5-2007

The Effects of Landmark Information on Navigation Performance, Attention to the Driving Environment, and Vehicle Control

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THE EFFECTS OF LANDMARK INFORMATION ON NAVIGATION
PERFORMANCE, ATTENTION TO THE DRIVING ENVIRONMENT, AND
VEHICLE CONTROL

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Applied Psychology.

by
Rachael MaryAn Daniels
May 2007

Accepted by:
Dr. Leo Gugerty, Committee Chair
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ABSTRACT

Recent research has helped confirm that landmarks are used as strong

navigational signals and assist with way-finding strategies. Current in-vehicle

information systems however, use little information in the way of landmarks, and

instead rely heavily on distance information in order to direct drivers to their

destination. It has been suggested that our spatial knowledge of an environment

rarely uses distance information accurately. Although, recent research has shown

that landmarks are helpful, a deeper understanding of what specific types of

landmarks help with navigation is lacking in the literature. The current study

attempts to fill in this gap in the literature and investigate in what sort of context -

as previews of upcoming turns or identifiers of imminent turns - landmarks can be

used. In the study, information about identification landmarks, preview

landmarks, or distance to the next turn was presented in an in-vehicle information

systems, and the effects on navigation performance, attention to the driving

environment, and vehicle control were measured. It was hypothesized that both

landmark conditions would lead to better navigation performance (e.g. fewer

incorrect turns and near navigational errors), better attention to the driving

environment (e.g. fewer driving errors and better performance on a recognition

memory test) and lower variations in speed and steering wheel control, than when

distance information is used on an IVIS to guide drivers. Results showed that both

types of landmark information led to fewer incorrect turns than with distance

information. Participants using distance information made many incorrect turns in

the first segment of the route, which suggests a learning effect with this type of information, because the other two conditions did not experience such results. Landmarks did not lead to fewer near navigational errors (incorrect signaling) or driving errors. Participants in the landmark conditions did not perform better than those using distance information on the recognition memory test. Variations in speed and steering wheel control were similar in all conditions.

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CHAPTER I

INTRODUCTION

Navigating through one's city, or a new city for that matter, can be an arduous task, especially in rush hour, mass congestions, or when one is under time constraints. Finding one's way during times like these can be stressful and take cognitive resources away from the task of driving. Car manufacturers are trying to ease the problem of navigation by implementing in-vehicle-information-systems (IVIS) in their cars. Thanks to the growing trend of modern day IVISs, drivers can now have digital maps and directions embedded in their dashboard for immediate navigational assistance. These systems, however, create a problem. Current IVISs use distance to turn and, in some systems, street name information to guide the driver along a route. However, these systems do not take in to account how people naturally navigate in a new environment or their spatial representations of it. For example, research has shown that people use landmarks when constructing cognitive maps of an environment (Cohen and Schuepfer, 1980). The goal of this project is to investigate the importance and usefulness of landmarks when navigating in a vehicle using an IVIS. The findings of this study will provide guidance regarding whether landmarks should be an option in IVISs.

Current vehicle navigation systems use little information in the way of landmarks. Instead, the majority of them employ maps and auditory turn-by-turn information in order to direct the driver to his or her destination. These systems

rely heavily on distance information (Burnett, 2000). A Global Positioning

System (GPS) determines location of the car and the driver manually enters in the

destination information via address, location, or from a previous trip. A digital

map is presented on the screen and often times moves along the route

simultaneously with vehicle movement. When approaching a maneuver, the

display will provide information regarding the upcoming turn. A direction arrow,

current street name, street name after the turn, and a periodic representation of

distance to turn will all be presented on the visual display of the IVIS. A digital

voice will also periodically give the distance to the next turn in an egocentric

manner, e.g., "turn right in 500 meters." Thus, today's systems provide both

visual and auditory information to the driver.

Although these systems can help drivers plan and follow routes,

navigating through an unfamiliar environment can still be a stressful, trying task.

Driving is a cognitively demanding task with multiple goals. Drivers' overall goal

is to reach their destination. This goal is called navigation. However, drivers also

want to reach their destination safely. In order to do this, they must attend to their

surroundings (e.g., other vehicles, road signs, and potential hazards) and avoid

hazards. Thus, attention and hazard avoidance are drivers' second goal. Finally,

drivers also have to maintain control of the vehicle (e.g., stay in proper lane,

maintain appropriate speed, avoid swerving). Vehicle control is the driver's third

and lowest goal. Adding any sort of technology into the vehicle can take attention

away from any of these goals and could lead to crashes. Wierwille (1995, as cited

in Burnett, 2000) noted that lack of driver attention in addition with distractions,

are leading causes of crashes. Therefore, IVIS must be well designed and provide information in a concise and timely manner so as to not take away too much attention from driving goals and tasks.

