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ORIGINAL ARTICLE

THE POSITIONING OF STREET NAMES ON EGOCENTRICALLY REFERENCED MAPS: ASSESSMENT OF READING TIME

O posicionamento de nomes de ruas em mapas referenciados egocentricamente: avaliação do tempo de leitura

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Abstract:

The main objective of this research is to evaluate the reading time of street names on dynamic egocentrically referenced maps for In-Car Route Guidance and Navigation Systems. Two different road network patterns (grid-like or non-grid-like) were considered and tasks were devised to search for street names in two different route segments (where the driver was, or where the driver would have to manoeuvre). Considering a non-grid-like road network pattern, for the task of searching for the name of a road where the driver would manoeuvre, street names aligned horizontally and next to the route were read significantly faster than street names positioned along the route. Street names positioned obliquely required more reading time than street names aligned horizontally. Dynamic maps egocentrically referenced should present street names horizontally aligned and next to the route for the segment related to where the driver will manoeuvre, for both road network patterns. Also, Street names should be positioned next to the car symbol.

Keywords: In-car Route Guidance and Navigation System, map design, egocentric map, text positioning, map reading

Resumo:

O principal objetivo desta pesquisa é avaliar o tempo de leitura de nomes de vias em mapas dinâmicos referenciados egocentricamente para sistemas de navegação e guias de rotas em automóvel. Foram considerados dois padrões

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diferentes de rede viária (regular ou não regular) e as tarefas de leitura foram planejadas para encontrar e ler nomes de vias em dois segmentos de rota diferentes (onde o motorista estava ou onde o motorista teria que manobrar). Considerando um padrão de rede viária irregular, para a tarefa de encontrar e ler o nome de uma via onde o motorista manobraria, os nomes das vias alinhados horizontalmente e próximos à via foram lidos significativamente mais rápido do que os nomes das vias posicionados ao longo da rota. Nomes de vias posicionados obliquamente exigem mais tempo de leitura do que nomes de vias alinhados horizontalmente. Os mapas dinâmicos referenciados egocentricamente deveriam apresentar nomes de vias alinhados horizontalmente e próximos à rota para o segmento relacionado ao qual o motorista irá manobrar, para ambos os padrões de rede viária. Além disso, os nomes das vias deveriam ser posicionados próximo do símbolo do automóvel.

Palavras-chave: Sistema de navegação e guia de rota em automóvel, projeto cartográfico, mapa egocêntrico, posicionamento de texto, leitura de mapa

1. Introduction

Reading a map can be facilitated by using texts because these can contribute to improving cartographic communication (Fairbain, 1993). Also, texts on a map can enhance the appearance (Karssen, 1980). Texts on the map face may be either toponymic or non-toponymic (Fairbain, 1993). Maps for In-Car Route Guidance and Navigation Systems (RGNS) use toponyms such as street names to aid drivers when they are navigating. Investigations into drivers' requirements for route guidance information have pointed out that street names are one of the most important elements for following a route (Burnett, 1998; Pugliesi *et al*., 2014). It is argued that street names contribute to developing cognitive maps (Burnett, 1998).

Texts on a map facilitate a connection between pictorial and verbal levels (Deeb *et al*., 2014). In addition to point, line and area, texts are considered the fourth type of map symbol and are an indispensable element (Fairbain, 1993). Their application is a practical, technical, aesthetic and linguistic question (Imhof, 1975). The transmission of spatial information through street names is achieved by employing cartographic communication principles. Designing labels may require selecting visual variables that have perceptual properties and are related to the fundamental relations (qualitative, ordered and quantitative).

Studies indicate that an inappropriate design of labels has a negative impact on the map's use (Deeb *et al*., 2012; Dent et al., 2009; Fairbairn, 1993; Slocum *et al*., 2009; Shirreffs, 1993). The less curved the names are, the faster the reading time seems to be (Phillips and Noyes, 1977). The improper positioning of labels may interfere with other features, reducing cartographic communication. Guidelines to improve text legibility are provided for positioning labels that describe point, line and area features (Imhof, 1975; Slocum *et al*., 2009).

