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Peculiarities of urban spatial cognition. A pilot study on the relationship of quantitative elements of mental maps and perceived success in navigation

Dóra Hegyesi[a]
[a] Institute of Geography and Earth Sciences, Department of Regional Studies, ELTE Eötvös Loránd University, Budapest, Hungary
Email: hegyesi.dora@ttk.elte.hu

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Abstract

During a single-event pilot data collection participants (n=48) were asked to draw their mental maps both in the style of Milgram (Milgram and Jodelet, 1970) and Lynch (1960), and to fill out a background survey and the Santa Barbara Sense of Direction Scale (Hegarty et al., 2002). This study focuses on the quantitative analysis of the Milgram style mental maps (Milgram and Jodelet, 1970), which relies solely on landmarks, the sense of direction scale results, and the background survey is included. The study is a pilot, with the aim of exploring the combined potential of the aforementioned tools. The results suggest that there is a correlation between one's sense of direction and the inner well-structuredness of their mental map. It can also be stated that the way someone travels in a city and the opportunities for observing the environment affects the detailedness of their mental (and probably cognitive) maps, specifically the number of landmarks shown. In addition, the elements of the mental maps might imply that using only landmarks is a less organic mental mapping method compared to Lynch's method which uses five element types. However, due to the small sample size the results cannot be seen as representative, and to validate these results a data collection with a bigger sample should be made, with a possibly more elaborate background survey.

Keywords: Mental Mapping, Sense of Space, Cognitive Map, Urban Spaces, Navigation

1. Introduction

Interacting with the environment is an essential type of behavioural competence (White, 1959). The most common of such interactions is navigating in an urban or natural landscape. While nowadays there are many tools in support of finding our way, people generally prefer their cognitive maps to navigate with (Golledge, 2002). The term "cognitive map" was coined by Tolman (1948), and in modern psychogeography it is used for the cognitive structure of known places. The cognitive map is a dynamic structure mainly consisting of landmarks (Epstein et al., 2017), which differ from person to person, and the degree of uniqueness of the landmarks seems to affect the efficiency of navigation (Golledge, 2004).

Mental maps have many definitions, but in general it is referred to an individual's construct of a given space (Gould and White, 1974). In this paper the term will be used based on a definition by Saarinen (1995), who described mental maps as sketch maps that illustrate an individual's spatial comprehension of a landscape or region. A mental map shows how someone perceives the world, incorporating socio-cultural structures and biases in spatial representations (Götz and Holmén, 2018). Lynch (1960) considered mental mapping a possible method for city planning and analysis. However, based on the aforementioned sources mental maps are always a result of an interpretation of a space, and thus do not represent the city itself, but one's personal interpretation and visualisation of an urban terrain. As a result, it is only possible to analyse the concept of a city through these products.

On the other hand, city images are products of social processes, and the changing circumstances affect our city image. According to Jász (2023) the COVID-19 pandemic and its effects changed how people view a city and its functions. Based on a study by Sugimoto et al. (2021), smartphone aided navigation also influences components of the cognitive map: research participants who navigated with smartphones could later name significantly fewer landmarks than their paper map using peers. Interestingly, they found that regardless of the navigational method, participants with a self-admittedly good sense of space felt confident during navigation.

Kozlowski and Bryant (1977) examined people's self-report on their sense of direction, and its connection to their navigation skill, and it was found that people with a good sense of direction remember routes even when being passengers, follow directions more easily, prioritise finding new routes and places when driving, and experience less anxiety when lost, compared to people with a worse sense of direction. Moreover, it was found that people often include their high level of sense of direction in their self-image.

