Cultural variation in perception and coding in IT students

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Abstract
The effects of cross-cultural differences in perception on computer work have not been studied systematically. If the existence of variation in perception of characters is confirmed, the finding would have significance on programming education. This study measured working memory performance in simple character recognition tasks in international information technology students. Unexpectedly large variation was found between cultural groups, which was tentatively explained by diverse practices in previous education.

Keywords
Programming, working memory, cognitive retooling, international students

INTRODUCTION
When university students begin their studies, they already have a background of approximately twelve years in education. During that time, they have adopted certain ways of learning and cognitive processing that effectively influence their study skills. When students move from one educational system to another, they usually need to readjust their learning methods accordingly. An ever-growing number of international students face this challenge globally (EJEE, 2006). Host universities are preparing to educate international students to a varying degree by offering preparatory courses, foundation semesters, etc. However, it is not well-understood how fundamental the differences in educational systems actually are, and how deeply they influence the cognitive capacity of students (Holvikivi, 2009).

In the field of IT, computer programming requires a particular set of cognitive skills such as understanding Latin characters and manipulating them correctly in code. Sorting information in a defined order is a typical case of character-based manipulation, which is practiced in the first programming assignments given to students. An assignment in which students were asked to create a phone directory and sort it alphabetically in an XML programming class illustrates how students with diverse backgrounds tackled the problem. The task was self-evident for European students, whereas it was very challenging for some students who have first learned a non-alphabetic character system. A few Chinese students made separate categories for each alphabetical character, because they did not trust that the sorting can be performed by software functions. Moreover, some students with Amharic, Devanagari or Arabic character backgrounds were not familiar with the concept of first names and last names, therefore confusing the phone number listing structure, as they understood names as one unit. The difficulty with alphabetisation extended to perception of characters, as well, causing many errors in code. Punctuation, which has a central role in coding, appeared to be especially demanding.

Furthermore, wider cultural issues regularly emerge in the software development context. One African student started thinking about family units, and created a phone book structure where there was a father of the family, who “owned” the mother and other family members. Structuring this as XML elements became a rather confusing effort, which did not contribute to the search of phone numbers or sorting. These examples illustrate how cultural backgrounds can have unexpected effects in software development (see also Holvikivi, 2010).

The model of cognitive retooling

Margaret Wilson (2010) introduced a model of cognitive retooling based on the current neuroscientific knowledge. She noted that culture influences the contents of cognition, but, furthermore, culture can in addition exercise a profound effect on the cognitive system of perceiving and thinking and its functioning. Humans have developed mental and physical tools that facilitate thinking and planning of activities, and transmit that knowledge through education to new generations. Wilson elaborated her model presenting four claims on re-engineering cognition. First of all, cognitive tools are ubiquitous; they are used in everyday life, in science and in engineering. Cognitive tools include representations of number, calculation techniques, maps, and of course, writing and literacy. The tools are used in all cultures, but the practical implementations are widely varied, such as the Latin and Chinese writing systems (Gaur, 1984).

Wilson emphasised that the use of cognitive tools alters an individual's neuro-cognitive architecture, and therefore, has profound effects on the behaviour of a person. Recent brain studies show how brain plasticity enables specialization in demanding tasks such as spatial navigation, or finger manipulation when playing musical instruments. Larger or new areas of brain can be allocated for cognitive functions when one part has suffered damage: deaf people use spoken language areas in brain for sign language but not for other hand movement. Certain brain areas are involved in language and writing, nevertheless, there is observable difference between users of ideographic and alphabetic systems (Bolger;Perfetti;& Schneider, 2005). The Chinese employ visuo-motor brain areas for reading and writing to a much larger extent than alphabet users; writing Chinese characters requires advanced hand movement control and visual memory (Chen;Xue;Mei;Chen;& Dong, 2009). Moreover, the brains of bilinguals have been found to be more flexible in various tasks such as problem-solving (Hansen & Kringelbach, 2010).

A further two claims introduced by Wilson are the claim that cognitive retooling exploits body representations and that flexible voluntary control of actions permitted the emergence of cognitive retooling in evolution. Cognition is essentially embodied, as large areas of the brain in the cerebral cortex are specialized in processing perceptual information, motor planning and linking action and perception. Humans use perceptual, motor and spatial representations to facilitate cognition (Kitayama & Park, 2010), for instance use of graphs and diagrams is part of the design practice in software engineering (Brockman, 2008).

