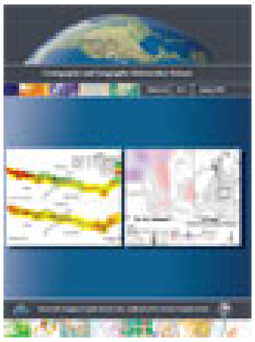

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ARTICLE

Cross-cultural differences in figure–ground perception of cartographic stimuli

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ABSTRACT
This article reports on an empirical study investigating cultural differences in the visuospatial perception and cognition of qualitative point symbols shown on reference maps. We developed two informationally equivalent symbol sets depicted on identical reference maps that were shown to Czech and Chinese map readers. The symbols varied in visual contrast with respect to the base map. Our empirical results suggest the existence of cultural influences on map reading, but not in the predicted direction based on the previous cross-cultural studies. Our findings stress the importance of considering the cultural background of map readers, especially when designing reference maps aimed for global online use.

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KEYWORDS
Cultural differences; map reading; visualization; visual perception; user testing

Introduction

Psychologists' interest in the relationship between culture and cognition dates back to the beginning of the twentieth century. Pioneering single-culture studies conducted by Rivers (1905) inspired further research in the field. Early research focused mostly on the role of the environment and past experience on perception. Segall (Segall, Dasen, Berry, & Poortinga, 1990) formulated hypotheses about the relationship between the physical characteristics of perception and the environment. Blakemore and Cooper (1970) demonstrated the influence of individual experience on the development of perceptual abilities. Hudson (1960) and Deregowski (1972) conducted experimental studies on the interpretation of depth cues in African cultures. Other experiments used visual illusions to explore cross-cultural differences in the perception of symmetry, spatial orientation, perceptual constancies, or object recognition (see Deregowski, 1980). The formulation of Gestalt principles of perceptual grouping and figure–ground organization (Wagemans et al., 2012) inspired an entire line of cross-cultural research based on the Navon hierarchical stimuli method (Navon, 1977).

The focus of more recent studies enriched the investigation of the role of experience and environmental factors in perception and cognition by the incorporation of socio-cultural, economic, and political factors (Berry, Poortinga, Breugelmans, Chasiotis, & Sam, 2012) into the model of relationships between culture and cognition. The theory of holistic and analytic perception was formulated on the basis of the earlier theories of cognitive styles that are defined as relatively stable modes of informational processing (Kozhevnikov, 2007; Tiedemann, 1989), primarily on Witkin's theory of field dependence (Witkin & Goodenough, 1977). The research projects conducted within the boundaries of the theory were so far mainly focused on the comparison of two economically developed cultural regions: The West (USA, Western Europe) and East Asia (China, Japan, South Korea).

The theory postulates that there are two distinct cognitive styles: holistic and analytic. Whereas the analytic style is typical for Westerners, who rather attend to focal (i.e. perceptually salient and semantically relevant) objects and their characteristics than to background or context information in a visual scene, the holistic style is typical for East Asians, who mostly attend to the relationships between objects in a visual scene and to context information (Nisbett & Miyamoto, 2005). Different sociocultural factors can produce the development of distinct cognitive styles, such as the differences in philosophical systems, the complexity of social relations, self-construals, social practices, and child-rearing practices (Nisbett & Masuda, 2003). The abovementioned differences between the two distinguished cognitive styles are further pronounced by the use of different writing systems, which require a different set of skills to master (Huang & Hanley, 1995).

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There are several methods commonly used to measure holistic and analytic cognitive style and its manifestations, which vary in their overall visual complexity from relatively simple tasks to more elaborate and complex tasks. The simplest of these methods is the Framed-line test (FLT; Kitayama, Duffy, Kawamura, & Larsen, 2003), currently considered the benchmark of holistic and analytic cognitive style diagnostics. The test is designed as a succession of geometrical figures that are comprised of a square frame and a vertical line. First, a frame with the vertical line is presented to a participant. Subsequently, a second frame is showed to the participants and the size of the second frame can be either the same as the original, or it can be increased/decreased. Participants are supposed to outline a line that is identical to the observed line in either the absolute length (in the absolute task) or in the ratio to the size of the surrounding frame (in the relative task). The difference in the length of the original and drawn lines is measured. "The absolute task is facilitated by the ability to decontextualize (i.e., analytic perception), whereas the relative task is facilitated by a contextualized mode of visual processing (i.e., holistic perception) (Kitayama & Cohen, 2010, p. 579)." The Western participants should perform better in the absolute task, whereas most of the people from East Asia should perform better in the relative task. These differences in the development of cultural strategies of attention become apparent at 5–7 years of age (Duffy, Toriyama, Itakura, & Kitayama, 2009).

Other studies used relatively more complex visual stimuli in order to identify the differences in visual perception and cognition among cultures. Several studies used change-blindness tasks for this purpose; in some cases, they were combined with priming manipulation. The studies compared members of various cultural groups and subgroups, such as American and Japanese (Masuda & Nisbett, 2006; Miyamoto, Nisbett, & Masuda, 2006), American and East Asian exchange students (Masuda & Nisbett, 2006), or Caucasian, African, Asian, Latino, and Multiracial American (Choi, Connor, Wason, & Kahan, 2015). The common feature of these studies is that they used real-world scenes as stimuli, and that participants were supposed to detect changes in objects and in the context (background). In all of the abovementioned research, participants with Western/Caucasian background had more difficulties (longer reaction times, lower success rates) with contextual information processing. Additionally, participants, who were primed with independence, which is considered to be a self-construal and value system typical for Westerners, showed patterns similar to those of Western participants (Choi et al., 2015).

