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Serbian affricates contrasts in foreign language perception investigated by means of a neurophysiological experiment

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ABSTRACT

This study addresses the question to which extent phonetic contrasts of a foreign language are perceived more easily by speakers of a native language that shares similar phonetic categories. The focus lies on two post-alveolar and two palatal affricates of Serbian: [tʃ] (post-alveolar, voiceless), [ʨ] (alveolo-palatal, voiceless), [ʤ] (post-alveolar, voiced) and [ʥ] (alveolo-palatal, voiced). Swiss-German dialects have the post-alveolar voiceless affricate [tʃ] only, while the Rhaeto-Romance variety of Sursilvan has three different affricates, e.g. [tʃ], [ʨ] and [ʥ].

In an EEG experiment using a MMN paradigm, 15 Swiss-German and 15 Rhaeto-Romance speakers between 20-30 years were instructed to focus on reading a random text while not paying attention to the auditory stimuli. The hypothesis was a significant difference in processing between the two groups: Swiss-Germans would not be able to reliably distinguish the four Serbian affricates. Rhaeto-Romance speakers, on the other hand, are expected to be able to distinguish all four affricates.

MMN curves revealed that both groups were able to perceive all phonetic contrasts. Swiss German speakers showed significantly higher amplitude peaks for four out of the twelve affricate contrasts. A significant group-effect was found to corroborate that Rhaeto-Romance speakers process the Serbian affricates differently than Swiss-German speakers do.

Keywords: Phonetic Contrasts, Serbian Affricates, Swiss-German, Rhaeto-Romance, MMN

1. INTRODUCTION

There is a diversified discussion on how and when we best learn a foreign language (L2). Some advocate that foreign-language learning is no longer possible without any accent after a 'Critical Period' (e.g., Lenneberg 1967; Kuhl 2004). Others plead in favor of a continuous mode of foreign-language learning which does not differ significantly between children and adults (e.g. Friederici 2005). This would conform to the assumption that language competence in the L2 affects processing patterns more significantly than age of acquisition (e.g. Winkler et al. 1999). Various models interpret the influence of the L1 on foreign language learning differently: the NLNC (Native Language Neural Commitment) and NLM (Native Language Magnet) (Kuhl 2004) propose that neural networks that are dedicated to the L1 are less sensitive towards non-native speech sounds the more established they become. According to the SLM (Speech Learning Model) (Flege 1993), new but not similar sound contrasts of the L2 are perceivable by the language learner. According to this hypothesis, only dissimilar phonetic contrasts would elicit a MMN and higher use of the L1 would influence the successful acquisition of L2 phonetic categories negatively. The PAM (Perceptual Assimilation Model) (Best et al. 2001), on the other hand, predicts that (similar) L2-sounds can be assimilated to the listener's L1 phonetic category and would elicit a MMN. As opposed to the SLM, NLNC and NLM, PAM views a well established L1 to be supportive for L2 learning.

Mismatch negativity paradigms have shown that fluent non-native speakers develop a cortical auditory memory for foreign language phonemes (Näätänen et al. 1997; Winkler et al. 1999). Even in a well-learned second language, however, phoneme representations of the native language were found to exert a strong influence on contrast detection (Nenonen et al. 2005). Consequently, different mother tongues (L1s) could out-fit one differently to learn a certain foreign language. The relevant question for our study is whether phonetic information that seems irrelevant to the acquired L1-specific representations is neglected or filtered out once L1-networks have been established, or whether listeners are still able to differentiate phonetic contrasts of a foreign language as the auditory cortex should not be considered an indispensible part of the language network.

MMN experiments have been conducted on various syllable types (compare Näätänen et al. 1997; Lipski 2006), but the considerable variety of affricate categories across the languages of the world (Ladefoged and Maddieson 1996; Gordon et al. 2002) calls for advanced research on this specific topic. Let us therefore briefly illustrate the affricate subsystems of the three languages involved in the present study: Serbian, Rhaeto-Romance and Swiss-German. Serbian differentiates four categories that are used in our experiment, namely [ʧ] (postalveolar, voiceless), [ʨ] (alveolo-palatal, voiceless), [ʤ] (postalveolar, voiced), and [ʥ] (alveolo-palatal, voiced); the fifth affricate [ts] (alveolar, voiceless) is not part of the experiment. For Rhaeto-Romance, we chose the most spoken dialect Sursilvan. It shares three of the four affricates with Serbian, namely [ʧ], [ʨ] and [ʥ] (Haiman and Beninca 1992). Sursilvan [ʧ] seems to share the typical lip rounding of Serbian (Morén 2006), but it lacks the voiced postalveolar affricate [ʤ] that exists in Serbian. For Swiss-German, we referred to the Zurich dialect, which contains four voiceless affricates, namely labial [pf], alveolar [ts], postalveolar [ʧ], and velar (sometimes uvular) [kx] (Fleischer and Schmid 2006). Thus, out of the manner of articulation we are interested in, Swiss-German only has [ʧ]. Considering that the four affricates in our study differ in voicing and place of articulation, it must be pointed out that Swiss-German speakers do not differentiate contrasts of the affricate category in either dimension.