Cross-cultural differences in cognition

The majority of the research on cross-cultural differences has been carried out psychologists and anthropologists using the methods of those sciences. Cross-cultural psychology in particular is concerned with cultural differences in individual behaviour, including cognitive differences. That has been limited to a few prominent questions, such as differences in colour perception, perspective, and visual perception more generally; the influence of language in thinking; and eventual differences in intelligence (Berry;Poortinga;Segall;& Dasden, 2002). Berry *et al* summarize the findings of traditional psychological research that on tasks for basic sensory functions, such as stimulus discrimination, an approximately equal level of performance is to be expected for all cultural groups. Nevertheless, the introduction of functional Magnetic Resonance Imaging (fMRI) and other direct brain function measuring has opened up new possibilities for studying basic sensory functions, as well as more complex cognitive functioning (Kitayama & Park, 2010).

However, some studies have found differences in sensory functions between cultural groups (van de Vijver, 2008). Fons van de Vijver made comparisons of reaction times of Zimbabwean and Dutch secondary school children using tasks of increasing cognitive complexity. He found that Dutch children were faster in more complex tasks, but the differences disappeared along a training effect over four days. On the other hand, Berry *et al* (2002) refer to a study where choice response times (CRTs) to visual and auditory stimuli of South African black and white students were measured, and even after extensive training, the CRTs of white students were faster.

The aim of this study is to explore further, whether the differences in student behaviour in programming tasks could be based on systematic variation in basic cognitive functioning. The pattern of problems in code writing in nationality groups points towards shared cultural working patterns that could have been adopted in earlier education.

METHODS

The body of international engineering students in Western universities consists of a varied mix of nationalities and background cultures. Comparisons of the effects of culture are challenging, as it is not possible to find "typical" representatives of a "culture". Expatriate students can seldom be considered typical representatives of their native culture because many have exceptional educational histories including studies in more than one country or in more than one language. In this study, no precise culture-specific features were sought after, rather, the aim was to explore to what extent diverse cultural and educational backgrounds might influence skills and perception that are needed in programming.

A simple verbal working memory test was performed to find possible differences in character perception. The test was conducted using the Presentation software developed by Neurobehavioral Systems Inc. The test measures three aspects of working memory function: maintenance, retrieval and manipulation (Lewis, *et al.,* 2003), and it can be performed using different types of symbols and characters.

Background: test population

All participants to the tests were young male undergraduate students in the ICT department of Helsinki Metropolia University of Applied Sciences. Test subjects were recruited on voluntary basis, with the permission of the department. Because of tight study schedules, not many were willing to sacrifice time for the test. The subjects were given a movie ticket as a reward after completing the test.

The test population consisted of three main nationality groups that included 10 Ethiopian students, 9 Chinese students, and 10 Finnish students. Most of them studied in English, except for 8 Finnish students who studied in a corresponding Finnish medium degree programme. The Finnish students received their instructions in Finnish. Additionally, one American, one British, one Ghanaian and two Nigerian students took the test. They had English as their school language. The ages of test subjects ranged from 20 to 30. The average age in the expanded groups was 26.5 (SD= 2.4) for African, 22.7 (SD= 1.6) for Chinese and 23.8 (SD= 2.8) for European (Finnish and other Westerners).

The Ethiopian students had all finished high-school in Ethiopia before emigrating. Most of them also had previous university studies, either in Ethiopia or in Finland. In the Ethiopian system, school language is Amharic until sixth grade, and after that English. Therefore, the students were assumed to be fluent in English. One of the Ethiopian students had Oromo background, a language that is written in Latin alphabet as opposed to the Amharic syllabary. The Chinese students had finished their high school in China, conducting all studies in Chinese. Many of the international students had studied in some other Finnish polytechnic before being admitted to their current university.

All subjects reported that they had always studied mathematics using Arabic numerals despite the existence of Chinese and Amharic numbers. Therefore, we can assume that all subjects were equally familiar with numbers. Indeed, everybody reported that the digits test was easiest. Chinese subjects, in particular, emphasized the easy, short number words in their language, which are easy to memorize and manipulate mentally. All subjects had done at least one course in programming; therefore they were certainly familiar with the special characters that were used in this test. One Chinese student pointed out that the # character resembles closely Chinese character “jin”. Indeed, many subject developed mental shortcuts for punctuation characters.

