., Slavic languages, Moroccan Arabic) and Georgian participants who knew languages with front rounded vowels (e.g., French, German, Azerbaijani).

2.2. Stimuli

2.2.1. French

The French stimuli consisted of $C_1V_1C_2V_2$ pseudo-words, which had 8 different C_1C_2 combinations (/bl/, /gl/, /pl/, /kl/, /sk/, /sp/, /ps/, and /pt/), and 4 different V_1 conditions (/a/, /u/, /ø/, and 'no vowel'). V_2 was fixed to /a/. This yielded four items per each C_1C_2 combination (e.g., /pata/, /puta/, /pøta/, and /pta/). All these sequences are attested in French, although /pta/ and /psa/ are considered 'rare' in their occurrence [6].

A female native speaker of French recorded the French stimuli in carrier sentences. Each of the 32 items (8 C_1C_2 combinations * 4 V_1) was repeated 4 times. Two tokens with similar V_2 durations were selected for each word, and then used to make stimulus pairs. The selected tokens were cut from the carrier sentences from the point when C_1 was free from the coarticulatory information of the previous vowel to the F2 offset of the V_2 /a/.

Four types of "same" pairs were composed by concatenating two tokens per word (e.g., /pata/$_1$-/pata/$_2$, /puta/$_1$-/puta/$_2$, /pøta/$_1$-/pøta/$_2$, and /pta/$_1$-/pta/$_2$). The "same" words in each pair were not acoustically identical, but phonologically (or lexically) equivalent to the speaker who produced the stimuli. The "different" pairs included CCV sequences paired with CVCVs (e.g., /pta/-/pata/, /pta/-/puta/, and /pta/-/pøta/), and two CVCV sequences with different V1 (e.g., /pøta/-/pata/, /pøta/-/puta/). The "words" in each pair were separated by a 500 ms inter stimulus interval. The ratio between same and different pairs were 4:5.

Table 1 shows the V_1 duration of the French stimuli, separating the C_1C_2 combinations into obstruent-obstruent (OBS-OBS) and obstruent-liquid (OBS-LIQ). None of the French 'no vowel' tokens were produced with a transitional vowel. We labelled as the transitional vowel any vocalic element between C_1 and C_2 with periodicity, voicing, and a clear discontinuity in spectrogram (when C_2 is /l/).

Table 1: V_1 durations (ms.) in French stimuli.

C_1C_2	V_1: a	V_1: ø	V_1: u
OBS-OBS	65.7	55.3	55.6
OBS-LIQ	73.8	67.0	56.6

2.2.2. Georgian

Georgian stimuli had the nearly identical structure to the French stimuli except for the following differences. First, 25 C_1C_2 combinations, that are phonotactically legal in Georgian, were included. This includes: OBS-OBS and OBS-LIQ licit in French (/pt/, /ps/, /sk/, /sp/, /pl/, /kl/, /bl/, /gl/), OBS-OBS illicit in French (/bd/, /bg/, /dg/, /gb/, /gd/, /tb/, /bz/, /gz/, /ks/, /zg/), obstruent-nasal (OBS-NAS: /bn/, /gm/, /gn/), nasal-obstruent (NAS-OBS: /mg/, /nb/, /ng/), and liquid-obstruent (LIQ-OBS: /lb/). Second, V_1 has only three conditions (/a/, /u/, and 'no vowel'), as Georgian lacks /ø/ in its inventory.

A total of 75 pseudo-words were produced 4 times by a female native speaker of Georgian. The recorded tokens were processed in the same way as the French tokens to make the stimulus pairs. Georgian stimulus pairs included three types of "same" pairs (e.g., /bada/$_1$-/bada/$_2$, /buda/$_1$-/buda/$_2$, and /bda/$_1$-/bda/$_2$), and two types of "different" pairs (e.g., /bda/-/bada/, and /bda/-/buda/). The ratio between same pairs and different pairs were 3:4. The V_1 durations of the Georgian stimuli are summarized in Table 2.

Table 2: V_1 durations (ms.) in Georgian stimuli. F denotes C_1C_2 combinations licit in both languages and G denotes those licit only in Georgian.

