CHERNOFF FACES AS AN ALTERNATIVE METHOD OF REPRESENTATION IN SCHOOLS: AUSTRIAN-HUNGARIAN SURVEY

Eszter Simonné Dombóvári[1], José Jesús Reyes Nunez[2], Georg Gartner[3], Manuela Schmidt[4], Anita Rohonczi[5]

(1,3,4) Vienna University of Technology, Institute of Geoinformation and Cartography, Research Group on Cartography
Erzherzog-Johann-Platz 1/127-2, A-1040 Wien. Austria
Tel.: +43-1-58801-12601 Fax: +43-1-58801-12699
Emails: (1) deszter@map.elte.hu (3) ggartner@mail.tuwien.ac.at,
(4) manuela.schmidt@tuwien.ac.at

(2) Eötvös Loránd University, Department of Cartography and Geoinformatics
Pázmány Péter sétány 1/A. Budapest 1117. Hungary
Tel.: +36 1 372 29 75 Fax: +36 1 372 29 51 E-mail: jesus@ludens.elte.hu, jesus@map.elte.hu

(5) Cartographia Editorial House
Fehérvári út 89-95. Budapest 1119. Hungary
Tel.: +36 1 463 90 25 Fax: +36 1 463 90 11 E-mail: rohonczi.anita@cartographia.org

Abstract: *During 2008 and 2009 was developed an international project on the possible use of Chernoff faces in School Cartography, with the participation of Argentine and Hungarian researchers, organizing a survey that finished with positive results, but also with some questions without a clear answer. This situation motivated Hungarian colleagues to organize a new project together with Austrian specialists in 2010 and 2011. The results of the Austrian survey were compared with the results obtained by Argentine and Hungarian pupils in 2009, finding answers to the previous contradictory results. A new Hungarian questionnaire was applied in grades 5 to7 of two Elementary Schools in Budapest, studying how younger children read the data represented using Chernoff faces and pictograms modified according to the Chernoff principle. This Hungarian survey determined the grade of acceptance between the younger pupils, as well as the grade of practical usability of these alternative methods in School Cartography.*

1. INTRODUCTION

1.1 What are the Chernoff faces?

This method for data representation was created by Hermann Chernoff (Professor Emeritus of Applied Mathematics, Department of Statistics at Harvard University) in 1973 (Figure 1). The essence of his method is the use of the features of a human face to represent different variables (Chernoff, 1973). According his article up to 18 themes or variables can be represented using a face. During a theoretical research made in 2008 (Reyes, 2009) participant researchers concluded that at same time six (6) variables can be represented with a Chernoff face in interest of a faster and easier reading of data (e.g. represented on a map).

From 1977 the Chernoff faces began to be introduced to cartography abroad. The first and more famous (today considered a classic) example is the map entitled "Life in Los Angeles, 1970", designed by Eugene Turner and drafted by Richard Doss from the Geography Department at the California State University in 1977 (Figure 1). Turner wrote about this map: "*It is probably one of the most interesting maps I've created because the expressions evoke an emotional association with the data. Some people don't like that.*" (Turner, 2004).

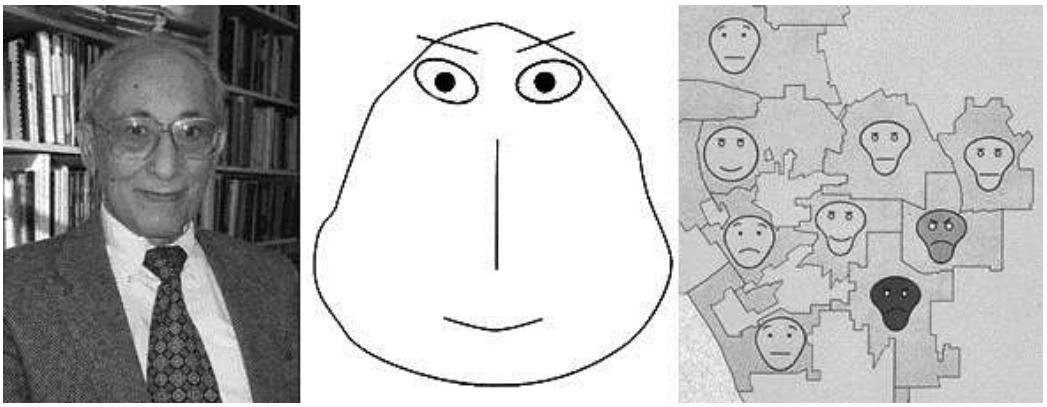

Figure 1. Herman Chernoff (2008), the first face from 1973 and a fragment of the first thematic map (Turner, 1977)

1.2 Hungarian-Argentine research project (2008-2009)

The Chernoff faces were not created for the data representation on maps. By this reason, the characteristics of this method need to be adapted to the cartographic requirements before using it on a map and in specific in School Cartography.

In 2008 Argentine and Hungarian researchers began a two years project entitled "The possible uses of the Chernoff faces for data visualisation in School Cartography". During the first year was followed the theoretical research (Reyes, 2009) to draft and to exchange principles and general lines to follow during a school survey, which was made in the second year (Reyes et al., 2010).

