Cross-cultural Differences in Special Character Perception – an Exploratory Study[1]

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Abstract

The research into cognitive diversity influenced by writing systems is starting to explore effects of European and East-Asian languages and character systems on cognition. However, African languages remain unexplored. Reading experience is different in Latin alphabet, Chinese logographic characters and Amharic syllabary. This study addresses variation of character perception by European, Chinese, and Ethiopian information technology students. Working memory performance was tested for numbers, letters, and special characters. Preliminary results indicate that a person's native character system affects the ability to memorize different types of characters. Working memory load seems to increase during the processing of less familiar characters.

Keywords: working memory; Chinese; Amharic; alphabet; cross-cultural neurolinguistics

Introduction

Cross-cultural research on cognitive processes has been hindered by difficulties in calibration and normalization of research conditions (Strauss, Sherman, & Spreen, 2006; Berry, Poortinga, Segall, & Dasden, 2002). However, the recent, fast development of brain research has introduced new methods that allow investigating cognitive processes at the physiological level. Kitayama and Park (2010) call this shift towards novel research methods the emergence of cultural neuroscience. Areas of cultural cognition that can be studied by neuroscientific methods include mathematics, reading, and writing. The brain functioning in reading seems to be affected by the particular writing system in use.

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Humankind has developed a great variety of writing and number systems during its history (Haarmann, 1990; Menninger, 1969). Arabic numerals are almost exclusively used in mathematics, whereas writing is divided between four major kinds of systems: Greek-derived alphabets; Chinese logograms and other East Asian systems based on them; syllabic writings in South Asia; and the Arabic consonant system. Research into the varied effects of these systems on cognition has commenced recently, especially in Japan and China, but most of the world's writing systems remain largely unexplored from the neuroscientific perspective (Kitayama & Park, 2010).

The aim of this study was to investigate how a person's native writing system affects the perception of program code that is written with Latin-based characters. Three groups of information technology students participated in the study: Western, Chinese, and Ethiopian. The groups had distinctly different backgrounds in learning characters and writing in school (alphabet, logograms, and syllabic characters, respectively), but all employed Latin characters in program coding. The students' working memory performance was tested in three tasks. The test aimed at measuring how much the student's native character system influences code perception and manipulation in working memory, and, indeed, significant differences were detected.

Cultural neuroscience and cognitive development

Most research concerning language and number processing has examined Indo-European language speakers (such as English, German, and Italian) who read alphabetic characters and use Arabic numerals (Hansen & Kringelbach, 2010; Anderson et al., 2013). A growing body of evidence points to differences in reading, processing numbers, and doing mental arithmetic in people who use predominantly logographic characters. Difficulties in reading such as dyslexia have already been shown to be caused by dysfunction in different brain areas in Chinese readers compared to English readers (Siok, Niu, Jin, Perfetti, & Tan, 2008).

Kitayama and Park (2010) give an overview of the current status of cultural neuroscience in a special issue of Social Cognitive and Affective Neuroscience. They define cultural neuroscience as an interdisciplinary field of research that investigates interrelations between culture, mind, and the brain. They underline that most of the research in this domain is very recent. After all, modern brain imagining methods, such as functional magnetic resonance imaging (fMRI) were only introduced about twenty years ago (Belliveau, et al., 1991). The technology develops rapidly, allowing safer, cheaper and more accurate experiments in the future. However, the growing body of research supports the hypothesis that recurrent, active, and long-term engagement in cultural tasks shapes and modifies brain pathways. Thus cultural tools and practices influence brain networks (Wilson 2010).

Brain development is fastest in infants when the process of genetically determined and experience dependent synaptogenesis followed by synaptic pruning shapes the connections between brain areas and leads to functional specialization of brain areas. Certain cognitive functions have an experience expectant period when that function or capability is sensitive to stimuli and develops particularly fast. Verbal ability (language) is a typical example: children learn to speak almost effortlessly between 18 months and 4 years of age. Just as linguistically sensitive periods have been linked to synaptic pruning in very young children, continuing synaptic pruning in adolescence suggests that there might be other sensitive periods. For example, research has shown that teenagers activate different areas of the brain from adults when learning algebraic equations and this difference has been associated with a more robust process of long-term storage than that used by adults (Howard-Jones, 2007).

According to Hannula and Lehtinen (2005) and Björklund (2007) mathematical abilities are built in early childhood, therefore, early education influences the development of mathematical competence. Young children do not spontaneously focus on numerosity, enumeration, and counting. Nonetheless, toddlers learn mathematical thinking in everyday activities supported by their caregivers. Adults working with young children play an important role in setting conditions for children’s experiences and possibilities to explore mathematical concepts and phenomena, and use mathematics in problem-solving.

Studies in reading and number processing

The Latin alphabet is one of the simplest writing systems. It is closely related to other Greek-derived alphabets such as Cyrillic writing (Gaur 1984). The Arabic consonant system is historically related to alphabets, but, significantly, it is written from right to left. Chinese characters are complex as such, moreover, the writing system contains thousands of logographs that can be pronounced in several ways. The perception of an individual character is visually demanding, as one character may consist of up to 23 strokes. Writing Chinese characters requires good hand movement control and visual memory, therefore Chinese speakers employ visuo-motor brain areas for reading and writing to a larger extent than alphabet users (Hansen & Kringelbach, 2010). Chinese is written in varied directions, including from left to right. Additionally, other contemporary writing systems include various syllabic writings in South Asia, and the Amharic system that is used in Ethiopia.

Intensive research concerning the processing of Chinese and Japanese languages has revealed significant differences in brain networks that are involved in reading logographic or alphabetic texts (Bolger, Perfetti, & Schneider, 2005; Perfetti, Cao, & Booth, 2013). The issue is further complicated by differences between transparent and non-transparent orthographies: languages with transparent orthographies such as Korean, Spanish, and Finnish employ phonologic brain circuits more than languages with non-transparent orthographies, such as Chinese, that activate more visuospatial functions, sublexical processing, and assembled phonology (Chen, et al., 2009). Languages that fall in-between such as English, French, Arabic, and Japanese presumably require both modes of processing.