C_1C_2	V_1: a	V_1: u	no V_1
OBS-OBS (F)	88.9	58.2	43.0
OBS-LIQ (F)	124.5	126.6	59.7
OBS-OBS (G)	124.7	98.9	68.7
OBS-NAS (G)	134.4	110.7	81.7
NAS-OBS (G)	120.3	94.5	79.3
LIQ-OBS (G)	114.3	106.6	83.7

2.3. Procedure and task

The experiment consisted of a same-different discrimination task, using an AX paradigm. On each trial, the participants heard a pair of "words" over headphones, and were asked to determine whether they heard two different words or two repetitions of one word. The participants were told that the stimuli may include a foreign language, but we did not tell them which language it might be.

All stimulus presentation was implemented using PsychoPy2 on a Macintosh laptop computer, with a response pad and headphones. Each participant heard one repetition of the native pairs and two repetitions of non-native pairs throughout the experiment. This yielded a total of 494 pairs for French participants (144 French + 175 Georgian * 2), 463 pairs for Georgian participants (144 French * 2 + 175 Georgian). Stimulus pairs were presented in a randomized order in three blocks separated by self-paced breaks. Each block contained one repetition of stimuli (either French or Georgian). The order of native and non-native blocks was counter-balanced.

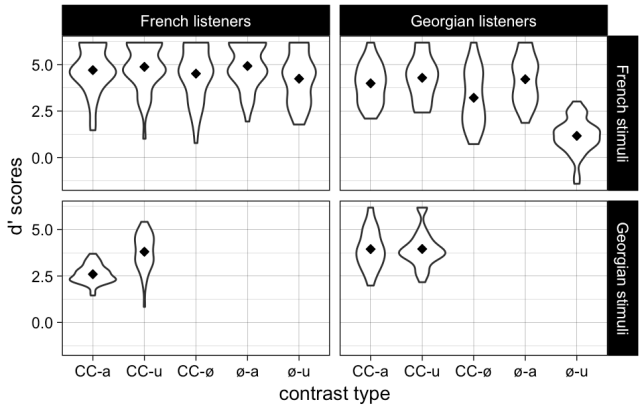
Each new pair was played one second after the participant hit the button for the previous item. Participants were first given 8 practice trials with feedback to familiarize themselves with the task and stimulus. No feedback was provided during the main experiment. After the experiment, participants completed a self-report language background form. All written instructions, survey and consent forms were provided in the participants' native language.

3. RESULTS

3.1. Overall results

D-prime scores (*d′*), a measure of sensitivity, were calculated for each tested contrast and each participant. The overall *d′* data are plotted in Fig. 1.

Figure 1: *d′* scores for each contrast type for French and Georgian stimuli by French and Georgian listeners. Black diamonds represent the mean.



The *d′* scores of the participants were analysed using a repeated-measures ANOVA. The within-subjects independent variables were CONTRAST TYPE (CCV-CaCV, CCV-CuCV, CCV-CøCV, CøCV-CaCV, CøCV-CuCV), and STIMULUS LANGUAGE (French, Georgian). LISTENER GROUP (French, Georgian) was included as a between-subjects independent variable. This ANOVA revealed a significant three-way interaction among CONTRAST TYPE, STIMULUS LANGUAGE, and LISTENER GROUP [$F(1,74) = 19.15$, $p < 0.001$]. To further investigate the interaction (see Fig. 1), separate ANOVAs were conducted for each listener group.

3.2. Georgian listeners

The *d′* scores of the Georgian listeners were analysed in a repeated-measure ANOVA with CONTRAST TYPE, and STIMULUS LANGUAGE as independent variables. The results revealed that the interaction was not significant [$F(1,32) = 1.37$, $p = 0.251$] although the main effects were significant for STIMULUS LANGUAGE [$F(1,32) = 8.38$, $p = 0.007$] and for CONTRAST TYPE [$F(4,128) = 84.86$, $p < 0.001$].

Tukey HSD post-hoc tests revealed the following patterns of *d′* results for contrast type: CCV-CaCV = CCV-CuCV = CøCV-CaCV > CCV-CøCV > CøCV-CuCV ('>' indicates significantly greater *d′* at $p < 0.05$). See the upper-right panel of Fig. 1. For stimulus language, Georgian listeners had higher *d′* for Georgian stimuli than for French stimuli.