Several other studies used complex visual stimuli in order to determine the manifestations of cognitive style across cultures. Kuwabara and Smith (2012) used cluttered cartoon scenes in a visual search task. American children showed more object-centered attention compared to their Japanese counterparts. Masuda and Nisbett (2001) used both static and animated scenes with animals in visual recognition tasks. In the first phase, the respondents were viewing the scenes, which contained animals on various backgrounds. In the second phase, they were supposed to recognize the animals presented in the first phase. The authors manipulated the background during the recognition phase. The Americans showed a better performance compared to the Japanese when recognizing animals on the background that differed from the original background presented in the scene viewing phase, which suggests a better ability of Westerners to decontextualize an object from its background.

Several eye-tracking studies support the existence of cultural differences in visual cognition. Zhang and Seo (2015) created a set of stimuli containing food items representing focal objects. The food items were placed on backgrounds that differed in the level of their visual saliency. They administered the method on a sample of Americans and Chinese, measuring first fixations on the food and overall food fixation time. They found that Americans fixated on the objects earlier and spent more time looking at the food. With the rising level of background saliency, both groups looked at the food later and spent less time looking at it. Similar results were obtained by Chua, Boland, and Nisbett (2005), who used pictures that contained living and nonliving objects with realistic backgrounds. They found that Americans looked at the objects sooner, had longer fixations on objects, and made fewer overall fixations.

As mentioned before, the elements of a visual scene can be characterized by perceptual salience (bottom-up process) and semantic relevance (top-down process) (Spotorno & Faure, 2011), which both determine the probability of a given object to be included in the mental representation of the stimulus. The salience of the element is determined by low-level visual characteristics of the element such as size, color, texture, spatial position of the element, overall complexity of the scene (Ma, Xu, Wong, Jiang, & Hu, 2013), and the relationships among the objects and between the object and the entire image (Spotorno & Faure, 2011). The semantic relevance is influenced, for example, by the task goals and instructions, and it is controlled by a top-down cognitive processes. Furthermore, the semantic relevance of the elements of a stimulus seems to be co-determined by cultural influences (Lee, Shin, Weldon, & Sohn, 2016). From this point of view, the attention allocation strategies among cultures differ due to the differences in adaptive benefits associated with each strategy.

Cartographers by themselves or in cooperation with psychologists began to systematically investigate group differences in empirical map studies 60 years ago (Montello, 2002). The general approach has changed overtime, but most of the studies typically use gender, age, cognitive abilities, and the style or expertise of users as explanatory variables (e.g. Brodersen, Andersen, & Weber, 2002; Fabrikant, Rebich-Hespaña, Andrienko, Andrienko, & Montello, 2008; Li, Çöltekin, & Kraak, 2010; Ooms et al., 2015; Kubíček et al., 2017; others). Far less attention has been brought to cultural differences in map perception, map reading, or analysis, with some exceptions. For example, Chang and Antes (1987) focused on gender and cultural differences between college students from the United States and Taiwan, where males performed significantly better than females in topographic map reading and Taiwanese students performed better than those students from the United States. Stea, Blaut, and Stephens (1996) asserted that mapping (as a way of communicating the nature of large environments) is a component of all contemporary cultures; thus, it constitutes cultural universality. Blades et al. (1998) focused on the cultural differences in mapping abilities of young children from England, South Africa, Iran, Mexico, and the United States. They stressed the fact that mapping abilities are well developed in all cultures, in the case of young children. Montello (1995) stressed the existence of cultural universals and differences in spatial cognition, but claims the importance of universality of cognitive structures and processes and also claims that cultural differences are often exaggerated. Davies and Pederson (2001) and Stachoň and Šašinka (2012) bring examples of differences in spatial processing and representation between people living in different environments. From other fields connected to cartography and geography, the work of Louis (2006) suggests that there are cultural differences in spatial planning strategies that are not only based on indigenous values of a landscape but also on differences in the cartographic techniques employed to represent indigenous spatial perceptions.

Contemporary critical cartography research incorporates cultural diversity approaches in mapping (e.g. Krygier & Wood, 2005) and turns our focus to the study of the cross-cultural differences in the cognitive processing of maps. The mentioned examples bring us to the different roles of spatial representations in the minds of people from various cultures and also to the issue of whether or not the cartographer should pay attention to the cross-cultural differences.

The aim of this article was to investigate the potential differences in the cognitive processing of maps. The rationale of the research is based on the theory of holistic and analytic cognitive style that provides a framework for the comparison of perceptual and cognitive processes across cultures. The abovementioned cross-cultural research in psychology inspired us to try to look at a map as a complex visual stimulus composed of multiple elements with various levels of visual salience and semantic relevance, and to explore possible cultural differences in the visual perception of maps. Figure 1 describes the expected relationships among key variables, and their operationalization. Nisbett and Masuda (2003) argue that specific sociocultural factors (e.g. individualism/collectivism, self-construal, language) influence the development of holistic or analytic cognitive style. Cognitive style as a psychological construct (Rayner & Riding, 1997) and latent trait (Allen & Yen, 2002) can be detected and measured with psychological tests (e.g. FLT) and manifests itself in daily life, e.g. during map work. Based on the theory, we expected that East Asians are generally more holistic and this would be manifested in the FLT by their ability to perform relatively better in the relative task. At the same time, users with holistic cognitive style would be relatively more effective in the exploration of map background in comparison to analytics who primarily pay attention to focal objects. We administered two performance methods to a sample of Czech and Chinese university students in order to measure cognitive style (FLT) and its manifestations in map reading (visual search task).