The literature recommends that linear features should be lettered along their correspondents when they are presented in a non-egocentric reference scheme (Dent *et al*., 2009; Imhof, 1975; Slocum *et al*., 2009). However, certain objects aligned horizontally or vertically are more easily perceived as figures than objects positioned diagonally (MacEachren, 1995). Humans observe diagonal elements with some instability and insecurity, because they use their own body vertically oriented on a plane surface (Frutiger, 2001).

On the other hand, RGNS maps are dynamic and presented in an egocentric reference scheme. Maps are rotated according to the vehicle's motion along a planned route. From the perspective of traffic safety, performing a tactical task (i.e., preparing for the next manoeuvre) requires the driver to make use of a great amount of information (Labiale, 2001; Michon, 1985). It is therefore crucial to be consider tactical tasks when designing RGNS maps (Pugliesi, Decanini, Tachibana, 2009). Performing the secondary task of reading texts on an RGNS map may be frustrating if they cannot be read easily. Hence the question arises whether street names should be positioned along the route segment of an egocentrically referenced map.

Two issues related to the legibility of street names on dynamic egocentrically referenced maps were addressed. The first concerns the graphic design of a street name, which is positioned along the route segment or aligned horizontally next to the route segment, by considering different road network patterns, grid-like or non-grid-like. We adopted the terms grid-like and non-grid-like for two types of road network patterns, as approached by Pugliesi, Decanini and Tachibana (2009). A grid-like road network pattern corresponds to the arrangement of perpendicular lines aligned predominantly on the horizontal and vertical axis in relation to the orientation of the human body. A non-grid-like road network pattern refers to the arrangement composed predominantly of oblique lines. The second issue concerns the evaluation of the reading time of street names used while accomplishing the tactical task.

2. Method

2.1 Map design

Representations were conceived to aid the driver when performing a tactical task before a simple manoeuvre. A total of 16 dynamic maps were designed on the scale of 1:6,000, which seemed most appropriate scale to use as researchers point out that route guidance maps should provide information to the driver on that scale when the car is approaching a manoeuvre (Ramos *et al*. 2014; Ramos *et al*. 2016; Ramos *et al*., 2018).

The maps were designed aiming to test the driver's performance at reading street names which were positioned in two different ways (H = aligned Horizontally next to the route; A = Along the route), considering different road network patterns (GL = grid-like; NGL = non-grid-like) with tasks to search for street names in two different route segments (L = where the driver was; T = where the driver would carry out a manoeuvre) (Figure 1). We considered eight groups of map design to position the street names. For each group there were two representations with similar characteristics, varying the direction of the simple manoeuvre. The concept of simple manoeuvre used here was adopted by Labiale (2001) and Pugliesi, Decanini and Tachibana (2009), and involves a change of direction on an orthogonal, or diagonal, road on the left or right side of the egocentric route segment where the driver is. Taking account of the road where the driver is, the location of the street name after the manoeuvre was to the left or to the right side (L1, L2 or T1, T2).

Two similar designs for street names showed the name of the road where the driver was, and another two similar designs represented the name where the driver would manoeuvre, making a total of four maps for each type of road network pattern. For the grid-like road network pattern, four maps were designed on which the street names were aligned horizontally next to the route (Figure 2) and four maps on which the street names were positioned along each route segment (Figure 3). Each route segment corresponded to a line that described parts of a route, before or after the turn. In the same way, eight maps were designed for the non-grid-like pattern, four maps with streets names aligned horizontally next to the route (Figure 4) and the other four following the route (Figure 5).