The Santa Barbara Sense of Direction Scale is a self-report tool specifically developed to assess environmental spatial ability (Hegarty et al., 2002). Even though there are many spatial ability tests, Montello and Golledge (1999) suggest that cognitive processing might differ at each scale of space. Based on the pilot results of the Santa Barbara Sense of Direction Scale, there is a strong correlation between an individual's sense of space (higher score on the scale) and their spatial expertise in environmental spaces, measured through circular pointing tasks (Hegarty et al., 2002). Environmental space is the level of space which is big enough that the individual must move in it to apprehend its qualities (Montello, 1993). Sense of direction seems to be related to success in navigational tasks while walking in unfamiliar natural environments or travelling through unknown urban landscape (Sholl et al., 2000). Piccardi et al. (2011) reported that the familiarity of an urban landscape correlates with success in orientation. In parallel with this, Jász (2018) suggests that the familiarity of a terrain or urban structure affects our sense of orientation, suggesting that getting a sense of the space in a city similar in transportation or structure to one's hometown might be somewhat easier for people, thus making people think of something as a cultural terrain.

Regarding research methodology, mental maps are traditional and reliable tools for collecting data on the correspondence of subjective images of a place and collective experiences or phenomena (Agrestini et al., 2023). In education-related research they are tools for measuring spatial literacy and comprehension, while increasing the range of spatial stimuli within the learning process (Kitchin, 1994). However, they should be used cautiously, as the comparative evaluation is not easily standardised (Saarinen and Maccabe, 1995), exposure-training can bring short term improvements (Chiodo, 1997), and both academic and ethnocentric experiences affect their content within a group (Sebastian et al., 2024).

In this research however, mental map analysis will be used on the level of individuals, identifying how the structuredness and detailedness of a mental map relates to the sense of direction of the creator of the map. The structuredness of mental maps have already been approached quantitatively by Waterman and Gordon (1984), who found that their participants, especially the females, tend to overestimate east-west oriented distances and underestimate distances on the north-south axis, creating distortions in the mental maps, and that the participants exaggerated the size of the landmarks which were in proximity. Kiss and Bajmóczy (1996) coded both orientation and distance errors in their study, and by using mixed methods found that the main source of location error was the result of placing landmarks that are thought to be similar closer to each other.

There are many approaches to mental map analysis. There are examples of mixed methods on preference maps exploring economic connections and possibilities in regional geography (Musolino, 2021). In regional geography, only quantitative analysis approaches can be found, in the form of studying and evaluating sketch maps (Didelon-Loiseau et al., 2018). These analyses focused mainly on identifying soft and hard regions based on subjective space, specifically the number of representations of a certain area on sketch world maps. In this paper the latter quantifying approach will also be applied within the descriptive statistics.

At this point of the research a quantitative method of analysis was chosen, since according to the literature on the topic the quantitative or quantifiable elements of mental maps seem to be connected to both sense of space and navigation skills.

2. Aims and hypotheses

The aim of the research was to explore what affects the structuredness of one's mental map, and to identify the possible correlations between the detailedness of one's mental map and one's sense of direction. Consequently, the research aims to explore how the Santa Barbara Sense of Direction Scale augments mental map analysis and how the subsequent system fits the theoretical background.

The following hypotheses were tested during the research:

- H1: The longer someone lived in a given city, the more detailed their mental map is.
- H2: There is a positive correlation between one's sense of direction and the structuredness of their mental map.

3. Methods

The study consisted of one sampling event conducted in 3 groups on the same day. The participants were 9th grade students (14-15 years old) (n=48) of a bilingual high school in Budapest, whose classwork was submitted anonymously, and both the students and their parents consented to the usage of the mental maps and related data. None of the collected data made the identification of the participants possible. The data collection was bilingual in Hungarian and English, since 22 participants were from Hungary and 26 were from abroad. During the 40-minute data collection session the participants were asked to complete a background survey, the Santa Barbara Sense of Direction Scale (Hegarty et al., 2002) (later: SBSDS_AVG as a variable), and to draw two mental maps. The Santa Barbara Sense of Direction Scale is a Likert-scale type self-assessment tool, that enables the participants to evaluate their sense of space and direction, specifically targeted at large-scale spaces. The first mental map was a route depiction in Lynch's style, with participants drawing the route between their school and their homes, including all the spatial elements (nodes, edges, landmarks, borders or paths) they find important. The second mental map was a city image, based on Milgram and Jodelet (1970) in which participants had to draw all the landmarks they find important in a given city (in this case Budapest), and synthesising these maps created a summative mental map of that city, displaying the city image of the participant group. In this paper the results from the background survey, the Santa Barbara Sense of Direction Scale, and the Milgram-type mental maps are analysed through descriptive statistics and inferential statistical methods regarding the quantitative elements.