<div align="center">Cognitive Maps</div>

A cognitive map is adaptable spatial knowledge that provides people with various routes that can be used to reach a destination (Foo, Warren, Duchon, & Tarr, 2005). "It is a map-like representation of the environment including distance and direction information" (Tolman, 1948, as cited in Parush & Berman, 2004, p. 377). Cognitive mapping, a process that involves gathering, encoding, and storing information about our environment, is used to complete spatial tasks such as navigation (Jackson, 1998). If we do not possess an external map or compass, spatial problem solving depends on internal representations that we have stored in memory regarding the world around us (Jackson, 1998). Our cognitive maps are one form these internal representations may take. The use of prominent landmarks elaborates our cognitive maps and contributes to the process of navigation (Jackson, 1998). How people function and make navigational decisions regarding their spatial environment is based on their cognitive representations of that environment. In summary, the ability to navigate and wayfind depends on one's cognitive maps (Arthur and Passini, 1992).

Spatial Knowledge

"The development of spatial knowledge begins with the representation of landmarks" (Cohen & Schuepfer, 1980, p. 1065). The theoretical framework proposed by Siegel and White (1975) regarding the development of spatial knowledge suggests a three stage process. The first stage is landmark knowledge. In a new environment, landmarks are the first type of knowledge we gather (Parush & Berman, 2004). This stage encompasses our basic knowledge of landmarks and is where they are recognized and remembered (Jackson, 1998; Aginsky, Harris, Rensink, & Beusmans, 1997). Landmarks lead to the second stage, the acquisition of route knowledge (Cohen & Schuepfer, 1980).

Route knowledge is knowledge about the routes that connect landmarks. It is gained through experience with the environment and helps people move from one location to another (Vinson, 1999). Route knowledge involves landmarks that are followed in sequence in order to form individual routes that lead us to our destination (Foo et al., 2005; Parush & Berman, 2004). This type of knowledge develops by combining navigational actions (e.g., turn right) with a landmark (Vinson, 1999).

As routes are learned, survey knowledge (the third stage) begins to form, with landmarks making up its elements and helping to construct the layout of the environment (Aginsky et al., 1997; Parush & Berman, 2004). Survey knowledge involves incorporating various routes so as to fabricate a holistic representation, or a map, of our world (Jackson, 1998; Vinson, 1999). In summary, spatial learning follows a sequence of landmark acquisition, connecting these landmarks

to make routes (route knowledge), and making configurational maps (survey knowledge).

<div align="center">Landmarks</div>

Acclimation to a new environment involves landmarks (Vinson, 1999). Landmarks are stationary, salient points of reference that serve to guide us through an environment and facilitate course-maintenance (Cohen & Schuepfer, 1980; Steck & Mallot, 2000). Landmarks have several roles. They serve to indicate when an action should occur, locate other landmarks, and confirm that one is still on the correct path (Michon & Denis, 2001). By definition landmarks indicate when to perform or not perform some maneuver along a route when there is a possibility of changing directions. "Landmarks contribute to creating a visual model of critical points of an environment, as seen from a route perspective, which prepares the moving agent to react appropriately to situations involving a decision" (Michon & Denis, 2001, p. 303).

There are two main types of landmarks: global and local (Steck & Mallot, 2004). Global landmarks include items such as mountains, skyscraper, or bodies of water. These items are used by the observer to maintain a constant frame of reference. Therefore, global landmarks can serve as a compass (Steck & Mallot, 2004). Conversely, local landmarks do not serve as large reference points, but can only be seen within a small distance. Local landmarks include: gas stations, houses, churches, and street signs. These types of landmarks offer sequential guidance for route navigation from one location to another.

When using landmark information in directions it is important to exploit certain ones and not mention just any type of roadside objects. The use of non-distinctive items along the road can actually be detrimental to way-finding and cause more confusion and navigational errors (May & Ross, 2006). The main characteristics of good landmarks include: being visible from a distance and from several directions, possessing a unique appearance so as to not be confused with other objects, located close to the road and near intersections, and being relatively permanent (Burnett, Smith, & May, 2001).