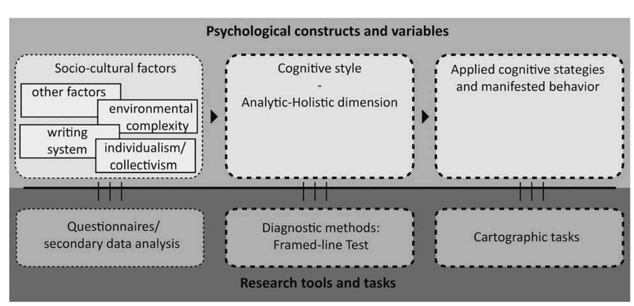

Figure 1. Model of cultural influence on perception and cognition.

Methods

The abovementioned interdisciplinary research in psychology, geography, and cartography suggests the existence of cross-cultural differences in mental representation of space and its understanding. Inspired by prior cross-cultural perception research, we wanted to investigate whether there might be differences in map-reading behaviors between Europeans and Asians. We thus included a version of the FLT to help explain potential map-reading differences across studied ethnic groups. Based on previous studies (e.g. Kitayama et al., 2003; Nisbett & Miyamoto, 2005), we hypothesized that:

(1) Both Europeans and Asians identify thematic figural symbols overlaid on a reference map more rapidly than background segments of this reference map.
(2) Europeans identify thematic figural symbols more rapidly than Asians, and Asians identify background segments of the map more rapidly than Europeans.
(3) An increased figure/ground contrast increases symbol localization speed for Europeans but not for Asians.
(4) In FLT, Asians perform better in the relative task and Europeans perform better in the absolute task.

Participants

We invited a total of 133 students from various undergraduate and postgraduate programs at Mendel University in Brno, Masaryk University in Brno, the University of Economics in Prague, and from Wuhan University in China to participate in our study. Of those participants, 64 participants were Czech (age: Mean = 22.0, SD = 2.96), and 69 were Chinese (age: Mean = 21.0, SD = 2.19), and all had normal or corrected-to-normal vision. We aimed for a balanced gender ratio in both ethnic groups (approx. 30% males in the Czech and 38% in the Chinese sample). Study participation was voluntary. Participants were invited to orally give their informed consent for participation in the study prior to taking part in the experiment.

Procedure and materials

The test was run on 21.5″ monitors (at 1600 × 900 pixel resolution). The distance between the computer screen and participants' eyes varied between 40 and 50 cm, and the size of the displayed map stimuli was 770 × 695 pixels. The test procedure was kept constant across the Czech and Chinese versions of the experiment, as shown in Figure 2. Participants solved the identical experiment, but in their native language (i.e. in Czech or in Standard Chinese). A maximum of five participants were tested in the same session. At the beginning of the test session, participants were informed that the experiment would consist of two test portions related to map reading and visual perception. The entire experiment took about 25 min on average.

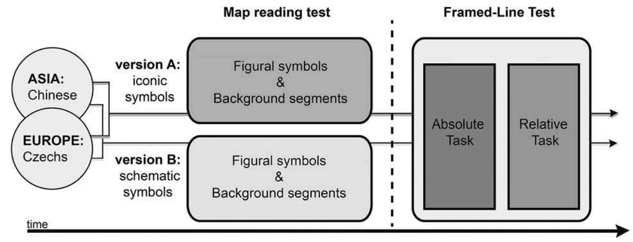

Figure 2. Schema of the testing procedure; both cultural groups passed through both versions of the test (A and B version).

The experiment was administered with the Hypothesis software, an online testing environment that runs in a web browser and captures participant responses in a digital database. For more details about Hypothesis, see Šašinka, Morong, and Stachoň (2017), Popelka, Stachoň, Šašinka, and Doležalová (2016), or Svatoňová and Kolejka (2017). Initially, participants were asked to complete the map portion of the experiment, and were randomly assigned to either stimuli version A or B. Map trials were randomized. Subsequently, all participants were asked to complete absolute and relative tasks of FLT.

Map stimuli

We designed a factorial experiment with informationally equivalent map stimuli to solve two typical map-reading tasks, including 1) localization of a given figural symbol in a reference map (21 trials), and 2) the localization of a given geometric configuration (background segment) from the map (20 trials). Both types of tasks were explained at the beginning of the test.

We prepared two test versions (A and B) with an identical background map showing a Greek city (including Greek map labels) that we selected from the OpenStreetMap database. We specifically chose Greek to avoid potential familiarity with a particular writing system for the chosen Czech and Chinese participant groups.

Test versions only differed in the visual contrast of the figural symbols to the background map. In test version B, figural symbols of different shapes and colors also include identical black outlines, to increase the visual saliency of the figural symbols from the background map (see Figure 3). In this version, the symbols thus appear more uniform in shape and size.

Figural symbols in both map versions are distributed equally across the background map. As previously mentioned, the background map is identical in both versions of map stimuli. Test version and culture are independent variables, whereas speed of localization of the figural symbols and the background map configurations are dependent variables.

The respondents were instructed to locate and select (by mouse click) the given figural symbol (see Figures 4 and 6) or given configuration (segment) selected from the background (see Figures 5 and 6). We measured participants' response time in milliseconds.

This was followed by an adaptation of the FLT which was identical for both groups (see further).

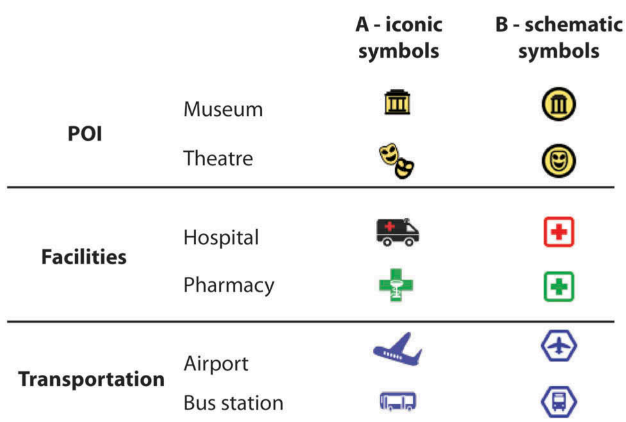

Figure 3. Examples of three groups of objects used for A and B versions of map stimuli.