The data was collected manually in paper format and therefore the results had to be digitised and, in some cases, coded. Some variables were quantitative (e.g. how much time one spends commuting, how long one has lived in the specific city), for which participants had to choose an interval on a list. Some other variables, for example the "Transportation" variable, which shows the most common use of transport for each participant, had to be quantified, based on the how possible it is to get to know the environment during that travelling experience. The original values of the "Transportation" variable were on a scale of 8, but based on the answers the variable was transformed into a scale of six derived from how much someone can see from the city during a certain type of commute, in increasing order (Table 1), e.g. if someone was commuting only by subway that would have been the lowest variable due to the lowest visibility of the environment, while walking requires the most amount of time and interaction with a terrain.

Value	Label
1	car
2	subway + tram/bus/train
3	car + tram/bus/train
4	tram/bus/train
5	bike/roller/skateboard
6	walking

Table 1. Values and labels of the "Transportation" variable. Source: Author's elaboration.

The complete background survey can be found in Appendix A. The mental map elements were simply counted based on their types: how many roads, cultural landmarks, and personal landmarks were labelled. In the case of the cultural landmarks a "relative orientation" was possible to identify, based on how well the landmarks are located relative to each other - not towards the general directions, since participants were not asked to orient their mental maps in any manner – and this factor was scored on a scale of 3: not oriented (0), somewhat oriented (1), well-oriented (2). The relative orientation of the landmarks was evaluated by multiple experts.

The data was analysed in JASP version 0.19.1. Since not all the variables showed normal distribution, both parametric and non-parametric tests were used to test the hypotheses. Moreover, an exploratory factor analysis was conducted to outline underlying correlations, based on a correlation matrix, with a maximum likelihood factoring method, in varimax rotation, with eigenvalues set to be above 1. The inappropriate KMO values led to further tests to explore the reliability and effect size of the correlations making the exploratory factor analyses rather a though experiment.

4. Results

4.1. Descriptive statistics

The background survey (Appendix A) explored how long the participants had been living in the city examined, what their main transportation method was, how often they played video games, how often they used route planning apps, and whether they explored the city from a tourist's point of view. This latter variable was excluded from the factor analysis because the results show a binary data pattern, but 26 of the 48 participants ticked "yes" at this variable. Regarding how long they had been living in the city, the majority of the participants (n=26) had been resident in Budapest for at least 10 years. However, 18 of them had been living in the city for less than a year. Of the remaining 9 participants 4 had been living in Budapest for over 1 year but less than 3 years, 4 participants for between 3 and 5 years, and 1 participant between 5 and 10 years. Most participants spent their daily commute on public transport, on surface transport (Figure 1).

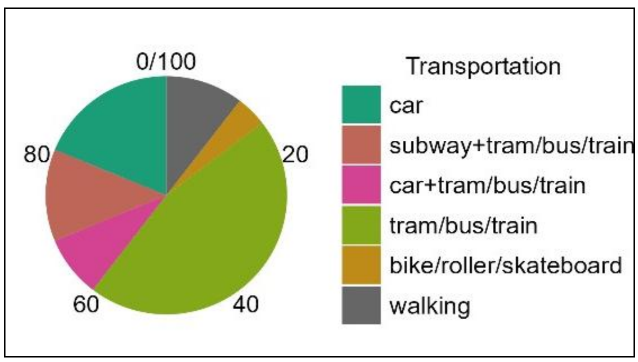

Figure 1. Distribution of transportation methods. Source: Author's elaboration.