2. METHODS

2.1. Subjects

Fifteen Swiss-German and fifteen Rhaeto-Romance speaking subjects participated. All subjects reported undisturbed speech and hearing capacities were right-handed and on average 23 years old. None of the participants had prior knowledge of any Slavic language nor were they professional musicians. Rhaeto-Romance speakers were generally bilingual; on average they learnt Swiss-German at the age of seven years – speaking it either regularly in school or with one of their parents. As the second language in the bilingual cases did not include an extra category of the phoneme category under investigation, the possible advantage is not relevant for the present investigation. Participants were asked to fill in a questionnaire to file their details and their language background. Influence of second language knowledge has been found on word recognition as well as on phoneme distinction abilities (compare Ventura et al. 2007; Pattamadilok et al. 2007).

2.2. Stimuli

The four Serbian syllables [ʨa], [ʥa], [ʤa], and [ʧa] served as experimental stimuli. Naturally spoken stimuli were chosen because it has been shown that natural material is processed more robustly than synthetic stimuli which are less immune against manipulations (Lacerda 2001). The speaker had to be a female due to more consistent inter-speaker variation (Titova and Näätänen 2001). For the recording we asked her to produce the phrases as naturally as possible to avoid over articulation. The recording was done twice. The usage of CV (consonant-vowel) syllables was motivated by the fact that isolated affricates, especially voiceless ones, resemble non-speech noise. Because the vowel [a] is universally unmarked, we decided to apply this vowel. In contrast to [u] and [o], [a] does not lead to anticipatory lip rounding during the production of the affricate and there is no co-articulatory influence of a palatal glide for [a].

All stimuli were digitally recorded in an anechoic chamber. A sampling rate of 44100 Hz and 16 bit quantization was used. Our native speaker of Serbian read the four syllables aloud in twelve variations each: three times each in a CV sequence, in a VCV sequence and in an existing Serbian word (*ćaskati* "to chat", *čarapa* "sock", *đavol* "devil", *džaba* "frog"). The syllables were pronounced inside a carrier phrase

(*Prvo ća, drugo ća, treće ća* - “first ća, second ća, third ća”). Acoustic analysis included manual measurement of duration, closure, release phase and duration of the syllables in all alternations on the basis of an inspection of wave forms and spectrograms provided by *Praat* (Boersma and Weenink 2009). The ‘Centre of Gravity’ (CoG) was calculated using the apposite function in *Praat.* The CoG represents the power-spectrum from the release burst to the voicing onset of the following vowel (compare Forrest et al. 1988; Gordon et al. 2002). Voicing clearly affected duration and spectral characteristics: the two voiceless affricates are longer and have higher values for the CoG than the voiced ones. Regarding the place of articulation, it results that the two alveolo-palatal affricates display a higher CoG, relatively shorter closure phase and a longer release phase than the two postalveolar affricates.

The four stimuli used in the experiment were selected according to the following criteria: Duration for affricate and vowel about 150 ms, even, constant fundamental frequency (F0) trend. Editing included stylizing the pitch using *Praat* 5045 (Boersma and Weenink 2009) and setting the overall intensity to 70 dB. Normalization was done using *Audition*[1]. This did not change the intensity relation between affricates and vowels in the individual syllables. A Butterworth filter was applied as low-pass filter (5000 Hz) to cut background- and click-sounds using *Audition.* At the onset and at the end of the syllables a smooth rising/falling ramp with duration of 10 ms was added (Gaussian filter). F0 was set to a constant value throughout the vowel with respect to initial F0 value. Duration was normalized by clipping the affricate onset and vowel offset so that each syllable had duration of between 120-185 ms. Finally, the vowel of the syllable [ʧa] was stabilized at a length of 92 ms and was used for all four syllables. The last step was done in full awareness of the loss of information that is provided by the specific transition of the affricate to the following vowel (compare Recasens and Espinosa 2007). After the final editing, three Serbian and three Rhaeto-Romance speakers were asked to judge the syllables for their ‘naturalness’ and their discriminability (e.g. Nenonen et al. 2005). Serbian speakers could reliably ascribe each syllable. Rhaeto-Romance speakers encountered increased difficulties, yet they clearly made out “three or more” different syllables.