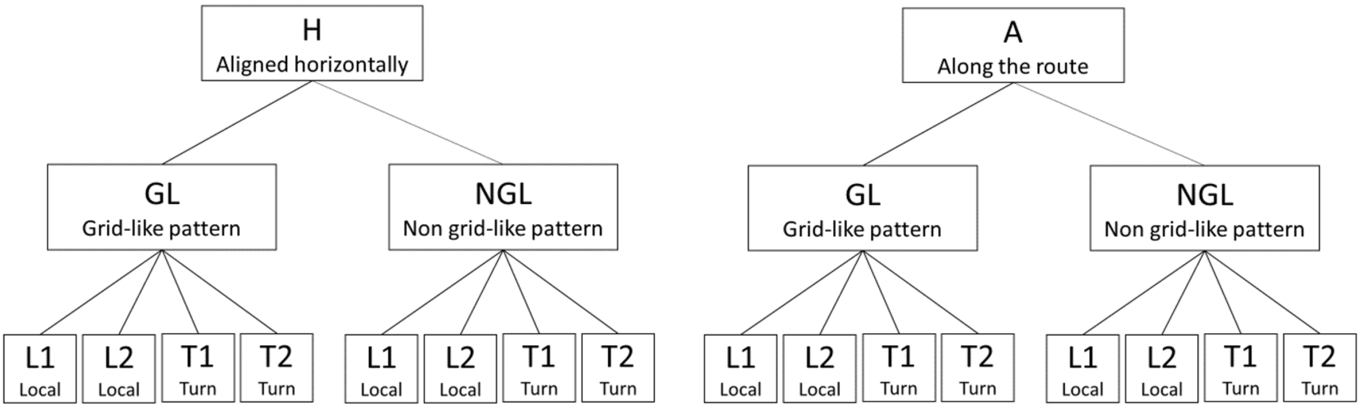

Figure 1: Schema showing the design of labels positioned in the road network and route segment.

Figure 2: Street names aligned horizontally in a grid-like road network pattern.

The study area is in the western region of Sao Paulo state. The cities of Presidente Prudente and Alvares Machado have road layouts that are predominantly grid-like and non-grid-like road network patterns, respectively. Route guidance information to aid the navigation task was composed of driver's location (car), manoeuvre direction (arrow), road, block, route, and street name. Selection of route guide information was conceived according to results of previous researches about drivers' needs (Burnett, 1998; May *et al*. 2003; Pugliesi *et al*., 2014).