In this survey, 818 pupils from 8 schools of the province of Buenos Aires and 1038 pupils from 12 schools in three Hungarian provinces (all of them from 12 to 15 years old) answered a questionnaire designed according to the specific characteristics of each educational system between March and June of 2009 (Juliarena , Garra, Rey, et al., 2009). The questionnaire was formed by four questions to examine four aspects of the use of Chernoff faces:

- Use of "traditional" Chernoff faces
- Use of Chernoff faces applying cartographic principles
- Applying the Chernoff principle on pictograms
- Drawing of thematic data by pupils on an outline map using Chernoff faces

The results of the Argentine-Hungarian survey can be read on the Table number 1 in the point 3.2 (Results of survey in Austria) of the present paper, comparing them with the results obtained in the Austrian survey in 2011. Apart from the positive results explained in earlier papers (Reyes, 2010), some contradictory and unexpected experiences were noted when the Argentine and Hungarian results were compared:

- Question applying the Chernoff principle on pictograms: the Hungarian pupils' obtained the best result between the four questions of the questionnaire, while it was the second worse result in the Argentine questionnaire.
- Reading of data represented by changing only the shape of a face ("traditional" Chernoff face) did not provoke more significant difficulties than if the representation is made changing the size and the fill (applying cartographic principles).

On other hand, the survey was made for older (13-14 years old) pupils, but one of the conclusions of the previous theoretical research was that use of the faces can be more successfully for children in early grades of Elementary Schools, an idea that was reaffirmed by some of the opinions written by the Hungarian pupils to comment their own answers.

In interest of giving answer to all those questions that remained open, colleagues from the Department of Cartography and Geoinformatics at Eotvos Lorand University (Budapest) decided to follow the research in a new international project with the participation of the Research Group on Cartography at the Institute of Cartography and Geoinformatics of the Vienna University of Technology.

2. ORGANIZATION OF THE AUSTRIAN-HUNGARIAN RESEARCH PROJECT

In 2010 both institutions began a project entitled "Further research and survey related to the theoretical and practical results of previous international projects about the possible cartographic uses of the Chernoff faces", financed by the bilateral agreement for research between Austria and Hungary. This research project presented different characteristics in relation to the Argentine-Hungarian one:

- The theoretical research was planned according to the results obtained during the Argentine-Hungarian project and it was focused to the optimization of the method for School Cartography.
- Both research teams organized a survey in their respective countries in 2011, which were planned to complete each other and not to compare their results.
- Austrian colleagues organized a survey similar to the Argentine-Hungarian one, and compared their results with the results obtained in 2009, finding answers to clarify the previous contradictory results.
- Hungarian colleagues organized a new survey for pupils in earlier grades (grades 5 to 6) in two selected Elementary Schools in Budapest. This test filled the gap left during the 2009 survey, studying how younger children can read the data represented using the method and the grade of acceptance between them.

Reading the last two characteristics it can be deduced that the present project was divided into two subprojects with results separated from each other, but completing each other and the previous Argentine-Hungarian project at same time.

3. AUSTRIAN RESEARCH SUBPROJECT

3.1 Design of the questionnaire in Austria

After the study of the results obtained in the theoretical research and common arrangements, Austrian colleagues followed similar principles to design their own questionnaire, that is to use similar solutions than in the Argentine-Hungarian project (the same number and content of questions, colour, symbols, paper size, pupils with similar cartographic knowledge), in interest of facilitating the comparison of results in both surveys.

The questionnaire was formed by four questions and it was printed in black and white and A5 format. Considering the specific characteristics of the Austrian educational system, the questionnaire was designed for pupils of grades 3 and 4 (13–14 years old) in Austrian Secondary Schools (AHS, allgemeinbildende höhere Schule – academic secondary school and HS, Hauptschule – general secondary school) with some experience using maps and school atlases.

The questions were penned as follows:

1) Question using "traditional" Chernoff faces (only the shape of a face can be changed to represent data and all the faces are unfilled): The selected data were the "Tourism in Austrian provinces" to compare the number of tourists, the overnight stays of domestic and foreign guests and the length of stay. There were two simple and one more difficult question (Figure 2).