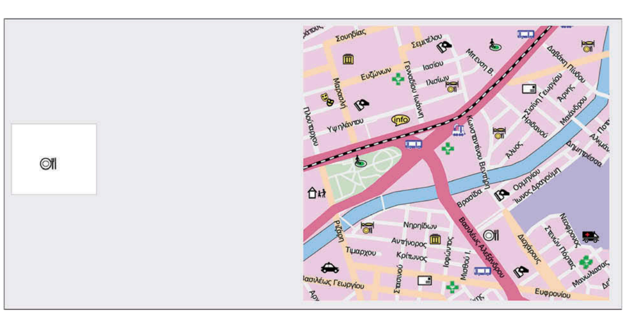

Figure 4. Example of the test stimulus used in map-reading test version A "Locate the symbol shown on the left." © OpenStreetMap Contributors.

FLT stimuli

The second portion of the experiment consisted of a modified version of the original FLT proposed by Kitayama et al. (2003). Our version is composed of a total of 16 stimuli, 8 stimuli each for both the absolute and relative tasks. The line-drawing practice task was put at the beginning of the test, followed by instructions for the absolute task. The absolute task preceded the relative task. Each stimulus started with a presentation of a square or circle frame with a line extended downward from the center of the upper edge (original stimulus; see left part of the Figure 7). The original figure was presented for 5 s. Immediately after the original figure, a blind screen was presented for 100 ms. After the blind screen, an empty frame with a dashed line was presented (test stimulus; central part of Figure 7).

A reference stimulus was shown first with either a square or a circle of a standardized edge/diameter length of 160 pixels. The geometric shape also contained a vertical line of a given length in the middle of the shape, as shown in Figure 8. The reference stimuli were all positioned in the center of an empty, white display. Participants were then shown a second stimulus, again containing a square/circle, but of a different size than the reference stimulus. They were then asked to draw a vertical line using the mouse, starting with a mouse click at the top edge of the rectangle/circle and by dragging the mouse downward. A second mouse click ended the line drawing. For the absolute task trials, participants were asked to draw a line of the same absolute length as presented in the preceding reference stimulus in the empty rectangle/circle shown second. For the relative task trials, participants were instructed to draw a line of the same length proportions in an empty rectangle/circle of a different size that corresponded to the same length proportion shown in the preceding reference stimulus (right part of Figure 7). Each task differed in the length of the given vertical line in the reference stimulus. Positions on the display and the sizes of the geometric shapes into which participants had to draw were randomized. We recorded the length of the drawn line (i.e. number of pixels) for each trial.

Results

Map-reading test

Below, we report on the quantitative results of the map-reading portion of the test. Of the 133 participants, we removed 6 participants because they did not

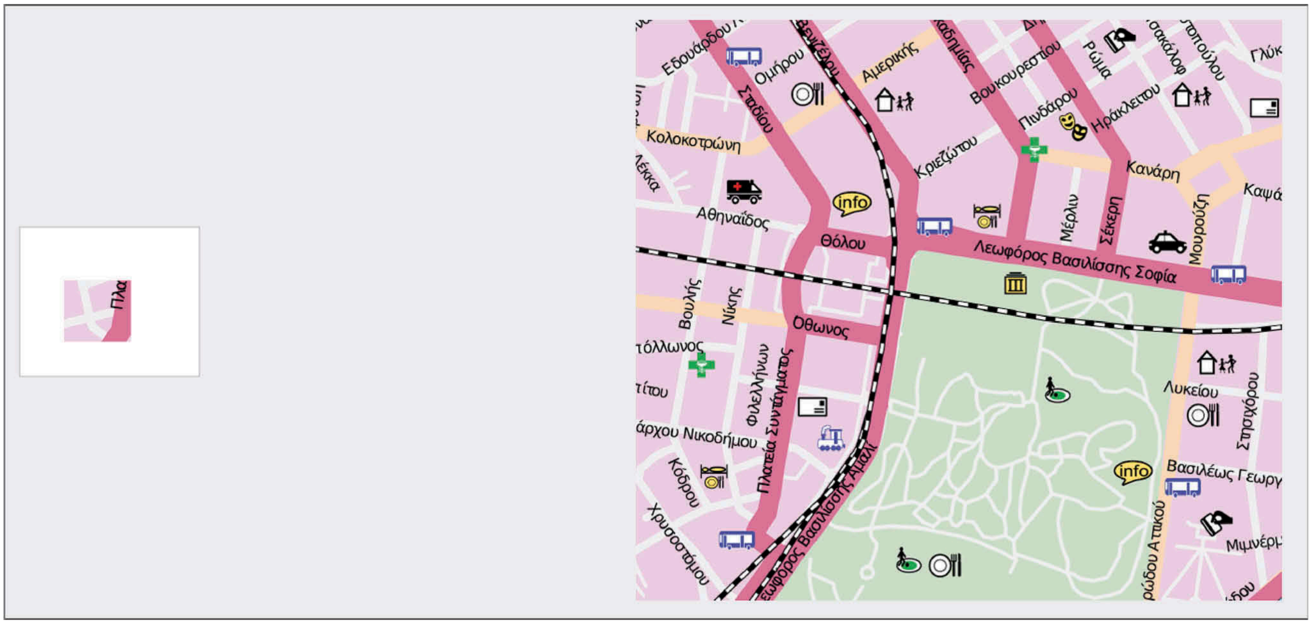

Figure 5. Example of the test stimulus used in map-reading test version B "Locate the background segment shown on the left." © OpenStreetMap contributors.