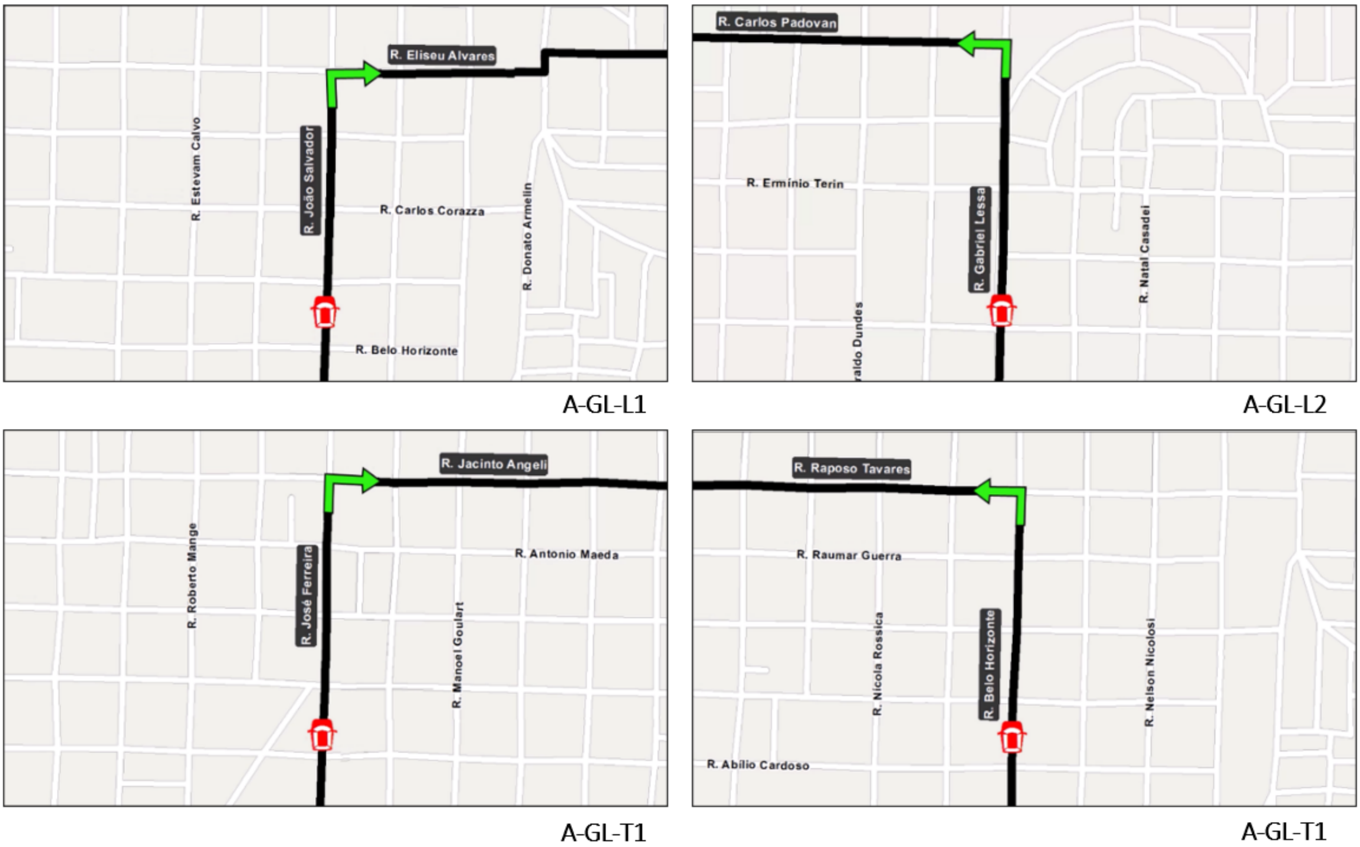

Figure 3: Street names along the route in a grid-like road network pattern.

Figure 4: Street names aligned horizontally in a non-grid-like road network pattern.