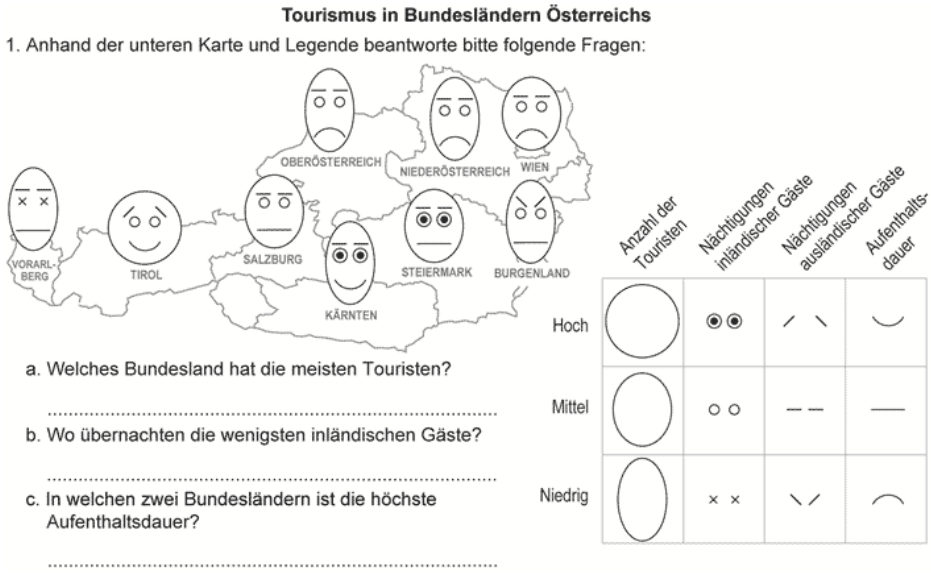

Figure 2. Question using "traditional" Chernoff faces

2) Question with Chernoff faces applying cartographic principles (size of the face varied according to the represented data): The theme was the agriculture in the Alpine countries and the number of farm animals in Austria (Figure 3).

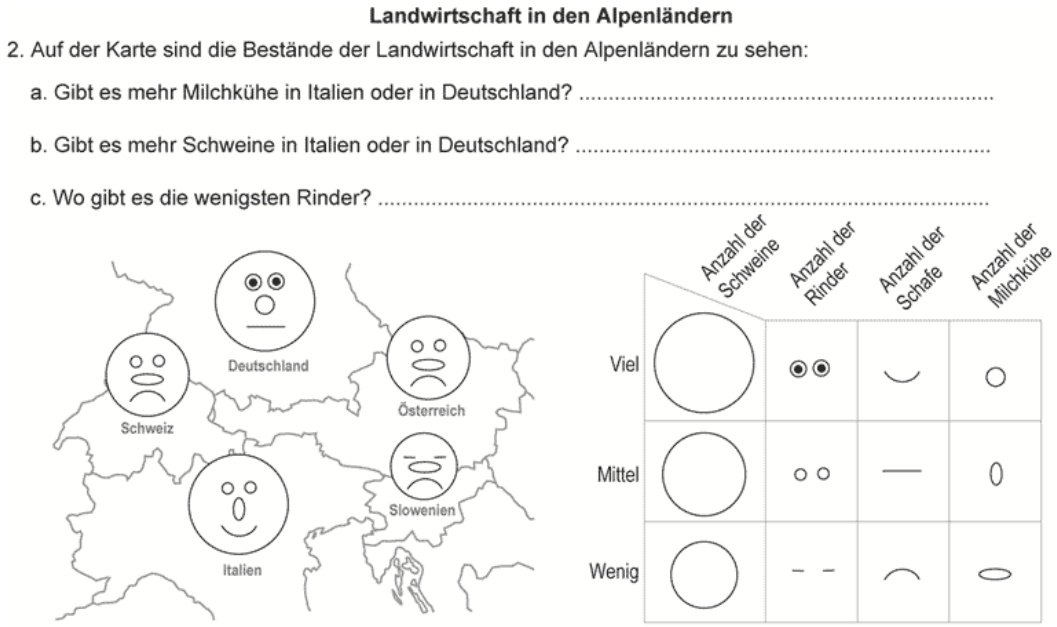

Figure 3. Question with Chernoff faces applying cartographic principles

3) Question applying the Chernoff principle on pictograms: In Austria the same pictogram (a tree) was chosen, changing similar parameters: leafage, trunk, etc. like in Hungary and Argentina (Figure 4). The topic was the data about forestry in some neighbouring countries (growth of the forest area, the proportion of forests and the gross value added of forestry).