Every participant had used a route planning application before, 15 of them labelled "rarely" and 33 of them "regularly". In the case of video game usage, the data is quite different. Eight participants had never played video games, 12 of them had tried such video games but did not play regularly, 16 participants played rarely, and 12 students played regularly on such platforms.

In the case of the Santa Barbara Sense of Direction Scale, the calculated averages ranged from 2.5 to 6, with a mean of 4.260, and a median of 4.233 (Figure 2). This scale measures from 1 to 7, with 1 being the most positive and 7 being the least positive. During the evaluation the positive sentences were reversed, as suggested in the scoring instructions, thus the higher the average the better the sense of direction of the participant. It can be said that most of the participants feel that they have a good sense of direction. However, it is important to note that the average is somewhat misleading, as can be seen in Figure 1, where 13 participants scored somewhere between 3.5 and 4 on average.

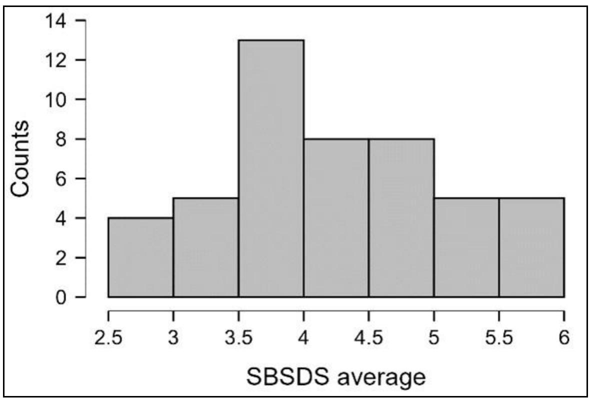

Figure 2. Distribution of the SBSDS_AVG variable. Source: Author's elaboration.

The mental maps were very different both in style and in content. The participants marked 78 different cultural landmarks altogether, and approximately the same number of personal landmarks. The average number of landmarks is 10.7, with the minimum of 2 and the maximum of 21. From the cultural landmarks the most commonly mentioned were the Danube and the House of Parliament.

Interestingly, even though most of the participants labelled the Danube, only 7 of them labelled the two sides of the river, Buda and Pest. There were 13 participants, who connected their landmarks with roads, creating network-like mental maps (Figure 3).

Even though Budapest is more of an agglomeration rather than a standalone city, 30 participants drew borders around their mental map. Based on the cultural landmarks there was a possibility to evaluate the inner orientation of the mental maps. If the landmarks were completely scattered, it was labelled with a 0, in the case of some structures a value of 1 was used, and in the case of a structure resembling the actual physical location of the landmarks related to each other a value of 2 was used.

4.2. Inferential statistics

Saphiro-Wilk tests were conducted for each variable in order to assess the distribution of the collected data. As Table 2 shows, variables are not normally distributed except for the average of the Santa Barbara Sense of Direction Scale, and the number of landmarks on the mental maps. The Bartlett Test (*p=0.032*) and the Chi-squared Test (*p=0.322*) allowed an exploratory factor analysis to be carried out. A correlation matrix was created with the maximum likelihood factoring method, with factor correlations shown in Table 2. Varimax rotation was applied. The factor matrix can be seen in Figure 4, and the factor loadings are shown in Table 3. The Chi-squared Test value is 3.488, with p=0.322, and df=3. These results suggest that the three most loaded variables in the matrix are the number of landmarks, the transportation method and the relative orientation of the mental maps. However, during the Kaiser-Meyer-Olkin Test the sampling adequacy was lower than 0.6 for all variables, thus the model suggested by the factor analysis was tested with correlation tests to further explore and potentially prove the latent relationship of the variables. Since most variables were not normally distributed, both Spearman and Pearson tests were administered depending on the parameters of the variables examined. The main focus was on exploring the correlation within a hypothesised factor 1, but further correlation tests were also administered to prove the underlying correlations within the whole dataset examined. The correlation of the SBSDS average with the number of landmark variables was tested with Pearson's correlation test as well, since they are normally distributed. The results did not show any significant correlation with this method either (*p=0.934, z=-0.012*). As a result of the Spearman Rank Correlation Tests (Table 4) the following findings can be mentioned:

Figure 3. Examples of sketch mental maps. Source: Author's elaboration.

