Abstract: This paper reports the development of researches on selection, presentation and evaluation of information for conceiving In-Car Route Guidance and Navigation Systems (RGNS). It also presents some studies that have been carried out in the Faculty of Sciences and Technology, at Sao Paulo State University (FCT-UNESP). In terms of selection of information, one of the greatest researchers’ goals is to find out the appropriate information that should be added in navigation systems. For answering the question “what do the drivers need?” a few studies have been carried out and a set of information have been emerged and discussed. Taking into account presentation of information, several studies have investigated different ‘formats of information’ and ‘display modalities’, as well their combinations. Maneuver direction, landmarks and distance to turn are presented on map or turn-by-turn, visually or aurally. To evaluate the usability of RGNS, including the cartographic communication performance, some experimental measures are taken into account such as satisfaction, easy of learning, efficiency and effectiveness. Some tests were conducted at FCT-UNESP in order to find out some driver’s basic requirements, as well point out a group of potential representations for developing navigation systems, by considering traffic safety. From the ‘format of information’ point of view, it was found out that most of the drivers prefer maps rather than turn-by-turns. Also, they prefer white background color when navigating during the day and black one during the night. To represent the position of the car on route by using moving-map display it was found out that drivers prefer car pictorial symbol as seen from the top. Some tests of interface usability were conducted in an in-house low-cost driving simulator and results point out that mimetic landmarks seem to influence higher visual demand. Finally, this paper presents important recommendations for conducting future researches and what the next steps have been planned from now on.
1. Introduction

In the context of researches about development of driver interfaces for In-Car Route Guidance and Navigation Systems (RGNS), a great effort have been done in European countries, the United Kingdom, the United States and Japan. In Brazil, although, the national Brazilian traffic laws had not permitted the effective use of RGNS before April, 2007 (CONTRAN, 2007), a few studies have started quite recently, giving especial attention to the cartographic design and communication, as well to the evaluation of cartographic representations (Pugliesi, 2002; Pugliesi et al., 2004; Pugliesi, 2007; Pugliesi and Decanini, 2009a; Pugliesi and Decanini, 2009b; Pugliesi and Decanini, 2009c; Pugliesi et al., 2009). Additionally, a preliminary research about choice of information for conceiving route guidance has also been started (Pugliesi and Decanini, 2005, Pugliesi, 2007; Pugliesi and Decanini, 2009c).

Human factors studies related to the conception of RGNS have been concerned with the choice and presentation of information, as well the individual differences (Zimmer, 1990 apud Burnett, 1998). In terms of selection and presentation of information, this paper provides some ideas about spatial cognition, visual perception and evaluation studies that have been done for conceiving, designing and evaluating RGNS. From the selection of information view, researchers have been interested about ‘what’ kinds of elements from the real world should be presented to the drivers (Alm, 1990; Obata et al., 1993; Burnett, 1998; Pugliesi and Decanini, 2005). Since cognitive maps are developed based on urban layouts and regional features, as well as their experiences in the environment (Lynch, 1960/2006), some evidences seem to indicate that drivers from different countries use different kinds of information for navigational purposes (Daimon et al., 2000).

By considering perception in visual displays, the central issue is ‘how’ and ‘when’ to present information to the drivers (Burnett and Journey, 1997). A number of studies have found out that information presentation of maneuvering direction, spatial context, and distance to the approaching maneuver are essential for drivers following a route in unknown urban places (Green et al., 1994; Ross et al., 1995; Burnett, 1998; Burnett, 2000; Pugliesi and Decanini, 2009a). However, these applications could be too visually and cognitively demanding, requiring immediate attention, which could override a focus on driving (Green, 2000).

For evaluating those systems, it is mostly required a clear experimental design, as well an appropriate technological apparatus, like an instrumented car or a driving simulator (Sweet and Green, 1993; Green, 2005; Lee et al., 2007; Pugliesi and Decanini, 2009b; Pugliesi et al., 2009). Furthermore, a minimal number of measures must be well thought-out for testing driver’s interface of in-car navigation systems (De Waard, 1996; Burnett, 1998; Labiale, 2001; Stanton et al., 2005; Pugliesi et al., 2009).
An actual project concerning the evaluation of the cartographic communication performance of multimodal representations of navigation system for route following is been developed in the Faculty of Sciences and Technology, at Sao Paulo State University (FCT-UNESP), Brazil. For supporting that objective, a study about development of driving simulators, as well basic considerations about appropriate variables for measuring driver’s mental workload was done in the first semester of this year at University of Michigan Transportation Research Institute, in the Human Factors Division with the Driver Interface Group. The main project aims to point out a group of ‘good’ cartographic representations for route following, as well those layouts that can bring some problem related to crash risk, by taking into accounts regional factors, urban layout, and characteristics of visual and aural information.