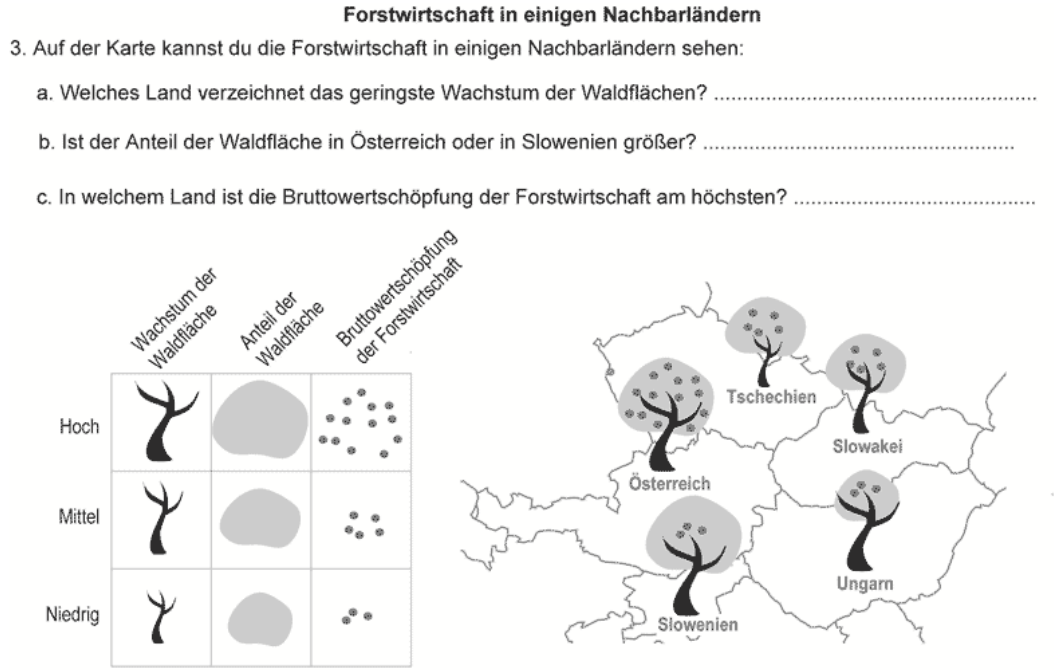

Figure 4. Question applying the Chernoff principle on pictograms

4) Question to draw thematic data on an outline map using Chernoff faces (Figure 5): In the last part the pupils have to draw their own Chernoff map with a table containing basic data and a legend. Data were about the cinema, theatre and museum visits in some Austrian counties. The shape of the face was given, pupils had only to draw the eyes, lips and eyebrows on the outline map.

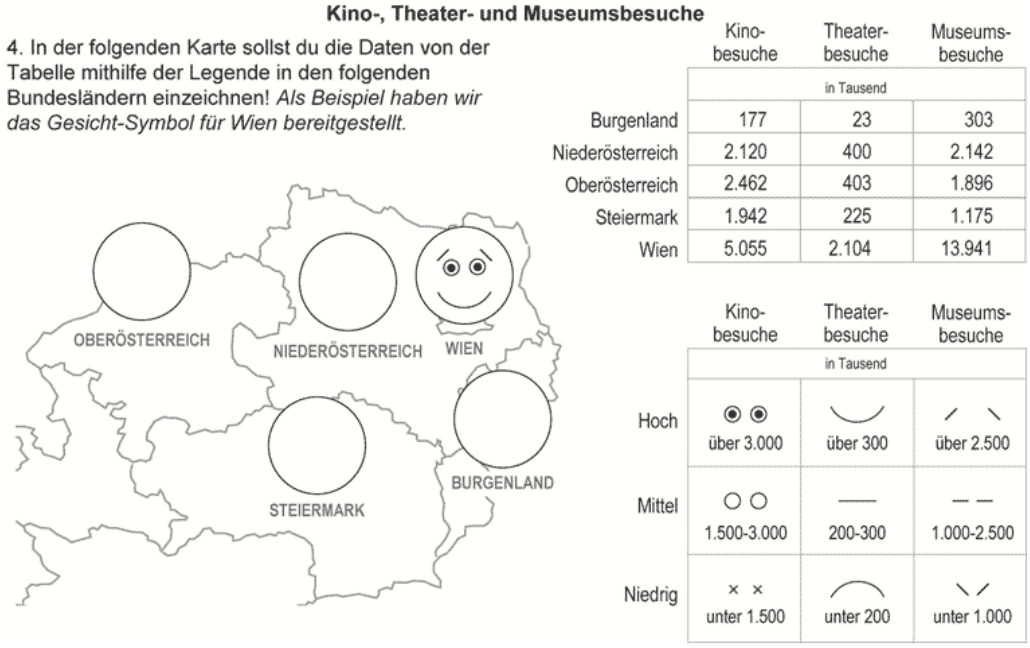

Figure 4. Question to draw thematic data on an outline map using Chernoff faces

3.2 Results of the survey in Austria

The questionnaire in Austria was applied between March and June 2011 and 11 schools from eight Austrian Federal States participated, the majority of the answers arriving from Lower Austria (Niederösterreich). A total of 1793 pupils answered the questions of the test, and the majority of participants were 13 years old (42,7%, 766 pupils) and 14 years old (33,5%, 601 pupils). From them 52,5% were girls (942 pupils) and 46,3% (830 pupils) were boys.

Table 1. Results of the surveys made in Argentina (2009), Hungary (2009) and Austria (2011)

MAIN RESULTS OF THE SURVEY									
QUESTIONNAIRE	**ARGENTINA (2009)**			**HUNGARY (2009)**			**AUSTRIA (2011)**		
	Correct answers	**Answers with one or more errors**	**No answer**	**Correct answers**	**Answers with one or more errors**	**No answer**	**Correct answers**	**Answers with one or more errors**	**No answer**
Question using "traditional" Chernoff faces	493	313	12	828	207	3	1584	209	0
Question with Chernoff faces applying cartographic principles	285	527	6	665	367	6	1514	273	6
Question applying the Chernoff principle on pictograms	294	520	4	908	123	7	1329	461	3
Question to draw thematic data on an outline map using Chernoff faces	540	257	21	798	211	29	1474	297	22

The Austrian results were proportionally better than in Hungary or in Argentina (Table 1). The number of correct answers is also interesting because in Austria the understanding and using of Chernoff faces on maps were the best (more than 80% of pupils answered the first, second and fourth questions correctly). But they gave the least right

answers about this principle on pictograms (only 74% of the pupils), while this was the best result in the Hungarian survey with 87% of the pupils.