	Std. Deviation	Variance	Shapiro-Wilk	P-value of Shapiro-Wilk	Range
Years in BP	1.984	3.936	0.750	< .001	5.000
Transportation	1.537	2.361	0.871	< .001	5.000
Video game	1.038	1.078	0.870	< .001	3.000
Route planning app	0.468	0.219	0.584	< .001	1.000
SBSDS_AVG	0.841	0.707	0.975	0.401	3.200
Relative orientation	0.743	0.551	0.775	< .001	2.000
Number of landmarks	5.005	25.053	0.977	0.446	21.000
Number of routes	2.372	5.627	0.433	< .001	13.000

Table 2. Results of Saphiro-Wilk Tests. Source: Author's elaboration.

	Factor 1	Factor 2	Factor 3	Uniqueness
Video game				0.975
Relative orientation	0.987			0.005
Transportation			0.955	0.005
Years in BP				0.846
Number of landmarks		0.995		0.005
Number of routes				0.796
SBSDS				0.856

Note. Applied rotation method is varimax.

Table 3. Factor Loadings. Source: Author's elaboration.

Variable		Transportation	SBSDS_AVG	Years in BP	Video game	Rel. orientation	Num. of landm.	Num. of routes
1. Transportation	Spearman's rho	—						
	p-value	—						
	Effect size (Fisher's z)	—						
	SE Effect size	—						
2. SBSDS_AVG	Spearman's rho	0.044	—					
	p-value	0.766	—					
	Effect size (Fisher's z)	0.044	—					
	SE Effect size	0.148	—					
3. Years in BP	Spearman's rho	-0.278	-0.073	—				
	p-value	0.055	0.622	—				
	Effect size (Fisher's z)	-0.286	-0.073	—				
	SE Effect size	0.151	0.148	—				
4. Video game	Spearman's rho	0.123	-0.079	0.139	—			
	p-value	0.404	0.594	0.348	—			
	Effect size (Fisher's z)	0.124	-0.079	0.139	—			
	SE Effect size	0.149	0.148	0.149	—			
5. Relative orientation	Spearman's rho	0.046	0.335	-0.113	0.024	—		
	p-value	0.754	0.020*	0.444	0.870	—		
	Effect size (Fisher's z)	0.046	0.349	-0.114	0.024	—		
	SE Effect size	0.148	0.151	0.149	0.148	—		
6. Number of landmarks	Spearman's rho	0.298	-0.061	0.076	-0.046	0.146	—	
	p-value	0.040*	0.682	0.608	0.756	0.322	—	
	Effect size (Fisher's z)	0.307	-0.061	0.076	-0.046	0.147	—	
	SE Effect size	0.151	0.148	0.148	0.148	0.149	—	
7. Number of routes	Spearman's rho	0.096	0.062	-0.053	0.126	0.264	0.086	—
	p-value	0.514	0.675	0.721	0.394	0.070	0.563	—
	Effect size (Fisher's z)	0.097	0.062	-0.053	0.127	0.270	0.086	—
	SE Effect size	0.149	0.148	0.148	0.149	0.150	0.148	—

* p < .05, ** p < .01, *** p < .001

Table 4. Results of the Spearman's Rank Correlation Tests. Source: Author's elaboration.

(1) This pilot dataset suggests that there is a significant correlation with a moderate effect size between the result of the Santa Barbara Sense of Direction Scale, so technically one's experienced success in navigation, and the well-orientedness of one's mental map (r_s (46)=0.335, p=0.020).
(2) There is a significant correlation in this sample between the "transportation" variable and how many landmarks were drawn on the mental map (r_s (46)=0.298, p=0.040), suggesting that the more the city is seen during commuting the more detailed person's cognitive map of a city is.
(3) There might be a possible correlation between the number of routes displayed on a mental map and its relative orientedness, but a bigger sample size study is necessary to further explore this hypothesis (r (46)=0.264, p=0.070).

