

# TESTING THE MAP READING SKILLS OF UNIVERSITY STUDENTS

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## **Abstract**

*The goal of the study was to quantify map reading skills with the results of an online test. The target group mainly (not exclusively) consisted of ongoing and graduated students from higher education from Hungary, Spain, Austria, Germany, Romania and Bulgaria, resulting in a total sample size of 488 people. The test consists of seven multiple-choice and one open ended question referring to four sample-maps. The subjects were categorized into three groups according to their performance: beginners, intermediates and experts. The performance of these groups was compared, based on their use of cartographic information, and their spatial abilities. The results revealed differences in the map reading competency regarding gender, nationalities and age. Since the selection of the subjects was uncontrolled, this study is considered as an exploratory analysis. The results can be used to produce personalized digital maps.*

**Keywords:** map reading, user studies, cognitive skills, personalized maps

## **INTRODUCTION**

When editing a map, it is important to design the content in a style, which is the most comprehensible for the readers to whom the map is created (Board 1978). Map readers can be categorized according to their map reading skills (Clarke 2003), and people in each category use different map data types (like the road network, or the hypsometry) in different ways (Szigeti & Albert 2015). The concept of the personalized map is based on this observation. Thus, if the map reading skill of a person is known, the style of the map can be created for that specific person's needs. The map reading skill depends on the memory and the cognitive capacity of the map reader (Petchenik 1977; Montello 2002; Guzmán et al. 2008), so the cognitive load theory (CLT) plays increasing role in researches on map reading (e.g. Gerber 1981; Ooms et al. 2013). The aim in the personalized map theory combined with CLT is to exploit the existing knowledge on geography and map symbols, and avoid overloading the working memory of the reader with too dense layout or too many different symbol types (Sweller 1988; Sweller 1994; Paas et al. 2003; Bunch & Lloyd 2006). The gender of the map reader may also influence the results of a map reading test (Lawton 1994). However, the gender mainly plays role in navigation-type tasks, not in the recognition of map symbols (Montello et al. 1999, Gilhooly et al. 1988). The navigation-type tasks are usually common on large-scale maps, for which spatial orientation skills are useful, while the understanding of small-scale maps rather require geographical knowledge (Wakabayashi 2013; Wakabayashi & Matsui 2013). Clarke (2003) has listed several other skills, like memory, recognition, estimation and comparison, which are responsible for the map reading skill of a person.

The time of understanding the map content depends on the map reading experience (Muir 1985, Clarke 2003, Allen et al. 2006, Ooms et al. 2012), but the type of the information also influences the speed of understanding – e.g. recognizing signs is easier than recognizing landforms (Wakabayashi & Matsui 2013).

According to Muir (1985) – who studied children's skills – map reading tasks can measure sign recognition, sense of directions, distance- coordinate- and scale reading, recognition of perspective depicts and morphology. Allen et al. (2006) have separated four types of tasks to measure cognitive skills: surveying (memorizing details on a large area), recognition (spotting specific objects in a messy context), completing (recognition of an object from a detail) and mapping (memorizing the place of objects relative to each other). Based on these techniques, the present study aims to analyse the map reading skills of people in a statistically robust sample group. The target subjects were mainly (but not exclusively) students from the higher education. The goal was to measure several competency-types in connection with the map reading skill on medium- and large scale maps. It was also the aim of the study to measure whether a map data

type is easy to read or not, for different users. The results - combined with the CLT - can be used in designing personalized maps.

## TEST SETTINGS

The map reading test included four maps and eight questions: seven of them were multi-choice questions with four answers. It was hosted on a web page, and it stored the input data in a MySQL database. The research was carried out with test of multiple languages: Hungarian, English, German, Spanish, Bulgarian and Romanian. Both the questions and the maps were translated to these languages. Due to linguistic differences, instead of direct translation we considered changing the geographic names, to achieve a more natural sounding (Figure 1).

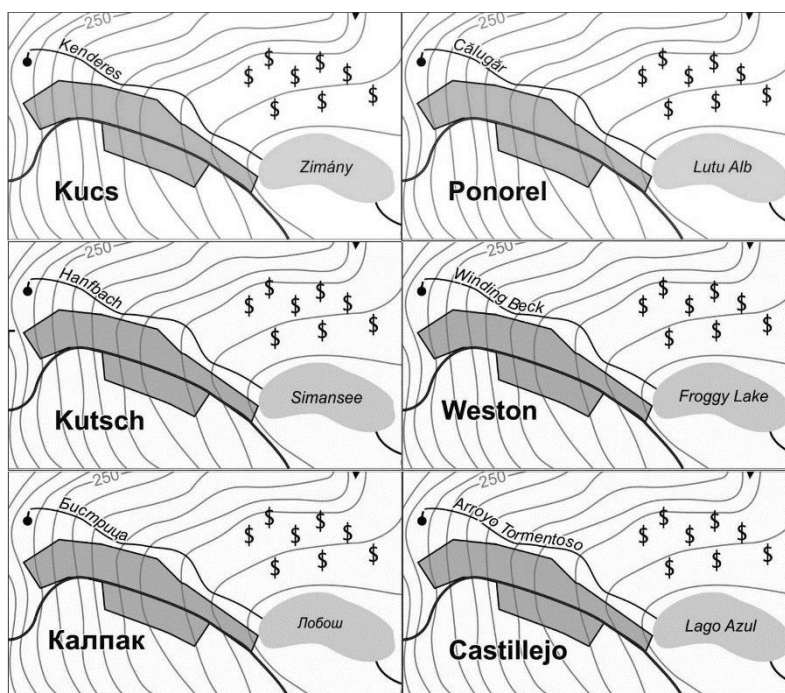


Figure 7. The geographic names on the maps were changed to have a natural sound in all languages. The maps' languages from top left: Hungarian, Romanian, German, English, Bulgarian, and Spanish

The test focused on the map reading competences defined by Muir (1985) and Clarke (2002), but they were narrowed down to large scale maps (Figure 2). The maps were designed only to solve the questions relating them, thus reducing the cognitive load during the test. Eight questions (numbered Q1-Q8) were asked from the subjects on four maps. The sequence of the maps and the questions were randomized for all test subjects. To develop this dynamic website, we used the Node.js environment.