In order for some feature in the environment to gain landmark status, it must be highly visible and distinctive from other features in the environment and it must be paired with a navigational action, e.g., turn left (Vinson, 1999; Aginsky et al., 1997). In order for a building to become more memorable, it needs to be located on a major path or near a major intersection (Vinson, 1999). Thus, the placement of landmarks is also important to the task of navigation. In a study conducted by Appleyard (1969), participants recalled as many buildings and places as they could in their current city. The participants then drew a map of the city indicating all these places, and thought of places on a path through the city. Some buildings near intersections were recalled by many participants in their description of the route, but buildings that were similar in stature were not recalled if they were not close to an intersection. Therefore, simply being visually distinctive does not guarantee that a building will be remembered. However, a visually distinctive building placed near a decision point is more likely to be recalled as a landmark (Appleyard, 1969).

Various studies have demonstrated that people use landmarks while navigating. Cohen & Schuepfer (1980) had second graders, six graders, and college students learn a route through a maze of hallways by viewing a slide presentation. Pictured on the slides were three landmarks and one turn. After the route was learned successfully, the participants were then given the slides in a scrambled manner and they had to recreate the route in its entirety. This was completed by rearranging the slides or drawing out a map of the route with correct turns. In the second experiment, the landmarks were removed and the participant was again asked to recreate the route. All age groups recalled more landmarks if they were situated near a turn along the route than if they were placed somewhere else. This finding supports the notion that placement of landmarks is important for navigation (Cohen & Schuepfer, 1980).

Parush and Berman (2004) had participants navigate through a 3-D environment depicted on a computer screen. Participants had to search for an object in the environment. They were either able to use a navigational aid to support them in their search or not. The screen image depicted landmarks in one condition and none in the other condition. The landmarks helped participants gain better route knowledge of the environment. And when the navigational aids were removed, navigation was not greatly affected because landmark information was still illustrated. When participants had to point toward the direction of an object from anywhere in the room (the orientation task), the use of navigational aids along with landmarks helped participants be able to point closer to the target location.

In another study, when participants were given street name instructions or landmark based instructions, participants took longer to process the street name based instructions than landmark based instructions (Tom & Denis, 2004). Additionally, landmarks were recalled better than street names when participants had to recreate the route. Finally, when asked to highlight on a map the route given in the instructions, this process was quicker for those who were given the landmark based instructions. This study suggests that landmarks and street names may be processed differently and it may cost more cognitively to process street names. Street names do not necessarily provide additional spatial knowledge of the environment. Tom and Denis (2004) summarized their findings quite clearly when they stated "landmarks may be more effective than streets when representing a previously unknown route, as it is easier to construct a mental representation of a route based on interconnected dots then one based on interconnected extended lines" (p. 1228).

The use of landmarks for guided navigation was also investigated in a study by Foo et al. (2005). In a fully immersive virtual environment, participants had to navigate between three poles with the help of landmarks or without. The virtual screen included a desert and a forest landscape. This experiment looked at how people make shortcuts through and environment and the types of information (i.e., distance or landmarks) they use to get from one specific location to another. If landmarks were present, participants relied on them extensively for accurate route navigation. Shortcut maneuvers were more precise when landmarks were

present. And lastly, Foo et al. (2005) suggested that our spatial knowledge of an environment rarely offers or uses accurate distance information.

Some reasons for incorporating landmarks into vehicle navigation systems are that human navigational strategies rely on landmarks, and that landmarks are a valued piece of information for drivers (Burnett, 2000). For instance, landmarks play a significant role in peoples' mental representations of the environment and are used when learning a new environment (Vinson, 1999). They serve as strong navigation signals and are used in way-finding strategies. Streeter and Vitello (1986) found that when receiving directions, one of the most important pieces of information people wanted was a description of the landmarks found along the route.

Another study that looked at giving guidance information to others was conducted by May, Ross, and Bayer (2003). They investigated what information is needed by drivers for successful navigation in an urban environment and how that information is described independent of an in vehicle navigation system. Thirty-six people participated in this study and were split into two groups. The video group watched a video of three urban routes. The video was produced to show a large section of the scene, with a clear view of side roads, exits, road signs and street names. This group had no prior knowledge of the route area. The cognitive map group received a schematic of the routes with start and end clearly labeled. Sufficient road layout information was provided so participants could gain a basic understanding of the routes in question. All other identifying information such as street names and landmarks were removed. This group

possessed extensive knowledge of the area, having worked or lived in the area for at least five years. Participants were instructed to write down the information they felt a driver would need to navigate these unfamiliar routes successfully. No diagrams were allowed.