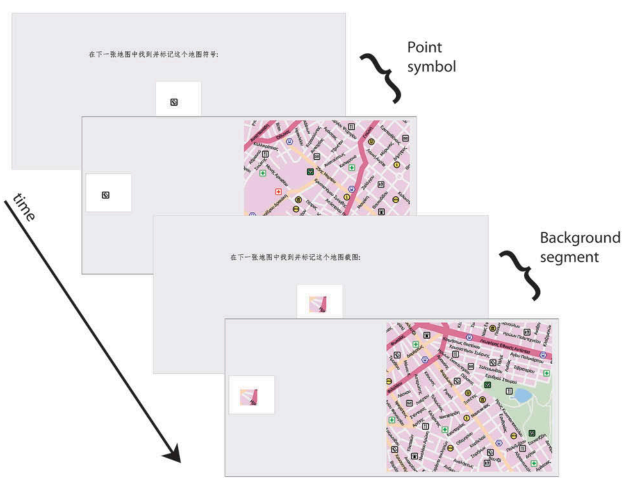

Figure 6. Map stimuli and presentation sequence for the map test version B, with increased figure/ground contrast (Chinese version of the test). © openstreetmap contributors.

finish the entire portion of the experiment due to technical problems with the Hypothesis application. This only happened with Chinese participants, because the required Internet connection at test locations in China was generally unstable. As a result of data pre-processing, we retained response data for 64 Czech and 63 Chinese participants.

Performances were assessed using two mixed, repeated measures ANOVAs, with the cultural background as a between-subject factor, and the figure-background search task as a within-subject factor. Because of the between-subject design of this portion of the experiment, we performed the analysis separately for versions A and B of the map-reading test. The cross-cultural differences were primarily measured by the relative performance in both types of tests. Additionally, we used a 2 × 2 ANOVA to discover potential interactions between culture and the level of visual contrast (symbol versions A vs. B). In all cases, we reported on participants' efficiency represented by their response times (in seconds).

As expected, both Czech and Chinese participants were faster in localizing figural symbols compared to the localization of the background segments from the maps (see Figure 9). A repeated measures ANOVA analysis of the map-reading test shows significant differences between both groups regarding the figural symbols and background segment tasks ($F(1, 67) = 224.63$, $p < .001$, $\omega_p^2 = .76$ in case of version A and $F(1,54) = 149.58$, $p < .001$, $\omega_p^2 = .73$ in case of version B).

Post hoc tests indicated that Czech respondents working with version A ($M = 3.11$, $SD = 1.81$) were significantly faster when searching for figural symbols than Chinese respondents ($M = 4.23$, $SD = 1.74$), $t(59.61) = -4.75$, $p < .001$, $d = .63$. Also Czech respondents working with version A ($M = 6.59$, $SD = 5.2$) were significantly faster when searching for background segments than Chinese respondents ($M = 9.91$, $SD = 4.98$), $t(70) = -4.79$, $p < .001$, $d = .65$. There were no significant differences in detection speed between the Czechs ($M = 3.86$, $SD = 1.65$) and Chinese ($M = 4.13$, $SD = 1.84$) when having to identify figural symbols in version B, while Czech respondents were