Thus, this paper aims to report a general overview about the development of researches on selection, presentation and evaluation of RGNS, as well to present a summary of the studies that have been carried out at FCT-UNESP.

2. Information for RGNS

2.1 Selection of Information

Cognitive map is a term established by Tolman (1948), and it has been widely used for many researchers in the human sciences field. A cognitive map specifies the internal representation of the spatial information in a way that its geometrical structure of the knowledge is compound of points, lines, areas and volumes (Golledge, 1999). By considering the navigational information in a higher level, paths, nodes, landmarks, districts and edges have been considered the elements of the city that are in the people’s mind (Lynch, 1960/2006). Taking into account the choice of information for navigational purposes, landmarks have been examined carefully in a number of studies (Burnett, 1998; Sorrows and Hirtle, 1999; Labiale, 2001; Raubal and Winter, 2002; Pugliesi and Decanini, 2005).

To understand the information that drivers use during navigation, cognitive processes are investigated based on cognitive maps (Alm, 1990; Obata et al., 1993; Aginsky et al., 1997; Burnett, 1998; Daimon et al., 2000). Those studies point out that paths, nodes and landmarks are the elements most commonly used by the drivers. Also, direction, distance to turn and traffic signals could be considered as ‘ideal’ information types for route following (Burnett, 1998). Burnett (1998) has summarized the approaches that researchers have been adopting in order to study the choice of information, by considering the following aspects: setting for study (such as paper and pen, road), sources of information (e.g., cognitive map, paper-map, map-based navigation system, videotape), tasks of information from the experimenter (such as writing and/or sketching directions, and giving verbal information), tasks of information given to the receiver (e.g., reaches a destination imagined, asks information when needed, and calls out information that is being used). The categorization scheme of the navigational
elements has being supported by Lynch (1960/2006), Kuipers (1978), Burnett (1998), 
Golledge (1999), or any own scheme.

2.2 Presentation of Information

Spatial information presentation for helping drivers when following a route in 
unfamiliar areas can be provided in different ways according to our perception stimuli.
Five modalities could be potentially used for receiving navigational information (Alm, 
1993). However, the stimuli most investigated by researches and used in navigation 
systems are visual and auditory, and they take place in particular kinds of interfaces 
(Burnett, 1998). These interfaces are generally classified according to the ‘format of 
information’ (maps, turn-by-turn or multi-format display) and type of ‘display modality’ 
(aural, visual and multi-modality display) (Burnett, 1998).

Although turn-by-turn systems have presented lower visual demand than maps, most of 
the studies had presented favorable results for the multi-modality display using map 
interface (Labiale, 1990; Labiale, 1992; Kishi e Sugiura, 1993; Srinivasan et al., 1994; 
Green et al., 1994; Ross et al., 1995; Srinivasan e Jovanis, 1997; Burnett, 1998; Liu, 
2000; Labiale, 2001; Pugliesi et al., 2009). However, to present appropriate visual and 
aural information to the drivers, the dynamic-audio-map need to be efficient and 
effective (Agrawala and Stolte, 2001; Ho and Li, 2002; Uang and Hwang, 2003; 
MacEachren, 2004; Lee et al., 2007; Pugliesi et al., 2009).

Thus, in order to improve moving-map interfaces for RGNS, perceptual grouping 
principles, such as proximity, similarity, good continuation, and figure–ground 
segregation should be taken into account in the design stage (Robinson et al. 1984; 
Sharpe, 1974 apud Dent, 1993; Forrest and Castner, 1985; Dent, 1993; MacEachren, 
2004; Slocum, 1999; Frutiger 1928/2001; Gomes Filho, 2002; Donnis, 1973). Besides, 
Pugliesi et al. (2009) state that knowledge about retinal sensitivity to different 
wavelengths (Wade and Swanston, 1991 apud MacEachren, 2004) can help the 
mapmaker to work better with colors when designing a RGNS. Also, in the context of 
reducing information overload while following a route, studies about cartographic 
generalization and map-scale size have provided important results (Agrawala and Stolte, 
2001; Uang and Hwang, 2003; Lee et al., 2007).

