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DRIVERS' PREFERENCE FOR MAP SCALES OF ROUTE GUIDANCE AND NAVIGATION SYSTEM

PREFERÊNCIA DOS MOTORISTAS POR ESCALAS DE MAPAS DE SISTEMAS DE NAVEGAÇÃO E GUIA DE ROTA

Ana Paula Marques Ramos [1]
Mônica Modesta Santos Decanini [2]
Edmur Azevedo Pugliesi [3]
Vilma Mayumi Tachibana [4]

[1,2,3,4] São Paulo State University – Faculty of Sciences and Technology
[1] Post Graduate Program in Cartographic Sciences;
[2, 3] Department of Cartography; [4] Department of Statistic
Roberto Simonsen Street, 305, 19060-900 Presidente Prudente city – São Paulo state - Brazil
[1]{marques.engcart@gmail.com}; [2, 3, 4]{edmur,monca,vilma}{@fct.unesp.br

ABSTRACT - This research work presents drivers' preference for map scale to perform simple and complex maneuver when they using in-car route guidance and navigation system. A total of 52 subjects (26 males and 26 females) participated of an experiment in a driving simulator. Drivers were required to navigate using maps at two different scales 1:3,000 and 1:6,000 and then to indicate the most preferable to perform simple and complex maneuver (ex.: roundabouts). Results show that both scales were equally satisfactory to support simple maneuver. However, a more detailed map was preferred in case of complex maneuver. No significant relation was found between drivers' gender or spatial ability and their subjective preference. It is suggested that map scale selection process should consider complexity of maneuver in order to improve usability of route guidance and navigation system.

Keywords: Cartographic scales, dynamic maps, subjective preference, usability.

RESUMO – Este trabalho apresenta a preferência dos motoristas pela escala do mapa para realizar manobra simples e complexa utilizando sistema de navegação e guia de rota. Um total de 52 pessoas (26 homens e 26 mulheres) participaram de um experimento em simulador de direção. Os motoristas foram convidados a navegar usando mapas em duas diferentes escalas, 1:3.000 e 1:6.000 e indicar qual destas escalas é a mais preferida para realizar manobra simples e complexa (ex.: rotatórias). Os resultados mostram que ambas as escalas são igualmente satisfatórias para auxiliar em manobra simples. No entanto, um mapa mais detalhado é preferido em caso de manobra complexa. Nenhuma relação foi encontrada entre o gênero ou a habilidade do motorista e sua preferência. Conclui-se que o processo de seleção da escala do mapa deveria considerar a complexidade da manobra para melhorar a usabilidade dos sistemas de navegação e guia de rota.

Palavras-chaves: Escalas cartográficas, mapas dinâmicos, preferência subjetiva, usabilidade.

1. Introduction

In-vehicle Route Guidance and Navigation Systems (RGNS) have become increasingly important devices to economy, especially for tourism and transportation sectors (Ei-Wen & Green, 2013). However, driving requires much concentration, and taking off eyes from the road to receive navigation information from these systems may

have serious impacts on traffic safety (JAMA, 2004, AAM, 2006, EC, 2009, ISO, 2010, NHTSA, 2012). Thus, designers of RGNS have pointed out the importance of usability issues (Green *et al.* 1993, Burnett, 1998, Labiale, 2001, Yung-Ching, 2001, Pugliesi, 2007, Lee & Jun, 2011, Burnett *et al.* 2013). Usability of RGNS has been evaluated using both objective and subjective measures (Bach *et al.* 2009, Akamatsu *et al.* 2013, Pugliesi *et al.* 2013), and a relevant subjective measure refers to drivers' satisfaction, as identifying preference for the system (Schofer *et al.* 1997, Pugliesi & Decanini, 2009, Wakabayashi, 2011, Ramos *et al.* 2014b)

A particular problem of current route guidance is that these systems are not carefully presenting information according to the navigation task that drivers are developing (Dillemuth, *et al.* 2007, Ramos *et al.* 2014a). Information is delivered regardless of its relationship to the current context of navigation, for example, the kind of maneuver (simple or complex) that will be performed (Wu & Zhang, 2009, Ramos *et al.* 2014a). To be effective, a RGNS should provide relevant information, providing a positive user experience, not overloading drivers' cognitive and perceptive processing system, and not being visually appealing (Labiale, 2001, Lee & Jun, 2011).