Bolger, Perfetti, & Schneider (2005) found in their meta-analysis of alphabetic systems, Chinese, and Japanese writings, that basically the same brain regions are involved in word reading in these language systems (mainly the visual word form area in the left mid-fusiform gyrus). Nevertheless, certain localization differences are obvious between logographic and alphabetic systems. In a recent fMRI study, Yang et al. (2011) identified a typical ”reading network” in Chinese readers that showed evidence for stimulus selectivity in a much broader network than has been indicated before. Throughout the reading network, activity was largely modulated by task difficulty, but some regions showed selectivity for particular forms of sublexical information. The results are consistent with models in which sublexical processing (using spelling-to-sound correspondences to convert a written word into a spoken word) is a natural part of reading in Chinese where more grammatical interpretation is needed (Yang, Wang, Shu, & Zevin, 2011).

The universal use of Arabic numbers in mathematics raises a question whether these digits are processed the same way in people speaking various languages, such as Chinese and English. Tang et al. (2006) demonstrated a differential cortical representation of numbers between native Chinese and English speakers using fMRI. According to their findings, native Chinese speakers engage a visuo-premotor association network for mental calculation such as a simple addition task, whereas native English speakers employ a language process that relies on the left perisylvian cortices. Different biological encoding of numbers may be shaped by reading experience during language acquisition. Other cultural factors such as mathematics learning strategies and education systems might have an influence, as well.

Coderre et al. (2009) compared reactions to kana, kanji and Arabic numerals in Japanese subjects, finding no difference in behavioural reaction time between kanji and Arabic numbers. Liu et al. (2011) emphasize that numerical information can be conveyed by either symbolic or non-symbolic representation in Chinese characters, and that such multi-representation of magnitude has a speed advantage in processing, as well as lower error rates. Cao, Li and Li (2010) also detected differences in Chinese subjects in the response speed and distribution activation in the brain in the processing of three different numerical representations that were kanji, complex Chinese numbers, and Arabic numbers.

The processing of quantifiers and numbers by alphabet users seems to take place in the same brain domain, the left intraparietal sulcus, as well as numeric magnitude and number symbols (Piazza, Pinel, Le Bihan, & Dehaene, 2007; Cohen Kadosh, Lammertyn, & Izard, 2008; Cappelletti, Butterworth, & Kopelman, 2006). A letter-specific area for alphabetic letters has been located in the left extrastriate cortex (Flowers, et al., 2004). However, the processing of encyclopedic numbers (mixed with letter codes) is separate from numbers (Cappelletti, Jansari, Kopelman, & Butterworth, 2008). Already the ground-breaking study by Polk and Farah (1998) indicated that separate brain regions are specialized in numbers and letters, and the processing usually does not overlap. If it overlaps, it requires considerably more effort. It was shown that processing of Canadian or UK postal codes, such as KY169UH, that mix numbers and letters is difficult and requires more concentration than exclusively numerical or alphabetical codes. Nevertheless, postal workers developed a brain mechanism to treat them together after practice.

Research questions and hypotheses

Computer programming entails a significant amount of character manipulation: programming commands, variables, and operations are usually abbreviated English words, or in some cases mathematical symbols. Therefore, previous exposure to Latin characters, including punctuation, may influence programming fluency especially during the learning period. In this study, information technology students with a background in different writing systems were tested. The aim was to investigate whether little exposure to Latin characters might cause difficulties in working with program codes.

Computer programming requires not only logical thinking but also close attention to detail and accuracy. Programming languages are formal languages with a condensed and precise vocabulary without any kind of redundancy; unlike natural languages that can contain ambiguous, vague, and superfluous statements. Ordinary tasks in programming include mathematical and logical operations, comparing values, and sorting lists for instance in alphabetical order. A weblink in common HTML code looks like this:

```
<a href=”http://news.bbc.co.uk”>News</a>
```

A script that calculates the sum of 5 first numbers and prints them on screen is written as follows:

```
for (i = 0; i <= 4; i++)
{
result += i;
document.write (i + ": " + result");
}
```

As the code examples show, quotes and brackets are essential in structuring the code. The code must be symmetrical: an opened quote has to be closed, as well. Even the smallest spelling mistake, such as a missing punctuation character, usually destroys the meaning of the rest of the code.

This study was prompted by the observation that information technology students in international groups learn code writing differently depending on their background. The difficulties and coding errors show different patterns among Arabic, Chinese, Ethiopian, and Nepalese students (Holvikivi, 2009). A closer analysis of the problems indicated that they might depend on the native character system of the student. Chinese logographic characters and Ethiopian (Amharic) syllabic scripts differ from the Latin character systems in their punctuation and sentence structure. Particularly interesting was the observation that coding errors were related to mistakes in English punctuation and spelling. Moreover, the punctuation problems were very hard for students themselves to detect, despite spell checkers that are included in word processing software. Code editors similarly have tools to point out wrong spelling and punctuation by highlighting code elements with colours, which helps to see the structure and eventual mistakes. Editors also have a preview mode that shows the result instantly. Nevertheless, some students failed to detect errors in code such as a missing bracket or semicolon, or a space missing between a command and its parameters.

Because the difficulties in producing error-free code concerned a considerable proportion of students, it seemed apparent that native character systems influenced students' ability to produce syntactically correct program code. The current study was designed to investigate this issue further, especially in the case of Chinese and Ethiopian students, who constituted a large share of the international students.

This study was designed to detect differences in remembering code elements, numbers or alphabetic characters between student groups. All test subjects were assumed to have an equal educational background, except for the experience of using Latin characters. It was hypothesized that early learning and regular use of Latin characters would give an advantage to students whose native language uses the Latin alphabet over users of other writing systems. Chinese was selected, because numerous studies show that reading and manipulating numbers takes place in other brain regions in Chinese than in English users. Amharic processing has not been studied previously, as far as we are aware of.

