

COGNITIVE COSTS OF BILINGUAL EDUCATION: THEORETICAL AND EMPIRICAL RESEARCH

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Abstract

Bilingual education is becoming more common throughout the world. There is no doubt that bilingualism comes with important advantages. The benefit of bilingualism has been shown even to extend to basic cognitive functions, namely to an improved ability of executive control. However, educational practitioners need to be aware that bilingual learning also comes with costs. They cannot expect that the information learned in one language can be retrieved in another language as well as in the language of instruction. But only little research has been done on the underlying cognitive mechanisms of learning in bi- or multilingual pedagogical settings. Despite of the obvious benefits and popularity of immersion education it is far from clear whether or not there are any risks for students who are trained in such programs. The aim of our research is to investigate the possible costs and the negative effects of bilingual education. In particular, it is necessary to identify and investigate the extent of the cognitive costs in situations when languages of instruction and of application are different. The formulated problem is fundamental, both in national and international contexts. The above situation arises, for example in secondary schools of Russia with native (Yakut, Tatar, North Ossetian, Circassian etc.) language of instruction, in which mathematics is taught bilingually by means of Russian and native languages. The teachers are using bilingual mode of teaching mathematics due to the fact that the Unified State Exam in mathematics is compulsory for all students of the Russian Federation, and it is conducted in Russian language. The interpretive approach was used in which data was collected by the transcription of video recordings of lessons and analysis of interviews with students and teachers. The data was analysed both qualitatively and quantitatively. Cognitive costs were investigated in the process of solving mathematical problems using two languages (Russian and Tatar) by students and pupils of schools and Universities in Tatarstan. The hypothesis that the negative effects from language-switching occur in the form of a time delay and deterioration of the accuracy of the solution of math problems was confirmed.

Keywords: cognitive cost, bilingual education, language of instruction.

1 INTRODUCTION

There is no doubt that bilingualism has major advances. In the age of globalization ability to communicate in another language is one of the most crucial competencies which become more urgent. Scientists have proven that bilingual education develops such cognitive skills, as understanding, cognizing, investigating, realizing, perceiving, and processing the information. It also improves executive control which is activated in revealing new stimuli providing brain plasticity [1-3]. However, bilingual education can have negative effects because it cannot be expected that information acquired in one language can be processed in the same way as it could be in native language [4].

The main purpose of the article is to investigate cognitive costs of bilingual education when the language of processing information and the language of instruction are different.

From our point of view, the issue has a fundamental nature at the national and international levels. For instance, Yakut students, Tatar students, and Ossetian students are taught bilingually: in the ethnic language and in the State language (Russian) as Unified State Exam is held in the Russian language. As for higher education, attraction of international students plays an essential role for such countries as Netherlands, Finland, Denmark, and Russia. International students receive education mainly in the English language as it is the international language for communication and cooperation. That is why it can be said that international students are taught bilingually too and have the same difficulties.

Analysis of researches on investigating cognitive costs in the process of bilingual teaching Mathematics confirm that the costs are revealed in cases when implementation of bilingual education programs do not provide that knowledges represented systematically are not depended from the language of instruction. Results of researches carried out by such scientists as D. Gentner, S. Goldin-

Meadow [5], J.J.Gumperz, S.C. Levinson [6], B.C. Malt, and P. Wolff [7], suggest that acquisition of knowledge is closely related to language of instruction and a student's native language.

According to the results, the native language in the field of Mathematics has impact on quantitative notions and correctness of computations. For instance, P. Gordon [8] has studied indigenous people of the tribe Pirahã who live in Brazil and number about 420 individuals. The Pirahã language is characterized with very limited vocabulary regarding general notions and absence of pronouns and numbers. Indigenous people use for numbers only such words, as one, two, and many. P. Gordon has found that indigenous people of the tribe cannot cope with such simple problem as copying lines drawn on a sheet of paper when they are more than two or three. Intercultural researches indicate that differences in language structures, for example, linguistic expression of number system reflect in subtle cross-linguistic differences in mathematical knowledge in developed communities too.