As a part of coding the route information generated by participants, each maneuver was categorized as either preview information, identify information, or confirmation information. Preview information is preparatory; it is used to warn the driver in advance of an upcoming maneuver. For example, "move into the left hand lane as you approach the roundabout." Identify information is used to identify an exact point on the route, such as "turn right at the McDonalds" or "turn left at the traffic lights." Lastly, confirmation information is used to indicate to the driver that he or she has made the correct maneuver and is on the correct path. Information was also coded in regards to importance, primary or secondary. Primary information is a requirement for the driver to complete a maneuver or identify a point on the route. Without primary information, it is nearly impossible to complete the route successfully; and this can create large amounts of confusion and uncertainty about the task. Secondary information is not necessary to make a maneuver, but simply assists with navigation. It is redundant information and can be removed without affecting the maneuver.

Results indicated strong support for the use of landmarks when giving directions to drivers. Among the general information categories (including distance, lane change, street name, and junction description) landmarks were referenced the most, about 450 times by both video and cognitive map groups.

Landmarks included traffic lights, gas stations, bridges, parks, restaurants, and other buildings. Junction descriptions were the second most noted category, with a frequency of about 350 times by both groups. Distance information was referred to less than 50 times by both groups, but was referred to more by the cognitive map group. This finding might be because the cognitive map group possessed extensive knowledge of the route and may have traveled it many times before and thus knew distance information better. The video group did not know the area prior to the study and thus, never traveled it before (distance information was not known to them). Plus, distance information might be very difficult to perceive when watching a video of a route and thus would be infrequently referenced by this group. When participants referenced landmarks in their directions, they overwhelmingly used identification landmarks, and rarely used preview or confirmatory landmarks. Junction information was also mainly used for identification, roughly 650 times. Although distance information was used infrequently, when it was used, it was used mainly as preview information. In regards to primary and secondary coding, landmarks were mainly used as primary information, along with junction description. Distance was regarded as a secondary source of information, implying that even without this type of information, successful navigation of the route can still occur.

To summarize the May et al. (2003) study, landmarks were the most used category when giving directions and were judged to be of primary importance; without that information, completion of the route would be unsuccessful. Distance information was infrequently given in the directions and was judged to be of

secondary importance. These findings do not fit with current vehicle navigation aids, which emphasize distance information and include few or no landmarks. These findings suggest that using distance information in IVISs will not be helpful, given that judging distance is a difficult task. On the other hand, giving landmark, junction descriptions and lane information to drivers should be more helpful.

Another study conducted by May and Ross (2006) studied how altering the quality of landmark information in instructions affected drivers' ability to follow an unfamiliar route. The quality of landmark information was compared to just distance-to-turn information as the main navigation prompt indicating an upcoming maneuver. The three groups of participants were given either good landmarks, poor landmarks, or distance to turn information. The landmark and distance information was presented to the driver in a visual and auditory manner. Good landmarks could be seen at a mean distance of 212 m, and poor landmarks at a mean distance of 103 m. The dependent variable measured driver behavior through visual glances to the display, driving errors, driver workload, navigation errors and confidence. Navigation errors were defined as actual and near incorrect turns. Near errors were those in which the participant indicated that he or she was going to make a turn (through the use of the signal indicator) but quickly made a correction and completed the turn correctly. Driving errors were divided into six categories: appropriate use of turn signals, response to road signals and signs, performance at junctions, lane position, planning and awareness, and the use of mirrors and rear observation when changing directions or signaling.

The study used an in-vehicle-navigation system that, as the driver approached a maneuver, would visually display: a direction arrow, the name of current road, the name of the road after maneuver, and a distance to turn countdown bar starting at 500 m. This information was displayed on approach to all maneuvers and in all three experimental conditions. Voice instructions were used along with the visual information. Depending on the condition, the voice instructions included either good landmarks, poor landmarks, or distance to turn information. The first voice instruction occurred at 500 m, and the second at 200 m. A beep was administered at 50 m in all conditions to remind the driver to turn. No distance to turn information was included in the voice instructions for the two landmark conditions. An example is, "turn right after the Texaco gas station."