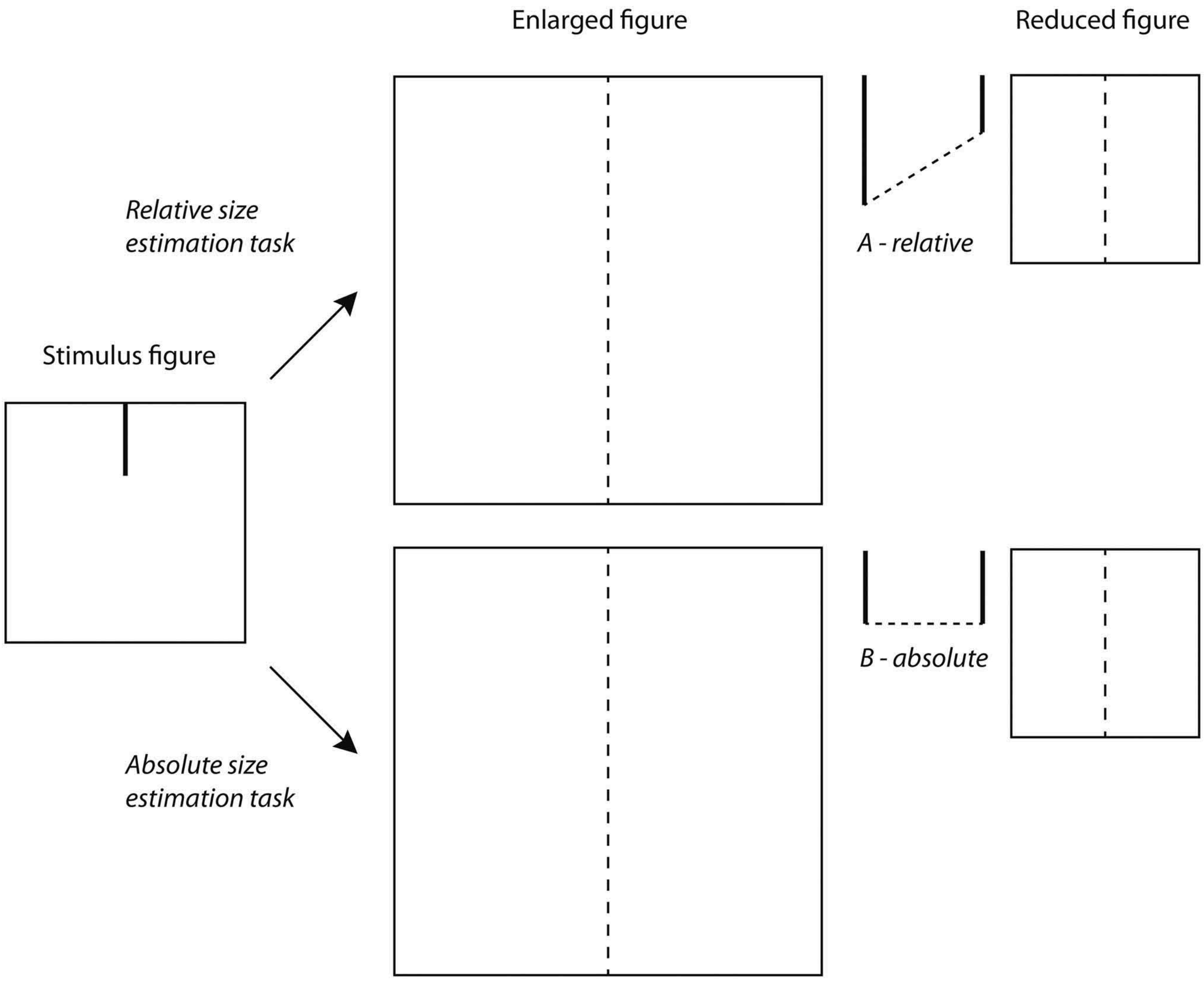

Figure 7. Principle of framed-line test.

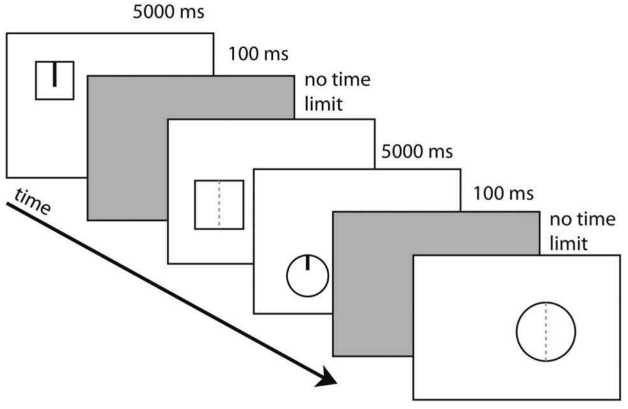

Figure 8. Stimuli and presentation sequence of the framed-line test.

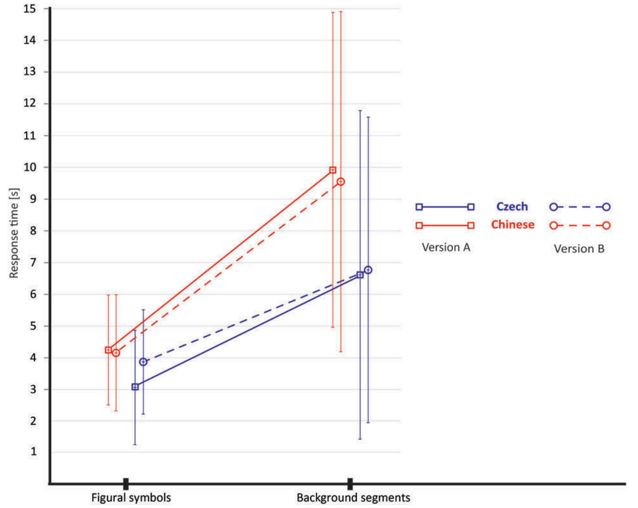

Figure 9. Mean response times with standard deviations (s) for the two cultural groups (Czechs and Chinese), two versions of map-reading test A and B and figural symbols (left) and background segments search (right).

significantly faster identifying background segments (M = 6.72, SD = 4.83) than the Chinese respondents (M = 9.56, SD = 5.38), $t(41.37) = -3.88$, $p < .001$, $d = .56$.

To test for potential interaction effects across participants' cultural backgrounds and the level of visual contrast (symbol versions A vs. B), the means were submitted to a 2 □ 2 ANOVA with two between-subject variables (culture of participant: Czech vs. Chinese; version of symbol: A vs. B). We found an interaction effect between culture and version of figural symbol set, $F(1, 126) = 6.06$, $p < .05$, $\omega_p^2 = .04$. *Post hoc* tests indicate that Czech participants perform significantly faster in localization of the figure in version A ($M = 3.11$, $SD = 1.81$) compared to version B ($M = 3.86$, $SD = 1.65$), $F(1, 63) = 1.66$, $p < .01$, $d = .43$. There were no significant differences in the speed of localization of figures between either version of the figural symbol sets in the case of the Chinese respondents.

Now we turn our attention to the results of the FLT to further investigate potential effects of cultural background on holistic and analytic cognitive style differences.

FLT

We analyzed the length of the response lines drawn by participants in comparison to the correct line lengths. Prior work suggests overall high accuracy rates for the FLT (Kitayama et al., 2003). We counted all responses that diverted horizontally from the dashed line as incorrect responses. We counted the number of incorrect responses of each participant and excluded participants with more than 20% of incorrect responses (i.e. 3 of 16 responses), suggesting that these participants either did not understand or did not follow the given test instructions, or there were other reasons for high error rates, unrelated to the actual tested concept. We also performed an outlier analysis (Hoaglin & Iglewitz, 1987; Hoaglin, Iglewitz, & Tukey, 1986), as a further adjustment of Tukey's (1977) outlier labeling method. The outlier analysis was conducted using the average absolute deviations of lines drawn by the participants from the correct lengths of lines (same absolute length in the absolute task/same proportion to the frame in the relative task). After these two data preprocessing procedures, 10 respondents were eliminated from further analysis and the overall response error rate dropped to approx. 4.5% on average.