In Figure 5 can be compared the results obtained in the three surveys. Based on these statistics can be determined that the Austrian results confirmed the results obtained in Hungary during the school survey in 2008.

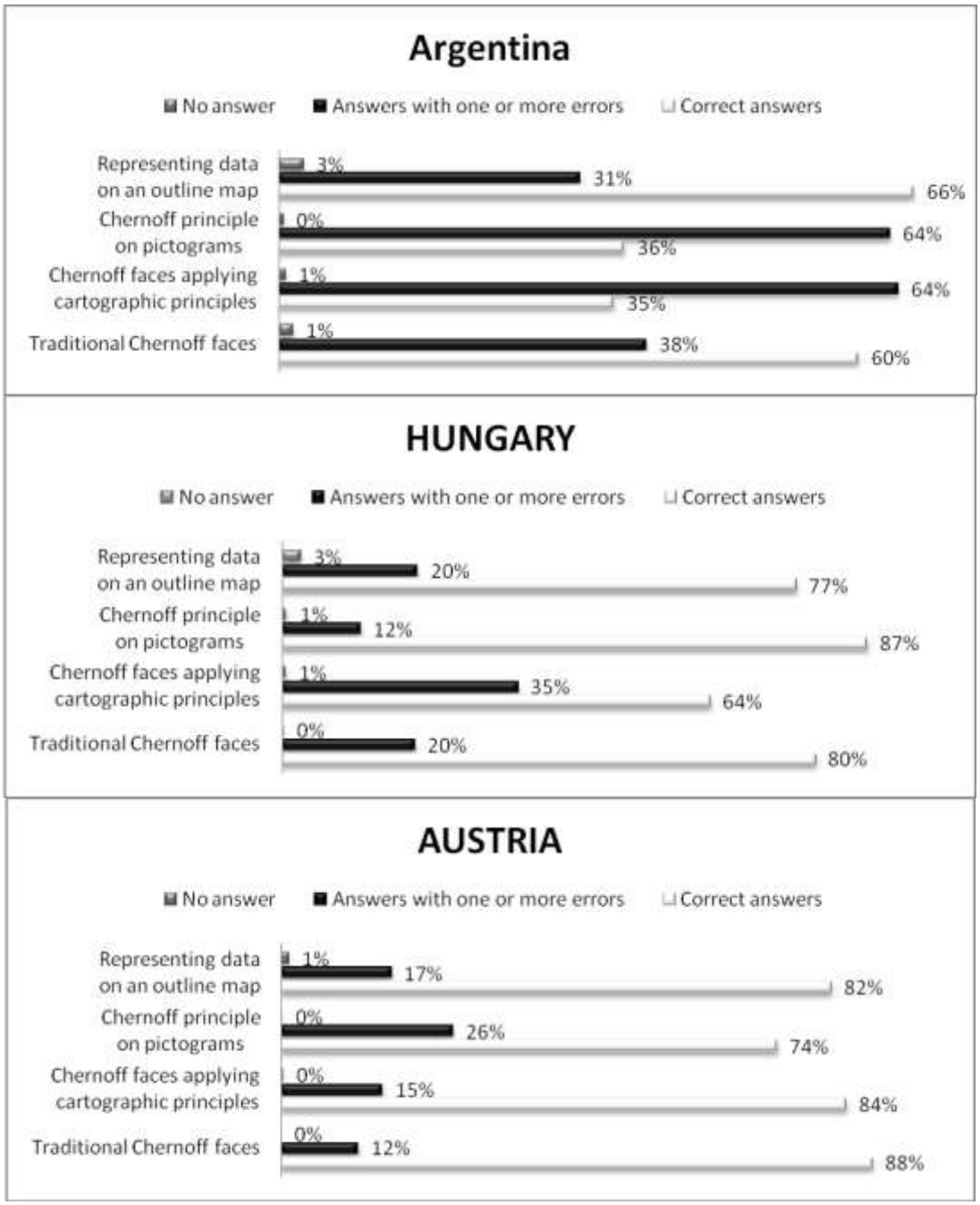

Figure 5. Diagram comparing the percentage of correct and incorrect answers by questions in the Argentine, Hungarian and Austrian survey

Other of the most interesting results was the comments and feedbacks of the pupils in the Austrian survey. A total of 1208 pupils (67,4%) wrote their opinions, which researchers categorized as positive, negative or neutral (Figure 6).