The comparison group consisted of students who had used exclusively Latin characters and Arabic numerals. All test subjects had always been working with Arabic numerals, therefore the test sets including digits were assumed to be equally challenging for all groups. The Chinese group had presumably least experience with Latin characters. The Ethiopian, Amharic speaking group was familiar with a different style of alphabet and orthography, which nevertheless, has the same direction (left to right) of writing as Latin characters. Therefore, differences based on writing system were expected in the letters task. Two measures were used: response time (RT) and accuracy. The hypothesis was that the influence of native character system would be displayed on RT or accuracy, or both. The level of difficulty of the test was expected to reflect in both.

Methods and procedures

Participants

The test group consisted of students who had Chinese logograms, Ethiopian Amharic syllabary, or Latin alphabetic characters as their first writing character set, including 9 Chinese students, 9 Ethiopian students, and 12 Finnish and other Latin character users as a control group. The number of test subjects was limited by the total number of students from different backgrounds. Of the Latin character users, 10 were native Finnish speakers who had Finnish as school language, but had also studied English in school. These languages are written with the same Latin script with minor variations. Two test subjects were native English speakers.

All 30 participants were healthy male undergraduate students in the Information and Communication Technology (ICT) department of a Helsinki area University of Applied Sciences. The research was ethically approved by the School of ICT. Test subjects were recruited on voluntary basis and they gave their informed consent to the anonymous use of test results. The subjects were given a movie ticket as a reward after undertaking the test that took nearly one hour to complete. Their ages ranged from 20 to 30 years, mean 24.4 years (SD= 2.9). The average age in the groups was 26.9 years (*SD*= 2.3) for Ethiopian, 22.7 years (*SD*= 1.6) for Chinese and 23.8 years (*SD*= 2.8) for Latin writers.

Most of the subjects studied in an English medium degree program, except for 6 Finnish students who studied in a corresponding Finnish medium degree program. The Ethiopian students had all finished high-school in Ethiopia before emigrating. Most of them had also previous university studies, either in Ethiopia or in Finland. In Ethiopia, the medium of instruction was Amharic until sixth grade, and after that English. The Chinese students had finished their high school in mainland China, conducting all studies in Chinese.

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. Because of the rather low retention rate in the information technology degree programmes (around 60%), the study records of test subjects were checked after the test. All recruited students had performed average or well in their studies.

All subjects reported that they had always studied mathematics using Arabic numerals despite the existence of native Chinese and Amharic numbers. Therefore, we can assume that all subjects were equally familiar with numbers. Chinese subjects, in particular, emphasized the easy, short number words in their language, which are easy to memorize and manipulate. The number words 0,1,2,3,4,5,6 in Chinese are: “ling, yi, er, san, si, wu, liu”; in Amharic: “zero, ande, hulet, sosit, arat, amest, sedeset”; in Finnish: “nolla, yksi, kaksi, kolme, neljä, viisi, kuusi”. Even though Finnish words have two syllables, people use in quick counting shortcuts [ȳ - kā - kō – nē - vī – kū], therefore Finnish students probably had no handicap in this part of the test. Similarly, the Ethiopian students pronounced their numbers quickly as one phoneme.

Amharic is written in a syllabic alphabet called the Ge'ez script. It is an abugida meaning that each symbol represents a consonant - vowel combination, and the symbols are organized in groups of similar symbols on the basis of both the consonant and the vowel. Ge'ez is written from left to right across the page. The Unicode range for Amharic is 1200 -137F.

ቊ k’^{w}i	ቋ k’^{w}a	ቌ k’^{w}e	ቊ k’^{w}i	ኊ h^{w}i
ጓ g^{w}a	ጔ g^{w}e	ጒ g^{w}i	ሏ l^{w}a	ቧ b^{w}a

A sample of Amharic characters

愛 Ài	呆 dāi	黑 hēi	馬 mǎ	山 shān
安 ān	但 dàn	很 hěn	民 mín	善 shàn

A sample of Chinese characters

Table 1: Examples of Amharic and Chinese characters

Experiments

The tasks were three versions of the verbal working memory task described Lewis et al. (2003). In the first task version, the memoranda were letters presented in upper and lower case. In the second version, the memoranda were Arabic numerals, and in the third version, programming symbols (punctuation and special characters). The tasks were programmed by using the Presentation software developed by Neurobehavioral Systems Inc. that also collected the correct and incorrect responses (button presses on the mouse) and RTs. The sequence of actions in the trial is shown in Figure 1.