2.3. Procedure

During the EEG experiment, subjects were seated in an electrically shielded and acoustically attenuated chamber. The data were recorded using a Biosemi active-two amplifier system. 64 active electrodes were installed according to the 10/20 electrode system (Jaspers 1958). The sampling rate was 512Hz. Impedance was kept below 40kΩ.[2] For off-line re-referencing, an electrode was attached to the tip of the nose. Vertical and horizontal eye movements were recorded by two bipolar channel pairs. For head and body movements, participants were monitored through a close-circuit camera system. The paradigm follows the idea of Näätänen et al. (2004)’s Optimal Paradigm. Three deviants were presented alongside the standard and not compared individually against the standard as in the classic oddball paradigm. We used an oddball paradigm with 50 percent standard (e.g. [ʧa]) and 50 percent deviant ([ʨa], [ʥa] and [ʤa]) proportion. This paradigm was chosen according to the Optimal-1-Paradigm of Näätänen (2004; compare Pakarinen et al. 2007). Furthermore, we used a Multiple-Deviant Paradigm which means that every deviant once acted as the standard. The Inter-stimulus Interval (ISI) was set to 750 ms. An additional Stimulus Onset Asynchrony (SOA) of 400 ms was jittered. A rapid and unpredictable rate of stimulus presentation was chosen to divert possible attention processes (compare Sinkkonen and Tervaniemi 2000; Muller-Gass et al. 2006). The first two minutes were recorded for closed and open eye-movements (resting EEG). Thereafter, eight passive listening blocks followed. Block sequences were randomized between subjects. Participants were asked to read an unrelated text and not pay attention to the syllables they heard. At the beginning of each block there were 15 repetitions of the standard to attune the subjects’ ears to the respective standard. Therefore a stimulus block included 150 deviants and 165 standards. In total 1200 deviant repetitions and 1320 standard repetitions were used, whereof each of the four stimuli appeared 330 times as a standard and 300 times as a deviant. On average, participants wished to recess for three minutes between blocks.

2.4. Data Analysis

The data was analyzed using *BrainVision Analyzer 1.05.0005*[3] and *eegLab 6.01*[4] (Matlab). EEGs were offline treated with a 24 dB zero-phase bandpass-filter from 0.1 to 30 Hz. To correct for artefacts, a manual and an automatic *Raw DataInspector* was applied, whereby changes exceeding 150μV at any channel were marked and neglected for further analysis. Unfortunately, we could not use the nose as reference, as the coordinates of this electrode are unknown to the *eegLab system.* Common average Reference (CAR) was therefore applied as reference. Eye blinks and horizontal movements were corrected by means of independent component analysis (ICA) (Stone, 2002) implemented in *eegLAB.* Due to technical problems while recording, six subjects (3 Rhaeto-Romance and 3 Swiss-German) had to be discarded. EEG recordings were segmented into 600-ms epochs (100 ms pre- and 500 ms post-stimulus) and averaged for each stimulus type separately with 100 ms pre-stimulus as a baseline. ERPs for all stimuli (each stimulus type as a standard and as a deviant) were averaged for each subject and across subjects. MMN difference waves were computed by subtracting ERPs (event related potentials) to the standard from ERPs to the deviant of a chosen stimulus and averaged. Being able to directly compare the response to a certain stimulus acting both as a standard and as a deviant is one of the main advantages of the MMN paradigm we applied (compare also Grimm et al. 2008). Peak-detection was carried out over a time-window of 180 ms (120-300 ms after stimulus onset). The presence of the MMN was statistically verified using analysis of variance, one-sample and independent *t*-tests with *SPSS*[5] at a significance level of 0.05. Analysis involved evaluation of factors group, stimuli, peaks and latencies. To verify the existence of a true MMN component, activations at Fz were compared with supra-temporal electrodes (TP7 and TP8; compare Näätänen et al. 2007).