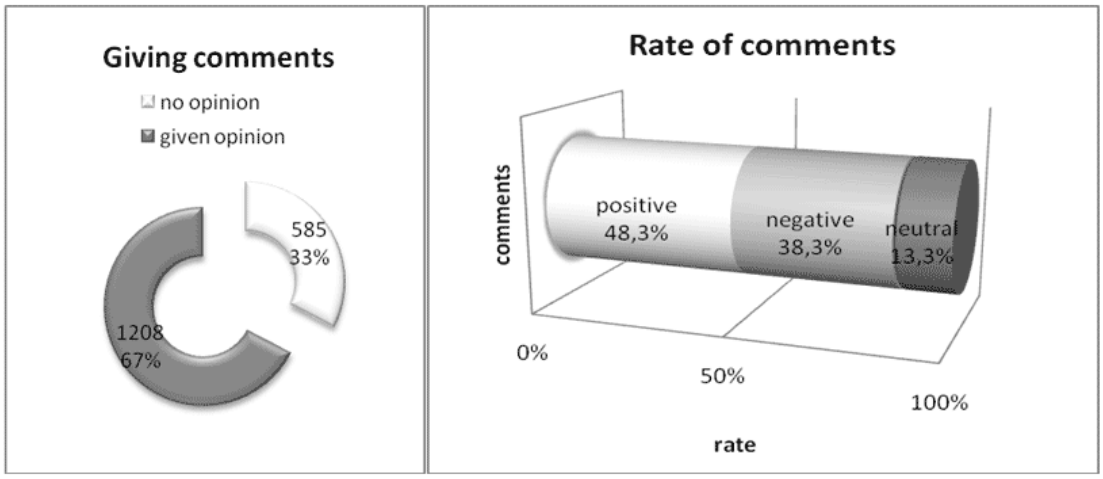

Figure 6. Proportion of positive, negative and neutral comments during the Austrian survey

4. HUNGARIAN RESEARCH SUBPROJECT

4.1 Design of the questionnaire in Hungary

The new questionnaire was designed considering the specific characteristics of the Hungarian educational system: in Elementary Schools pupils began to learn some basic map concepts (mainly related to orientation and sketches of their classroom and immediate environment) from grade 3, but they learn more detailed these concepts in grade 5. The situation with the school atlases is similar: they begin to use "My First Atlas" from grade 3, but the use of maps and school atlas became more systematic from grade 5. The final decision was to apply the questionnaire for pupils in grades 5 to 6, when they have at least a minimal experience using maps and school atlases in the classroom.

The new questionnaire was planned to complete the results obtained in 2009, giving answer to a main question: Will the pupils select the alternative methods of representation (in this specific case the Chernoff faces and the pictograms designed according to the Chernoff principle) if they have the same information represented using traditional methods of thematic representation?

Table 2. Description of the Hungarian questionnaire

TASKS	QUESTIONS	METHOD OF REPRESENTATION
First task	Which is the region of the country with the highest number of Secondary Schools?	Traditional method: Simplified bar graph
	Where is the number of elementary schools lower: in Central Transdanubia or North Hungary?	Alternative method: Pictogram made according to the Chernoff principle
Second task	Which is the region of the country with the highest number of pupils in elementary schools?	Two traditional methods applied together: - Choroplets (hatching) - Proportional circles (change of size and fill)
	Where is the number of Secondary School pupils lower: in West Transdanubia or Northern Alföld (Great Hungarian Plain)?	Alternative method: Chernoff faces

The Hungarian questionnaire was designed with two tasks including two-two questions and two thematic maps by task: one map made with a traditional method of representation and a second map using an alternative method of representation. The content of this test is described in Table 2, and the questionnaire (which because of financial

limitations was printed in a black and white A5 format) is presented in Figure 7. Based on our theoretical research and practical experiences during the previous survey, we decided to ask not about provinces (19 plus Budapest), but regions of Hungary (only seven). The same data were represented in two maps: the first one using a traditional method of representation (A map) and the second one made using a Chernoff pictogram or Chernoff faces (B map). Pupils had to answer the questions specifying which of both maps they used to give the answer (A, B or both). Intentionally, researchers planned questions with easy answers (demanding only basic knowledge about map reading from the pupils), because our main aim was to determine which method of representation they prefer to answer the question.