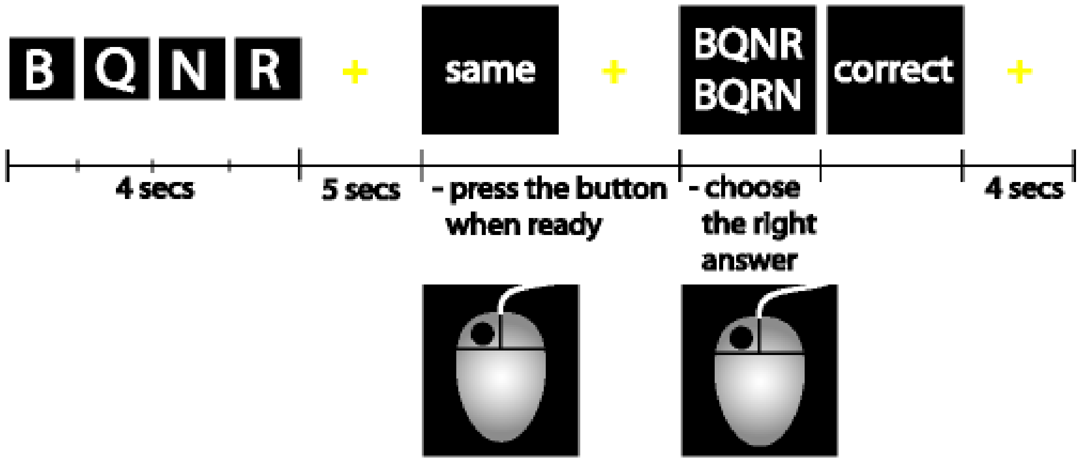

Figure 1: A trial sequence in the working memory task

In one trial sequence, four different characters were presented to the test participant, one per second. A five second retention period with a blank screen followed, when the participant was advised to rehearse the order in his mind. After the retention period, a cue word (either same, pairs or middle) appeared on the screen that instructed the participant either to maintain the original order of the characters (same), or to manipulate the order in their mind by changing the order of the first and second pair of characters (pairs), or to change the order of the two middle characters (middle). After completing the manipulation, the participant was instructed to press the left mouse button. Following the button press, two alternative sets of four characters were presented, one above and the other below the centre of the screen. The participant was instructed to select the correct set of characters that corresponded to the requested manipulation by pressing the left mouse button if the upper set was correct, and the right button if the lower set was correct. The participants were instructed to press the button as fast and as accurately as possible. After the response, feedback on the correctness of the selection was given on the screen. After the feedback, there was a pause of four seconds before the next set of characters was presented. One set of trials included 15 sequences, and took about 5 minutes.

The conditions measured three aspects of working memory: **same** for maintenance and retrieval, **pairs** and **middle** for maintenance, manipulation and retrieval. The cues were:

same: BQNR -> BQNR

pairs: BQNR -> NRBQ

middle: BQNR -> BNQR

The trials were performed using three different types of symbols and characters. In the first trial, letters were presented in upper and lower case; in the second trial, Arabic numerals (digits); and in the third trial, programming symbols (punctuation). After that, three more trials were presented in a counterbalanced order of punctuation, digits, and letters.

The character sets in the test were as follows:

Letters: f H B g j K R

Digits: 4 0 1 5 6 2 3

Punctuation: # $ % < ; { }

The task including punctuation symbols was expected to be the most difficult. Most of the symbols that were used in this test, namely # $ % < { }, are usually connected with mathematics and, thus, with numbers, whereas the semicolon also appears in written text. Therefore, processing these characters was expected to be slower and more difficult than processing ordinary small numbers or letters. Because of the absence or at least minor importance of punctuation in Chinese and Amharic, the punctuation task was expected to be more demanding for students from these backgrounds than for Latin character users.

Procedure and handling of behavioural data

All subjects were tested individually by the same investigator in a quiet office room in the university building. The tasks were presented with a portable computer. 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 subjects were first given an instruction sheet to read, and then the procedure was explained by the investigator. The instruction sheet for Finnish subjects was in Finnish, for others in English. The participants did first a practice test set that consisted of 15 letter combinations (trials). After that they were asked if they wanted to practice more, and all but two decided to take the test immediately, the remaining two subjects did an additional practice set. A break between test sets was allowed, but rarely used. The instruction advised for a verbal memorizing strategy, but test subjects also reported using other strategies in the actual test, which are described below. After the test was completed, the subjects were given a questionnaire that inquired about test –taking strategies, and another short questionnaire about their schooling background.

The accuracy was measured as the number of correct responses in the tasks. Response times (RTs) of the first and second responses, i.e. the time needed to manipulate the characters and to select the correct answer, respectively, were combined for statistical analysis. The results were analysed by a repeated measures ANOVA with two within-subjects variables: Task with three levels (letters, digits, punctuation) and Condition with three levels (same, middle, pairs), and one between-subjects variable, the language Group (Latin, Chinese, Ethiopian).

Results

Accuracy

Across groups, there was a main effect of Task on accuracy ($F(2,26) = 13.644$, $p<.01$), but no significant main effect of Condition ($F(2,26) = 1.056$, $p = .362$), and no significant two- or three-way interactions. The mean number of correct responses for punctuation and digits tasks is presented in figures 2 and 3 by Group and Condition. As hypothesized, across groups, the digits were easiest to remember and manipulate, followed by letters. The punctuation task was the most difficult.