For the visual glance data, there was a significant effect for type of instruction (good, poor or distance) on the mean number of glances made towards the in-vehicle display while approaching the maneuver. The use of poor or good landmark information resulted in 40% fewer glances to the visual display than use of distance information, even though the visual display was the same in all conditions. This finding of fewer display glances with landmarks also occurred when comparing just good landmarks to distance only information, for five of the eight turns. These results probably occurred because drivers in the distance condition looked at the distance countdown bar more frequently on approach to the maneuver.

However, there were more glances to the in-vehicle display when using good landmarks versus poor landmarks for particular maneuvers. Poor landmarks

were probably harder to locate at certain turns and thus may have caused more glances to be directed to the driving scene, resulting in fewer glances to the visual display. Because good landmarks were easy to find in the environment, more attentional resources could be directed to the in-vehicle display.

Driver confidence was highest with the use of distance information on initial approach to a turn. When comparing good versus poor landmarks, driver confidence was higher with good landmarks. Interestingly, driving and navigational errors were both significantly lower when using good landmarks to locate a maneuver than when using poor landmarks or distance information. This result indicates that even though people might feel more confident with the use of distance information, their performance indicates more mistakes when relying on this type of information.

A countdown bar was visually displayed to inform drivers in all conditions of their relative distance to the turn. Therefore, even if drivers could not determine how far they were from the turn by looking at the environment, they could look at the navigation display and determine their distance. It is interesting to note that despite having the countdown bar, those that were following distance instructions still made the most errors. This result indicates that the task of navigating by distances is difficult and that even with detailed information (countdown bar) regarding an upcoming maneuver, errors are still high when compared to using landmarks. It appears that cognitively we might not be able to use distance information accurately (Foo et al., 2005).

<u>Current Study</u>

All of these studies provide evidence that people exploit landmarks for the use of navigation in an environment, whether it is on paper, in a fully immersive virtual environment, or driving in an urban setting. As stated previously, May et al. (2003) found that when giving directions to others as guidance for successful navigation through an unfamiliar environment, landmarks were of primary importance (as opposed to secondary) and were mainly used as identification information. It was also found that preview landmark information was rarely used. However, these findings are indicative of *generating* or giving directions to others. Participants simply gave information they thought would help someone navigate the route successfully. Research has not investigated if similar results would be found when one is *following* directions, especially when following directions from an in-vehicle navigation system. That is, given that identification landmarks are generated most often when giving directions, do these types of landmarks actually lead to better navigation performance while following directions and driving through an unfamiliar environment? Preview landmarks were rarely indicated when giving directions, but when following directions do they assist with successful navigation of a route? Perhaps both types of landmark information will improve navigation performance to an equal extent, relative to distance instructions alone (which are used in today's navigation systems).

The current study attempts to fill in this gap in the literature and investigate what kinds of information help drivers navigate through an environment the best. May and Ross (2006) showed that good landmarks

presented in an in-vehicle information system (i.e., landmarks visible from a distance) helped drivers follow directions more than presenting distance information. The current study attempts to add to this understanding by investigation in what sort of context - as previews of upcoming turns or identifiers of imminent turns - good landmarks can be used.

In the current study, three types of information, identification landmarks, preview landmarks, or distance information, will be included in verbal and visual instructions given to drivers in a simulated motor vehicle. Then, the effects of these three types of information on navigation performance, attention, and vehicle control will be measured.

<div align="center">Hypotheses</div>

Navigation hypotheses

May and Ross (2006) found that people using visible identification landmarks made 3 navigation errors, whereas those that used distance information made 17 navigation errors. Therefore, it is hypothesized that navigation performance - as measured by incorrect turns and near navigational errors (incorrect signaling) - will be better when identification landmark instructions are used than when just distance information is used.

Additionally, it is hypothesized that those using preview landmark information will show better navigation performance than those using only distance information. Although there is no prior empirical data on the effects of preview landmark on navigation errors during direction following, it is important

to remember that people use landmarks in general when navigating through an environment. There are instances when preview landmarks information might be used, such as when there is no identification landmark available at the turn, or to indicate that someone is moving along the correct path. Therefore, I expect that preview landmark information will help with navigation when compared to distance information.

