World Academy of Science, Engineering and Technology
International Journal of Cognitive and Language Sciences
Vol:9, No:12, 2015

Behavioral and EEG Reactions in Native Turkic-Speaking Inhabitants of Siberia and Siberian Russians during Recognition of Syntactic Errors in Sentences in Native and Foreign Languages

Tatiana N. Astakhova, Alexander E. Saprygin, Tatiana A. Golovko, Alexander N. Savostyanov, Mikhail S. Vlasov, Natalia V. Borisova, Alexandera G. Karpova, Urana N. Kavai-ool, Elena Mokur-ool, Nikolay A. Kolchano, Lyubomir I. Aftanas

Abstract**—**The aim of the study is to compare behavioral and EEG reactions in Turkic-speaking inhabitants of Siberia (Tuvinians and Yakuts) and Russians during the recognition of syntax errors in native and foreign languages. Sixty-three healthy aboriginals of the Tyva Republic, 29 inhabitants of the Sakha (Yakutia) Republic, and 55 Russians from Novosibirsk participated in the study. EEG were recorded during execution of error-recognition task in Russian and English language (in all participants) and in native languages (Tuvinian or Yakut Turkic-speaking inhabitants). Reaction time (RT) and quality of task execution were chosen as behavioral measures. Amplitude and cortical distribution of P300 and P600 peaks of ERP were used as a measure of speech-related brain activity. In Tuvinians, there were no differences in the P300 and P600 amplitudes as well as in cortical topology for Russian and Tuvinian languages, but there was a difference for English. In Yakuts, the P300 and P600 amplitudes and topology of ERP for Russian language were the same as Russians had for native language. In Yakuts, brain reactions during Yakut and English language comprehension had no difference, while the Russian language comprehension was differed from both Yakut and English.

We found out that the Tuvinians recognized both Russian and Tuvinian as native languages, and English as a foreign language. The Yakuts recognized both English and Yakut as foreign languages, but Russian as a native language. According to the inquirer, both Tuvinians and Yakuts use the national language as a spoken language, whereas they do not use it for writing. It can well be a reason that Yakuts perceive the Yakut writing language as a foreign language while writing Russian as their native.

Tatiana N. Astakhova and Tatiana A. Golovko are with the Novosibirsk National Research State University, Novosibirsk, Pirogova Str., 2, 630090, Russia (phone: +79134612743; fax: +7 (383) 335-97-54; e-mail: tastahova95@yandex.ru, golovkotatiana@bk.ru).

Alexander E. Saprygin, Alexander N. Savostyanov and Lyubomir I. Aftanas are with the Institute of Physiology and Fundamental Medicine, Novosibirsk, Russia (e-mail: saprigyn@mail.ru, alexander.Savostyanov@gmail.com, liaftanas@gmail.com).

Mikhail S. Vlasov is with the Shukshin Altay State Academy of Education, Biysk, Russia (e-mail: vlasov_mikhailo@mail.ru).

Natalia V. Borisova and Alexandra G. Karpova are with the North-Eastern Federal University, Yakutsk, Russia (e-mail: borinat@yandex.ru, karpova74@list.ru).

Urana N. Kavai-ool and Elena Mokur-ool are with the Tuvan State University, Kyzyl, Russia (e-mail: dr.urana63@mail.ru, lerco-m@mail.ru).

Nikolay A. Kolchanov is with the Institute of Cytology and Genetics of RAS, Novosibirsk, Russia (e-mail: kol@bionet.nsc.ru).

Keywords**—**EEG, brain activity, syntactic analysis, native and foreign language.

I. INTRODUCTION

EVENT-RELATED potentials (ERP) are widely used to study neuronal processes of human brain underlying the recognition of writing speech [1], [2]. Comparison of brain and behavioral reactions during native and foreign languages comprehension is an important theme of neurolinguistic studies [3]. The theme has a fundamental importance for understanding of brain processes related to the organization of human mind. In addition, there are studies in which it was revealed that psychiatric diseases could be shown in different ways during native and foreign languages comprehension [4]. This allows using results of the comparative study for diagnostic of mental disorders. Now many comparative studies of brain activity in native and foreign languages for different European languages speakers were made [5]. In addition, there are many studies dedicated to differences between European languages comprehension and Chinese and Japanese languages comprehension [4], [6], [7]. It was found out that topology of brain activity for European languages did not dependent on the language, but depended on whether the language of the test was native or foreign for a subject. On the other hand, brain activity during reading of written sentences in Chinese also had topological features, not depending on whether the language was native or foreign. However, the theme of comparison of brain activity in Turkic languages speakers in general, and in languages of Siberian inhabitants particularly, almost was not studied.