3.3. French listeners

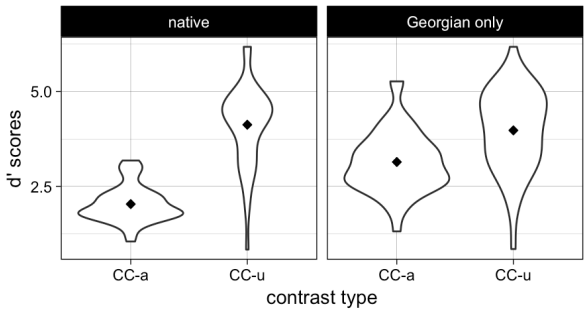
Unlike Georgian listeners, the analysis of French listeners' *d′* scores revealed a significant two-way interaction between STIMULUS LANGUAGE and CONTRAST TYPE [$F(1,42) = 30.97$, $p < 0.001$]. Tukey HSD post-hoc tests revealed the following patterns of *d′* results: all French pairs > Georgian CCV-CuCV > Georgian CCV-CaCV. See left panels in Fig. 1.

To further investigate the role of French phonotactics in French listeners' sensitivity to Georgian CCV-CVCV pairs, another ANOVA was conducted on French listeners' *d′* scores on Georgian stimuli. This time, NATIVENESS of the clusters (native, foreign (Georgian-only)) was included as a within-subjects independent variable. This variable differed from STIMULUS LANGUAGE, as it considered clusters produced by the Georgian speaker "native" as long as the segmental composition is licit in French.

The results of this ANOVA revealed a significant interaction between NATIVENESS and CONTRAST TYPE [$F(1,42) = 89.84$, $p < 0.001$]. Tukey HSD post-hoc tests revealed the following patterns of *d′* results: (1) French listeners' *d′* was higher for CCV-CuCV than for CCV-CaCV for both native and foreign

clusters. (2) For CCV-CuCV, native = foreign. (3) For CCV-CaCV, foreign > native. See Fig. 2.

Figure 2: *d'* scores for Georgian stimuli by French listeners for native (phonotactically licit in French) and foreign (Georgian-only) clusters.



This outcome indicates that French listeners' discrimination of Georgian CCV-'CaCV was less accurate when the CC clusters were licit in their native language than when the clusters were illicit. To understand the source of this low sensitivity to Georgian CCV-CaCV, we further examined the French listeners' accuracy for each manner-based category of C_1C_2 combinations (Table 3). It turned out that the French listeners' accuracy was the lowest for the OBS-LIQ, followed by the OBS-NAS, presumably due to the phonetic properties of the stimuli. Notably, the accuracy for the OBS-OBS did not differ whether the clusters are phonotactically licit or not.

Table 3: French listeners' accuracy (% correct on "different" trials) for Georgian stimuli. (F: C_1C_2 licit in French/Georgian; G: licit only in Georgian)

C_1C_2	CC-CaC	CC-CuC
OBS-OBS (F)	85.0	96.1
OBS-LIQ (F)	49.0	95.9
OBS-OBS (G)	85.5	94.8
OBS-NAS (G)	69.5	96.7
NAS-OBS (G)	76.3	81.9
LIQ-OBS (G)	90.6	91.9

4. DISCUSSION

This study examined how native speakers of Georgian and French perceive word-initial CC clusters with phonetic patterns that are atypical in their respective native languages in discrimination tests contrasting CCVs with CVCVs.

The Georgian results demonstrate that Georgian listeners had difficulty with non-native /ø/. French Cø'CV was the most confusable with French Cu'CV, which can be straightforwardly explained by the Perceptual Assimilation Model [1]. French /ø/ was perceptually assimilated to Georgian /u/, the closest native category. Both French Cø'CV and Cu'CV were assimilated to Georgian 'CuCV, resulting in low discrimination accuracy for Cø'CV-Cu'CV.