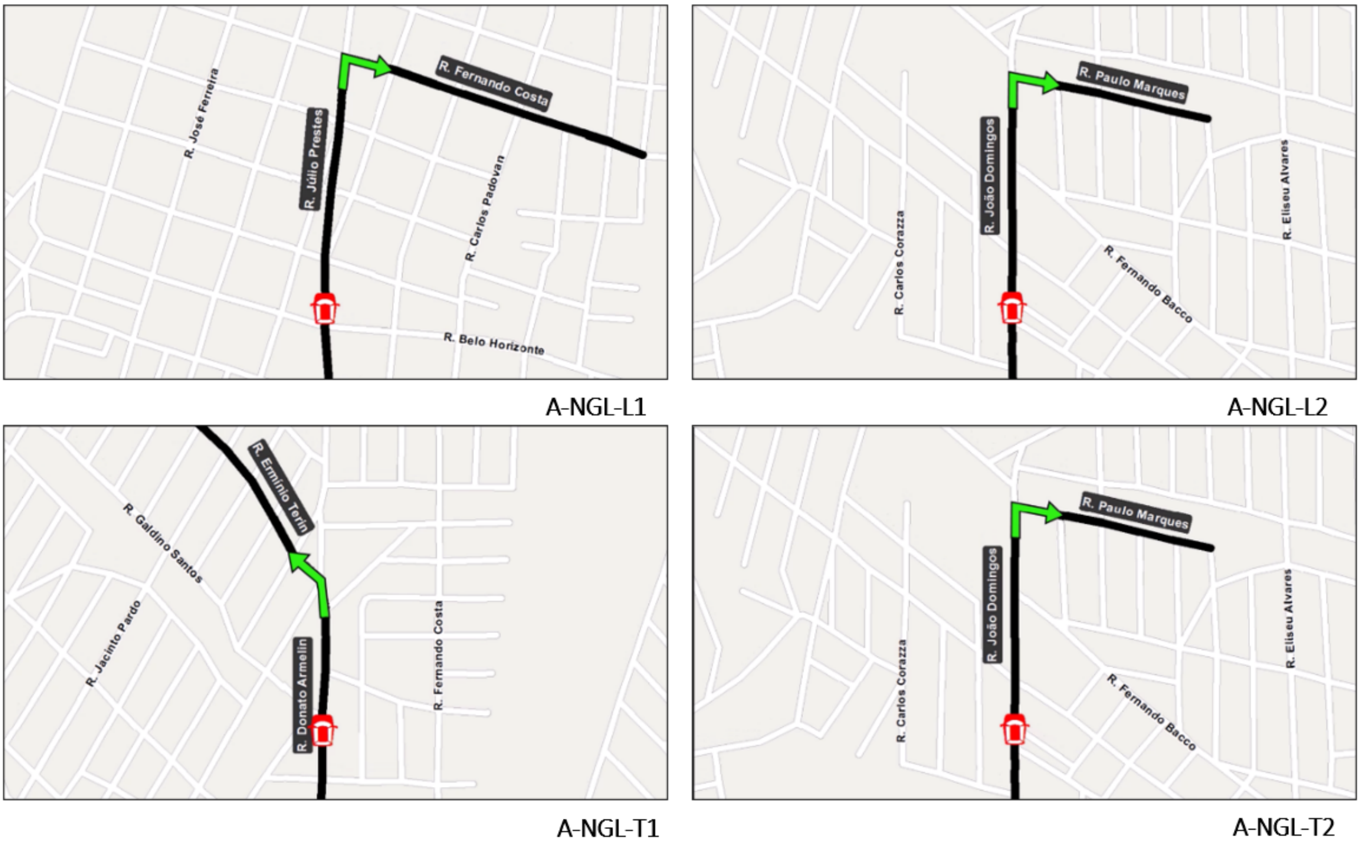

Figure 5: Street names along the route in a non-grid-like road network pattern.

The graphic design for thematic symbols (car, arrow and route) followed the recommendations of previous investigations about map design for in-car route guidance and navigation systems, specifically for the task of following a route (Pugliesi, Decanini, Tachibana, 2009; Marques *et al*., 2011). Those recommendations pointed out that this kind of map design should consider some perceptual organization principles such as those defined by Gestalt and suggested by MacEachren, (1995). Heterogeneity and contour were therefore used to create figure ground segregation, as well as proximity, similarity, good continuation, and simplicity to produce perceptual grouping.

Color and shape were used to determine heterogeneity between figure and ground. It was intended to provide a perception of simplicity by using a reduced number of graphic elements. To emphasize thematic symbols, block was depicted with a light gray (RGB 240, 240, 233) contoured by a thick line in a slightly darker gray (RGB 178, 178, 178). A pictorial symbol for the car provides a similar appearance to its referent, and a red color was used because rods in the fovea region of the eye are highly sensitive (MacEachren, 1995). The green color for the arrow presented a contrast with the other symbols and is associated with traffic signals, such as traffic lights (Marques *et al*., 2011). The arrow was contoured in black to segregate it from the ground and provide a perception of continuity for the route. The label design was conceived so that the street names that labeled the route should stand out.

Considering the semiology of graphics (Bertin, 1983), some visual characteristics were applied to street names, helping them to stand out. Font size was used so that street names that labeled the route were in 18 points while others were in 17. Having the initial letter in uppercase and the rest in lower case assists visual search (Phillips, 1979). Size provides selective and ordered perception (Bertin 1983; Deeb *et al*., 2012). Boldness was used to facilitate visual search; Arial was chosen because of the absence of serifs; and normal orientation was the same for all names. Even though Arial contributes to increasing map legibility and enhancing legibility, the space between letters was expanded slightly to 5 points.

Street names off the route were presented in black and contoured with a thick line in white, while street names that labeled the route were depicted in white inside a thick mask of dark gray (RGB=55,53,56). The route and names that labeled the route presented similarity by value and proximity of placement, creating the idea of unity. The higher the number of label units, the greater the time spent searching for names on an RGNS map (Morita, Mashiko and Okada, 1997). Hence, only a few labels were given.

The distribution of street names throughout the area could be used as clues to indicate shortcuts before the turn. The labeling of the streets, to right or left of the direction, was decided taking account of a vertical axis of the route where the driver was placed. Reading time would be influenced by the different levels of complexity of the names so it was decided to use well known short names composed of only two words, totaling 12 or 13 letters, not mentioning the type of the road (ex.: R. = Rua). Road names were fictitious to reach a pattern size in terms of number of letters. Search time is largely dependent on the number of names that need to be fixed (Phillips *et al*., 1978).