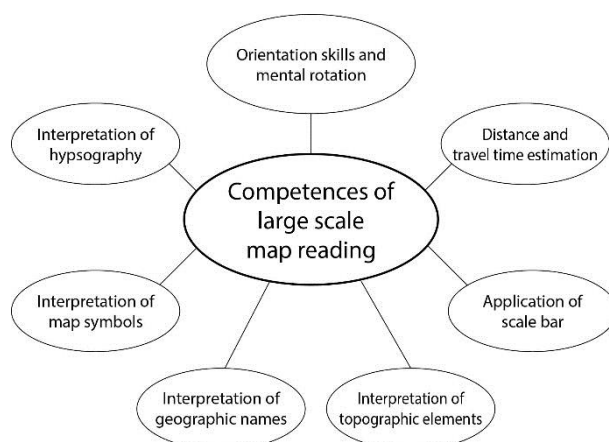


Figure 8. Competences required for reading large scale maps

The first map is a relief map with contour lines (Figure 3). It includes a North arrow (the map was not oriented to North) and a scale bar. The map tested three map reading competences. Question number Q1 measured the interpretation of hypsography by defining the relative heights of points found on the map. Answering this question required both spatial abilities and the comprehension of contour lines. Q2 tested orientation skills and mental rotation by defining the absolute direction from one point to another. Q3 measured the distance and travel-time estimation by defining the length of a path between two points, using the scale bar. Each answer had both distances and time spans to help the proper estimation.

The second map (Figure 4) is also a relief map with contour lines, but it also contains hydrography. Similarly to the previous map, it isn't oriented to North. Question number Q4 tested the interpretation of hypsography, orienting skills and mental rotation in a complex way, by defining the flow direction of the stream.

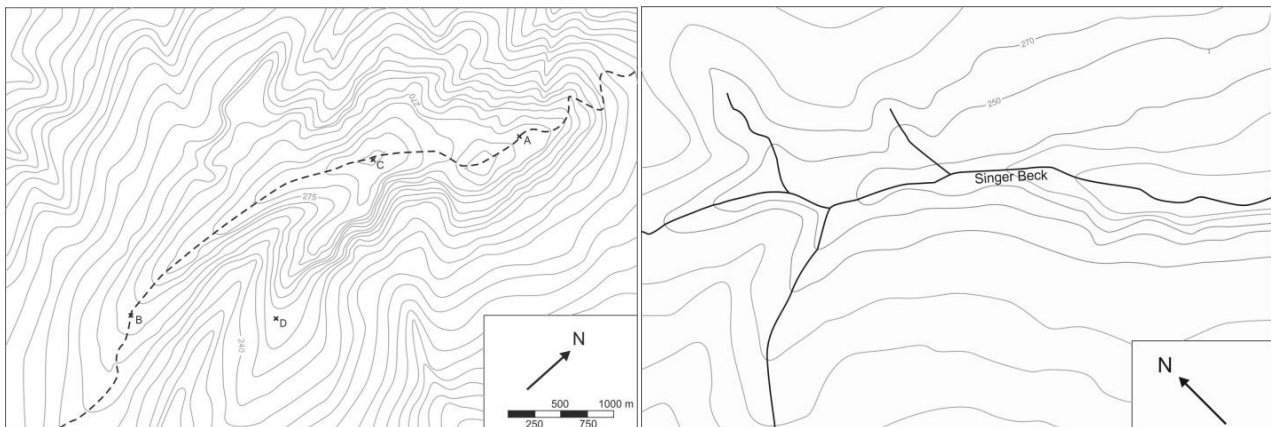


Figure 9 - 4. The relief map used for the test and the relief map with hydrography used for the test (English version)

The third map (Figure 5) is a simplified topographic map, although it has higher information density than the previous ones. Q5 measured the interpretation of map symbols by defining the coverage of a certain region. The applied symbols are commonly used on tourist maps, so experienced map readers could be familiar with them. Q6 tested the interpretation of geographic names, by defining the name of a certain region. To do so, the participants had to recognize and categorize the geographic names. This is the only question in the test that does not have multiple answers, the participants had to type in the answer instead.

The fourth map (Figure 6) does not include contour lines, but it has other topographic elements, geographic names and a scale bar. Question number Q7 tested the interpretation of topographic objects by defining the number of rail crossings between two points. This required the categorization of linear objects and recognition of different road types. Q8 measured the use of a scale bar, and distance estimation by measuring the distance between two points.

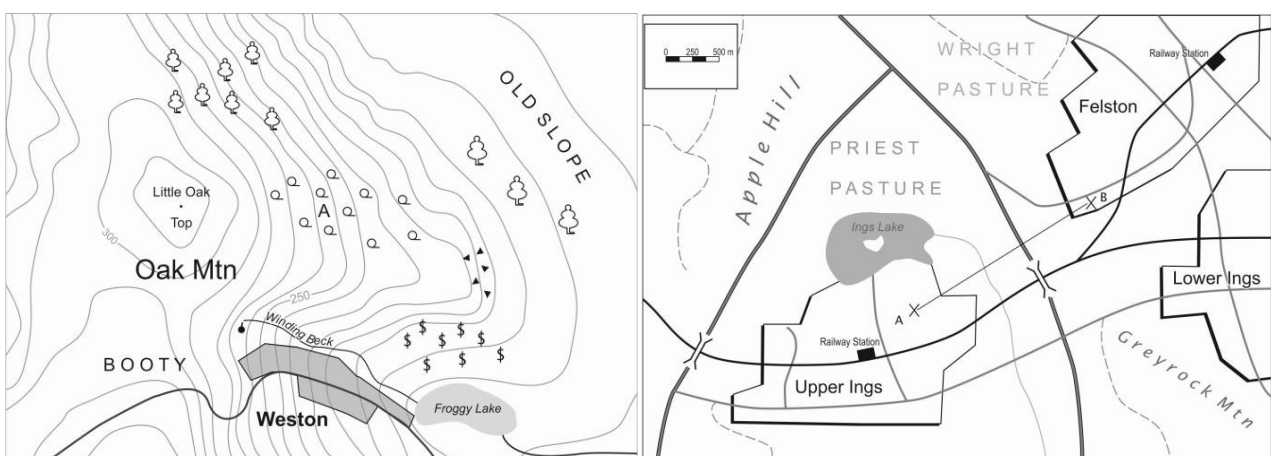


Figure 10-6. The simplified topographic map used for the test and the other simplified topographic map (without contour lines) used for the test (English version)

For the more precise evaluation of the data, we asked some personal information from the participants (e.g. age, education) and information about map using habits (e.g. the frequency of map use).

## **SAMPLING METHOD AND THE COMPOSITION OF THE SAMPLE**

The data collection started in autumn 2015 and lasted for nearly a month. The target population of the Hungarian sample were mainly students from the Eötvös Loránd University. The students' unions of the faculties helped distributing the tests on Facebook, e-mail lists and their own websites. Due to the variety of platforms, the number of participants was high, although the research is not representative because of difficulties of involving foreign students. There were 611 participants, but only 488 of tests were evaluated, because the unfinished ones or the tests with fill time less than 2 minutes were filtered.

