MEASURING THE MAP READERS' INTERPRETATION OF HYPSOGRAPHY

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Abstract
This paper presents the work of the Research Group on Experimental Cartography at Eötvös Loránd University, Hungary. Our goal is to create a quick and effective test method to categorize map readers according to their map reading skills. In the presented part of our study, we created an online user test with six multi-choice questions that tested various competences required for interpreting hypsography. During a pre-test questionnaire, we asked demographic information of the participants for a deeper analysis. We used two tailed t-tests to find significant differences among the participants, according to their traits. A total of 195 test subjects participated in the research. The results show that the relative height definition, interpretation of slope direction, recognition of landforms and map-terrain association is significantly more difficult for unexperienced participants. It was concluded that questions involving mental rotation and comparison of relative heights are more appropriate to predict the subjets' expertise.

Keywords: *experimental cartography, user testing, user oriented maps, interpretation of hypsography*

INTRODUCTION

Interpretation of information on large scale maps requires numerous competences, such as sign recognition, recognition of morphology and hypsography, sense of directions, coordinate-, distance-, and scale-reading (Muir 1985; Clarke 2003). These competences help map readers to understand the various data types found on large scale maps, such as linear features, hydrography, land cover, hypsography, point-like objects, geographic names (Thompson 1979; Buckley et al. 2004; Usery et al. 2009). Skills can be defined that are required for reading large scale maps. By connecting the competences and map data types mentioned previously, these skills include the interpretation of hypsography, interpretation of map symbols, orientation skills and mental rotation, distance and travel time estimation, interpretation of geographic names, application of scale bar, and interpretation of topographic elements (Albert et al. 2016). User studies, designed to understand map readers' strengths in these skills, include the common methods of tests and surveys (e.g., Deeb et al. 2011; Wakabayashi et al. 2013), eye tracking (e.g., Çöltekin et al. 2009; Ooms et al. 2013), thinking aloud method (e.g., Ooms et al. 2015; Szigeti and Albert, 2015) or participant observation (e.g., Pick et al. 1995; Ito and Sano 2011). It was found that the experience of map readers has a noteworthy effect on these skills (Guzmán et al. 2008; Ooms et al. 2013; Wakabayashi, 2013). Also, there are other factors that can affect the map reading skill, such as the map readers' gender (Lawton 1994), cultural background (Ito and Sano 2011), cognitive skills and memory (Petchenik 1977; Montello 2002; Guzmán et al. 2008). However, several of the mentioned studies, and our previous testing experiences show that map reading is a skill that can be improved by practice, and Muir (1985) highlights that this can be done especially at a young age.

Considering the testing methods of reading hypsography, topographic maps are the most common stimuli (Potash et al. 1978; Eley 1992; Tkacz 1998, Murakoshi and Higashi 2016). Partly based on these works Murakoshi and Higashi (2016.) presented a research, testing four types of competences to define the hypsography interpretation skill: recognition of landforms, line-of-sight judgement, high-low judgement and map-terrain association. They found a significant dependency of experience of all kind of tasks. However, the experiment involved 50 map items, which makes such a test time consuming. Albert et al. (2016) carried out a research that tested multiple map reading skills, including the interpretation of hypsography in eight questions and four stimuli maps. Related to the interpretation of hypsography, two skills were tested in their study, namely the definition of relative heights and interpretation of slope directions. This condensed way of testing also revealed dependency on experience, suggesting that these skills can be revealed based only on a few questions. However, statistically significant differences were only detected in one of the two related questions. Based on previously mentioned studies and our experiences the here presented study aims to find more appropriate tasks to test map reading skills related to interpreting hypsography. The results can be used to update our existing quick-test aimed to estimate complex map reading skills.

STUDY DESIGN

For the study, we created an online test that included six questions, each regarding a different skill of hypsography interpretation: definition of relative heights; interpretation of slope direction; recognition of landforms; line-of-sight judgement; high-low judgement; map-terrain association. The test also included a pre-test questionnaire, to get information about the age, gender, qualification, general map-use and hiking habits of the participants. All tasks were multi-choice questions, each of them only had one correct answer. The sequence of the questions and the possible answers were both randomized for the participants. Finishing the test took between five to six minutes.