K.F. Miller, C.M. Smith, J.Zhu, H. Zhang [9], K. F. Miller, and J.W. Stigler [10] have found that at the initial stage of teaching Mathematics computation Chinese children who speak Mandarin have advantages in comparison with English speaking children.

Therefore, notion of knowledge depends on the specific language of instruction it follows that negative effects can be revealed in their transferring from one representation system due to which a person perceives information and uses it to another. Consequently negative effects can be revealed in cases when the language of instruction and language of retrieving knowledge are different. The negative effects had been confirmed by E.S. Spelke and S. Tsivkin [11]. The scientists had observed two balanced Russian-English bilingual adults who solved different mathematical problems in two languages (Russian and English). The tasks were formulated verbally in the following way: "What is the sum of fifty- four and forty eight?" and so on. The main purpose of the research was included in revealing existence or absence of cognitive cost in cases when the language of instruction differed from language of control. Adult bilinguals were solving four types of mathematical problems.

In two types of problems it was demanded to process accurate facts as adding a number 54 to two-digit numbers or making the operation in the system of base 6 (accurate problems). In other types of problems demanded to solve problems with irrational and transcendental numbers. For instance, it was needed to find cube root of a number or logarithm of a number (problems of approximation).

Test conducted after exercise training was in two languages - Russian and English. Results of the test suggest that participants of the experiment needed more time on solving accurate problems when language of instruction was different from the language of achievement test in comparison with situation when language of instruction and language of achievement test coincided. In solving problems of approximation cognitive cost had not been found. Negative effects of code-switching in solving accurate problems were revealed again after additionally carried out experiment.

E.S. Spelke, S. Tsivkin [11] found that negative effects of code-switching also occurred in solving "accurate problems" on processing numerical information in non-mathematical contexts, for example, in remembering historical dates, solving chemical equations or biological and physical problems.

Results of the research correlate with a famous "Triple Code Model" of S.Dehaene, L.Cohen [12], who have hypothesized that there are three types of concepts of numbers in human mind:

- 1 Notion of quantity not dependent on language;
- 2 Auditory-verbal code;
- 3 Visual notion, written with Arabian numbers.

The scientists have come to the conclusion that solving "approximation problems" is related to the notion of quantity independent of language. Solving of "accurate problems" is related to auditory-verbal code.

V. Marian, C.M. Fausey [13] have also come to the conclusion about cognitive costs of code-switching in bilingual education. They have observed adult Spanish- English bilinguals who were learning some themes of Chemistry, Biology, and History in the one of these two languages. After the training the participants should answer the questions on examined material. V. Marian, C.M. Fausey found that the participants of the experiment had given answers on questions quicker when the language of instruction and the language of achievement test coincided.

Therefore, if the language of achievement test differs from the language of instruction it can lead to cognitive costs included in decreasing accuracy and speed of language processing. But is it possible

to draw global conclusions about practical meaning for implementation and valuation of bilingual education programs? There are a few reasons to challenge the previous conclusions:

- Participants of the researches were students of universities or adults but not students who study on bilingual education programs;
- Negative effects of code-switching were observed in "balanced bilinguals";
- Achievement test was held immediately after short-term training (at school themes have been studied for several days).

Due to limitations of the previous researches it is highly necessary to carry out research which should meet real conditions of educational practice.

We have formulated theoretical hypothesis the correctness of which should be empirically verified.

2 HYPOTHESES OF THE RESEARCH

It was necessary to ascertain whether students of the high school of Tatarstan Republic with bilingual (Tatar-Russian) education program would have the same code-switching costs in solving mathematical problems which adult bilinguals had in the previous researches?

Bilingual education program in Mathematics is chosen by teachers at schools where the language of instruction is the Tatar language because Unified State Exam in Mathematics is obligatory and held in the Russian language all over Russian Federation.

Targeted attendances of the bilingual lessons in Mathematics, interviewing teachers who implement bilingual education program and students of the school, examining the results of the previous theoretical and empirical researches allowed formulating the following hypotheses which should be verified.