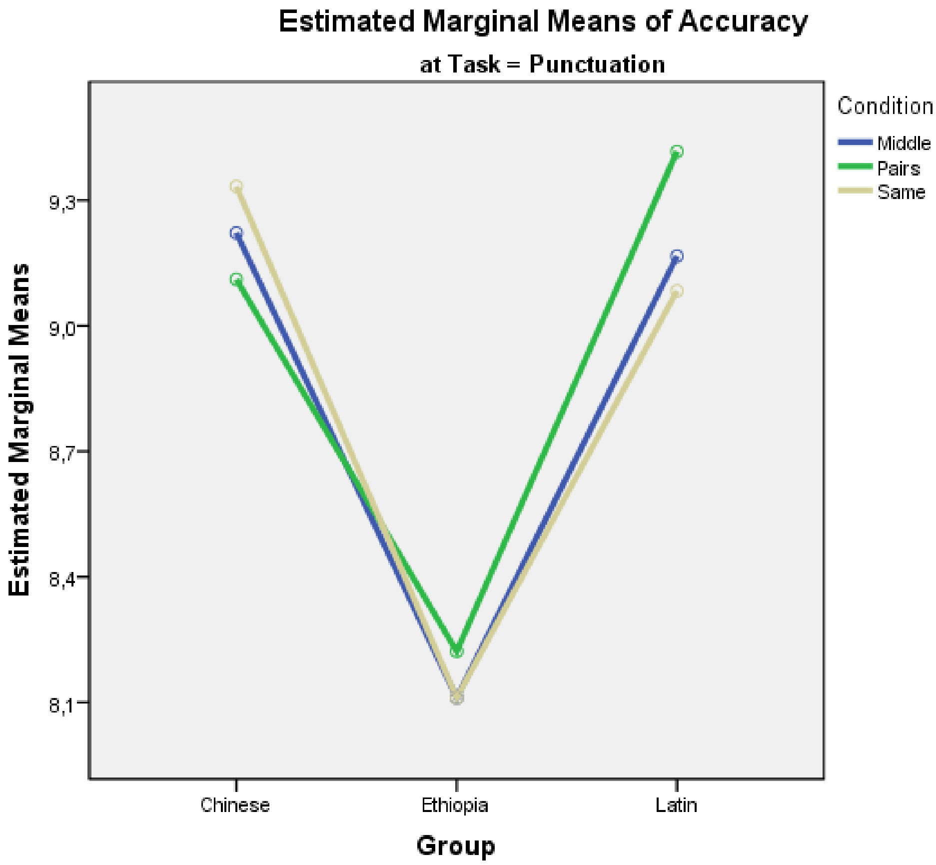

Figure 2: Correct answers in punctuation task by group and condition

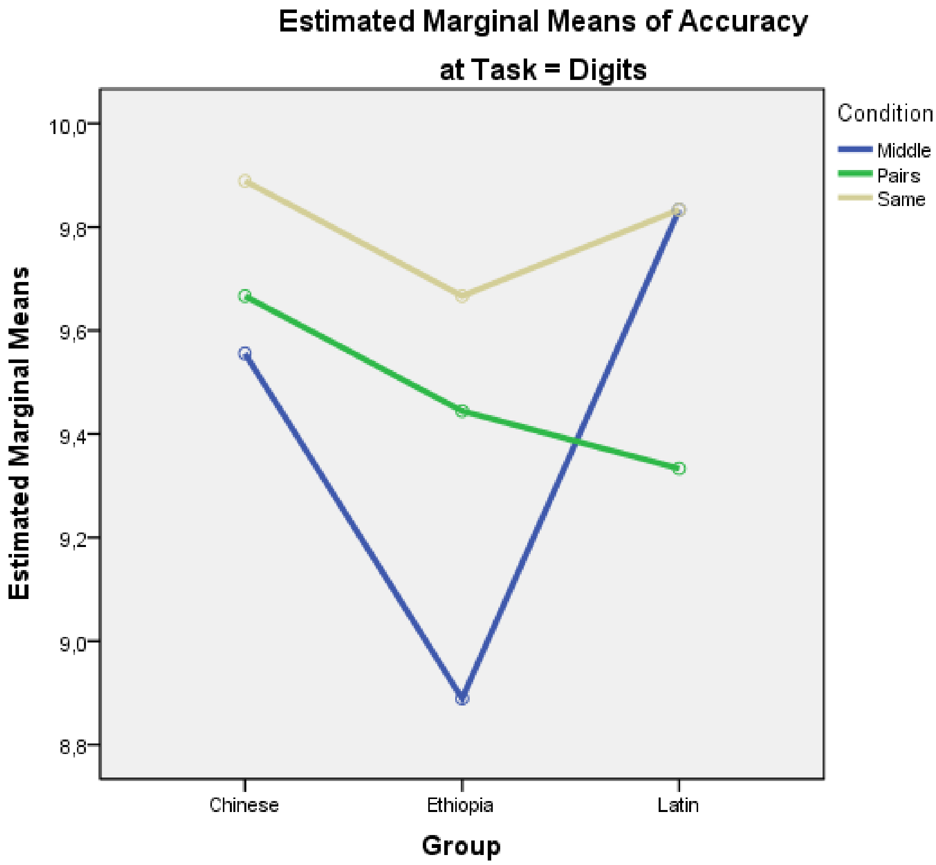

Figure 3: Correct answers in digits task by group and condition

There was also a main effect of Group on accuracy (F(2,26)=4.068, p=.029). The Chinese group made least errors per test set (correct selections mean 9.47, SD=0.80), with only a small difference to the Latin group (mean 9.46, SD=0.71), but a larger difference to the Ethiopian group (mean 8.78, SD=1.50). The Chinese and Latin groups made roughly similar number of errors over all conditions, but the Ethiopian group was significantly less accurate over all conditions when compared with the Chinese group and with the Latin group. A post-hoc Tukey test showed a significant difference in means between the Latin and Ethiopian groups p=.041. The difference between Chinese and Ethiopian failed to be significant, p=.056, and between Latin and Chinese there was no difference. (Table 2)

Table 2: Post Hoc Tests: Group and Response Time

Multiple Comparisons

Measure:ResponseTime

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Tukey HSD	Chinese	Ethiopia	-3640,0090*	880,85576	,001	-5824,0184	-1455,9997
		Latin	1097,8352	823,96511	,390	-945,1185	3140,7889
	Ethiopia	Chinese	3640,0090*	880,85576	,001	1455,9997	5824,0184
		Latin	4737,8442*	823,96511	,000	2694,8906	6780,7979
	Latin	Chinese	-1097,8352	823,96511	,390	-3140,7889	945,1185
		Ethiopia	-4737,8442*	823,96511	,000	-6780,7979	-2694,8906

Response times

The RTs differed between the Tasks (a main effect of Task, $F(2,26) = 13.644$, $p<.01$). The digits task was performed fastest (mean RTs 4983 ms, SD=3862), followed by the letters task (mean 5970 ms, SD=4654) (figure 4), and the punctuation task (mean 6399 ms, SD=4844) (Figure 5). The difference in the RTs between the digits and the letters tasks was significant (Tukey, $p<.01$), and between the digits and the punctuation tasks ($p<.01$). The difference in the RTs between the letters and the punctuation tasks did not quite reach significance ($p=.06$).