Participants

A total of 195 participants' answers were processed in the study. 63% of the participants were males, and 37% were females. The test subjects were classified into four age groups: below 28 (28%), 29–34 (23%). 35–40 (22%) and above 41 (27%). Groups regarding map use frequency were also created. Since it was shown that the frequency of map use is the most predictive factor regarding the proficiency of map reading (Albert et al. 2016), participants, who used maps at least once a month on average were considered experienced map readers, and those who used maps less frequently were considered novice map readers. The test was primarily disseminated via mailing lists, with the help of the Friends of Nature Sport Association of Budapest. It was also propagated on Facebook and on the research group's website.

Questions and Competences

The goal of each question was to test a specific skill required for interpreting hypsography. Each question had four answers and an "I don't know" option, but only one of the answers was correct. Questions Q1 and Q2 were also evaluated in our previous study aimed to test university students (Albert et al. 2016).

Definition of relative heights (Q1): in this question, test subjects were presented with a hypsographic map with four points indicated on it. The task was to decide the correct answer from the four statements (fig. 1.). The statements concerned information about the relative positions of the points. The question tested how the participants interpret relative heights of points, using the contour lines.

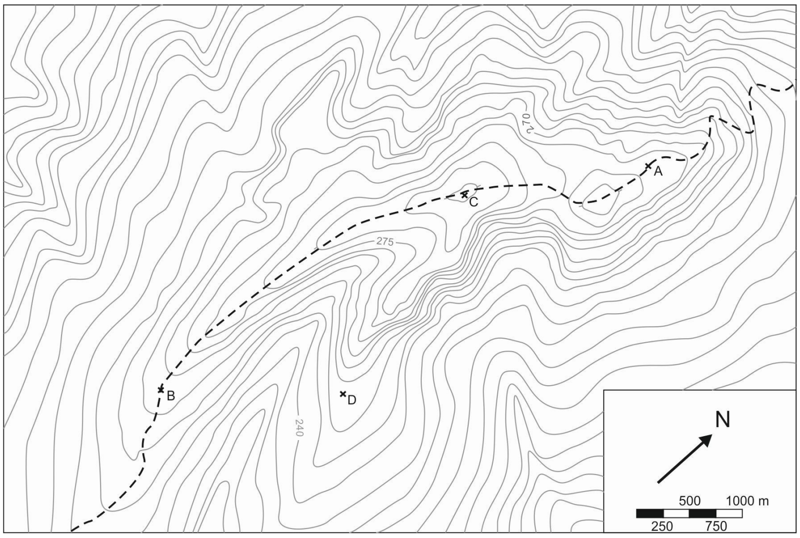

Figure 1. The task for testing the definition of relative heights. Question: which statement is correct? Possible answers: 1) Point C is the lowest; 2) Points B and D are the same height; 3) ***Point D is lower than point A;*** *4) Point B is higher than point A. The correct answer is given a bold font.*

Interpretation of slope direction (Q2): during this task, participants had to decide the relief's slope direction from a hypsographic map with a stream on it. The map was intentionally not oriented to North. The answers included various directions (fig. 2.). For this complex task, it was both required to interpret slopes using the contour lines, and to orientate the map north, using mental rotation.

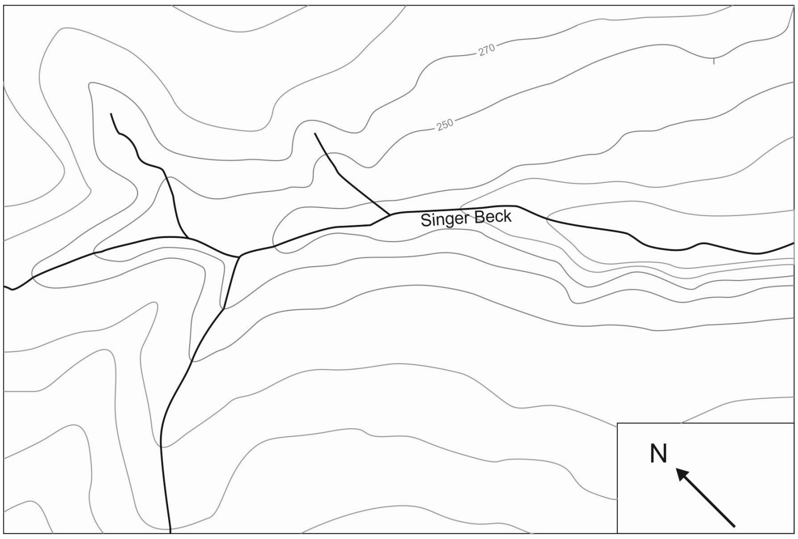

Figure 2. The task for testing the interpretation of slope direction. Question: In which direction does the Singer Beck flow? Possible answers: 1) Northwest; 2) ***Southeast****; 3) Southwest; 4) Northeast.*

Recognition of landforms (Q3): the participants in this question were presented with a hypsographic map that contained four lines indicating various landform features. The task was to decide which one of them indicates a valley (fig. 3.). For this task, participants needed to understand various landform shapes displayed with contour lines.