ArcGIS 10.1 software was used to create static maps with no car symbology. Animated maps were generated in MP4 format file using Microsoft Power Point depicting a moving car. Windows Movie Maker software was used to create a video beginning with a beep, moving on to a car on the map face to collect data about reading time during the experiment.

2.2 Participants and apparatus

Twenty participants, 11 men and 9 women aged between 18 and 31 years, were recruited for this experiment (mean age = 25 years). They were experienced drivers familiar with RGNS, and they were reported as having normal color vision. A tablet Samsung Galaxy Tab 4 model T330, with video resolution of 1024x768, eight-inch screen, was used to display the maps. The screen was fixed to the central part of the windscreen and directed towards the drivers' face. The experiment was carried out on a 2011 Ford Ka car model, parked on a road, inside the university campus, to provide driving context during the experiment. A procedure was applied to train the researcher and correct any unforeseen inconsistencies. Participants had no knowledge (or little knowledge) of the routes used in the experiment. It was employed the same protocol used by Ramos et al. (2014) and Ramos et al. (2016), which do not consider experiment on roads to keep driver safety.

2.3 Procedure

The experiment was carried out to ascertain what kind of text positioning would be most appropriate for the labeling of street names (along the route or aligned horizontally next to the route). After the driver got into the car, he or she was asked to adjust the equipment (e.g. seat, seat belt, mirror), as they regularly use. The purpose of the experiment was then explained, emphasizing its importance to cartographical research, as well as for designing improved route guidance maps that could enhance drivers' performance when using an RGNS.

A manual containing map symbols like those used during the test was given to the participant. The use of each representation was explained, emphasizing the use of street names along the route for tactical task. The travel scenario was carefully read and explained. The experiment started after the participant confirmed having understood each detail of the manual.

At the start, the display was totally black, as if turned off. The participant was asked to keep their hands on the steering wheel, eyes fixed on the center of the road. He or she was asked to wait for a question spoken by the experimenter who asked for a street name, which might be where he or she was located or where she or he would turn. The question was followed by a beep indicating that the map was available on the display and a street name could be searched for visually.

Two different questions were applied to collect information about reading time: “What is the name of the street where you are?” and “What is the name of the street where you will turn?”. The driver was supposed to respond rapidly with three sequential tasks: to look at the map, search for the street name and answer the question in a clear voice. Time for visual searching corresponded to the interval between the beep sound and the beginning of participant’s voice. All participants used the same maps. The sequence of presenting the maps and questions were made randomly to avoid trends. The tablet recorded the experimenter’s question, beep, and the participant’s answer in audio files.

2.4 Organization of data and statistical analysis

Reading time data were extracted by using Power Sound Editor Free software, and then organized with Microsoft Excel. Data organization was made according to the type of text positioning (along the route or aligned horizontally next to the route) in different road network patterns (grid-like or non-grid-like), considering the street name where the driver was or where the driver would turn.

Detailed statistical analyses were carried out. A significant influence recorded for different designs was defined as the significance level, being less than or equal to 0.05 (the confidence level equal to or more than 95%). Minitab 14 software was used to perform statistical analyses, which were carried out according to the driver’s needs in knowing the street name.

3. Results and discussions

In the case of preliminary analyses, data about mean time from each representation outlined in Figure 1 (ex.: H-GL-L1) were used as shown in Table 1. To perform detailed analyses, it was used the simple arithmetic mean was calculated from two representations, by using maps having similar designs in terms of text positioning, road network pattern, and street name location (ex.: the mean time of H-GL-L1 and H-GL-L2) (Figure 5).

A normality test (Shapiro-Wilk) was performed for each group of maps and not all data followed a normal distribution. The Student test was then applied to the data with normal distribution, and the Wilcoxon test was used for data that did not follow a normal distribution, or to analyse two data sets having different distributions (normal and abnormal).