One fundamental variable for designing effective RGNS is the map scale (Dillemuth *et al.* 2007, Marques *et al.* 2012, Lavie & Oron-Gilad, 2013). Selecting an appropriate scale for navigation map may not only improve the visual balance of the cartographic representation (Ho & Li, 2004, Lavie *et al.* 2011), but also optimize map information according to current navigation task; improving performance of drivers at decision points on route (Lee *et al.* 2008, Sheleiby *et al.* 2008).

The aim of this work is to evaluate drivers' preference for map scale to perform simple and complex maneuver when they using RGNS. The following questions are

investigated: "Is there a favorable scale for maps of RGNS to support navigation task?"; "Does the complexity of maneuver interfere in the drivers' preference for different scales?" and; "Are gender or drivers' spatial ability related to subjective preference for map scale?".

2. Method

Subjective preference was evaluated using a questionnaire applied for accomplish tactical task. This task refers to the preparation for making maneuvers (Michon, 1985), and so may overload drivers' cognitive processing system (Kaber *et al.* 2012).

2.1 Subjects

A group of 52 drivers (26 males and 26 females) from Presidente Prudente town, Sao Paulo state, Brazil, participated voluntarily of a simulated experiment. The subjects' age was between 21 and 38 years with mean of 28 and standard deviation (SD) equal to 4.4 years. All subjects were required to be regular drivers for at least two years, having normal color vision, and having no or little knowledge of the town used in the experiment.

A spatial ability test was applied to analyze if drivers' spatial abilities have influence on their preference for map scales. Spatial ability was measured using the Perspective Taking/Spatial Orientation Test (PT/SOT) (Hegarty & Waller, 2004). The PT/SOT is a 12-item survey that asks for subjects estimate angles from varied orientations. The score for each item is the absolute deviation in degrees between the participant's response and the correct direction to the target. A subject's total score was the average deviation across all attempted items.

2.2 Experimental route

A route located in a small town was used in the experiment. The route comprised a total length of 3.4 km and it is composed of thirteen maneuvers, which were classified as simple or complex, according to previous researches (Pugliesi *et al.* 2009). Simple maneuvers are decision points where the exit is delineated as being the first road to be taken on the right or left side of the junction. Complex maneuvers are decision points where driver has multiple options (i.e. roundabouts) which may difficult the decision process (Labiale, 2001, Pugliesi *et al.* 2009). The experimental route includes three roundabouts.

2.3 Cartographic representations

Two different scales 1:3,000 and 1:6,000 were selected to navigation maps. These cartographic representations were developed in a prototype, by using ESRI MapObjects with Microsoft Visual Basic taking into account cartographic communication principles (Pugliesi *et al.* 2009, Marques *et al.* 2012, Ramos *et al.* 2014b).

The prototype presents the map display in heading-up orientation with orthogonal view. Information elements on maps are: car (RGB = 250,0,0), route (RGB = 0,0,0), direction arrow (RGB = 0,255,0), street name (RGB = 0,0,0) and road network which was divided into main (RGB=255,166,0) and secondary (RGB=255,255,255) road types. A beep, presented from 100 meters before each maneuver, was used to indicate the beginning of each tactical task (Pugliesi *et al.* 2009). Some maps at 1:3,000 (Figures 1 and 3) and 1:6,000 (Figure 2 and 4) are shown to represent simple (Figure 1 and 3) and complex maneuver (Figures 2 and 4).

Figure 1. Map at 1:3,000 scale for simple maneuver.

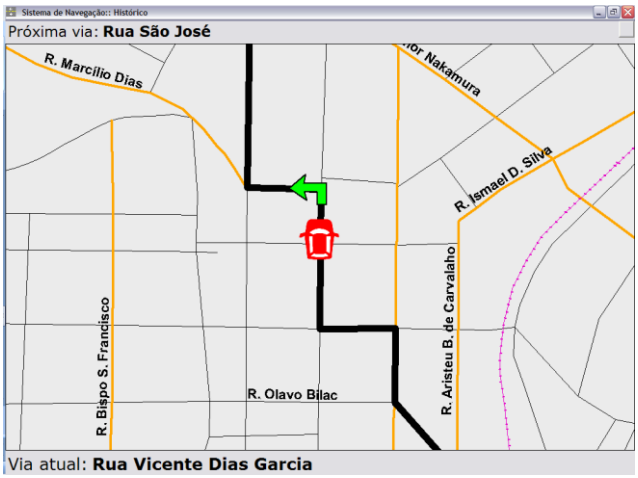

Figure 2. Map at 1:6,000 scale for simple maneuver.