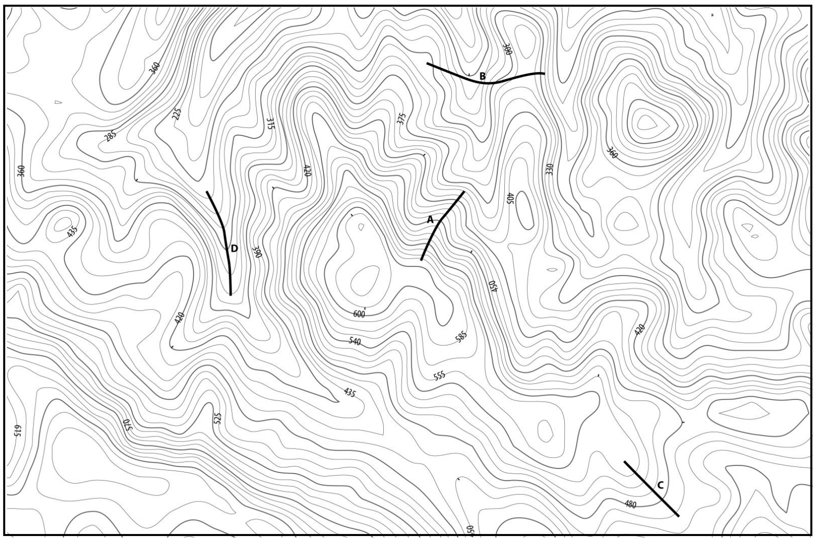

Figure 3. The task for testing the recognition of landforms. Question: which of the following lines indicates a valley? Possible answers: A; B; C; ***D****.*

Line-of-sight judgement (Q4): in this task, participants were presented with a map containing a vantage point (point A), and two other points (point 1 and 2). The task was to decide whether point 1, point 2, both, or none of them can be seen from point A (fig. 4). This task required participants to understand the hypsography in a smaller scale than in the previous questions. To decide whether a point is in line of sight, participants had to interpret the relations of landforms to see that nothing is blocking the view.

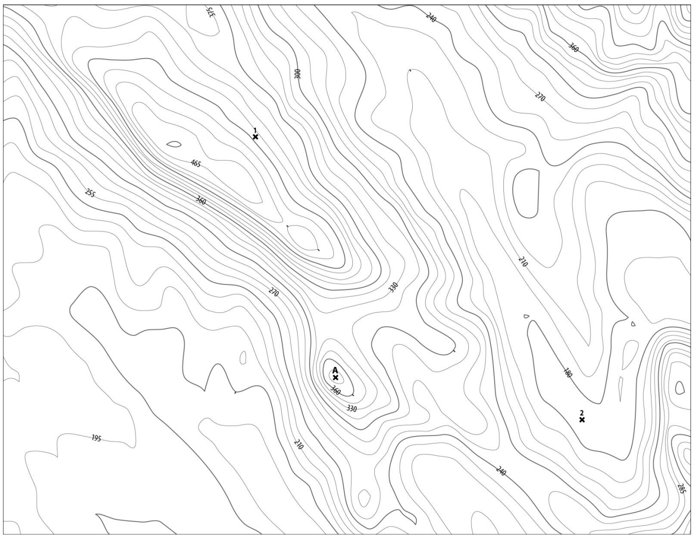

Figure 4. The task for testing the line-of-sight judgement. Question: which point can be seen from point A? Possible answers: 1) Point 1; 2) ***Point 2****; 3) Both points; 4) None of the points.*

High-low judgement (Q5): during this task, participants had to choose the highest point out of four options on a hypsographic map. Unlike the first questions, the answers weren't "true or false like" statements, instead the test subjects only had to give the name of the highest points (fig. 5). Despite the similarity, we believed that this is a simpler task, because it only required to find the highest point on the map.