Table 1: Descriptive statistical for preliminary analysis

Design	Mean	Minimum time	Maximum time	Variance	Shapiro-Wilk (p-value)
H-GL-L1	1.83	1.05	5.26	0.807575	< 0.010
H-GL-L2	1.69	1.05	2.36	0.169044	
H-GL-T1	1.70	1.01	2.33	0.168853	> 0.100
H-GL-T2	1.59	1.05	2.28	0.105049	
H-NGL-L1	1.66	1.07	2.50	0.15346	> 0.100
H-NGL-L2	1.61	1.01	2.49	0.171248	
H-NGL-T1	1.84	1.18	3.37	0.261416	< 0.010
H-NGL-T2	1.60	1.03	2.74	0.174457	
A-GL-L1	1.76	1.01	3.98	0.365947	< 0.010
A-GL-L2	1.62	0.92	2.39	0.142481	
A-GL-T1	1.69	1.18	2.59	0.219445	> 0.100
A-GL-T2	1.70	1.08	2.27	0.104448	
A-NGL-L1	1.74	0.91	2.43	0.133801	> 0.100
A-NGL-L2	1.70	1.07	3.21	0.226267	
A-NGL-T1	2.23	1.07	3.28	0.362515	> 0.100
A-NGL-T2	1.71	1.07	2.77	0.137324	

3.1 Basic analysis

In the basic analysis we considered the mean duration (Table 1). Comparing H-GL-L1 and H-GL-L2, as well A-GL-L1 and A-GL-L2, it was observed that reading time was slightly faster when the street name was positioned next to the car. The closer the street name was to the car, the quicker the reading time, possibly reaching perceptual grouping between car and street name. According to Gestalt Law, proximity is a rule used to create unity (MacEachren, 1995). Another point was observed, in which A-NGL-T1 and H-NGL-T1 presented a higher reading time than A-NGL-T2 and H-NGL-T2. For each route segment, before and after manoeuvre, street names were positioned along the line, as suggested by the literature (Slocum *et al*., 2009 e Imhof, 1975). The arrow could be used as reference point for reading. The initial letter of the street names for both different route segments (where the driver was or where the driver would manoeuvre) started from opposite directions. Also, characteristics of the arrow having irregular form and bent orientation after the junction may have been a source of instability when reading the name where the manoeuvre was to be made.

3.2 Analysing the influence of different positioning in the same road network pattern

For each type of road network pattern (grid-like or non-grid-like), we analysed whether the reading time between street names aligned horizontally next to the route or along the route was significantly different. A hypothesis test was applied having the following considerations: (H_0) there is no significant difference between different kinds of positioning, or (H_1) there is significant difference between different kinds of positioning. The results are shown in Table 2.

For the grid-like road network pattern and task of searching for the street name where the driver was (p =

0.463) or where the driver would manoeuvre (p = 0.565), as well for the non-grid-like pattern and task of searching for the street name where the driver was (p = 0.272), there were no significant differences. However, in a non-grid-like road network pattern, for the task of reading the street name where the driver would manoeuvre, a significant value was found (p = 0.004).

Table 2: Statistical description of analyses for different positioning in the same road network

Road network	Task	Statistical test	P-value
Grid-like	Street name where you are	Wilcoxon	0.463
	Street name where you would turn	T-Student	0.565
Non-grid-like	Street name where you are	T-Student	0.272
	Street name where you would turn	Wilcoxon	0.004

The arrow indicating manoeuvre direction was possibly taken as a reference point for reading. As stated by Yoeli (1972), the importance of name placement is not established by the position of the label isolated, but by the integral form of map elements and name placement elements. The bright green arrow well established by the black contour contributed to get the reader's attention. When searching for the street name where the driver would manoeuvre in a grid-like road network pattern, street names will always be positioned horizontally above or below the route. On the other hand, considering the route segment where the driver would manoeuvre in a non-grid-like road network pattern, when the turn was directed to the left side of the junction, the initial letter of the street name was more distant from the arrow. Also, the point of start the reading varied in terms of street name location (ex.: directed to the top or the bottom of the left side) due to differences in the angle of inclination between the next segment and the segment where the driver was.

In the case of the non-grid-like road network pattern and the task of reading the street name where the driver would manoeuvre, several participants declared that, although they had lack of familiarity with the street names aligned horizontally next to the route, reading them was easier than reading names along the route. Also, the farther the street name was placed from the car, the higher the reading time was.