Figure 3. Map at 1:3,000 scale for complex maneuver.

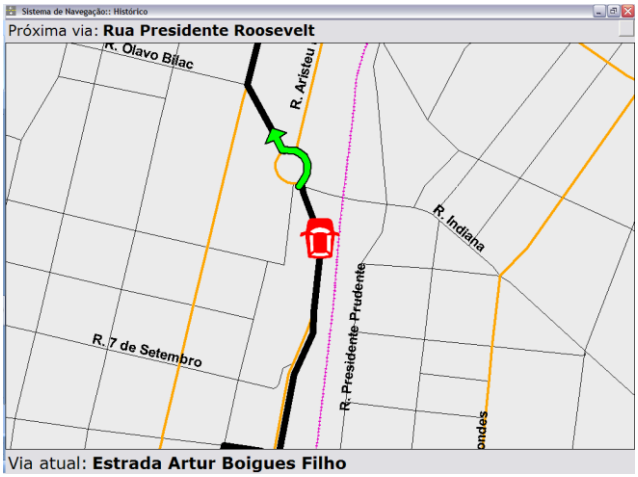

Figure 4. Map at 1:6,000 scale for complex maneuver.

2.4 Apparatus

The experiment was performed in a low-cost and fixed-base driving simulator. The driving simulator comprises two visual output channels. A large screen-image (180 cm height and 240 cm width; video resolution of 1024 x 768) located in front of the car and was used to display a video movie of the road test. The distance of the screen from the driver was 2.5 meters. The second output channel consists of a 7-inch LCD screen (XENARC 700-TSV; video resolution of 1024 x 768) was used as navigation display. This monitor was placed on the dashboard, in the right side of the steering wheel, as recommended by literature (Wittmann *et al.* 2006, Burnett *et al.* 2012).

A computer was connected via a serial connection to a video projector to display the video movie of the road test on the screen-image. Another computer was used to run the RGNS prototype, which was connected via VGA port to the navigation display. The auditory information was presented using personal computer speakers which were positioned behind the driver's and passenger's seats. Drivers' preference was recorded using a mobile device Tablet Asus FonePad ME371MG.

2.5 Experimental design

Drivers were divided into two equal-sized groups of 13 males and 13 females. Group 1 started driving simulation task using maps at 1:3,000 scale (maneuvers 1 to 6) and ended it using maps at 1:6,000 scale (maneuvers 7 to 13). Group 2 experienced the opposite order. First, maps were displayed at 1:6,000 scale (maneuvers 1 to 6) and then at 1:3,000 (maneuvers 7 to 13).

Before starting the driving simulation task, drivers were familiarized with the simulator. Next, the experimenter explained the purpose of the test and showed system's symbol guidelines to familiarize drivers with both visual cartographic representations and beep. Finally, drivers were asked to complete the spatial ability test (PT/SOT) and to sign a consent form. For driving simulation task, drivers were required to suppose that they should be navigating by car in an unknown town using a RGNS. Drivers were also advised to pay the necessary attention to the video movie to avoid traffic accidents. Moreover, drivers were asked to look at the navigation display using quick glances to get map information presented by the RGNS, preferably after the beep. The driving simulation task started after driver saying the test could begin.

A subjective preference questionnaire was initiated after drivers completed the journey. First, the experimenter presented maps at two different scales for simple maneuver (Figures 2 and 3) and then the following question was applied: "To perform simple maneuver which scale do you prefer 1:3,000 or 1:6,000, and why?". Second, the experimenter presented maps at two different scales (Figure 4 and 5) to represent complex maneuver applying the following question: "To perform complex maneuver which scale do you prefer 1:3,000 or 1:6,000, and why?". Drivers' preference was recorded in a Tablet device.

3. Results

The collected data were processed using the SPSS 16.0 (Statistical Package for the Social Sciences Software). A confidence level of 95% was used for all statistical analyses. Table 1 lists the descriptive statistics for spatial ability.