Most of the participants were Hungarian (45% - 220 participants), 23% were Romanian (110 participants), 17% Spanish (83 participants), 10% Bulgarian (50 participants), 3% German (15 participants) and 2% English (10 participants). Overall, 44% of the participants were men, and 56% were women. Our sampling method aimed students of higher education. The few participants from primary and secondary education could also provide useful information.

## **EVALUATION OF THE QUESTIONS**

The results show that 74.3% of the participants answered correctly to Q1 (interpretation of hypsography) although 17.7% answered the most frequent answer. 66.6% of the participants answered correctly to Q2 (orientation skills and mental rotation) and 71.3% marked the correct answer to Q3 (distance and travel time estimation), yet 19% of the participants over-estimated both the distance and travel time. 61% of the test subjects answered correctly to Q4 (mental rotation skills and interpretation of hypsography), and 75.4% of them gave the correct answer to Q5 (interpretation of map symbols). 55.1% of all participants could answer correctly to Q6 (interpretation of geographic names), and only 32.3% of the test subjects answered correctly to Q7 (interpretation of topographic objects). It is likely that most participants had problems distinguishing the different road types and identifying the rail crossings (although its definition was given), because 49.8% of all participants confused the rail crossing with the overpass. Finally, 75.9% of test subjects answered correctly to Q8 (application of scale bar).

## **CONCENTRATING ON CORRECT ANSWERS**

Regarding the focus of the research, not only the proportion of correct answers, but also the distribution of them in respect to relevant covariates – characteristics of respondents – could provide useful information. In this chapter, differences in the distribution of correct answers by age, gender, survey language and map reading frequency are examined.

In the case of the Q1 (interpretation of hypsography) a significant difference can be observed by age categories. The youngest, 16-20-year-olds' group – where 58.7% was the rate of correct answers – fares significantly worse than the 21-25-year-olds' group, where 75.9% of respondents gave the correct answer. By gender there is also a difference: 75.1% of men gave correct answers, which result is 8.1 percentage point higher than the one of women. In the Q2 (orientation skills and mental rotation) there is no significant difference in respect to the mentioned relevant covariates. At question number Q3 (distance and travel-time estimation) high differences can be found with regards to map reading frequency. Of those who use maps on a weekly basis 71.0% answered correctly, which is better than the ratio of monthly or less frequent map users – 70% and 48.7% respectively. Concerning the Q4 (interpretation of hypsography and mental rotation) a significant difference by education is present: the midlings' average result is smaller than the same of the group with higher education, the former being 32.3% while latter is 62.1%. Further differences emerge between the youngest and oldest respondent groups, with the latter bearing a significantly higher correct answer rate. Men also gave more correct answers (71.1%) than women (54.1%). Weekly map users tended to answer correctly more than those who use maps less than once a month – 66.9% and 43.7% respectively. Question number Q5 (interpretation of map symbols) is the first where the language of the taken test is a significant factor of the observed correct answer rate. Hungarian (76.8%) and Bulgarian (62.7%) respondents fared the best, while Spanish respondents earned a significantly smaller rate, 41%. Map reading frequency also played a critical role. The group of weekly and monthly map users gave correct answers more probably, than others (less than once per month). In the case of Q6 (interpretation of geographic names) along with the increase of the age better average results are observed, also regarding gender significant difference can be found: males performed better than females with 17.9 percentage point. From the aspect of languages: 34.1% of Hungarians answered correctly, which is the worst average result compared to the other ones. The Romanian (76.4%), Spanish (80.7%), English (100%) and German (73.3%) groups performed better. The latter two languages' results should be handled with precaution due to the low filling base. The Bulgarian language users' average result – similar to the Hungarian's – was also a bit worse, the correct answer rate is 44%. In the case of map reading frequency the before mentioned tendency appears again, more frequent map using results in better average results. In the case of Q7 (interpretation of topographic objects) the language differences produce interesting findings again. The Romanian participants performed the worst, only 6% of them answered correctly. The latter result significantly differs from the Hungarian participants' result (39.5%), furthermore from the English (60%) and German (46.7%) results as well – the

latter two should be handled with precaution. Along with the map reading frequency groups the above mentioned tendency appears again. Significant difference can be found in the case of Q8 (use of a scale bar and distance estimation) by age groups: relative to the 16-20-years-olds' group the 21-25 and the 26-30 -years-olds' groups performed better (consecutively 65.7%, 74.3%, 82.5%).

Regarding the total scores significant differences are present by gender, age group and map reading frequency. 16-20 years olds are outperformed by both the 21-25 and 26-30-years-olds' groups. Men on average earned 0.6 points more in total than women. The more someone uses maps, the higher average score she/he gets.

Table 1. Proportion of good answers

Note: Values in the same row and subtable not sharing the same subscript are significantly different at  $p < 0.05$  in the two-sided test of equality for column means. Cells with no subscript are not included in the test. Tests assume equal variances.