3.3 Analysing the influence of road network pattern with the same text positioning

For each type of positioning (either aligned horizontally next to the route or along the route), reading time between street names presented in a grid-like or in non-grid-like road network pattern was analysed for significant difference. A hypothesis test was applied having the following two considerations: (H0) there is no significant difference between different road network patterns, or (H1) there is significant difference between different road network patterns. The results are shown in the Table 3.

Table 3: Statistical description of analyses for different road network patterns in the same positioning

Positioning	Task	Statistical test	P-value
Aligned horizontally next to the route	Name of street where you are	Wilcoxon	0.108
	Name of street where you will turn	Wilcoxon	0.433
Along the route	Name of street where you are	Wilcoxon	0.896
	Name of street where you will turn	T-Student	< 0.000

For the task of searching for a street name aligned horizontally next to the route where the driver was, there was no significant difference between different road network patterns ($p = 0.108$). However, this result can be considered as a trend, even though the result was not statistically significant. Additionally, there was no significant influence for street names aligned horizontally and the task of searching for the street name where the driver would manoeuvre ($p = 0.433$), as well for positioning along the route and the task of searching for the street name where the driver was ($p = 0.896$). Nevertheless, a significant value was found in the reading time when names were along the route in the task of searching for the street name where the driver would manoeuvre ($p < 0.000$).

4. Conclusions and recommendations

We designed two different groups of dynamic maps with egocentric reference schemes labeling two route segments, on a map for an In-Car Route Guidance and Navigation System. In one case, street names were aligned horizontally next to the route and, in the other, street names were positioned along the route segment. Reading times were then investigated of those different designs considering different road network patterns (grid-like versus non-grid-like).

Overall analyses allowed us to find indications about street name positioning. The more distant the street name was from the car, the higher was the reading time when reading the street name where the driver was located. And manoeuvre direction after the junction may have influenced the reading time in both cases of positioning the street name. When the route indicated a turn to the right, the arrow was used as a reference point to the eye to get the initial letter. However, in the case of route describing a turn to the left side, the initial letter was more distant from the arrow. This resulted in slower reading time. Also, it appeared that visual instability happened when searching for a street name next to an arrow that was presented in an irregular shape.

The influence of different positioning in the same road network pattern was not significant for searching for street names in a grid-like road network pattern (for a street name where the driver was or where the driver would manoeuvre) and in a non-grid-like road network pattern (for a street name where the driver was). On the other hand, in a non-grid-like road network pattern, street names aligned horizontally next to the route were read significantly faster than street names along the route for the task related to where the driver would manoeuvre.

Considering different road network patterns as well as same text positioning, significant difference was not found when reading the street name where the driver was located. However, considering the non-grid-like road pattern, reading the street name where the driver would manoeuvre was faster when the text was aligned horizontally.

To reduce reading time and enhance legibility, it is possible to suggest recommendations for positioning street names that label route segments in RGNS maps. This research work suggests that dynamic maps egocentrically referenced should present street names aligned horizontally and next to the route for the segment related to the task where driver will manoeuvre, for both road network patterns. Also, street names that label the route segment where the driver is should be positioned next to the car, independently of the road network pattern.

It is necessary to design street names considering different positions around the car. The effects of proximity between street name and manoeuvre should be examined by regarding the turn direction to the right in an irregular road network pattern. Further studies are needed to design and evaluate texts for labelling street names in complex manoeuvres, considering map scale and orthogonal or perspective map view. A driving simulator should be considered to investigate time spent with the eyes off the road when reading street names to be compared with the threshold recommended in the literature. Usability and aesthetics measures should be contemplated too.

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AUTHOR´S CONTRIBUTION

Researched and selected theoretical references M.P.R.; Data collection: M.P.R.; Data processing: M.P.R.; Preparation of draft manuscript: M.P.R.; Review of the proposed method: M.P.R., E.A.P. and V.M.T; Supervision: E.A.P. and V.M.T.; Discussion of the results, data analysis and paper revision and refinement: all authors.

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