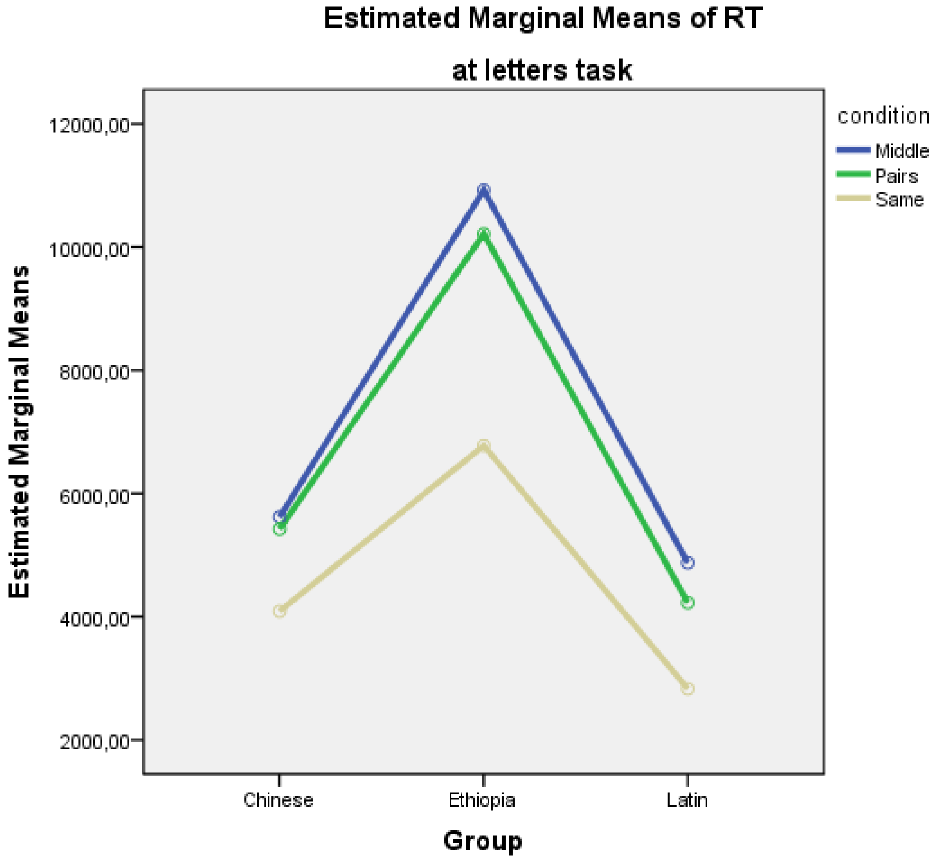

Figure 4: Response time means in letters tasks by group and condition

There was also a main effect of Condition on RTs ($F(2,26) = 70.836$, $p<.01$). The same condition was performed fastest, and the RTs of the same differed significantly from the RTs of the other conditions (same vs. pairs and same vs. middle, $p<.01$in all). There was no significant interaction in the RTs between Task and Condition ($F(4,24) = 2.229$, $p=.096$).

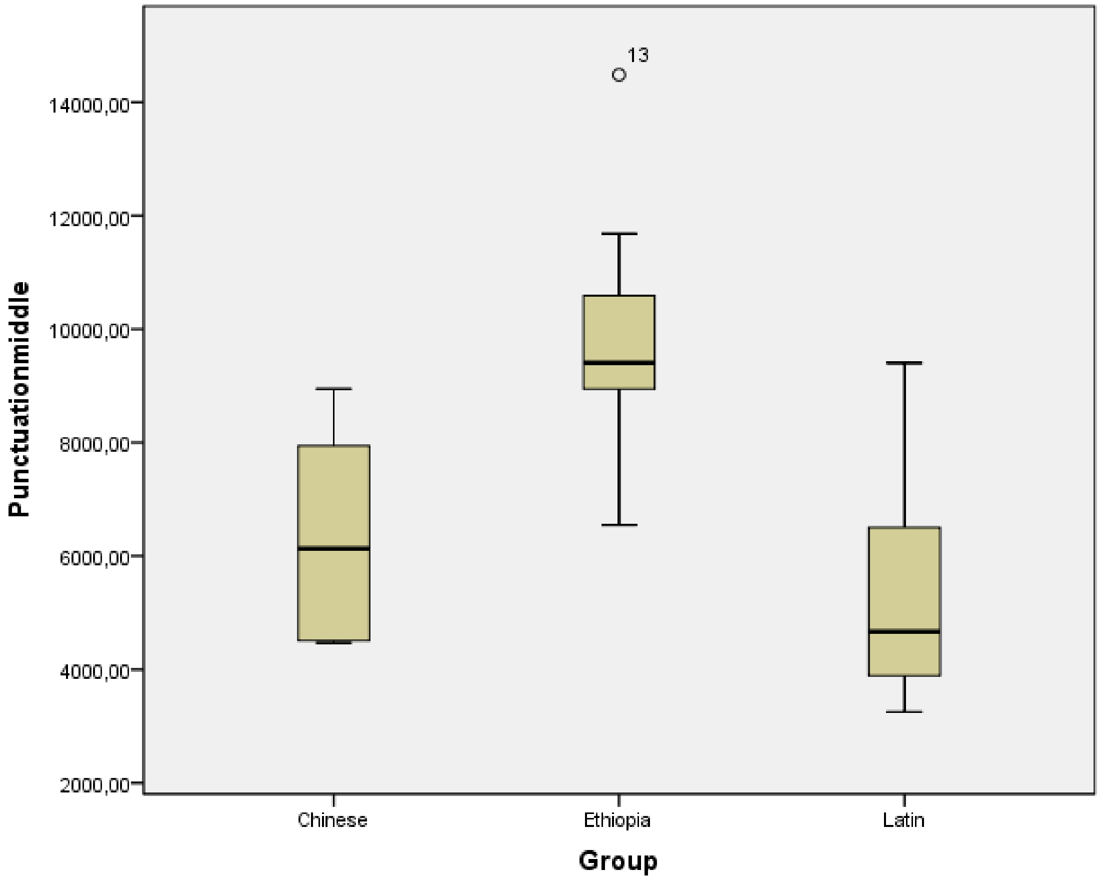

Figure 5: Response time means in punctuation tasks, middle condition by group

The RTs differed between the groups (main effect of Group ($F(2,27)=17.316$, $p<.01$) and there were significant two-way interactions in the RTs between Task and Group ($F(4,52) =2.626$, $p=.045$) and between Condition and Group ($F(4,52) = 3.752$, $p=.009$). A post-hoc Tukey test showed a significant difference in means between the Latin and Ethiopian groups $p<.01$, and between Chinese and Ethiopian $p<.01$, and between Latin and Chinese there was no significant difference $p=.390$. There was a remarkable difference between the Ethiopian and other groups even in the digits task, which obviously indicates a basic difference in response speed (motor reaction), figure 6.