Test procedure

All test subjects used the same Dell Latitude laptop with Windows XP operating system and no-glare 14 inch display, and a standard right-handed mouse. The program showed four characters, one character at a time, and after a short pause, the four characters were displayed in one of the specified orders: same (for example digits 4015), pairs (order of digits now 1540) or middle (order of digits 4105). The test subject had to choose between two alternatives which one was correct. The system recorded test response times for each mouse click, as well as correct and incorrect answers.

The test sets had two dimensions of difficulty: types of characters and the mental manipulation involved. The order of the test sets was as follows: first a letters set with 15 tasks, then a digits set, then a punctuation set, then another punctuation set, a set of digits, and a set of letters, all with 15 manipulation tasks respectively. The three manipulation conditions were “same” (working memory retention), and two conditions consisting manipulation of character order: “middle” where the second and third character changed place, and “pairs” where two last characters were shifted before the first characters. The letters test sets included consonant letters, 4 in upper case and 3 in lower case. The punctuation marks that were included are all regularly used as symbols in programming and code writing (table 1). The digits were included as a kind of control sets.

Letters	f H B g j K R
Digits	4 0 1 5 6 2 3
Punctuation	# $ % < ; { }

Table 1: Test character sets

All subjects were tested by the same investigator in a quiet office room in the university building. The subjects were first given an instruction sheet to read, and then the procedure was explained by the investigator. They first did a practice test set that consisted of 15 letter combinations. A break between test sets was allowed, but rarely used. After the test was completed, the subjects were given a questionnaire that inquired about test –taking strategies, and another questionnaire about their school background. The instruction advised using a verbal memorizing strategy, but in the end, test subjects also reported using other strategies in the actual test.

The results were analysed by a repeated measures ANOVA with two within-subjects variables: task with three levels (letters, digits, punctuation) and difficulty with three levels (same, middle, pairs), and one between-subjects variable, the cultural group.

RESULTS

Test data were analysed statistically with Statistical Package for Social Sciences (SPSS) and Excel software from different angles, some of which are presented below. The immediate analysis of test results indicated that there was conspicuous variation among subjects in response times as well as in accuracy. The majority of Chinese and Finnish test subjects performed evenly but among the other subjects, the variation between individuals appeared to be larger. Therefore, subjects were grouped according to their educational and cultural backgrounds, and groups were compared. The total test taking time ranged among African students from 1700 seconds to 2634 seconds (cases 10 to 18 and 30-33 in fig. 1), among the Chinese from 1640 s to 1949 s (cases 1 to 9 in fig.1), among the Europeans (including one American student) from 1593 s to 1859 s. The shortest total time was thus less than 27 minutes and longest nearly 44 minutes. Individual differences are shown in figure 1.