Question		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Points
		Hypso-graphy	Orientation skills, mental rotation	Distance, travel-time estimation	Hypso-graphy, mental rotation	Map symbols	Geographic names	Topo-graphic objects	Scale bar use, distance estimation	Average points
Qualification	Higher	72.7% <sub>a</sub>	65.9% <sub>a</sub>	66.4% <sub>a</sub>	62.1% <sub>a</sub>	65.7% <sub>a</sub>	55.5% <sub>a</sub>	30.2% <sub>a</sub>	72.2% <sub>a</sub>	4.352 <sub>a</sub>
	Secondary	64.5% <sub>a</sub>	54.8% <sub>a</sub>	71.0% <sub>a</sub>	32.3% <sub>b</sub>	58.1% <sub>a</sub>	45.2% <sub>a</sub>	25.8% <sub>a</sub>	71.0% <sub>a</sub>	3.774 <sub>a</sub>
	Elementary	57.1% <sub>a</sub>	71.4% <sub>a</sub>	71.4% <sub>a</sub>	42.9% <sub>o,a,b</sub>	71.4% <sub>a</sub>	28.6% <sub>a</sub>	71.4% <sub>a</sub>	42.9% <sub>a</sub>	4.286 <sub>a</sub>
Age groups	16 - 20 y.o.	58.7% <sub>a</sub>	66.7% <sub>a</sub>	54.7% <sub>a</sub>	45.3% <sub>a</sub>	66.7% <sub>a</sub>	48.0% <sub>a</sub>	29.3% <sub>a</sub>	54.7% <sub>a</sub>	3.760 <sub>a</sub>
	21 - 25 y.o.	75.9% <sub>b</sub>	65.4% <sub>a</sub>	67.1% <sub>a</sub>	58.2% <sub>o,a,b</sub>	65.8% <sub>a</sub>	46.4% <sub>a</sub>	29.1% <sub>a</sub>	74.3% <sub>b</sub>	4.359 <sub>b</sub>
	26 - 30 y.o.	76.3% <sub>o,a,b</sub>	68.8% <sub>a</sub>	73.8% <sub>a</sub>	67.5% <sub>b</sub>	66.3% <sub>a</sub>	60.0% <sub>o,a,b</sub>	32.5% <sub>a</sub>	82.5% <sub>b</sub>	4.675 <sub>b</sub>
	31 - 75 y.o.	66.7% <sub>o,a,b</sub>	61.5% <sub>a</sub>	69.8% <sub>a</sub>	67.7% <sub>b</sub>	61.5% <sub>a</sub>	78.1% <sub>b</sub>	32.3% <sub>a</sub>	71.9% <sub>o,a,b</sub>	4.313 <sub>a,b</sub>
Gender	Man	75.1% <sub>a</sub>	67.0% <sub>a</sub>	70.3% <sub>a</sub>	71.1% <sub>a</sub>	66.7% <sub>a</sub>	63.0% <sub>a</sub>	31.1% <sub>a</sub>	74.4% <sub>a</sub>	4.557 <sub>a</sub>
	Women	67.0% <sub>b</sub>	63.3% <sub>a</sub>	62.3% <sub>a</sub>	45.1% <sub>b</sub>	63.3% <sub>a</sub>	45.1% <sub>b</sub>	29.3% <sub>a</sub>	69.3% <sub>a</sub>	3.995 <sub>b</sub>
Language	Hungarian	70.0% <sub>a</sub>	68.2% <sub>a</sub>	66.4% <sub>a</sub>	57.7% <sub>a</sub>	76.8% <sub>a</sub>	34.1% <sub>a</sub>	39.5% <sub>a</sub>	76.8% <sub>a</sub>	4.555 <sub>a</sub>
	Romanian	70.0% <sub>a</sub>	56.4% <sub>a</sub>	68.2% <sub>a</sub>	68.2% <sub>a</sub>	62.7% <sub>a</sub>	76.4% <sub>b</sub>	20.0% <sub>b,c,d</sub>	64.5% <sub>a</sub>	4.100 <sub>a</sub>
	Bulgarian	76.0% <sub>a</sub>	64.0% <sub>a</sub>	58.0% <sub>a</sub>	54.0% <sub>a</sub>	62.0% <sub>o,a,b</sub>	44.0% <sub>o,a,c</sub>	6.0% <sub>b</sub>	70.0% <sub>a</sub>	3.900 <sub>a</sub>
	Spanish	72.3% <sub>a</sub>	63.9% <sub>a</sub>	69.9% <sub>a</sub>	54.2% <sub>a</sub>	41.0% <sub>b</sub>	80.7% <sub>b</sub>	27.7% <sub>o,a,b</sub>	69.9% <sub>a</sub>	3.988 <sub>a</sub>
	English	90.0% <sub>a</sub>	90.0% <sub>a</sub>	80.0% <sub>a</sub>	60.0% <sub>a</sub>	70.0% <sub>o,a,b</sub>	100.0% <sub>b</sub>	60.0% <sub>o,a,c</sub>	90.0% <sub>a</sub>	5.400 <sub>a</sub>
	German	73.3% <sub>a</sub>	86.7% <sub>a</sub>	66.7% <sub>a</sub>	73.3% <sub>a</sub>	53.3% <sub>o,a,b</sub>	73.3% <sub>b,b,c</sub>	46.7% <sub>o,a,d</sub>	66.7% <sub>a</sub>	4.667 <sub>a</sub>
Map reading	Weekly	75.0% <sub>a</sub>	67.3% <sub>a</sub>	71.0% <sub>a</sub>	66.9% <sub>a</sub>	66.9% <sub>a</sub>	61.7% <sub>a</sub>	36.3% <sub>a</sub>	76.2% <sub>a</sub>	4.597 <sub>a</sub>
	Monthly	70.6% <sub>a</sub>	66.9% <sub>a</sub>	70.0% <sub>a</sub>	55.6% <sub>o,a,b</sub>	68.8% <sub>a</sub>	53.1% <sub>o,a,b</sub>	25.0% <sub>b</sub>	71.2% <sub>a</sub>	4.281 <sub>a</sub>
	Less frequently	61.8% <sub>a</sub>	57.9% <sub>a</sub>	48.7% <sub>b</sub>	43.4% <sub>b</sub>	51.3% <sub>b</sub>	38.2% <sub>b</sub>	21.1% <sub>b</sub>	63.2% <sub>a</sub>	3.474 <sub>b</sub>

In order to test further the relations discussed above we used logistic regression methods<sup>3</sup>, in which we measure the effects of the independent variables on the outcome variable – the correct/false variable. The fitted models for the eight different test questions generally showed further evidence for the previously detailed relations. However, in some cases those observed correlations disappeared, while in some cases new effects emerged due to controlling for multiple variables in the model. The difference by gender in the answers for Q1 – men giving correct answer more probably – vanished. It seems likely that gender was not the main factor for the difference, but a joint effect of more variables. In the case of Q2 previously there was no significant difference by language, but the regression showed that an effect was obscured by the interaction of other variables, according to the more precise model Hungarian respondents fared

<sup>3</sup> Logistic regression is a statistical method which is aimed to predict the probability of a binary outcome (answer correctly or not), furthermore to divide and estimate the effects of relevant factors. The logistic regression model measures the effects of the independent variables (for example gender, education) in such way that it calculates effects of changing only one factor at a time, while holding the rest of them fixed. In this way it separates the influential factors' effects. See e.g.: Wooldridge (2009)

significantly better than Romanian ones. Similarly, 21-25 years old respondents gave the right answer for Q3 more probably than 16-20 year olds. At Q6 the previously observed relations regarding age groups dissolved. Finally, in the case of Q8 a similar relation emerged like at Q2: Hungarian respondents outperformed Romanian ones.

## FOCUSING ON MISTAKES

Information could also be gained from inspecting the frequencies of the types of given mistakes. The proportion of mistakes was the highest in Q7 question's case (70%), followed by Q6 and Q4 consecutively (45%, 40%). The most easily answerable question was Q1 and Q8, only the 28% of the respondents gave wrong answer to both. In the remaining three questions' case the wrong answers' average proportion was 33-35%.