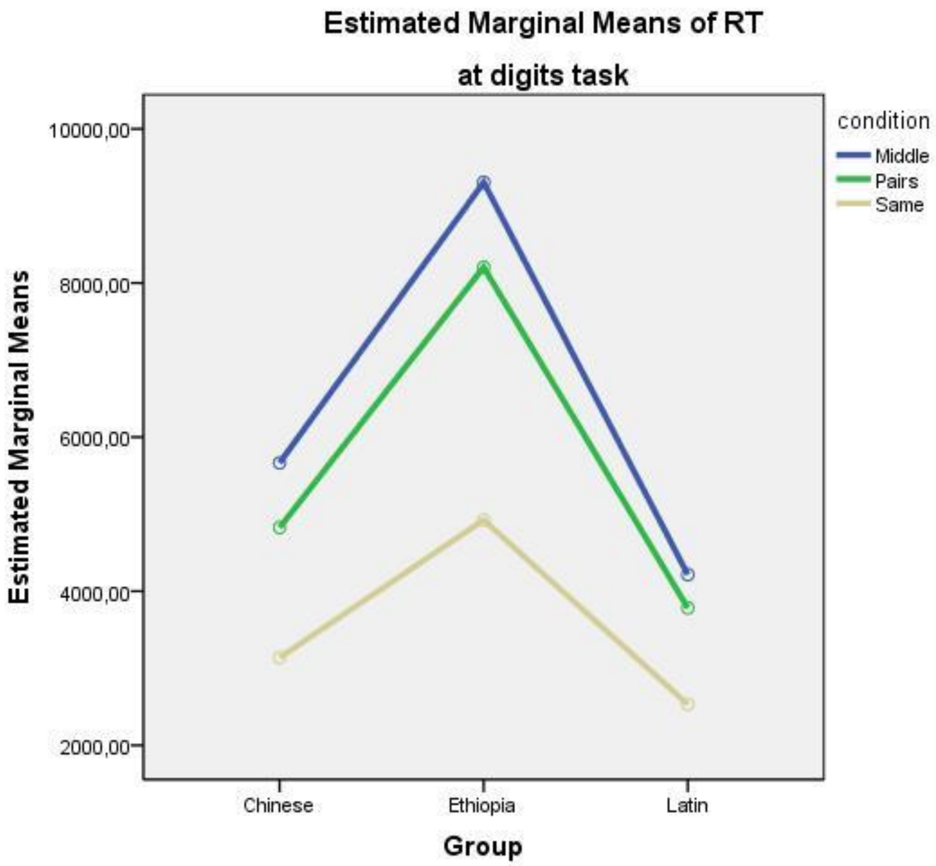

Figure 6: Response time means in digits tasks by group and condition

Treatment of results

The data analysis at the group level revealed that the Chinese group and the Ethiopian group were clearly distinct from each other in both response times and accuracy. The Finnish/ Latin group turned out to be the fastest group in terms of average response times. However, the Chinese group was most accurate in their answers.

In the earlier study (Lewis et al, 2003), where this memory test was applied, response time 1 (RT1) was assumed to include thinking time, and response time 2 (RT2) was assumed to be used mainly for selection, which would mean that it included only motor response time. The relation between RT1 and RT2 was analyzed in this study, but no clear separation on reflection and selection could be found. The interviews on test taking strategies revealed that subjects did not follow the instruction to memorize first. Apparently, test subjects also used the second pause for deciding, which is discernible from the length of the time for RT2. There was no correlation between RT1 and RT2, in fact the Pearson correlation value was positive 0.27, meaning that a difficult case took more time in both phases. Because no evident difference between thinking in phases 1 and 2 could be detected, the two response times have been added together in the analysis of the results, assuming that both include reflection and motor response.

Response times for correct answers were compared to all response times. Very little difference was detected between RT values in case of correct or incorrect answers, therefore giving a right choice did not consistently take longer or shorter time than making a mistaken choice. As a conclusion, responses for correct and mistaken selections were treated together in the analysis.

Test taking strategies

Test subjects were instructed to memorize the characters verbally and to practice subvocal rehearsal. Some subjects used this technique auditorily, and mumbled the words half-loud, but most subjects did not stick to one approach exclusively. The post-test questionnaire inquired which technique was used in which part of the test. Most subjects described using verbal strategy, i.e. repeating names of characters in their mind, but actually most also used some supporting or short-cut approach. Among those visual images, memorizing in pairs, or memorizing only part of the set were mentioned.

One Chinese student reported combining two letters into a word, such as fB facebook, and gf girlfriend. Two Chinese converted punctuation characters to similar Chinese characters in their minds, and memorized their names. One Chinese student pointed out that the # character resembles closely Chinese character “jin”. One Ethiopian student reported making up a story of the letters. One Finnish student used a technique that he had adopted in his military training, applying fire control coordinates to numbers and letters. One student informed that he “cleared” his memory after each set by repeating small numbers in his mind. Ericsson (2003) notes that practice effects are found with tests of basic perceptual and perceptual- motor performance for virtually every task, and the improvements are considerable. Many subjects reported having developed their technique during the test, which could be seen in faster performance closer to the end. However, subjects generally found it hard to explain exactly what kind of technique they actually used.