The aim of the study was to explore brain bioelectrical activity during recognition of syntax errors in native and foreign languages in Turkic-speaking inhabitants of Siberia (Tuvinians and Yakuts) and Russian people living in Siberia. We chose two Turkic-speaking groups. The first group consisted of healthy young participants, predominantly students and university staff who were born and lived in the Tyva Republic. Tyva is located in the Southern Siberia near Mongolia border. The second group consisted of similar age, sex and social status people living in Sakha (Yakutia) Republic. Yakutia is located in the North-East of Siberia near

Arctic border of Russia. Both groups are native speakers of Turkic-speaking languages (the Tuvinian language and the Yakut language). The third group was students and staff of Novosibirsk State University, predominantly Russians, or other Caucasoids who did not speak Turkic languages. Novosibirsk is a city with a population of 1.5 million people, which is located in central Siberia.

All inhabitants of Siberia are fluent in Russian not depending on their nationality. The Russian language is used by all of them as a language of everyday communication, secondary and higher education, the media. Turkic languages are used in some regions of Siberia as everyday languages and as the second official language of these Russian regions. At present, there is a tendency of displacement of the Turkic languages and using Russian as everyday language in big industrial cities. The English language is not used in Siberia as a language of everyday life, but it is a language for study in secondary school and in universities. We chose English as a foreign language because all students of Russian universities must know English at a certain level. Russian was chosen as native language for all participants. Brain and behavioral reactions on respective national languages were compared with both Russian and English.

We compared behavioral reactions, such as the response latency and the accuracy of solving, obtained during the recognition of syntax errors in different languages. We used amplitudes and cortical topology of P300 and P600 as parameters of brain activity, which was registered with multichannel electroencephalography. As well known, the peak P300 in frontal cortical areas reflects the level of concentration of voluntary attention to the tasks [3]. In the parietal cortex, the amplitude of peak P300 reflects the level of spontaneous non-voluntary attention. The amplitude of peak P600 is associated with recognition of syntax [1], [2], [4]. According to [8], the amplitudes of the peaks are different during native and foreign languages comprehension.

We supposed that results obtained in the study could be used in the planning of neurological and psychiatric diagnostic, associated with speech disorders in native population of Siberia.

II. Participants and Procedure

A. Participants

63 healthy aboriginals of the Tyva Republic (24.3±3.1 ages, 32 males and 31 females), 29 inhabitants of the Sakha (Yakutia) Republic (21.7±2.6 ages, 12 males and 17 females), and 55 Russians from Novosibirsk (25.1±2.7 ages, 25 males and 30 females) participated in the study. All Russian participants were native Russian-speakers. The participants from Tyva and Yakutia were Russian- Turkic bilinguals. All of them had the higher or non-finished higher education. All participants knew English at intermediate level. All participants gave informed written consent prior to the experiment. The study was approved by the Research Ethics Committee at the Institute of Physiology and Fundamental Medicine.

B. Experimental Procedure

120 sentences in English (English task) and 200 sentences in Russian (Russian task), Tuvinian (Tuvinian task) and Yakut (Yakut task) were selected for the experiment. Half of the sentence list for each language contained a syntax error.

The tasks in different languages were presented separately in two (for Russians) or three (for Tuvinians and Yakuts) sessions. The order of sessions was randomized around the subjects. Correct and incorrect samples were presented randomly with inter-trial interval varying between 4 and 7 s. Time for stimulus presentation was not limited and the participants had no time limitation to make a decision but they were instructed to do it as quickly as possible. EEG was continuously recorded. During the EEG experiment, each participant sat comfortably in a chair with opened eyes in a dimly lighted soundproof room. The tasks were presented in white and black (Arial, 36pt) via a 24.4 cm x 18.3 cm monitor located 60 cm away in front of a participant. The subjects were instructed to judge whether a presented sample contains an error by pressing one of two buttons by dominant hand. Participants had three practice trials before task execution.

C. EEG Recording

In Russian group, the signals were amplified using 114 EEG + VEOG and HEOG channels Neuroscan amplifiers (USA). In Tuvinian and Yakut groups, the signals were amplified using 63 EEG + VEOG channels Brain Products GmbH (Germany) amplifiers (www.brainproducts.com). In all groups the signals were recorded via Ag/AgCl electrodes, with 0.1–100 Hz analog bandpass filtering and digitized at 1000 Hz. The EEG electrodes were placed according to the extended International 10–10 system using Quik-Cap128 NSL and referred to Cz with ground at FzA. Electrodes impedance was maintained below 5 kΩ.