This left us with response data from 106 respondents (i.e. 52 Czech and 54 Chinese) in total. We subjected these data to a mixed repeated measures ANOVA with one between-subjects factor (cultural background: Czech and Chinese), and one within-subjects factor (task: absolute vs. relative length judgements).

Figure 10 shows the response mean absolute line length errors of the FLT. As predicted, we can immediately see differences in response accuracy across cultural background. Surprisingly, however, the pattern of differences does not seem to be the same as prior work suggested (Duffy et al., 2009; Kitayama et al., 2003). In aforementioned studies, Asian participants performed consistently and more accurately in judging the line length in the relative task condition. Contrary to these studies and to our expectations, Asians in our study judged line lengths more accurately in the absolute task condition compared to the relative task condition. Czech participants show no clear advantage in the performance, in either the absolute or the relative task condition.

As predicted, the interaction between cultural background of the participants and the perceptual line drawing task is significant, $F(1, 104) = 14.65$, $p < .0001$, $\omega_p^2 =$ 0,11. However, the effect size is small. *Post hoc* tests reveal that Chinese participants are significantly more accurate in judging absolute length than Czech participants (Chinese: $M = 11.88$, $SD = 4.49$; Czech: $M = 15.46$, $SD = 6.71$, $t(88.61) = 3.21$, $p < .01$, $d = .63$). Conversely, Czech participants seem to be more accurate in the relative task trials (Czech: $M = 15.71$, $SD = 4.33$; Chinese: $M = 17.15$, $SD = 3.64$). However, these differences are not significant ($t(104) = -1.86$, $p = .066$).

Moreover, contrary to the results of previous research, the Chinese are also significantly ($t(53) = -7.90$, $p < .001$, $d = 1.29$) more accurate with their absolute length task ($M = 11.88$, $SD = 4.49$) compared to their relative task ($M = 17.15$, $SD = 3.64$). Accuracy does not significantly differ ($t(51) = -.22$, $p = .83$) for the Czech participants, for any of their tasks (Absolute task: $M = 15.46$, $SD = 6.71$; Relative task: $M = 15.71$, $SD = 4.33$).

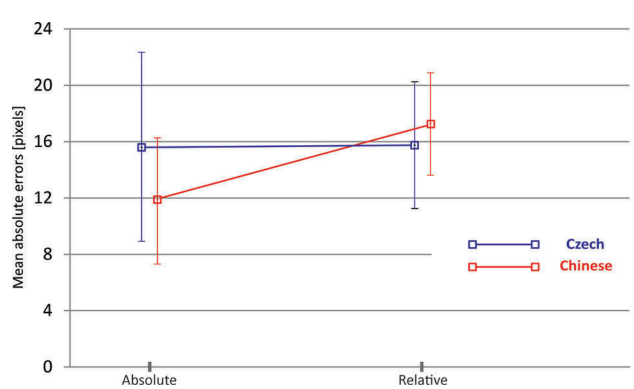

Figure 10. Mean error scores with standard deviations (in pixels) in the absolute and relative task of framed-line test.

Discussion

The goal of this study was to investigate whether holistic and analytic perception described by Nisbett and Masuda (2003) or Kitayama and Cohen (2010) would be relevant to the context of map reading. We set out to reveal possible cross-cultural differences in the map-reading processes of Czech and Chinese map users, explained by a cognitive style assessment using the FLT. In the first part of the article, we introduced the relevant psychological research on cross-cultural differences in visual perception and cognition. In the second part, we discussed the role of culture in the visual search of figural symbols and background segments of the map. In the third part, we discussed the results of the FLT, and we related these to participants' performance in the map-reading portion of the experiment.

First, we found that both Czech and Chinese participants are able to locate figural symbols faster in a reference map, than geometric configurations (background segments) on the same reference map. Overall, this is a gratifying result, meaning that thematically relevant information can be rendered as perceptually salient (Fabrikant, Rebich-Hespaña, & Hegarty, 2010; Garlandini & Fabrikant, 2009; Hegarty, Canham, & Fabrikant, 2010), and this information can be detected rapidly across various cultural backgrounds. The results are also in consonance with the Gestalt principles of perceptual organization (for a comprehensive review, see Wagemans et al., 2012).

As hypothesized, we were also able to detect cross-cultural differences in our map-reading study. Surprisingly, however, our findings are opposite to what prior research outside of cartography had suggested. The theory of holistic and analytic perception proposed by Varnum, Grossman, Kitayama, and Nisbett (2010) claims that Western cultures perceive visuo-spatial information more analytically, and less holistically, than Eastern cultures. Hence, we would have predicted that Czech participants would be able to locate figural symbols more rapidly than the Chinese, and that Chinese participants would be able to locate the background segments relatively faster. Contrary to our expectations, Czechs are significantly faster compared to Chinese participants in the localization of background segments, irrespective of figural symbol design. Furthermore, there are significant differences between the groups in localization of the figural symbols in version A of our map test. No significant differences were found between the groups in the speed of localization of the figural symbols in version B.

Perhaps, some of our contradictory results in the map-reading portion of the experiment can simply be explained by the equally unexpected results we obtained in the FLT. Our FLT results contradict the suggested theoretical model as well (Varnum et al., 2010). Our Chinese participants defied our expectations and the model predictions by being more accurate with the absolute task compared to the Czechs. Conversely, the Czechs were more accurate in the relative task compared to the Chinese. This in essence means that Czech participants show a more holistic cognitive style than our Chinese participants, whereas our tested Chinese participants display a more analytic cognitive style than Czechs. Moreover, a more predictable pattern emerges when systematically comparing FLT and map-reading results. Chinese participants, who show relatively stronger tendencies to analytical visual processing (higher precision in absolute than in relative task in FLT), also show relatively higher differences in the speed of figural symbols localization compared to the speed of background segments' localization and vice versa.