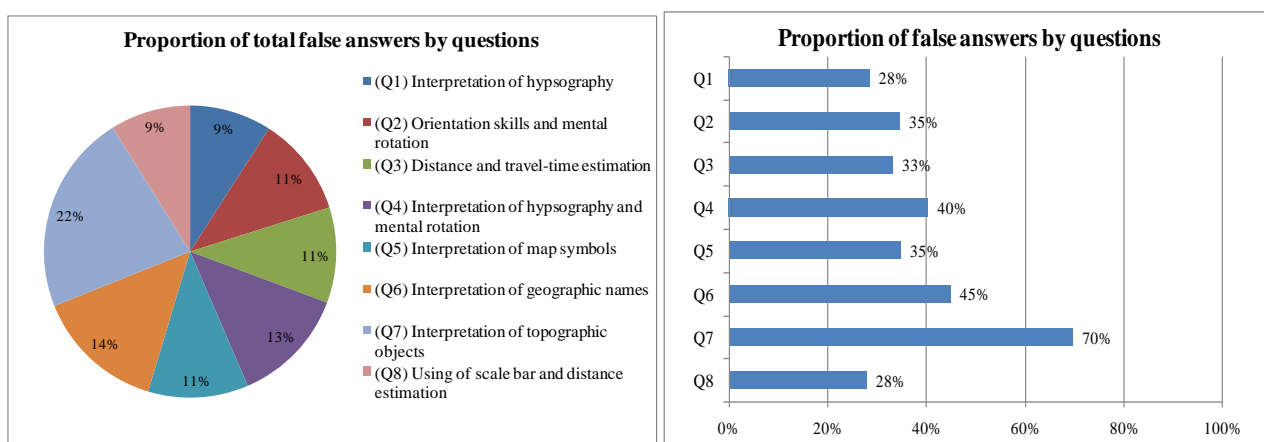


Figure 7-8. Proportion of total false answers by questions (left) and proportion of false answers by questions (right).

For further analysis, we examined the database aggregated by the number of mistakes. In figure 9, the benchmark group (first row) consists of those who committed 8 mistakes, the probability of giving false answer to each question is the same – every mistake type was committed by 13% of the respondents. As the cumulative number of mistakes decrease, the deviation from the latter proportion becomes interesting: in the case of those who gave 7 wrong answers the proportion of mistakes in Q1, Q5 decreases, and in Q8 increases. From the opposite perspective: for those who gave only one correct answer the interpretation of hypsography and map symbols seemed easier, while distance estimation with the use of scale bar appeared more difficult. The group with six wrong answers typically answered Q1 and Q5 correctly, dominantly Q7, Q4, and Q3 questions caused trouble for them (interpretation of topographic objects, hypsography and mental rotation, distance and travel-time estimation). In the case of those who committed four or five mistakes the same tendencies show up: along with the decrease of the cumulative number of mistakes the proportion of wrong answers increases for the Q4, Q6, Q7 questions (interpretation of hypsography and mental rotation, geographic names and topographic objects). Based on the latter groups' performance Q1, Q2, and Q3 seemed easier to answer (interpretation of hypsography, orientation skills and mental rotation, distance and travel-time estimation). For those who committed three mistakes Q4, Q6 and Q7 caused problems, in the case of two wrong answers the latter two. Finally, Q7 caused most trouble for participants with only one wrong answer.



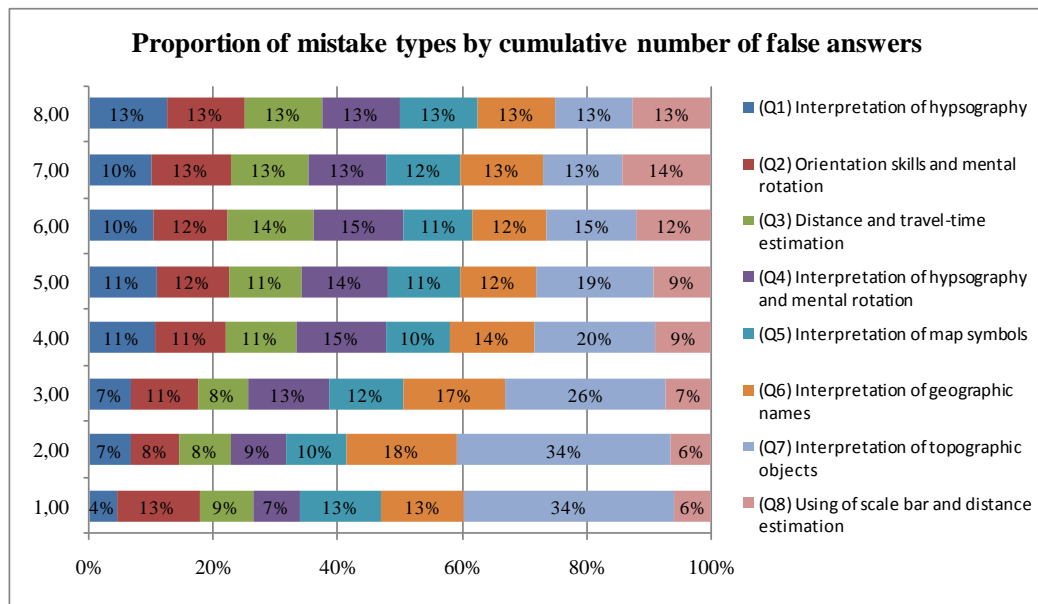


Figure 9. Proportion of mistake types by cumulative number of false answers

## THE CREATION OF MAP READING GROUPS

The research's goal was besides the testing of the questionnaire to create map reading groups based on the amount of good answers. Based on preliminary considerations and previous researches (Gerber 1981; Clarke 2003) the tripartition seemed the best option – two groups would be trivially few for the further examinations, while for the experimental settings' number would be too large for more than three groups. For the tripartition we tried to find the cumulative points' optimal cut points. Based on the research's sample and the cumulative points' distribution, we examined at what cut points could the proportion that is the most similar to the perfect tripartition be reached (when the 33.3% of the respondents fall under each map reading groups). The distributions of respondents' along the different cut points can be viewed in figure 10, with the square deviation decreasing downwards. For the cut points determination it was necessary to take into account the fact, that our research's sample mainly consists of participants with higher education background who – as our research's consequences show – averagely perform better than the lower education participants. Based on the previous consideration we chose the cut points with the lowest square deviation, which generate the closest proportion in each group when the people with primary and secondary education are also counted in. The chosen cut points are 4 and 6, so the beginner group consists of participants with 0-3 points; the intermediate map readers are those who achieved 4-5 points, and the expert map readers above 6 points.