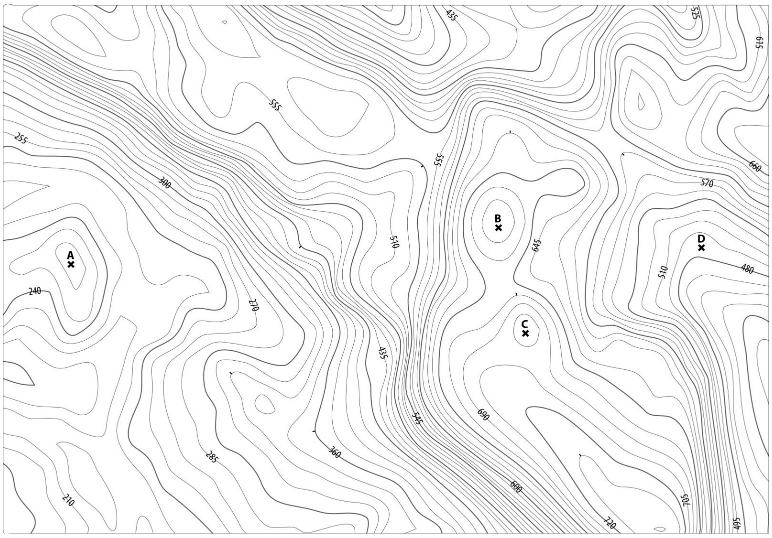

Figure 5. The task for testing the high-low judgement. Task: choose the highest point!
*Possible answers: A, B, **C**, D.*

Map-terrain association (Q6): in this task, the participants were presented with a hypsographic map, and four pictures of various mountains. The task was to compare the images with the map and find which one of them is shown on it (fig. 6). Participants had to create a mental connection between the “top view-like” hypsographic map, and each of the “side view-like” photographs to find the matching pair.

Figure 6. The task for testing map-terrain association. Task: click on the mountain that is shown on the hypsographic map! The correct answer is highlighted with green.

RESULTS AND DISCUSSION

By comparing the rate of correct answers of each question, it is possible to compare the difficulty level of each task (fig. 7). According to the results, Q4 and Q5 were the easiest tasks for the participants in average, with rates of correct answers of 92% and 89%. On the other hand, the two most difficult tasks were Q2 and Q6, with rates as low as 63% and 71%. Interestingly, although Q1 and Q4 were somewhat similar skills, choosing correct statements regarding relative heights seems to be a more difficult task, than choosing the highest point on the map.

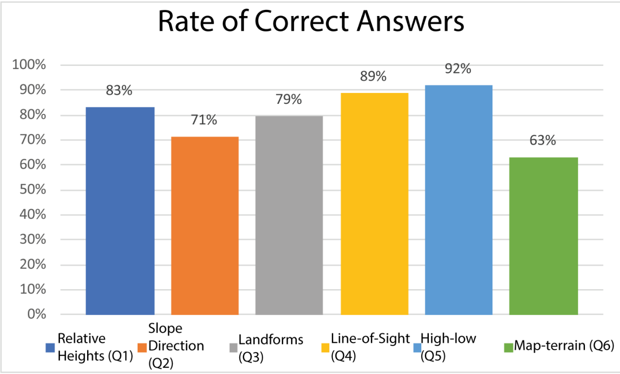

Figure 7. The total rate of correct answers gives an insight into the difficulty of each task.

We compared the results by age groups, gender and map use frequency (expertise). The goal was to find statistically significant differences between the map user groups (Table 1.) by using two sided t-test, where significant difference shows at $p<0.05$. The results of the four age groups didn't show any noteworthy differences. This means that our study couldn't find any connection between age and the interpretation of hypsography, which implies that this skill doesn't depend on the map readers' age.

Table 1. Proportion of correct answers by various demographic properties. Values with blue background show significant difference from other values of the same row within the same sub-table ($p<0.05$).