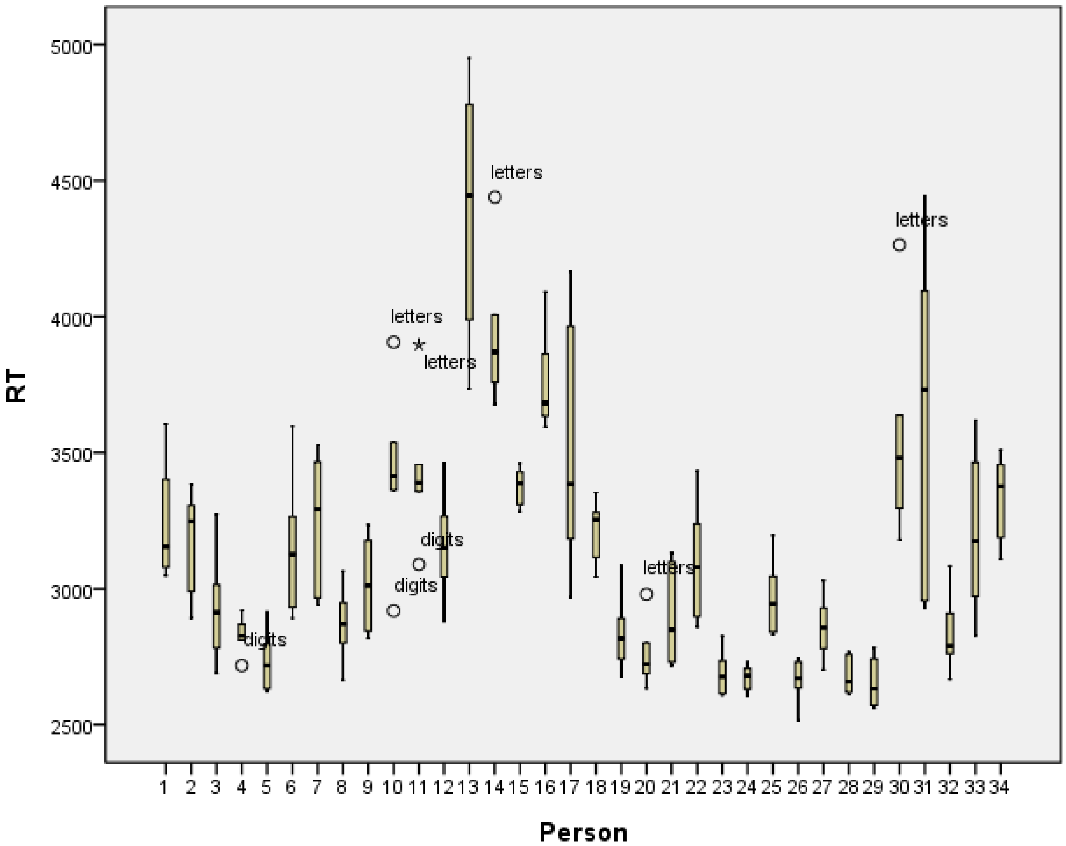

Figure 1: Individual response times variation

Response time analysis

A repeated measures ANOVA with two within-subjects variables (task, 3 levels and difficulty, 3 levels) and one between-subjects variable, the cultural group, gave no significant three-way interactions. Across groups, there was a main effect on task F(2,31) = 30.736, p<.01, and difficulty level F(2,31) = 69.823, p<.01. There were significant two-way interactions between task and group (p=.041) and difficulty level and group (p=.004) but not between task and difficulty level (p=.203). There was a main effect on group, F(2,31)=15.564, p<.01.

Figure 2 shows the response time variation within groups: in the African group mean was 3495 ms, SD=484, Chinese mean 3014 ms, SD= 253, and in the European group mean was 2843 ms, SD= 234.