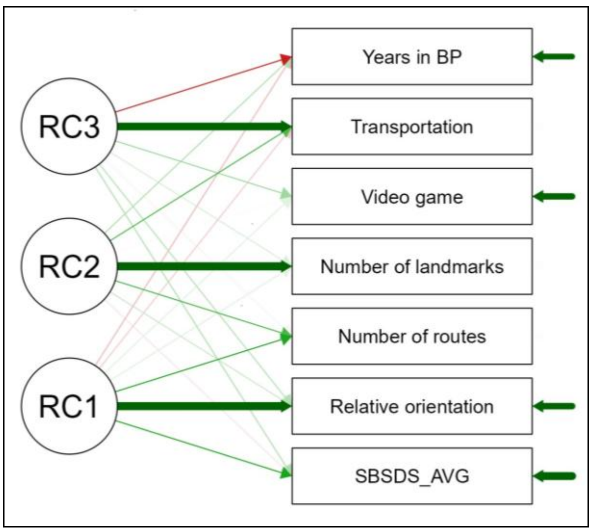

Figure 4. Visualization of the factor analysis results. Source: Author's elaboration.

5. Discussion

The descriptive statistics highlight the most prominent landmarks in Budapest for this group of people. These results can only be representative at the 9th grade level of this particular school, due to the number and nature of the participants. It is worth mentioning that even though only landmarks were requested to be labelled on the mental maps, participants intuitively visualised elements of the four other possible components from Lynch's mental map theory, in particular nodes, edges, and paths, but there was one participant who drew exclusively districts instead of landmarks (see examples in Figure 2). The two sides of the river, Buda and Pest, despite being areas rather than landmarks, were also frequently visualised. This might suggest that Lynch's mental mapping method is closer to an organic representation of an individual's cognitive spatial structure than including landmarks alone. Even though on this sample size the number of routes on a mental map are only weakly correlated to the relative orientedness of these spatial representations, it brings the attention to a possibility that those people who think in networks of landmarks connected by routes might be more aware of the actual physical location of landmarks and their distance and orientation from each other.

There is a significant correlation between the way someone travels in a city, so basically how much someone observes from a city, and the number of landmarks displayed on a mental map. On the one hand this is an interesting result, because it implies that the number of landmarks in an individual's cognitive map is more related to how possible it is for them to see or remember it, and not to their sense of direction. This corresponds with the findings of Sebastian et al. (2024), stating that those students who commute autonomously present a more detailed mental map.

On the other hand, based on Piccardi (2011), the familiarity of a city can be helpful in navigation, and sense of direction should be an indicator of success in navigation (Hegarty et al., 2002). However, no correlation between the sense of direction and the number of landmarks or routes was found, regardless of the fact that Budapest was the hometown of most participants. Moreover, the amount of time one has lived in the city does not seem to affect these variables either on such a sample size, despite Rosyinda et al. (2016) finding a correlation between the amount of exposure and the detailedness of a mental map. As a result, the first hypothesis of the study can be rejected, especially since the effect size is very small (*z=0.076*) and the significance level is very low (*p=0.608*), thus the result cannot be explained with the small sample size.

There is a significant correlation between sense of direction and the inner structure of the mental maps, more precisely if the position of the landmarks related to each other actually represent their physical structure with each other. Thus, the second hypothesis of this study can be accepted. This result could imply that those people with a better sense of direction might connect a physical location to the landmarks in their cognitive maps. Based on this, further exploration is required on whether there are types in spatial thinking, focusing on whether people connect the physical space details to the elements of their mental spatial networks. In addition, there might be a correlation between habits in route planning application usage and the cognitive storage of physical spatial details, which might be possible to identify with a more detailed background survey on route planning application usage and a more representative sample size. This possibility also calls for further exploration, which is planned to be carried out with a two-step mental mapping exercise in which after drawing their mental map participants have to locate their landmarks on a city-grid map which is stripped of labels (e.g. street names). This latter research is being conducted in parallel with the writing of this paper.