	Age Categories				**Gender**		**Map Use Frequency**	
	0–28	29–34	35–40	41–	Male	Female	Less than a month	More than a month
Relative Heights (Q1)	84%	84%	86%	79%	85%	81%	71%	88%
Slope Direction (Q2)	72%	68%	71%	73%	76%	63%	54%	78%
Landforms (Q3)	74%	75%	81%	88%	82%	75%	68%	84%
Line-of-sight (Q4)	95%	89%	81%	88%	91%	85%	91%	88%
High-low judg. (Q5)	89%	93%	93%	92%	93%	89%	93%	91%
Map-terrain assoc. (Q6)	70%	61%	60%	60%	66%	58%	48%	69%

Regarding genders, statistically significant differences could only be found at Q2. In this task, male participants performed 13% better (with 76% correct answer rate) than females. This difference between the two genders may be caused by the task's complexity: participant simultaneously had to understand the contour lines and hypsography, while performing mental rotation on the non-North oriented map. This result seems to verify previous studies (e.g. Lawton 1994; Albert et al. 2016) that show how mental rotation is a more difficult task for females. On the other hand, opposed to the current results, question Q1 showed significance regarding genders, in the study mentioned prior. The different outcome can be explained with the different target groups of the two experiments: previously we focused on university students, while in the here presented study a more general group of people was tested.

Even more differences can be found when comparing the results of experienced and non-experienced map readers. There were four tasks that showed significant differences between the two groups: Q1, Q2, Q3 and Q6. The Q1 (definition of relative heights) also appeared in our previous study (Albert et al. 2016). In that experiment the same question did not produce significant differences between the results of groups by map use frequency, although the frequent map users performed better. This difference, similarly to the earlier one, can be caused by the different target groups of the two studies. Comparing the result of questions related to heights of points (Q1 and Q5) we found that experienced map readers performed almost the same at these two tasks, having slightly better results at Q5. On the other hand, there's a clear difference in the performance of the novice map users. While their results at Q5 was almost the same as the experts', they had a significantly worse performance regarding Q1. This suggests that defining relative heights is a more difficult task for beginners than the high-low judgement, while both tasks seem to be fairly simple for experienced map readers.

In the case of Q2, the complexity of the interpretation of slope direction appeared to be too difficult for unexperienced participants. This result shows that similarly to females, novice users have more difficulties with tasks regarding mental rotation, while this doesn't seem to be a problem for experienced map readers.

During the recognition of landforms (Q3), experts also made a better performance than novices. Similarly, during the map-terrain association (Q6), experts performed significantly better. Taking into account that map using and hiking frequency shows a correlation with each other, it is possible that experienced map readers also have more experience in on-field navigation. Thus, the reason for these differences could be that experienced map readers use these skills more often than the novices.

The results imply that skills as the definition of relative heights, interpretation of slope direction, recognition of landforms and map-terrain association can be applied to measure map readers' skills of hypsography interpretation.

We also found a correlation between the participants' map reading and hiking frequency. Using Pearson's correlation, the result shows a moderate connection between the two factors with $r = 0.36$ correlation coefficient, implying that active hikers have more map reading experience than those, who hike less often than once a month.

CONCLUSION

At the Research Group on Experimental Cartography (RGEC) at Eötvös Loránd University, Hungary (for details, visit: https://ktk.elte.hu/en) we are working on a multi-phase study to create online test that can effectively determine the map reading skills of users. The goal of the presented study was to statistically determine which competences of hypsography interpretation are experienced map readers better at than novice ones. To do so, we created an online test including 6 questions, each of them measuring a specific competence: definition of relative heights, interpretation of slope direction, recognition of landforms, line-of-sight judgement, high-low judgement and map-terrain association. All tasks included a multi-choice question and a simplified relief map. In total, the results of 195 participants were evaluated. The results showed 4 different competences, where significant differences can be found between the performance of novice and experienced map readers, namely the definition of relative heights, interpretation of slope direction, recognition of landforms and map-terrain association. This means that it is possible to draw a conclusion of a person's hypsography interpretation skill by testing these specific competences. Morover, we also showed that the question Q2, used in both our previous and the here presented experiments, combining the hypsometry-reading and the mental rotation skill is the most appropriate type of question in a quick-test to predict the map-reading skill of a user.

The results can be used for our multi-phase study at RGEC, where we aim to create a method to categorize users according to their map reading skills in quick-tests.

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Csaba is a PhD student at the Department of Cartography and Geoinformatics of Eötvös Loránd University. At the Research Group on Experimental Cartography, his work is to create the maps used in the tests, planning the database containing the test results and improving the experimental map keys accordingly with the latest results. He also participates in the writing of scientific publications and reports.

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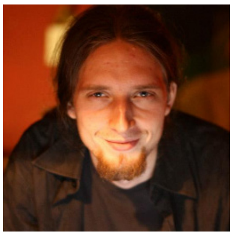

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