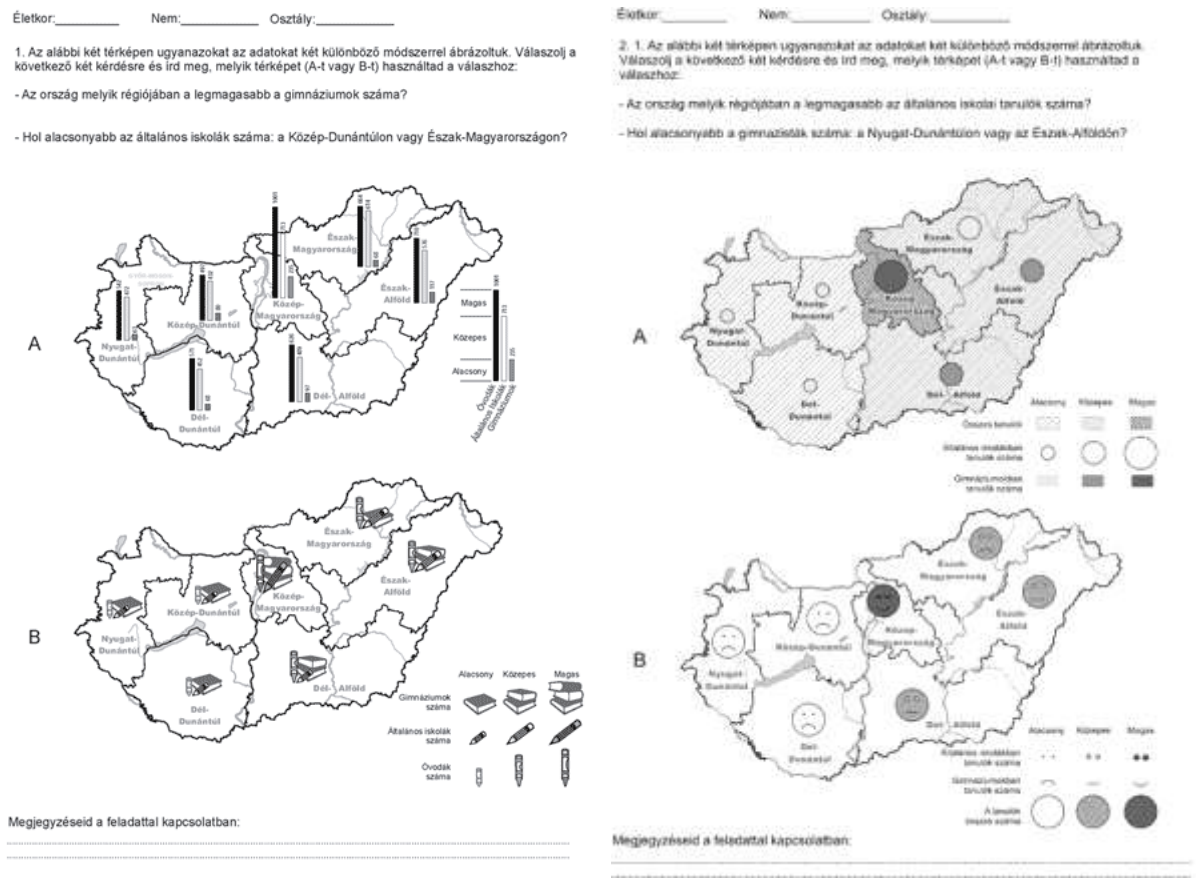

Figure 7. Questions and maps in the Hungarian questionnaire

4.2 Organization and results of the survey in Hungary

Two elementary schools (both placed in Budapest) were selected to participate in the survey. The participation was anonymous, not only for the pupils, but also for the schools. School no. 1 is a small institution in the 2nd district that can be considered an "average" elementary school. School no. 2 is a nationally recognized, "elite" institution, with a 100 years long high level tradition in all the fields of education and its' pupils have won multiple national and international competitions.

The survey was applied between April and May 2011, counting with the participation of 106 pupils (52 from School no.1 and 54 from School no. 2), and from them 55 were girls (52%) and 51 boys (48%).

The general results of the survey are presented in Table 3, using percentages to present how many pupils selected the traditional or alternative method of representation to answer a question. Together with the general results presented in the table, specialists also calculated the partial results by each question and by schools, which are presented by different diagrams on the website of the project (http://cartography.tuwien.ac.at/chernoff/). Based on these diagrams we can have more genuine background information about the results of the survey.

In both tasks the number of correct answers surpassed considerably the incorrect ones: summing up both schools the 1st task was answered correctly by 97% and 81% of the pupils, while the 2nd task was answered without any mistake by 98% and 87% of the pupils.

Table 3. Comparison of results obtained in both Hungarian schools, considering the total of answers and only correct answers separately

SELECTION OF THE METHOD OF REPRESENTATION IN BOTH SCHOOLS								
	First task				Second task			
	1st question		2nd question		1st question		2nd question	
	T.M.	A.M.	T.M.	A.M.	T.M.	A.M.	T.M.	A.M.
All the answers	78 (74%)	25 (24%)	82 (77%)	21 (20%)	56 (53%)	44 (42%)	54 (51%)	47 (44%)
Difference	53 (50%)		61 (57%)		12 (11%)		7 (7%)	
Only correct answers	75 (73%)	25 (24%)	63 (73%)	20 (23%)	54 (52%)	44 (42%)	46 (49%)	44 (47%)
Difference	50 (49%)		43 (50%)		10 (10%)		2 (2%)	
T.M. – *Traditional method of thematic representation* A.M. – *Alternative method of thematic representation*								