6. Limitations

Regarding the background survey it is important to mention, that the time spent travelling, and the activity during travelling (e.g. reading, using social media) can further affect the underlying correlations of one's cognitive map of a given city. Moreover, since this was a relatively small pilot study with only 48 participants, the hypothesised model must be tested on a larger, more representative sample size, and confirmatory factor analysis should be conducted to further validate these results.

7. Conclusions

To conclude, this small sample pilot study supports previous results in two cases: the sense of direction is in positive correlation with the structuredness of the mental maps, and those people whose mental maps were well-oriented actually displayed more routes. This also brought to light the fact that the Santa Barbara Sense of Direction Scale is a good fit for such analyses. Moreover, this study suggests that even when people are specifically asked to represent their ideas using landmarks, those who have network-like or differently detailed cognitive maps will find it essential to include other elements, such as routes, borders, and areas. This overlaps with the Lynch-type mental maps, which might suggest that the inclusion of these elements is a more organic solution to mental mapping than solely using landmarks.

On the other hand, in contrasting previous studies the familiarity of the urban landscape does not seem to affect the variables of the mental maps that are connected to navigation skills. Nevertheless, this raises questions about how people might or might not attach physical location to the landmarks in their cognitive maps, and further research is called for regarding the underlying factors affecting this phenomenon. During the latter research a method for a more precise structure and orientation measurement must be developed.

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Appendix A. The background survey of the study

Háttérkérdőív – Background survey

Please answer the questions either by marking the answer applicable to you, or write your own answer.

1. Melyik nyelven szeretnél kommunikálni?
What is your preferred language of communication? English / magyar

2. Mi az anyanyelved?
What is your mother tongue?

3. Hány éve élsz Budapesten vagy jársz ide napi rendszerességgel?
How many years have you either lived in Budapest or visited it on a daily basis?

A. kevesebb mint 1 / *less than 1*

B. kevesebb mint 3 / *less than 3*

C. kevesebb mint 5 / *less than 5*

D. kevesebb mint 7 / *less than 7*

E. kevesebb mint 10 / *less than 10*

F. több mint 10 / *more than 10*

4. Milyen módon szoktál általában közlekedni az otthonod és az iskola között?
What means of transportation do you usually use between the school and your home?

A. sétálok / *I walk*

B. kocsival hoznak / *I am brought by car*

C. biciklizem/rollerezem/gördeszkázom / *I ride my bike/roller/skateboard*

D. metróval jövök / *I use the subway*

E. Busszal/villamossal/vonattal jövök / *I use a tram/bus/train*

F. Egyéb / Other:

5. Játszottál valaha belső nézőpontú videojátékkal? (Olyan videojátékkal, amelyben a teret olyan szempontból láttad, mintha a te magad sétálnál az adott területen.)
Have you ever played first-person view video games? "In video games, first-person (also spelled first person) is any graphical perspective rendered from the viewpoint of the player character, or from the inside of a device or vehicle controlled by the player character." (Wikipedia)

A. Nem, soha. */ No, never.*

B. Igen, egyszer-kétszer. */ Yes, once or twice*

C. Igen, de ritkán. */ Yes, but rarely*

D. Igen, gyakran. */ Yes, regularly*

6. Szoktál csak a felfedezés öröméért, turista nézőpontba helyezkedve sétálni Budapesten? *Are you accustomed to walking around Budapest for the pleasure of exploring it through a tourist's perspective?*

A. Igen / *Yes*

B. Nem / *No*

7. Szoktál digitális útvonaltervező alkalmazásokat (pl. Google Maps) használni?
Are you accustomed to using any route planning program or application, such as Google Maps?

A. Soha / *I have never used it*

B. Ritkán / *I rarely use it*

C. Rendszeresen / *I use it regularly*