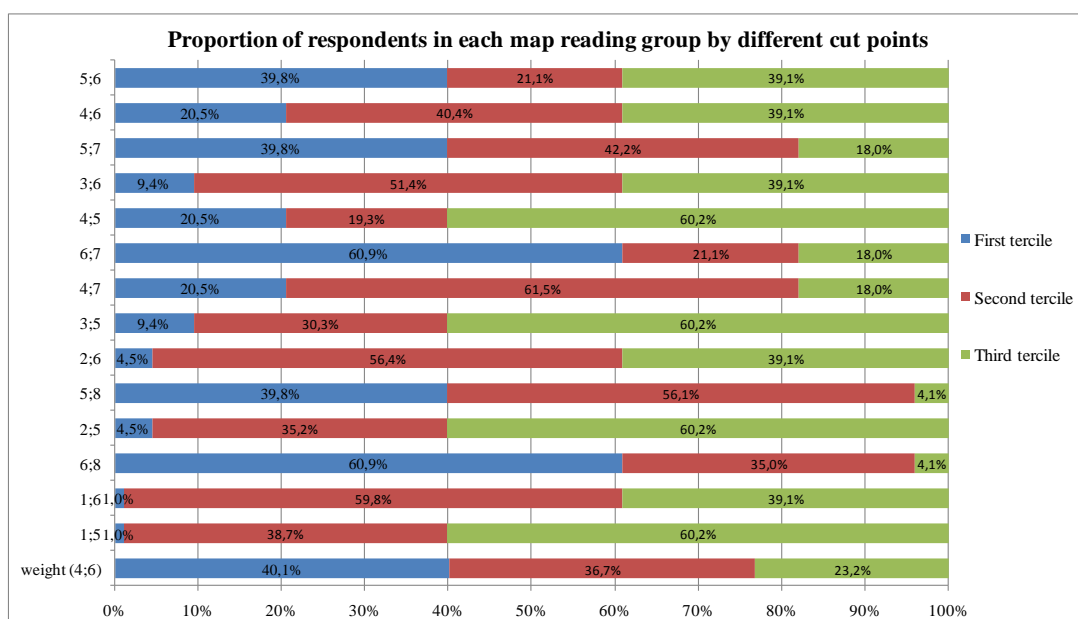


Figure 10. Proportion of respondents in each map reading group by different cut points

For testing the latter cut points, we weighted the Hungarian subsample by relevant covariates – gender and education – which resulted in such group proportions that we expected. The chosen cut points' validity can be strengthened by the relationship between the created map reading groups and the map reading frequency. Clear-cut tendency shows up: more frequent map reading corresponds to better map reading level.

The created map reading groups' compositions differ, in the beginner group the female and younger participants' dominance is typical, along with those who read and use maps less frequently. Regarding education, mainly primary and secondary education participants characterize this group, and the examined languages appeared in approximately the same proportion. In the intermediate map readers' group, a nearly equal distribution can be found by gender and age, the group mainly comprises of those who use maps weekly or monthly and are dominantly Hungarian or Romanian. The expert map users' group mainly consists of male, elder and highly educated participants. Mostly Spanish, Hungarian and Romanian languages are dominant. The filling times do not differ significantly, the average time for beginners was 12 minutes, for intermediate readers 8 minutes, and in the expert group 9 minutes.

## MAIN FINDINGS BY MAP READING GROUPS

In the examination of committed mistakes by the different map reading groups it is better to take a “reversed logic” as a basis, and start with the expert group. In the latter's case the best average result was observable in the Q1 and Q8 questions, nearly 91% of the participants gave right answers for these. The most mistakes appeared typically in the Q7 question's case – only 50.8% of the participants answered correctly – followed by Q6 (75.9%). Generally, interpretation of topographic objects and geographic names caused the biggest problems for this group. When we focus on the intermediate map reading group – so we allow more mistakes for the respondents – beside the mentioned two competences Q4 – orientation skills and mental rotation – also appears problematic. Of course the correct answers proportion is smaller compared to the expert group, in the case of Q7 21.8%, for Q6 48.2% and for Q4 51.8% of the participants answered correctly. In the beginners group the problematic questions' list widens. Among other questions Q3 – distance and travel-time estimation – also caused difficulties. Naturally, in this group besides the mentioned ones nearly all of the questions required serious effort from the respondents, the correct answers' proportion is radically lower compared to the previous two groups – naturally due to the characteristic of the group formation method.

Table 2. Proportion of good answers by map reading groups

	Beginner	Intermediate	Expert
(Q1) Interpretation of hypsography	39.0% <sub>a</sub>	69.0% <sub>b</sub>	91.1% <sub>c</sub>
(Q2) Orientation skills and mental rotation	31.0% <sub>a</sub>	61.9% <sub>b</sub>	86.9% <sub>c</sub>
(Q3) Distance and travel-time estimation	29.0% <sub>a</sub>	65.5% <sub>b</sub>	88.0% <sub>c</sub>
(Q4) Interpretation of hypsography and mental rotation	21.0% <sub>a</sub>	51.8% <sub>b</sub>	88.0% <sub>c</sub>
(Q5) Interpretation of map symbols	34.0% <sub>a</sub>	61.9% <sub>b</sub>	84.8% <sub>c</sub>
(Q6) Interpretation of geographic names	29.0% <sub>a</sub>	48.2% <sub>b</sub>	75.9% <sub>c</sub>
(Q7) Interpretation of topographic objects	8.0% <sub>a</sub>	21.8% <sub>b</sub>	50.8% <sub>c</sub>
(Q8) Using of scale bar and distance estimation	36.0% <sub>a</sub>	72.1% <sub>b</sub>	91.1% <sub>c</sub>

## RESPONSE PATTERNS

Another goal of the research was to discover the response patterns of each map reader group to provide further information for creating individualized maps. To achieve this, we used pattern finding algorithms to define which are the most frequently repeating patterns of each map reader group and the whole sample. Figure 11–14 in the appendix show the visualization of the 25 most frequent response patterns (each column representing a pattern). The results of the whole sample (all 488 participants) show that 23 participants shared the same, most common pattern where they could not answer Q7 (interpretation of topographic objects) correctly (Figure 11 in appendix). The second most common pattern (with 22 participants) shows problems with both Q7 and Q6 (interpretation of geographic names). Faultless tests are also frequent (20 participants) along with answering incorrectly to Q5 (interpretation of map symbols) and Q7 (14 participants) or missing Q5, Q6, Q7 (12 participants).

Beginner map readers (100 participants) didn't have much exact pattern, so we had to concentrate on the correct answers instead of the incorrect ones. According to the results most participants could answer question number Q1 (interpretation of hypsography), Q5 and Q8 (use of a scale bar, and distance). In the most common pattern (5 participants) only Q1 was answered correctly, or none of them. The patterns also show that despite Q3 (distance and travel-time estimation) and Q8 requires similar competences Q3 had more incorrect answers.



The intermediate map readers' (197 participants) most common pattern (12 participants) consists of three main mistakes: Q5, Q6, Q7 (Figure 13 in appendix). In the second most frequent pattern, participants gave incorrect answers to Q1, Q2 (orientation skills and mental rotation), Q4 (interpretation of hypsography) and Q7, while in the third most frequent pattern they gave wrong answers to three questions: Q4, Q5 and Q7. The remaining patterns of this group mainly show the combinations of the previous faults.