Related to sound displays, voice commands should present appropriate direction context 
and voice intonation, as well suitable tone, in terms of differencing sound and voice 
expression (Green et al., 1994; Ross et al., 1995; Wickens et al., 2004). By relating 
spatial information to beeps, they should be used to require driver’s attention for a new 
visual or aural message (Pugliesi, 2007).
2.3 Evaluation: condition of study and experimental measures

Literature on driver behavior using in-car navigation systems has presented a considerable advance in the human factors, cartography, transportation, and psychology fields. Basically, studies have been conducted on road and in fixed-base driving simulators (Labiale, 1990; Labiale, 1992; Sweet and Green, 1993; Green et al., 1994; Ross et al., 1995; De Waard, 1996; Srinivasan, 1997; Burnett, 1998; Liu, 2000; Green, 2000; Labiale, 1989; Labiale, 1990; Labiale, 2001; Tsimhoni e Green, 2001; Cnossen, 2000; Uang and Hwang, 2003; Pugliesi, 2007; Lee et al., 2007; Pugliesi and Decanini, 2009b; Pugliesi et al., 2009). All of those studies intend to determine the usability of route guidance and navigation systems, as Burnett (1998) has studied in terms of satisfaction, easy of learning, effectiveness and efficiency.

In order to obtain the drivers' satisfaction with the system, questionnaires and interviews have been employed (De Waard, 1996; Burnett, 1998). Related to easy of learning, there are two aspects to get the system usability: learning ability and memory ability (Nielsen, 1993 apud Burnett, 1998). In terms of effectiveness two important measures are navigational errors and journey time (Burnett, 1998; Liu, 2001; Pugliesi et al., 2009). On the other hand, there are two sub-elements related to the efficiency of RGNS, which are associated with secondary driving tasks and traffic safety: the use of system’s resource (driver’s mental workload and visual demand) and driving errors or driving behavior (De Waard, 1996; Burnett, 1998; Cnossen, 2000). Some examples of driving behavior/errors are: speed, variations in lateral position, change of lane, steering wheel variability, use of brakes and indicators, etc. The mental workload has been measured through mental effort measures, as psycho-physiological measures (heart rate and its variability) and self-reported measures (such as short questionnaires and rating scales: the NASA TLX – Task Load Index) (Hart and Staveland, 1988; De Waard, 1996; Burnett, 1998; Cnossen, 2000; Stanton et al., 2005). The visual demand for in-vehicle displays has been associated with the number and duration of glances through the eye-movement analysis (De Waard, 1996; Burnett, 1998; Cnossen, 2000; Labiale, 2001; Pugliesi et al., 2009). Additionally, a more number of measures can be used as variables for evaluating driver’s interface of RGNS (De Waard, 1996; Stanton et al., 2005).

3. Requirement Studies and Evaluation of Cartographic Representations

3.1 Preliminary study: choice of information in the Brazilian context

Two preliminary studies were conducted about the choice of information for developing a navigation system (Pugliesi and Decanini, 2005; Pugliesi, 2007; Pugliesi and Decanini, 2009c). The first work aimed to introduce a brainstorm about a set of landmarks that could be used by Brazilian drivers, when following a route in unfamiliar urban areas. In the first stage, it was evaluated a list of 29 landmarks considered to be of use in the navigation task for the United Kingdom, as presented by Burnett (1998). A total of 10 specialists in Psychology, Transportation, Geography and Architecture and
Urbanism, as well three specialists in Survey Engineering participated of the test. It was used the same question as presented by Burnett (1998), and the task was to classify if the element is appropriate or not. From the landmarks presented to the subjects the most important, with more than 90% of elements checked were bridge over road, church and river, superstore, public house, street name signs, traffic light, monument, factory, bus/coach station, school, gas station and park. These findings provide some indications that Brazilian people could valorize specific landmarks differently from British people and vice-versa.

In the second study a field survey was conducted in a small city, located in Sao Paulo State (Pugliesi and Decanini, 2005; Pugliesi, 2007; Pugliesi and Decanini, 2009c). The landscape was observed and the most salient landmarks were chose in a specific route in order to develop a RGNS. In that work it was taken into account some related studies like Lynch (1960/2006), Burnett (1998), Sorrows and Hirtle (1999), Labiale (2001), Raubal and Winter (2002). Table 1 shows an example with a picture of a shop, its location on a map and the main attributes taken into account.

<table>
<thead>
<tr>
<th>Picture</th>
<th>Map</th>
<th>Attributes</th>
</tr>
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| ![Shop Symbol](image) | ![Map with Shop Symbol](image) | Visual: shape, color and visibility.  
Detection: permanence, visibility and openness.  
Identification: uniqueness.  
Integration: importance of the localization. |

Table 1. Example of a landmark selected in function to its locations and other attributes.  
Source: Pugliesi and Decanini (2009c).