As noted at Table 1, both group of drivers had similar spatial ability score (p=0.469). However, males have approximately twice more spatial ability than females. These results have also been shown by previous researches (Dabbs *et al*. 1998, Galea & Kimura, 1993, Voyer *et al*. 1995, Weiss *et al.* 2003, Coluccia *et al*, 2007, Wakabayashi, 2011, Wilkening & Fabrikant, 2011).

The Shapiro Wilk test showed that spatial ability had no normal probability distribution (p<0.0001). Thus, results for subjective preference were analyzed using statistical non-parametric, like Mann-Whitney and Chi-squared tests for two independent samples as suggested by Conover (1999).

Table 1. Descriptive statistics for spatial ability data.

Group of drivers	PT/SOT scores (degrees)		
	Mean	SD	p-value *
1	52	48	0.469
2	45	46	
Gender	PT/SOT scores (degrees)		
	Mean	SD	p-value *
Males	33	35	0.007
Females	64	53	

* p-value was calculated by Mann-Whitney test.

To perform simple maneuver considering all 52 subjects, the results of Chi-squared test showed that both scales are equally acceptable for maps of RGNS (p=0.782). Maps at 1:3,000 scale were preferred by 52% of the drivers, while 48% preferred using maps at 1:6,000 to perform this kind of maneuver. According to drivers'

comments, maps at these two scales can support to identify quickly and easily the direction of the maneuver.

To perform complex maneuver, the results showed that drivers preferred maps at 1:3,000 significantly ($p<0.001$) considering all 52 subjects. This scale was preferred by 73% of the drivers. According to drivers' comments, in complex maneuvers it is necessary to visualize more detail about the junction in order to identify clearly what should be done in this kind of decision point. Drivers also reported more confident in themselves to perform complex maneuver using maps at 1:3,000. So, maps less generalized were more appropriate to support drivers at complex maneuver task.

The final analysis was conducted to verify if preference for maps at 1:3,000 scale to perform complex maneuver is related to the spatial ability or drivers' gender. Although men has presented more spatial ability than women, the results reveled that this individual characteristic does not interfered at subjective preference ($p=0.347$). So, drivers' preference may not be explained by spatial ability or gender.,

4. Discussion

Several researchers have introduced models for how navigation occurs during a driving task (Michon, 1985, Burnett, 1998, Ross and Burnett, 2001). Considering the proposed model by Burnett (1998), which consists of an extended Michon's (1985) model and was reviewed by Ross and Burnett (2001), navigation task may be divided at five different stages, such as preview, identify, confirm, trust, and orientation.

In the preview stage, drivers require to gain perception of remaining time and distance to the next maneuver, and build a mental picture of the maneuver. In the identify stage, drivers require to identify the direction to travel, control suitable speed of

the vehicle, and establish correct positioning of the vehicle on the road. In the confirm stage, drivers require to verify whether the correct maneuver has been made, while in the trust stage, drivers require to gain assurance that the correct route is being driven, and, finally, in the orientation stage, drivers require to remain aware of their current location in the entire route, especially in relation to final destination (Burnett, 1998, Ross and Burnett, 2001).

Maps for in-vehicle route guidance and navigation systems should support drivers at these different stages of navigation and for this purpose maps should present a proper visual balance. Since in complex maneuver drivers have preferred more detailed maps (i.e.: 1:3,000), it could be implied that drivers' concern in this kind of maneuver is related to preview and indentify stages and not necessarily to confirm, trust or orientation stages.

Cartographic representations at 1:3,000 scales seem to communicate information about the distance to the next maneuver and the direction to travel in more legible way on maps, and receive these two group of informations consist of two main goals of drivers at preview and identify stages, respectively. Thus, RGNS presenting maps at 1:6,000 or maps at smaller scales may not support appropriately drivers to perform complex maneuver.

5. Conclusions and Recommendations

This work evaluated drivers' preference for map scale to perform simple and complex maneuver using a route guidance and navigation system.

To perform simple maneuver, we identified that scales at 1:3,000 and 1:6,000 were equally accepted. However, a more detailed map was preferred in case of complex

maneuver. It can be concluded that maneuver complexity interferes in usability of RGNS. Thus, in the process of map scale selection, the kind of maneuver should be taken into account before to define map scale.

This work corroborate that drivers' satisfaction for system can effectively support information communication in maps and so should be always adopted in the design of RGNS interfaces. We recommend associating subjective preference with objective measures in order to estimate a more accurate drivers' mental workload.

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