To assess changes in brain activity associated with error recognition in different conditions, the indexes of event-related potentials were computed using the EEGLAB toolbox [9]. Artifacts resulted from eye movements; blinks, muscle electrical activity, and line noise were cleaned by independent component analysis (ICA) [10]. A separation of brain activity from artifacts was performed by an automatic approach based on the reference signals in the VEOG, Fp1, and Fp2 channels. After the ICA preprocessing, ERP indexes were computed for each participant, separately for each experimental condition at each channel.

Individually computed ERPs were averaged across all participants, channels separately for each experimental condition to obtain the general pattern of brain activity. The random permutation method with $p<0.05$ significance level was applied in the statistical analysis of ERPs for all conditions. The time-frequency intervals of interest for further analysis were selected by visual inspection of the averaged ERP plot.

Statistical data processing: EEG channels were grouped into nine regions: left (10 channels), midline (11), and right frontal (10); left (17) and right temporal (17); all central (27); left (11), midline (12) and right occipital-parietal (11). ERPs were averaged across channels within each region for each individual participant. These indexes were used for repeated measures ANOVA with the Greenhouse-Geisser correction to test the main effects of such factors as "group" (Russians vs Tuvinians vs Yakuts), languages (Russian vs English vs Tuvinian or Yakut), the sagittal (anterior vs central vs posterior cortical regions), the laterality (left vs medial vs right cortical regions) and interactions between these factors.

III. Results

A. Behavioral Results

Comparing the response latency in Russian task in all groups we obtained the valid value of factor "group", F (2, 144) = 18.33, p< 0.0001. The average reaction times (RTs) for correct and incorrect sentences in Russians (2594 ± 740 ms) was less than in Tuvinians (3619 ± 1057 ms) and Yakuts (3335 ± 915 ms). The method of contrasts showed that the RTs was authentically different for Russians and Tuvinians (p< 0.001) and for Russians and Yakuts (p = 0.024), but it was not different for Tuvinians and Yakuts (p> 0.17). The valid value of factor "group" (F (2, 144) = 21.09, p< 0.0001) was discovered for the response accuracy in Russian tasks. Russian participants showed the best quality of task solving (93.5 ± 3.7 %), Tuvinians showed the worst quality (81.4 ± 13.6 %), Yakuts showed intermediate result (88.1 ± 9.1 %). The percent of correct answers was authentically different for Russians and Tuvinians (p< 0.0001), Russians and Yakuts (p = 0.020), Tuvinians and Yakuts (p = 0.004).

By the comparison of the RTs for tasks in the English language for all participants from three ethnic groups we did not obtain the valid value of the factor "group" (p= 0.31). However, this factor was valid for comparison of the response accuracy, F (2, 139) = 172.4, p< 0.0001. In addition, Russian participants showed the best accuracy for English tasks as well as for Russian tasks (90.1 ± 8.0 %), Yakut participants showed average result (65.8 ± 12.3 %), Tuvinian participants showed bad accuracy for the task (56.8 ± 9.8 %). The comparison of all groups showed valid differences between all groups: Russian and Yakut groups (p< 0.0001), Russian and Tuvinian groups (p< 0.0001), Tuvinian and Yakut groups (p< 0.0001).

The comparison of behavioral reactions for Russian and English tasks in Russians showed the factor "language" was valid both for the RTs, F (1, 53) = 16.47, p< 0.0001, and the response accuracy, F(1, 53) = 10.9, p = 0.002. Russian participants showed faster reactions (2594 ± 740 ms) and better response accuracy (93.5 ± 3.7 %) in Russian task as compared with English tasks.

In Yakuts, the comparison of behavioral reactions for tasks in Russian, English and Yakut did not show valid differences of response speed (p = 0.58). However, Yakut participants showed the valid value of factor "language" by the comparison of the response accuracy. The quality of solving of tasks in Russian (88.1 ± 9.1%) and Yakut (88.3 ± 10.2%) was the same but they were worse for the tasks in English (65.8 ± 12.3%). In Tuvinians, the comparison of behavioral reactions for tasks in Russian, English and Tuvinian obtained the valid value of the factor "language" was obtained for the response speed, F(2, 114) = 27.9, p< 0.0001 and the accuracy of solving of tasks, F (2, 114) = 85.7, p < 0.0001. Paradoxically, the RTs was the fastest for English (3147 ± 216 ms), average for Russian (3619 ± 1057 ms) and the slowest for Tuvinian (4669 ± 207 ms). The comparison showed that differences of the RTs were valid for all groups (p< 0.05). The quality of solving of tasks in Russian was the best (81.4 ± 13.6%), a little lower for tasks in Tuvinian (77.6 ± 2.4 %), the lowest for tasks in English (56.8 ± 1.3 %). Paired comparisons showed the quality of solving of tasks in Russian and Tuvinian was the same authentically (p = 0.76), but was different for Russian and English and for Tuvinian and English (p< 0.001 for both).