In the letters condition, a verbal technique was indicated by 24 subjects, whereas 3 mentioned verbal- visual, 2 visual and one auditory or combined visual – verbal – auditory technique. In the numbers condition, the use of a verbal technique was indicated by 19 subjects, whereas 3 mentioned verbal- visual, 5 visual and 1 auditory or combined visual – verbal – auditory technique. In the punctuation condition, verbal technique was indicated by 12 subjects, whereas 4 mentioned verbal- visual, 11 visual and one a combined visual – verbal – auditory technique. Two subjects used a visuo-sensory or verbal-sensory strategy, such as tapping a finger on left side of the knee for opening bracket and right side for closing bracket. There is no correlation between the indicated approach and response times or correctness of the results on the individual level.

On the group level, a verbal approach was mentioned 20 times, and visual 8 times by the Chinese in selecting their strategies. The Ethiopian subjects mentioned verbal 15 times, and visual 15 times. Latin character users chose verbal 34 times, and visual 9 times. Because more than one selection was allowed, the sums are not equal to the number of subjects. It is somewhat surprising that the Chinese chose verbal strategies more frequently than the alphabet users.

Subjects were also asked to evaluate the difficulty of different tasks on the scale 1 to 5. As expected, the number task was evaluated as easiest (mean 1.3), followed by the letters task (2.1), and memorizing punctuation characters was considered most difficult (3.3). Similarly, the “same” condition, retaining characters in memory, was found to be easiest (1.2). Subjects had varied opinions of whether the pairs condition (2.3) or middle condition (2.9) was more difficult.

Many studies such as Tang et al.’s (2006) suggest that Chinese speakers use a visuo-spatial system in representing Arabic numerals. In this study, however, Chinese subjects did not report visuo-motor strategies in number processing more than others. One Chinese subject complained that the mouse selection for correct and incorrect answers was counterintuitive when the upper selection was mapped to the left mouse button and lower selection to the right mouse button.

Individual reaction speed

In this test, Finns and other Westerners had faster reactions than the Chinese. Ethiopians turned out to work slower. This result is partially consistent with earlier findings on elementary cognitive tasks where African subjects tended to have longer reaction times. Van de Vijver (2008) made comparisons of Zimbabwean and Dutch school children, and according to his results, the differences disappeared along a training effect. However, in this study the size of training effect was the same for all groups so that the second task took on average 15 seconds less than the first similar task.

Berry et al. (2002) summarize 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. Based on the hypothesis of cognitive retooling (Wilson, 2010), the African students could have background factors that influence the 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 on mouse are less automatic. Factors such previous testing experience and computer gaming could also influence the result, because anticipation has a critical role in rapid response (Ericsson, 2003).

Discussion

The typical difficulties incurring in cross-cultural experiments were present in this study, as well: first, comparing factors of intelligence, and second, familiarity with test taking. Numerous studies document lower performance estimates on cognitive tests in minority populations including tests of nonverbal intelligence that claim to be culture-free (Strauss, Sherman, & Spreen, 2006; Sternberg, 2005). Ethnicity has an impact on intelligence test scores, and therefore, calibration should be done within groups. Forming comparable groups of international students was challenging, however, because the student population was diverse in all aspects, also within nationality groups. Moreover, the composition of the particular student body under examination limited the choice of nationalities and number of test subjects.

Laboratory experiments such as those conducted here are based on a Western model, placing other cultures in a disadvantaged position. Western tests presuppose conventions and values that are shared by the test taker and the test administrator, but that are unlikely to apply in other societies (Ericsson, 2003). We cannot be sure that our test subjects comprehended task instructions, and generated a strategy for completing the tasks exactly in the same manner. Even though basic cognitive processes are universal and shared by all humans, varying cultural contingencies and affordances may result in functional differences in cognitive strategies (Henrich, Heine, & Norenzayan, 2010).

The subjects in this test were selected from the same degree program, therefore, they were assumed to be professionally comparable and with approximately equal cognitive capacities. The hypothesis was that their results differ only in letter and special character manipulation depending on their native character system. The effect of the native character system was apparent in the accuracy and response times in particular in the Ethiopian subjects. Differences between Chinese and Western subjects were also detected, but they were ambiguous, and not significant. The digits task that was assumed to be easiest for all subjects, indeed turned out to be so. This finding is consistent with other studies, which show that subjects are better at identifying digits than letters under conditions of brief exposure (Starrfelt & Behrmann, 2011).

Conclusion

We might conclude from this study that the lack of familiarity with the Latin alphabet could be detected in the test results for the Ethiopian group that had Amharic characters as their native character set. Moreover, the effect was strong and persistent taking into account that the subjects had at least ten years of study with the alphabet. On the other hand, it did not seem to affect the performance of Chinese students. Presumably, use of Chinese characters develops working memory capacity and ability to recognize all kinds of character shapes.

The mental processing of numbers in test subjects remains partly unaccounted for: they reported of having repeated native number words in their minds, but many earlier studies indicate that actual processing could also have used symbolic, visual representation (Chen, Xue, Mei, Chen, & Dong, 2009). Culture-specific early experience influences the formation of brain networks, and determines how numbers are processed. Finnish language has a transparent orthography, which makes it similar to Italian but different to English which has a less regular spelling. In some studies, reading Italian has been shown to rely on phonologic circuits more than English. The Chinese logographic script results in symbolic instead of phonological processing (ibid.). The vocalization of numbers has in earlier studies prolonged response times, but there is no indication here of that phenomenon. Coderre et al. (2009) claim that the numerical memory span differs depending on the use of phonology. Symbol use would results is shorter memory span than phonological memorizing. The results here were inconclusive.

The interpretation of the results of the present study is hypothetical only, and the mechanisms that produce the results need to be studied separately. Self-reporting gave very little enlightenment to the internal processes. Brain scans of users of different types of characters would increase our knowledge of reading and writing processes, their variation and universals. Additionally, users of some other languages and scripts would be worth of studying, such as people from the Indian subcontinent who also have a syllabic native writing system (Nag, Snowling, Quinlan, & Hulme, 2014).

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