Hypothesis 1a was that cognitive costs of code-switching in solving mathematical problems after the training would be revealed in both groups of experiment participants: students who finished the training in the Tatar language and in the Russian language.

Hypothesis 1b was that negative effects of code-switching would not be revealed in solving "new" unknown mathematical problems in none of two groups.

We have also investigated the issue whether revealing of cognitive costs depends on switching from Russian to Tatar or depends on types of mathematical problems (i.e. there are differences in solving problems on subtraction or multiplication). It was proposed that degree of their revealing should be stronger in solving multiplication problems (hypothesis 2).

It was supposed (hypothesis 3) that cognitive costs are revealed stronger when a pupil switches from dominant language (the Tatar language) to the second language (the Russian language).

3 METHODS

Balanced and unbalanced bilinguals, 20 male and 19 female 15-17 years old students from bilingual (Tatar-Russian) schools participated in the experiment. The native language of students was the Tatar language and they had not spoken the Russian language before starting school. Bilingual (Tatar-Russian) education program in Mathematics was implemented at high school where the experiment was held. The participants of the experiment had spoken Russian fluently because they have been learning the Russian language since first grade at school. Moreover, they had been in bilingual (Tatar-Russian) environment due to television, radio, and the Internet. However, using the Russian language had been limited with school context.

Participants of the experiment had three trainings for four days. As soon as lessons finished the first training had held at under the supervision of experimenters. As for the second training, participants could choose to do it at school or at home and choose a day of it. Students could train using school computers at any time. Results of the training were sent to experimenter via e-mail.

Students of 9th and 11th grades were assigned equally by the language of instruction (Tatar or Russian). Duration of training was about 20 minutes. The training had started with reading numbers and students were suggested 5 training modules. The training included solving 14 problems on

subtraction and 14 problems on multiplication. The half of the problems was formulated in the Tatar language the other one - in Russian.

The achievement test had included additionally 14 new problems on subtraction and 14 ones on multiplication. The new problems were introduced to verify how students can cope with solving new problems.

Analyzing the results of the achievement test by two criteria ("time of acquiring correct answers" and "accuracy of computation") the multifactorial regressive analysis had been done. The following had been taken as independent variables: "teaching" (old and new problems), "code-switching", "operations" (subtraction and multiplication). As dependent variable had been "language of instruction" (Tatar or Russian).

4 RESULTS AND DISCUSSION

As predicted (hypothesis 1a) results indicated the negative impact of code-switching on speed and accuracy of multiplication and subtraction problem solving which students had during the trainings. The negative effect of language switching on solving "new" problems revealed in increasing average time of doing the task (hypothesis 1b). It was found that a type of operation (multiplication and subtraction) had impact on latency and accuracy of results in problem solving, as predicted, had not related to code-switching (hypothesis 2). Moreover, according to the hypothesis 3, effect of code-switching had revealed more for dominant (Tatar) language than for the second (Russian) language. This study broadened understanding of cognitive costs. First, students of high schools with a bilingual educational program can have code-switching costs. Second, before doing the achievement test, students had been learning a theme for a few days in comparison with the previous studies in which either training or an achievement test was held on the same day. Finally, not only balanced bilinguals but also unbalanced bilinguals whose level of the Russian language is lower have code-switching costs. However, the effect depends on the direction of language switching during instruction. Switching from dominant language of instruction to the second language leads to increasing the time of carrying out in comparison with cases when switching is in the opposite direction. Accordingly, unbalanced bilinguals have not relied only on the second language in coding the information during the training but also used their native language. Therefore, transition to dominant language leads to less revealing of cognitive costs. As for balanced bilinguals, in coding the information they rely only on the current language of instruction. In the process of subject studying, knowledge acquisition and knowledge representation are related to the language of instruction. In general it was proved that if the language of knowledge test and the language of instruction are different, students can have cognitive costs, such as decreasing accuracy of problem solving and speed of information processing.

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