B. ERP Results

In Russian group, there were differences in the P300 and P600 amplitudes during the solving of tasks in Russian and English. The P300 amplitudes in frontal cortex were higher for English than for Russian, whereas the P600 amplitudes in the left temporal cortex (Broca's and Wernicke's areas) were higher for Russian than for English (Fig. 1).

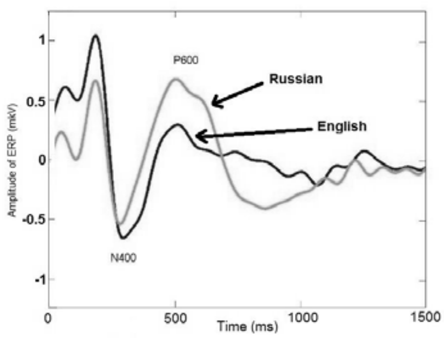

Fig. 1 ERP plot in left temporal cortex in Russians

In Tuvinian group, the P600 amplitudes in the left temporal cortex were the same for Russian and Tuvinian, but authentically less for English (Fig. 2). The P300 amplitudes in frontal and parietal cortex in Tuvinians were maximum for Russian, average for Tuvinian and minimum for English.

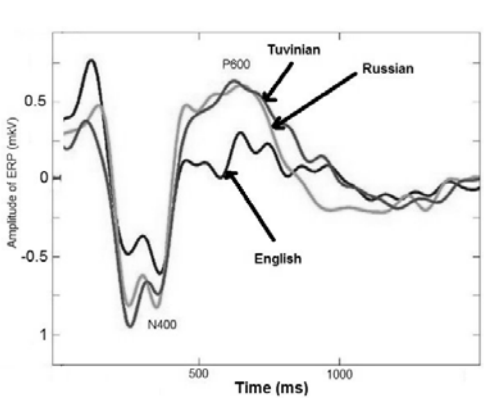

Fig. 2 ERP plot in left temporal cortex in Tuvinians

In Yakuts, the P300 amplitudes were maximum for both

Yakut and English, less for Russian. The P600 amplitudes in the left temporal cortex were authentically higher for Russian than for English and Yakut. The P600 amplitudes for Russian and English were the same (Fig. 3).

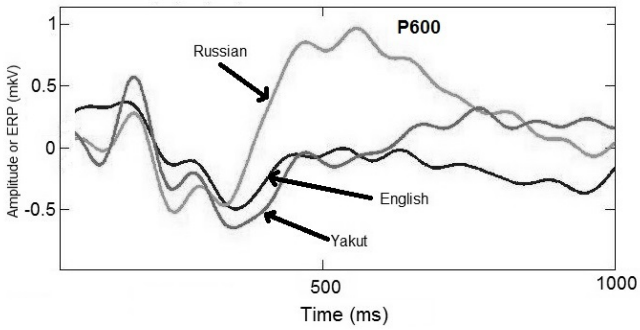

Fig. 3 ERP plot in left temporal cortex in Yakuts

IV. Discussion

Behavioral reactions and Event related potentials in Russians performing Russian and English tasks were in agreement with the theory. Russian participants recognized syntax errors in native language faster and more accurate than in foreign language (English). The P300 amplitudes were higher for foreign language than for native language. This parameter of brain activity reflected the focus of voluntary attention. The results obtained for Russian group can be interpreted as the participants paid more attention to more difficult task in foreign language than to easy task in native language. The P600 amplitudes reflected the recognition of syntax. According to the theory, the reaction must be higher for native language than for foreign language that is illustrated by our results.

In Tuvinians, the quality of the solving of tasks in Russian and Tuvinian was the same, whereas the averageRT was higher for Russian than for Tuvinian. Thus, it was easier for Tuvinians to solve tasks in Russian than in their national language. Solving the tasks in English, Tuvinians showed bad accuracy and high RTs of the solving of tasks. Actually, the most of Tuvinians did not solve the tasks carefully they made decision randomly. According to the education standards of higher professional education in the Russian Federation, Tuvinian students must be proficient in English; however, they showed bad quality of the solving of tasks. According to the P600 amplitudes, both Russian and Tuvinian were native for Tuvinians, whereas the English language comprehension correlated with the brain activity of foreign language comprehension. The P300 amplitudes in Tuvinians can be interpreted as a greater concentration of directed attention to tasks in Russian than to tasks in English and Tuvinian.