The most common pattern of the expert map readers (191 participants) occurred at 23 test subjects, where they only answered Q7 incorrectly (Figure 14 in appendix). In the second most frequent pattern (22 participants), they answered Q6 and Q7 incorrectly, yet in the third most frequent pattern (20 participants) they answered all questions correctly. In other common patterns, the experts were mistaking both Q5 and Q7 (14 participants), Q7 and Q8 (9 participants), but mistaking both Q1 and Q3 occurred rarely.

## CONCLUSION

The here presented study's primary goal was to quantify map reading skills by using the results of an online test developed for this purpose (Szigeti & Albert 2015). With the questionnaire's evaluation based upon a huge sample of respondents of higher education, our aim was to gain information about the respondents' map reading skills, and the factors influencing it as well.

In the questions' case, the most correct answer appeared when respondents faced with interpretation of hypsography, distance and travel-time estimation, interpretation of map symbols, distance estimation with scale bar using – with the proportion of good answers above 70%. This rate is between 60-70% in two question's case: orientation skills and mental rotation and interpretation of hypsography and mental rotation. The worst performance was observable in two questions' case: interpretation of geographic names and interpretation of topographic objects. Concerning good answers significant difference can be observed by education, age categories, gender, language and map reading frequency. Regarding particular questions – interpretation of hypsography, orientation skills and mental rotation, interpretation of map symbols, cumulative number of good answers – a strong tendency shows up: male respondents perform significantly better than female ones. Regarding age, the 16-20-year-olds' results are significantly worse compared to higher age categories at interpretation of hypsography, distance and travel-time estimation and cumulative number of good answers. Also an occurring tendency is that more frequent map using results in better average performance – mainly in distance and travel-time estimation, interpretation of map symbols, interpretation of geographic names and cumulative number of good answers. In two questions' case – interpretation of hypsography and interpretation of hypsography and mental rotation – the proportion of good answers is increasing by the level of education. Regarding to the survey language, the Romanian respondents perform better than Hungarians in the competences of orientation skills and mental rotation. In the case of map symbol interpretation, the good answers' proportion was the highest from Hungarian and Bulgarian respondents, and the lowest from Spanish respondents. The interpretation of geographic names caused problems especially to Hungarian and Bulgarian respondents, while Romanians performed best. In the case of topographic objects' interpretation, the Bulgarian respondents' average result was again a bit worse. Concerning distance estimation with scale bar, Hungarian respondents faired significantly better than Romanian ones.

Our further goal was to create optimal groups of map-reading skills based on the test performance – total points earned – of the respondent and to find those group level characteristics which could help us in preparing the second module of our research and designing personalized maps. For separating these groups, we chose such cut-points, which generate the (three) most similar sized groups. We have taken in account the nature of our sample and the lessons learned from the weighted – by gender and age – Hungarian subsample. By synthesizing the observations made, the following grouping principle was formed: respondents with 0-3 correct answers are beginners, 4-5 points stand for the intermediate group and those who gave 6 or more good answers are labelled as expert map readers. The beginner group consists of mainly female respondents, mainly members of younger generations, persons with low or middle education and those who does not use maps frequently. The ratio of beginners is similar across the language the test was taken in. In this group the rate of correct answers is small for all question, and the worse performance can be observed at questions Q7, Q6, Q4 and Q3 – interpretation of hypsography, use of a scale bar and distance estimation, interpretation of hypsography and mental rotation, distance and travel-time estimation. Mistakes do not follow clear patterns; wrong answers are present at almost all tasks – due to the forming rule of groups. The most frequent detectable patterns are based on correctly answering the questions focusing on interpretation of hypsography, interpretation of map symbols, distance and travel-time estimation. It seems like these questions were easier to answer for correctly for the group. Members of the intermediate group mainly use maps weekly or monthly, are mainly Romanian or Hungarian. There are no distinctive differences in the gender and age distributions. For respondents of this group questions Q7, Q6 and Q4 proved to be the most difficult – interpretation of hypsography, use of a scale bar and distance estimation, interpretation of hypsography and mental rotation. Combinations of the following tasks form the most frequent response patterns for this group: 1) interpretation of geographic names, 2) interpretation of topographic objects, 3) interpretation of hypsography and mental rotation. Finally, the expert group consists of older, more highly educated – compared to the

other two groups – male respondents who use maps quite frequently. Spanish, Romanian and Hungarian group members are the most common. The dominant part of mistakes made by this group was about questions Q7 and Q6 – interpretation of geographic names, interpretation of topographic objects –, most frequent response patterns are also characterized by these two wrong answers.