However, Georgian listeners' discrimination accuracy of French CCV-Cø'CV pairs was not as good as those of CCV-Ca'CV, CCV-Cu'CV, and Cø'CV-Ca'CV pairs. Since French CCV tokens never included a transitional vowel between the two consonants, this suggests that Georgian listeners, at least sometimes, assimilated French Cø'CV to Georgian CCV instead of 'CVCV. In this case, the Georgian target for perceptual assimilation of French /ø/ in /C_1ø'C_2a/ could arguably be (1) a part of C_1 in /C_1C_2a/ (presumably a long release of C_1, which could take the form of a transitional vowel) or (2) the long inter-consonantal timing lag between C_1 and C_2, which could be acoustically equivalent to 'C_1 release,' or 'longer C_1 release + C_2 closure silence' if C_2 is a stop. The current result cannot discriminate these two possibilities. Nonetheless, it clearly indicates that the preferred phonetic patterns in Georgian contributed to Georgian listeners' perception of French Cø'CV sequences.

On the other hand, the French results show that French listeners confused Georgian C_1C_2V and 'C_1aC_2V even when the C_1C_2 clusters were licit in their native phonotactics, especially when C_2 is /l/. This is against the prediction of phonotactics. For instance, /pla/ is licit in French, and there is no reason for French listeners to confuse it with /pala/ if their perception is guided exclusively by native phonotactics. The current outcome corroborates previous findings [5], suggesting different manner combinations can lead to different perceptual repairs.

French listeners' poor discrimination of Georgian CCV-'CaCV is presumably due to the phonetic pattern of the Georgian CCV stimuli. Due to its longer C_1-C_2 lag and frequent transitional vowels, Georgian CCV sequences, even when the CC cluster is attested in French, are a closer match to French Ca'CV than to French CCV.

In sum, the current results suggest the perceptual repair does not solely depend on the segmental composition of the non-native clusters. Even when onset CC clusters are attested in the listeners' native language, the mismatch in the phonetic patterns of the stimuli language and the listeners' native language can lead to confusion between CCV and CVCV.

5. ACKNOWLEDGMENTS

This work is supported by an ANR-DFG grant for the project *Paths to Phonological Complexity: Onset clusters in speech production, perception and disorders*. We thank Ramaz Kurdadze, Natia Botkoveli, Maka Tetradze and Ivane Lezhava at Tbilisi State University for their help with collecting Georgian data.

6. REFERENCES

[1] Best, C. T. 1995. A direct realist perspective on cross-language speech perception. In: Strange, W., Jenkins, J. (eds), *Speech Perception and Linguistic Experience: Issues in Cross-Language Research*. 171-204.

[2] Chitoran, I., Goldstein, L., Byrd, D. 2002. Gestural overlap and recoverability: Articulatory evidence from Georgian. *Laboratory Phonology* 7, 419-447.

[3] Chitoran, I., Kwon, H. 2016. Timing lag matters in the perception of Georgian stop sequences by native speakers. Talk presented at *LabPhon15*.

[4] Chitoran, I., Tiede, M. 2013. Gestural reorganization under rate pressure interacts with learned language-specific phonotactics. *POMA* 19*,* 060199.

[5] Davidson, L., Shaw, J. A. 2012. Sources of illusion in consonant cluster perception. *J. Phon.* 40, 234-248.

[6] Dell, F. 1995. Consonant clusters and phonological syllables in French. *Lingua* 95, 5–26.

[7] Dupoux, E., Kakehi, K., Hirose, Y., Pallier, C., Mehler, J. 1999. Epenthetic vowels in Japanese: A perceptual illusion? *J. Exp. Psychol. Hum. Percept. Perform.* 25, 1568-1578.

[8] Dupoux, E., Parlato, E., Frota, S., Hirose, Y., Peperkamp, S. 2011. Where do illusory vowels come from? *J. Mem. Lang.* 64, 199-210.

[9] Hallé, P. A., Best, C. T. 2007. Dental-to-velar perceptual assimilation: A cross-linguistic study of the perception of dental stop+/l/ clusters. *J. Acoust. Soc. Am*. 121, 2899-2914.

[10] Hoole, P., Bombien, L., Kühnert, B., Mooshammer, C. 2009. Intrinsic and prosodic effects on articulatory coordination in initial consonant clusters. In: Fant, G., Fujisaki, H., Shen, J. (eds), *Frontiers in Phonetics and Speech Science*. Commercial Press, Beijing, 275-286.