3. RESULTS

Deviant-related MMN potentials were measured by subtracting ERPs elicited by the stimulus operating as a standard sound from ERPs elicited by the same stimulus operating as a deviant sound. This allowed a direct comparison of the physically identical stimulus differing only in its probability of occurrence. The Acoustic Event Related Potential (AERP) for both groups showed orderly N1 and P2 components at central Cz electrode. All MMN curves displayed a typical fronto-central maximum (Fz) with a polarity inversion at the mastoid leads (TP7 and TP8). With respect to the statistical evaluation of the MMN, a repeated-measures ANOVA was performed for peaks and latencies separately. Normal distribution was assured with a *Kolmogorov Smirnov* test. The ANOVA included the between-subject factor "Group" (Rhaeto-Romance vs. Swiss-German) and the within-subject factors "Stimulus" ([ʧa], [ʨa], [ʥa] and [ʤa]) and "Peak" or "Latency" (three peak or latency values per stimulus, representing the three deviant conditions). All main effects or interactions with two or more degrees of freedom in the numerator were adjusted with the procedure suggested by Huynh and Feldt (1970) and revealed a main effect of Group ($p < 0.05$, Greenhouse-Geisser $p = 0.010$) for the MMN amplitude. Our main hypothesis was therefore successfully confirmed. As expected, the comparison Group * Stimulus * Latency revealed no main effect Group. Due to slightly different stimulus length (up to 65 ms difference), a systematic latency effect was anticipated. Tests of Within-Subjects Effects indicated a significant main effect Stimulus (Greenhouse-Geisser $p = 0.013$). The one-sample *t*-Tests in both groups for the comparison of both peaks and latencies were all significant at the $p < 0.001$ level. Independent Samples *t*-Tests provide evidence that Rhaeto-Romance speakers process phonological contrasts significantly differently. Surprisingly, the stimulus [ʨa] elicited no significant group difference. Stimulus [ʥa] was processed significantly different if it served as a deviant beside the standard [tʃa] ($p = 0.01$) and if [ʤa] served as standard ($p = 0.03$) compared to acting itself as a standard. Stimulus [ʤa] also displayed significant differences between Rhaeto-Romance and Swiss-German speakers when serving as a deviant in standard blocks [ʨa] and [tʃa]. As expected, no differences in processing were found for the stimulus [tʃa]. This stimulus is common to speakers of both language groups and should therefore not evoke a significant difference in processing. MMN reliability was inspected by comparing the amplitudes of the MMN component at the frontal Fz electrode with the zero level. For both language groups in all deviant conditions, negative peaks were observed in the deviant-minus-standard difference waves.

4. DISCUSSION

The overall goals of the MMN experiment were two-fold: first and foremost, to examine the implications of the different language-backgrounds of the two groups, and second to test whether place of articulation or voicing had a stronger influence on the perception of a foreign language phonological contrast. A significant main effect Group confirmed a general difference as a function of language processing. The direction of the effect, however, was unexpected. There are two possible explanations for this finding. On the one hand, Swiss-German speakers might previously have attained cortical representations of the foreign sound category that enabled them to perform in a comparable way to the Rhaeto-Romance speakers. This would confirm the assumption that linguistic experience affects the critical time window for speech acquisition (compare Gandour et al., 2007). On the other hand, overlearning could have yielded smaller responses to the phonetic contrast in the Rhaeto-Romance group. The higher amplitudes in the Swiss-German subjects could be interpreted as increased neural activity reflecting the processing of unknown information (compare Tervaniemi et al. 2000; van Zuijen et al. 2005; Kujala et al. 2007).

The notion of establishing memory traces is cuncures with the idea of neural commitment proposed by Kuhl (2004): one assumes a reference between the input signal and stored regularities that have been established during language acquisition. The SLM by Flege (1993) and the PAM by Best (2001) both accentuate the automatic assimilation through which non-native sounds are mapped onto the nearest native speech sound representation. Here it seemed that having an equivalent phoneme in one's native language caused a smaller MMN amplitude for the processing of affricate sounds than having no equivalent phoneme in the L1. However, in both cases the ability to discriminate and categorize was not eliminated. Our results support the notion that phonetic information that seems irrelevant to the acquired L1-specific representations is not completely neglected or filtered out (compare e.g. Zhang et al. 2005). This strongly speaks in favour of the continuous ability to learn foreign language phonemes that are similar or dissimilar to the L1 phonetic category in adulthood.

This study contributed to research in language learning with the observation that language experience in auditory processing is also involved in the processing of affricates. A possible ambiguity of the mode of perception of these sounds might be in line with Lipski's findings (2006) who detected a less categorical perception for fricative sounds. Given the great variety of affricate categories across languages (Ladefoged and Maddieson 1996; Gordon et al. 2002) further research on this topic is needed. For instance, only coronal affricates were investigated in this study; the way dorsal affricates are processed and distinguished could be a future project. Moreover, most studies investigate the 'products' of language learning, whereas in order to make statements about the 'process' of language acquisition, longitudinal studies would be fruitful.

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NOTES

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