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**APPENDIX**

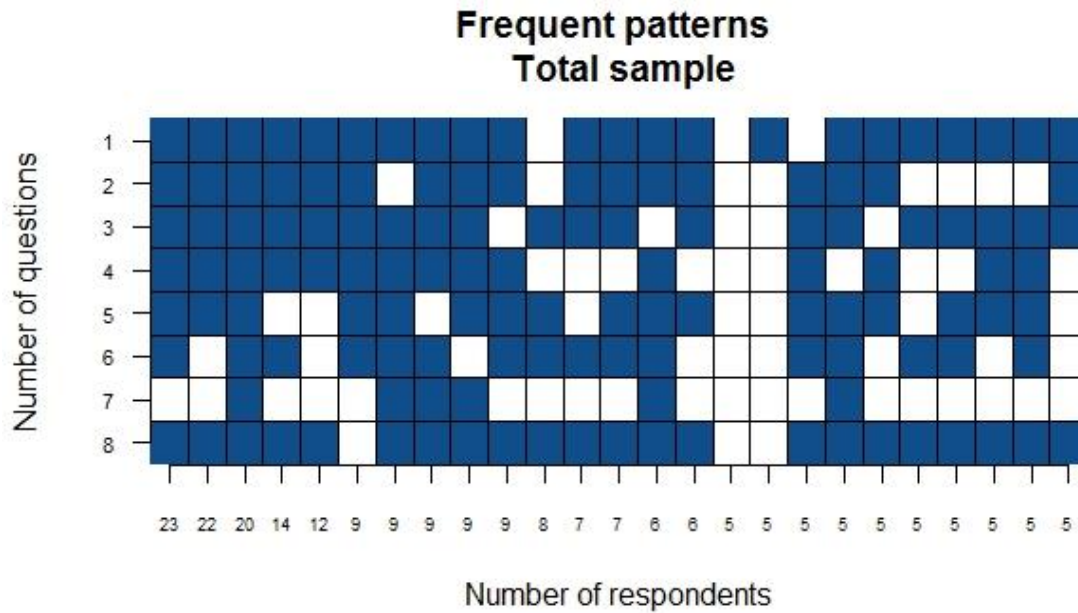


Figure 11. Frequent patterns in the total sample

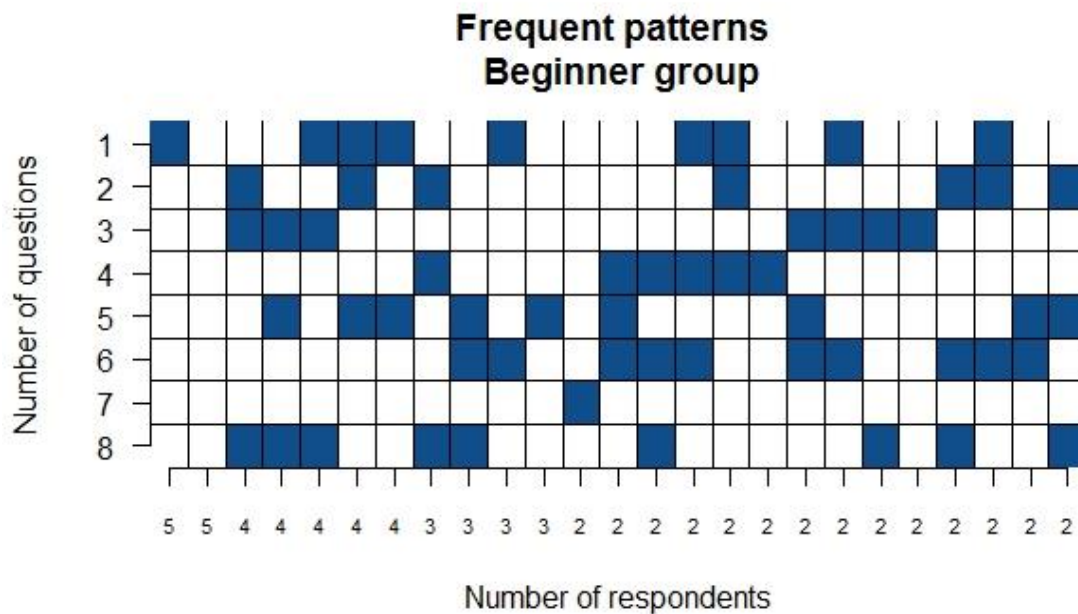


Figure 12. Frequent patterns in the beginner group

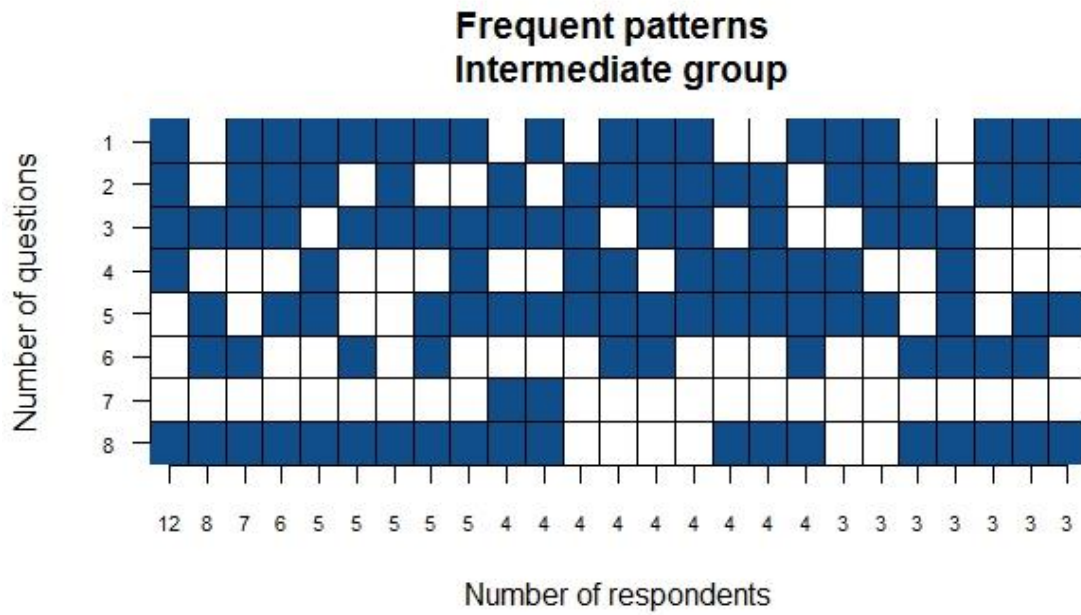


Figure 13. Frequent patterns in the intermediate group

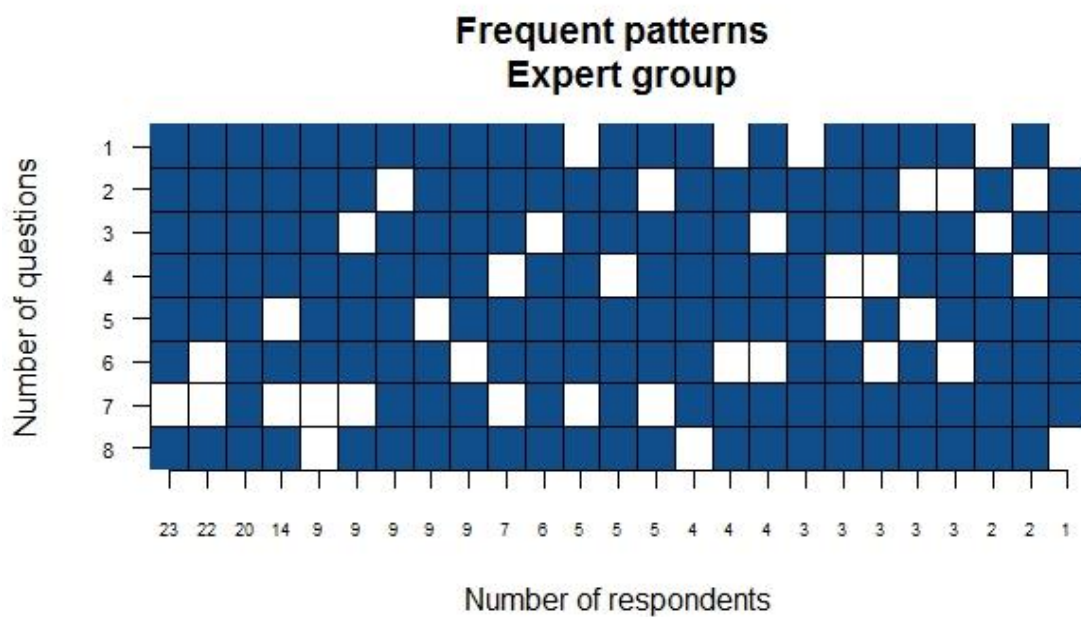


Figure 14. Frequent patterns in the expert group