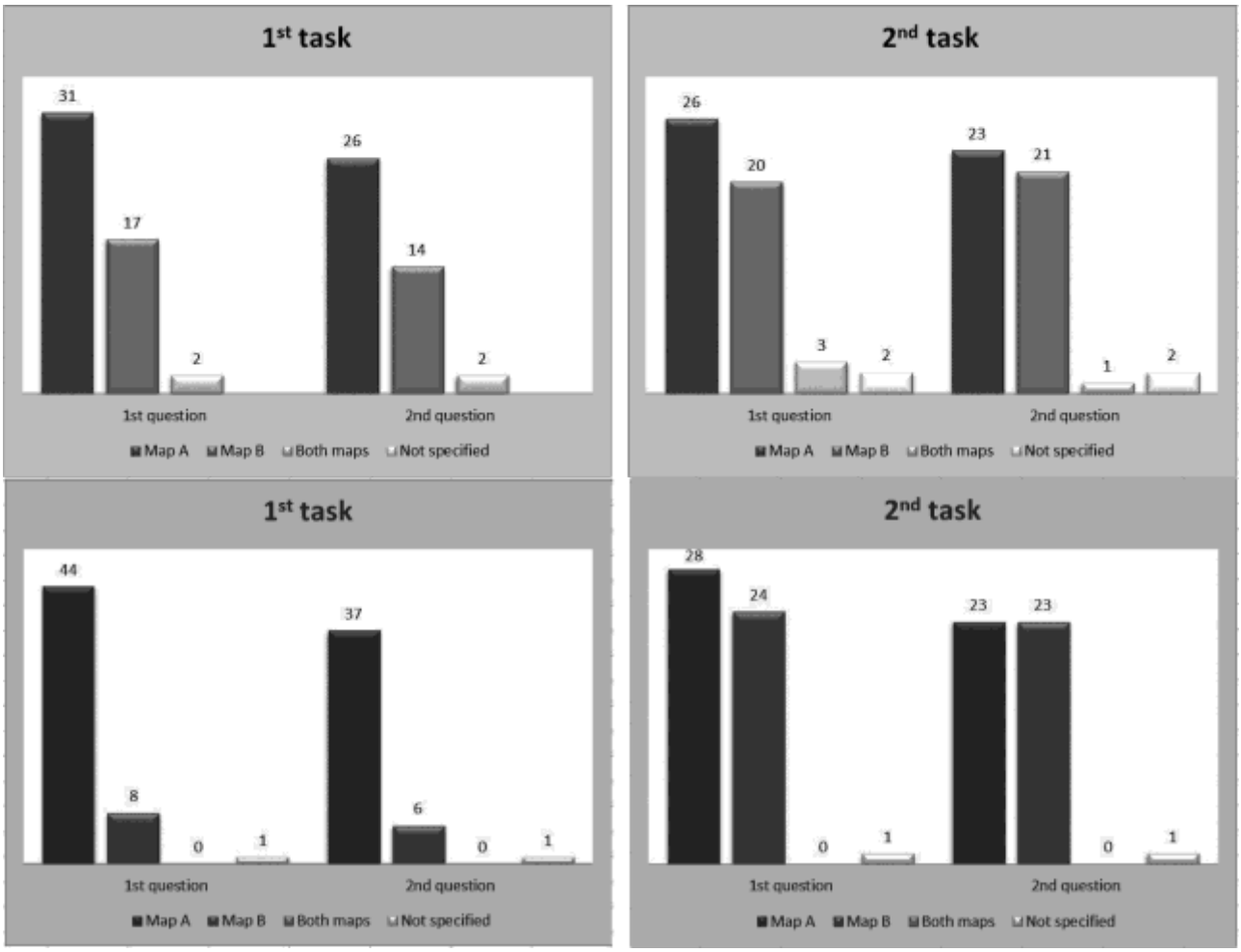

Figure 8. Results represented by schools (Hungarian survey): The two diagrams on the top represent the results obtained in school 1, and the two diagrams on the bottom correspond to school 2 (diagrams were made using only the correct answers)

Analysing the results of both schools can be affirmed that in the 1st task the largest number of pupils selected convincingly the traditional method of representation, in this case a stylized bar chart, because this diagram let them read quicker and clearer the differences between the represented data. In the 2nd task the results varied and the number of pupils selecting the traditional or alternative method was relatively the same. In this case more children were more

perceptive to the message transmitted by the Chernoff faces, which let them recognize quicker and easier the differences of the represented data than using the two combined traditional methods in the other map.

Interesting results were obtained when researchers examined the answers given by each school separately (Figure 8):

- Task 1: In school no. 1 the number of pupils that selected the pictogram map surpassed 2,1 and 2,3 times the number of pupils that chose the same map in school no. 2.
- Task 2: In school no. 2 the number of pupils that selected the Chernoff faces was larger than the number of pupils that chose this method in school no. 1.

4. CONCLUSIONS

Both research teams worked out suggestions related to the possible use of Chernoff faces in School Cartography that can be applied in a more general context. Resuming our proposals we can affirm that:

- The alternative methods of representation (in this specific case the Chernoff faces and pictograms made following the Chernoff principle) cannot and should not substitute the role of traditional methods of representation in thematic cartography, but they can also play a significant role in the spreading of map use (reading) for those children and young people, who by different reasons do not dispose of the knowledge and practice needed to use the traditional methods of representation without any kind of difficulty.
- Chernoff faces can be used in atlases and maps made for children in lower grades of elementary schools. An essential condition for their successful use is that that the planning and making of faces should fulfil the cartographic principles followed by the traditional cartography along centuries, and they should convey a clear and understandable psychological message, making adequate use of the feature salience and natural correspondence (Nelson 1997–2007).
- Chernoff pictograms are recommended to be used in school atlases for older students, or in atlases working out specific themes for the general public, because their graphic design can wake up better the attention of users with less knowledge and practice using maps.

The final results of our project can be accessed on the project website (http://cartography.tuwien.ac.at/chernoff/), including also more detailed information: questionnaires, results in tables, etc.

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