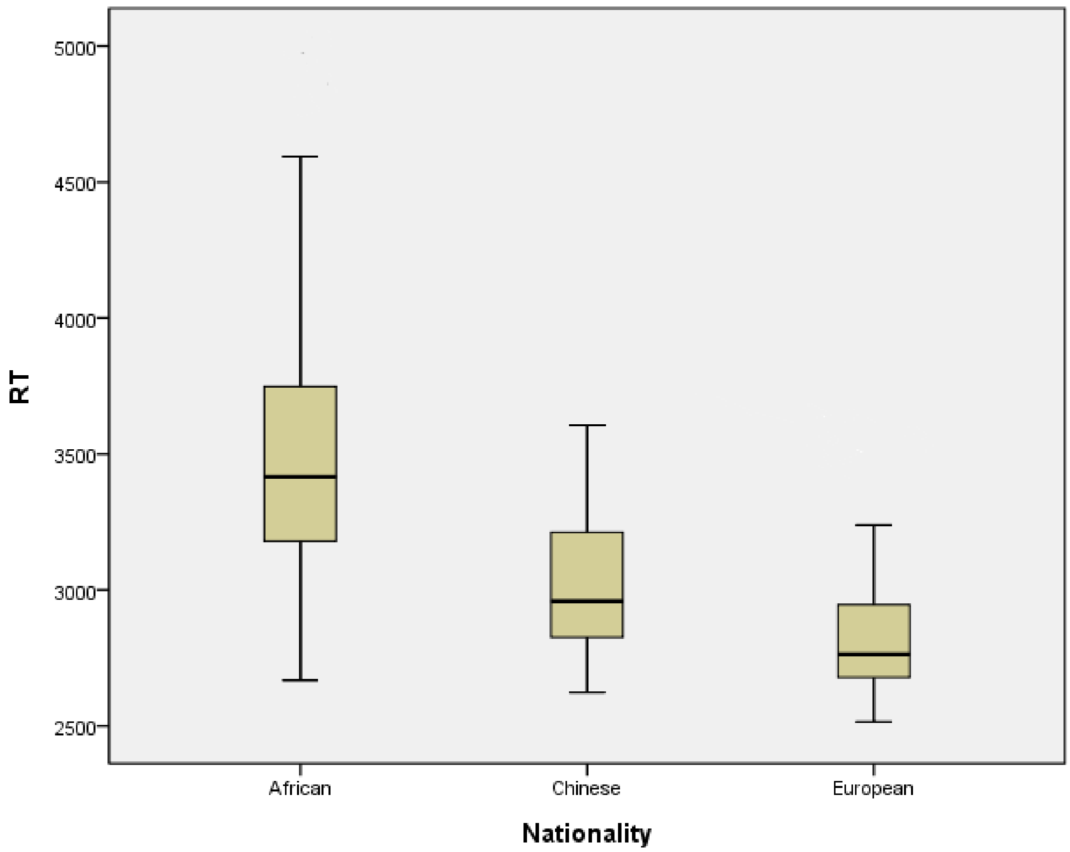

Figure 2: Response time means (ms) by cultural (“nationality”) group

The mean response times among all subjects reflected the difficulty of the task: the digits task was easiest (mean 3018 ms, SD=411), followed by the letters task (mean 3168 ms, SD=501), and the punctuation task turned out to be the most difficult (mean 3229 ms, SD=439). There was a significant difference between groups in all tasks (p<.01). Accordingly, the same condition was easiest, followed by pairs, and the middle condition was most difficult.

Unexpectedly, a difference in response times appeared even in the digits task, which obviously indicates a basic difference in response speed when working with computers (fig. 3). There was a small training effect from the first set to the second set, which was the same for all groups: the second task took about 15 seconds less than the first similar task.

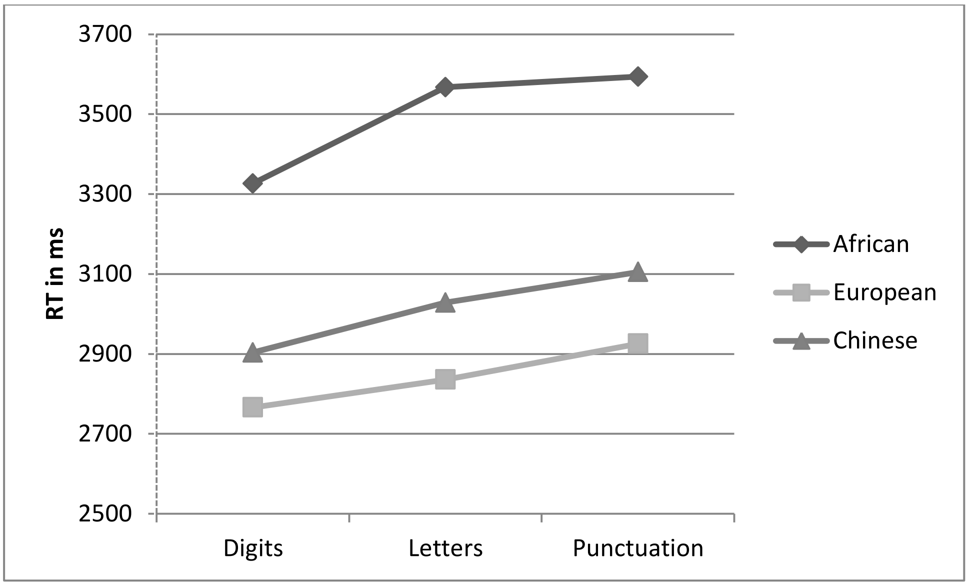

Figure 3: Response time means in digits, letters and punctuation tasks by group

In order to eliminate the impact on data of differences in individual-level reaction speed, the differences in processing times of letters and punctuation tests compared to digits test were calculated. The differences were calculated from averages of total times needed for one complete task. Response times increased more for punctuation and letters tasks in the African group compared to the European and Chinese groups, thus reflection time was longer for the more demanding tasks.

Accuracy
Similarly, the accuracy of selections was recorded. Figure 4 shows that accuracy of answers was very similar in the Chinese and European groups.