These surprising results could be explained in several ways. Changes of socio-cultural factors can influence the formation of a cognitive style which, in turn, can result in the change of a cognitive style and its manifestations (Matsumoto, Kudoh, & Takeuchi, 1996). Our Chinese participant sample (i.e. young university students) might already show recent cultural factor changes in China. This might be facilitated by increasing access to information disseminated through the various Western digital media channels (i.e. Web, social media, etc.), and increased exposure to hardware, software, learning materials, and digital methods produced by Western tech companies, fostering particular cognitive styles.

Results of several priming studies show that a cognitive style is sensitive to priming manipulations (Ishii, 2013; Nisbett & Miyamoto, 2005; Oyserman & Lee, 2008). We aimed to eliminate possible priming effects using a tight control of the experimental conditions. More research with other control factors related to the participant sample, for example, different age and socioeconomic groups of respondents or longitudinal studies, is needed to systematically identify possible shifts in cognitive style. Furthermore, the theory of "cognitive flexibility" (e.g. Shin & Kim, 2015; Yeatts & Strag, 2014) says that different people differ in the ability to adaptively change their cognitive strategies. This concept stresses the flexibility and adjustability of cognitive processes by human, and thus supports the assumption that changing sociocultural factors may relatively fast modified cognitive style of whole groups.

Perhaps, this result is due to the relatively low overall diversity of tested participants. Irrespective of nationality differences, all tested (Czech and Chinese) participants were in their twenties, living in large urban areas, and studying at a university. We tried to use samples as similar in the key background characteristics as possible in order to avoid sample bias, as described by van de Vijver (van de Vijver & Poortinga, 2005). The field of study was one difference between samples that might have caused the observed differences between the groups. Czech participants were students in various fields without a geographic background. Chinese participants, however, were mainly students with a background in GIS, and also from related fields including Land Resource Management or Urban–Rural Planning. It could be expected that the experience of Chinese students with GIS and maps should have resulted in a slightly superior performance in both cartographic tasks. However, the results did not reflect this tendency at all.

The secondary goal of our study was to identify which type of figural symbol set might lead to greater efficiency in visual search tasks for participants with different cultural background. Symbol sets were designed in order to specifically provide a performance advantage based on the preferred (holistic or analytic) cognitive style. That is, figural symbol set A was designed with relatively more variation in shape and color across individual symbols, while figural symbol set B was designed as more uniform in shape and color, using identical symbol outlines, and with greater visual contrast to the reference map in the background. Consequently, figural symbol set B as a whole would more easily act as a (Gestalt) figure, and hypothetically provide a cognitive advantage for European participants. Contrary to our expectations, Czech participants performed better with figural symbol set A. This might be explained by the relatively more complex set of internal parts of chosen symbols for figural symbol set B. These are crucial for the differentiation between symbols (aside from the shape of the symbol outlines). Although the entire structure of symbols in symbol set B is more distinctive from the background due to the added symbol outlines, and thus its apprehension should be easier (see Stachoň et al., 2013), difficulties with discriminability slowed Czech participants down when working with figural symbol set B. Another explanation offers Lloyd (1997) who found that targets with unique features pop out of the map and search efficiency is independent of number of distractors. In a follow-up study, one could redesign symbol set B to be more distinct from symbol set A by further abstracting the interior shapes of the symbols. One could also further increase figure–ground contrast with the background by reducing the color range of symbol set B.

On the other hand, Chinese participants show relatively better results in the case of figural symbol set B, but the differences were not significant. Perhaps, this could be explained by the different writing systems of Europeans and Asians. Europeans use the Latin alphabet where a particular sign carries no meaning, even though shape differences can be detected. Chinese characters, in contrast, are logograms with mostly visually complex structure, where a single character can have various meanings. Therefore, Chinese participants are perhaps more familiar with studying visual details and parts of a particular figural symbol. This could influence the detection speed in figural symbol set B, where the internal symbol structure is more similar to the structure of Chinese characters.

Conclusions and outlook

The aim of our study was to investigate whether holistic and analytic cognitive styles would be relevant in the context of map reading, and whether map users of different cultural backgrounds (i.e. Westerners and Asians) might differ in their map-reading style. The results of our experiment offer strong evidence that cultural background can indeed influence the map-reading style of map users, which can take shape in figure–ground searching efficiency. However, our findings are in contrast to what the theory of holistic and analytic cognition (Nisbett & Masuda, 2003) would suggest, which describes Westerners as more analytical and East Asians as more holistic. Furthermore, we discovered that the cartographic design of figural symbol sets influences visual search efficiency on reference maps, and this again could be mediated by the varying cultural background of the map users. Our results show that figural symbols with relatively bigger variance in shape are significantly more suitable for the Czech participants compared to the relatively more uniform symbols (symbols with outlines). Conversely, Chinese participants are relatively faster when performing visual search tasks with more uniform figural symbols (i.e. having the same black outline).

Our results underline the importance of varying the cartographic design solutions for map readers with different cultural background. Differences may appear not only in the shape and color of figural symbols but also in the size of the symbol, their anchor point, etc.

Future research should not only be extended geographically (using respondents from other countries) but also thematically, for example, by comparing respondents living in settlements of various densities and sizes (see Stachoň et al., 2013), respondents of various socioeconomic status (see Grossmann & Varnum, 2011), or respondents from different age groups (see Duffy et al., 2009; Waxman et al., 2016).

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