3.2. Design and Evaluation of Representations for Route Following

To design information for route following pictorial symbols were produced through generalization processes of a picture taken from each selected landmark based on the methods presented by Lessa (1995) and Horton (1996). The aim was to provide more spatial context to the drivers, by supposing that high iconicity landmarks may help them in route following tasks (Pugliesi, 2007; Pugliesi and Decanini, 2009c). Three kinds of representation levels was studied and developed, by considering the complexity of the landmarks: low, medium and high iconicity (Pugliesi and Decanini, 2009c). Table 2 presents the shop symbol in three different stages of simplification: outline, first simplification and second simplification. The last one was created to fulfill the RGNS’s legibility requirements.
In relation to the evaluation of representations for route following, three preliminary tests were conducted. The first test was performed to understand if drivers prefer dark (black color) or light (white color) background for navigation systems with map interface, during the day and in the night (Pugliesi, 2007). The aim was to find out an appropriate color for the background in order to create a good presentation with emphasis on information for route following. From the responses obtained through a structured questionnaire, which was conducted inside of the car, the results pointed out that most participants prefer maps with light background color in the day and all of them preferred dark background in the night.

The second experiment was related to the type of car symbol that should be presented in the moving-map display in order to improve the spatial context to the driver. The test was conducted with three kinds of symbols: arrow, car pictorial symbol as seen from the front end, and car pictorial symbol as seen from the top (Pugliesi, 2007). From the findings, the car pictorial symbol as seen from the top was the most preferred. The main reason was that it is more similar with a real car allowing them to form a correlated mental image of the space because the map and the car icon were seen from the top.

The third test took into account the ‘format of information’ presented to the driver. It was conducted in an in-house low-cost driving simulator and the results reported that most of the drivers preferred maps instead turn-by-turns (Pugliesi, 2007; Pugliesi and Decanini 2009a). This finding corroborates with Labiale’s (2001) statement that drivers prefer complex representations for enabling them to form an unambiguous mental representation. Figure 1 shows an example of the representation for simple maneuver that was tested with a group of Brazilian drivers.

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<tr>
<th>Picture</th>
<th>Outline</th>
<th>1st simplification</th>
<th>2nd simplification</th>
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Table 2. Example of a landmark graphically simplified. Source: Pugliesi and Decanini (2009c).
A number of cartographic representations was created to perform a final experiment by using an in-house low-cost driving simulator (Pugliesi et al., 2009). The following representations were taken into account to understand the visual demand, navigational errors and subjective preference: route, route + static arrow, route + static arrow + landmark, route + landmark, route + dynamic arrow. The study was organized in terms of maneuver and urban layout complexity. Results also confirm Labiale’s (2001) findings that higher the number of elements higher the visual demand. However, arrow located on the junction of the map seems to reduce the visual demand when preparing to maneuver. Irregular urban layout with just route representation influenced high number of navigational errors. Landmarks with high iconicity seem influence the visual demand. The cartographic design and the evaluation conditions are described detailed by Pugliesi et al. (2009).

4. Discussion and Recommendation

This paper reported some preliminary studies about selection, presentation and evaluation of information for conceiving RGNS. The results show that Brazilian people seem to valorize landmarks differently from British people. Particular characteristics of the landmarks can make them important elements for developing better route guidance. Navigation systems with light background for route following during the day and dark background for the nocturne period are most preferred by the drivers. Car symbol as seen from the top on the moving-map display in an orthogonal view was the most preferred. Dynamic map was considered the most appropriate visual ‘format of information’ for route following. In relation to the cartographic communication performance, mimetic landmarks and urban layout with irregular characteristics seem to influence the visual demand.

Considering the size of Brazil, which is divided into four large regions, having strong variety of cultures and differences on landscape, researches might focus on finding out what is required by the drivers in each region. Future researches might pin down on specific designs of route, by taking into account different colors, thickness and lightness in order to minimize information complexity of moving-map displays. In relation to the complexity of the interface presentation, a study about cartographic generalization and scale size should be taken into account in order to find out better maps in terms of usability. Future research is required on RGNS design for colorblind people, as Brazilian national laws permit them to driver cars. When developing maneuvers interfaces for RGNS a better idea could be combines haptic feedback in the driver’s seat as well provides aural information by considering only one channel of the car’s speakers, like left or right side according to the maneuver direction. For the future, experiments will be conducted in an improved driving simulator, followed by tests on-road in an instrumented car.
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References