In Yakuts, the quality of solving of tasks was the same for Russian and Yakut, less for English. The average RT was the same for all tasks. Unlike Tuvinians, Yakuts were motivated to solve the tasks in English as fast as possible; however, the quality of solving of tasks was less than Russians has for English. Despite this, the answers of Yakuts were not random as compared with Tuvinians.

Distribution and amplitudes of the peaks P300 and P600 for Yakut participants are unusual: Yakuts showed high amplitudes of P300 both high amplitudes of P300 for both English and Yakut and low amplitudes for Russian. We can provide interpretation for this: it was difficult to recognize both English and Yakut, whereas it was easier to recognize Russian. In Yakuts, the P600 amplitudes for Russian tasks were the same as Russians and Tuvinians had their native language the P600 amplitudes for English and Yakut tasks were the same as Russians and Tuvinian had for foreign language.

The results obtained can be explained by the social situation in areas of Siberia with Turkic-speaking inhabitants. Among the urban population of Tuva and Yakutia, Turkic languages were used as everyday languages, not used as languages for writing, literature, official documents, and the media. Therefore, Turkic-speaking inhabitants did not use written language in their national languages. This feature is more typical for industrialized Yakutia than for agricultural Tuva. The Russian language was used as both everyday and literary language.

V.Conclusion

Thus, in Yakuts, the Yakut language was perceived physiologically as a foreign language, brain reactions to Yakut language were the same as reactions to English, whereas reactions to the Russian language were related to reactions to native language. In Tuvinians, both Russian and Tuvinian were perceived as native language, but behavioral reactions showed that Russian was easier for them than Tuvinian.

Acknowledgment

The authors gratefully acknowledge the support from the №14-15-00202 grant from the Russian Science Foundation.

References

[1] S. Bentin, *Electrophysiological studies of visual word perception, lexical organization, and semantic processing: a tutorial review.* Lang. Speech, 1989, vol. 32 (Pt 3), pp. 205-20.

[2] S. Bentin, Y. Mouchetant-Rostaing, M. H. Giard, J. F. Echallier, J. Pernier, *ERP manifestations of processing printed words at different psycholinguistic levels: time course and scalp distribution.* J. Cogn. Neuroci., 1999, vol. 11, № 3, pp.235-60.

[3] E. Pihko, V. V. Nikulin, R. J. Ilmoniemi, *Visual attention to words in different languages in bilinguals: a magnetoencephalographic study.* Neuroimage, 2002, vol. 17, № 4, pp. 1830-6.

[4] A.C. Tsai, A. N., Savostyanov, A. Wu, J. P. Evans, V. S. C. Chien, H. H. Yang, D. Y. Yang, M. Liou, *Recognizing syntactic errors in Chinese and English sentences: Brain electrical activity in Asperger's syndrom.,* Research in Autism Spectrum Disorders, 2013, vol. 7, pp. 889-905.

[5] J. Pellikka, P. Heleniu, J. P. Mäkelä, M. Lehtonen, *Context affects L1 but not L2 during bilingual word recognition: an MEG study.* Brain Lang., 2015, vol. 42, pp. 8-17.

[6] X. Meng, J. Jian, H. Shu, X. Tian, X. Zhou, *ERP correlates of the development of orthographical and phonological processing during Chinese sentence reading.* Brain Res., 2008, vol. 1219, pp. 91-102.

[7] Y. N. Yum, S. P. Law, I. F. Su, K. Y. Lau, K. N. Mo, *An ERP study of effects of regularity and consistency in delayed naming and lexicality judgment in a logographic writing system.* Front Psychol., 2014, vol. 5:315.

[8] H. W. Boweden, K. Steinhauer, C. Sanz, M. T. Ullman, *Native-like brain processing of syntax can be attained by university foreign language learners.* Neuropsychologia, 2013, vol. 51, № 13, pp. 2492-511.
[9] A. Delorme, S. Makeig *EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis,* J. Neurosci. Methods, 2004, vol. 134, № 1, pp. 9–21.
[10] S. Makeig, A. J. Bell, T. P. Jung, T. J. Sejnowski *Independent component analysis of electroencephalografic data* Adv. Neural Inf. Process. Syst., 1996, vol. 8, pp. 145–151.