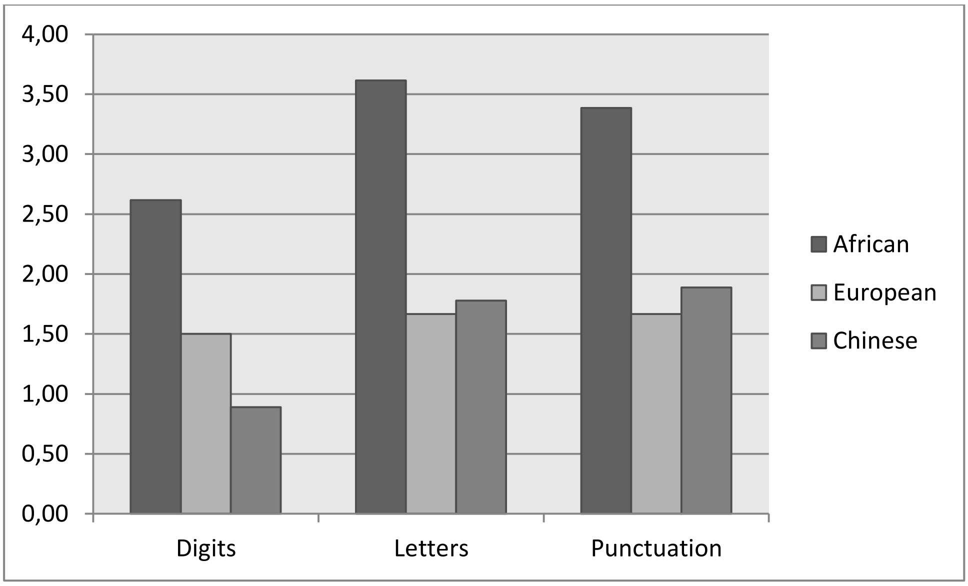

Figure 4: Average number of errors by person in each task type

Basically, subjects made only few mistaken selections, but again a pattern of differences emerged. Subjects that made few errors were among the faster students; therefore slow response did not increase accuracy. Three students made no wrong selections at all, whereas one subject made 28 errors. The average number of errors was about 7 per person (8% of selections).

DISCUSSION

Stereotypically, Finns are believed to be slow in their reactions. Africans are assumed to be easy-going and take their time. Chinese, on the other hand, practice multitasking. However, the stereotypes were not confirmed by this test: Finns had slightly faster reactions than the Chinese. Africans indeed turned out to work slower in average. Nevertheless, a "cultural" explanation is generally not tenable, as West-Africans and Ethiopians actually have very distinct cultures. Genetically they are also far from each other, thus genetic factors cannot explain the results (Tishkoff, et al, 2009).

Based on the hypothesis of cognitive retooling (Wilson, 2010), the African students apparently have background factors that influence their reaction speed: their personal use of technology and computers has usually been of shorter duration than in other groups, and therefore it is possible that actions such as responding to computer stimulus and clicking a mouse are less automatic. Factors such as previous test taking and computer gaming experience could also influence the result, because they give practice in anticipation that has a critical role in rapid response (Ericsson, 2003). On the other hand, Africans generally appreciate reflective and composed behaviour as opposed to making haste, which could have a subconscious effect to response speed (Milhouse;Asante;Nwosu;& (Eds.), 2001).

Boles (2011) has reassessed a number of studies concerning brain lateralization, discovering that a lower socioeconomic status (SES) has a negative impact on brain maturation. Even though none of student groups in this study come from lowest SES in their countries, some subjects may have had less rich environment for academic development in their childhoods than average Western students (Sternberg, 2005). A high level of economic development in a country usually guarantees a stimulating and varied learning environment for cognitive skills to thrive, which schools in poor countries seldom can offer.

However, the uniform performance of Chinese subjects in this study shows that economic conditions in a country offer only a partial explanation. The educational system seems to have a strong influence, as well. Presumably, the Chinese educational system includes a large amount of practice in writing characters. That has been shown to change brain specialization in reading and writing differently from alphabet users (Yang;Wang;Shu;& Zevin, 2011). No studies related to African or South Asian character systems and their effects on the brain are known yet. Nevertheless, school systems in developing countries tend to emphasize rote learning instead of hands-on practice. Writing practice is related to character recognition, and less practice leads to weaker character manipulation, consequently reducing accuracy.

CONCLUSION

Early school background seems to have far-reaching effects on later studies. It does not only affect the daily practices in studies and study skills but it also influences cognition and character perception considerably. Students with little previous exposure to IT practices and strict analytical work have to struggle more to learn programming fluency. Educators of international students need to be aware of the differences, and consequently, give more practice to students who need it. Apparently, the training should cover character manipulation and recognition skills and drilling type of practice that are not included in current academic curricula.

Our current understanding of the connection between writing practice and programming ability is very limited, particularly in the global scale. Especially now, when even primary school students increasingly work with keyboards and touch-screens, handwriting practice is decreasing everywhere in the world. The changes in cognitive tasks will lead to unanticipated changes in brain wiring. More research on its ramifications is definitely needed.

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Biography

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