As stated above, there is no empirical data on preview landmarks and navigational errors when following directions, and therefore the following hypothesis is advanced in an exploratory manner. I hypothesize that those using identification landmarks will show better navigational performance than those using preview landmarks. May et al. (2003) found that when giving directions, participants generated preview landmarks infrequently, while identification landmarks were used most often. This may be because when following directions during navigation, preview landmarks are harder to notice and use than identification landmarks. If this is the case, then preview landmarks would be expected to benefit navigation less than identification landmarks.

Attention hypotheses

May and Ross (2006) showed that, compared to distance information, landmarks with good visibility improved navigation performance, and also led to fewer eye movements to the in-vehicle navigation display and more eye movements to the road. This suggests that the type of information presented in the IVIS affects not only the top-level driving goal of navigation but also the second-

level goal of attending to and avoiding hazards in the roadway environment. A possible mechanism for this effect is that providing better information in an IVIS (e.g., landmark information) could free up cognitive resources that would have gone to navigation and allow them to be used for tasks such as road monitoring and hazard avoidance. On the other hand, providing poorer IVIS information demands cognitive resources that are then not available for road monitoring and hazard avoidance. It seems likely that navigating by distance information will create more of a cognitive load for the driver than navigating by landmark information, because displaying distance information in verbal form (e.g., 1 mile) requires drivers to think about and estimate non-visible concepts, whereas landmarks are concrete objects that are highly visible in the drivers' environment.

Other studies have shown that in-vehicle technologies such as cell phones can also degrade drivers' ability to attend to and avoid hazards (Gugerty, Rakauskas & Brooks, 2004; Strayer, Drews, & Johnston, 2003; Strayer, Cooper & Drews, 2004). Given these empirical results and the mechanism just described, I hypothesize that participants in the two landmark conditions will be better able to attend to the driving environment than those in the distance only condition. Since both the identification and preview conditions use landmarks in the instructions to the driver, it is believed that they would create a roughly equal amount of cognitive demand. Therefore, their effect on attention to the road is expected to be roughly equal as well.

In this study, attention to the driving environment will be measured in two ways: by driving errors made during the driving session (e.g., running a red light);

and by a recognition memory test given after the driving session. The recognition

test follows a procedure used by Strayer et al. (2003, 2004). These researchers

used the 2 alternative forced choice recognition memory paradigm, in which 30

objects were placed in a simulator driving scene in clear view to the driver. The

objects included: cars, trucks, pedestrians, billboards. There were also pictures of

30 objects that were not used in the scene (foils). At the end of a driving scene,

participants were shown pictures of the objects and indicated which objects they

saw in the previous scene. Two choices were given for each trial, one picture of

an item that was actually in the scene and one picture of an item that was not in

the scene. Strayer and colleagues (2003, 2004) provided evidence that

performance on this recognition memory test assessed drivers' ability to attend to

roadway objects during the drive. In the current study, a single-item recognition

memory test was used instead. On each trial of the test, participants looked at 1 of

30 pictures (15 pictures of events that occurred in the driving scenario and 15

pictures of foil events) and indicated yes or no as to whether the picture of the

event occurred in the driving scene.

Vehicle Control Hypotheses

With respect to the lowest-level driving goal, vehicle control, Fox (1998)

found that IVISs degrade drivers' vehicle control. Fox (1998) used a visual

display, which presented a direction arrow, distance to turn and distance to

destination information. When compared to driving without using an IVIS, IVIS

users more frequently drove outside the lane boundaries and drove more to the

left of the center of the lane (i.e. lacked good lateral placement). IVIS users also had greater speed variations, in that they slowed down to receive the direction information but sped up again once they had received it. This result may have occurred because the drivers using the IVIS slowed down so that they could assess the visual display information, or, because these drivers experienced a higher cognitive load while estimating a specific distances. Liu (2001) also found that those using a visual display for driving directions had greater variance in steering wheel position and lateral position. Thus, display of distance information in an IVIS was associated with poor vehicle control in both of these studies.

For the current study, it is hypothesized that drivers in the two landmark conditions will display lower variations in speed and in lane position (i.e., swerving or varying the position of the car in the lane will be low) than those in the distance only condition. This is expected because of the empirical results above and because understanding distance information may require more cognitive load than perceiving landmarks. It is believed that the landmark conditions require a roughly equal amount of cognitive demand, thus identification and preview landmarks are not expected to differ in terms of their effect on vehicle control.

CHAPTER II

METHODS

Participants

Forty-one Clemson University graduate and undergraduate students participated in the study. Participants were randomly assigned to the three experimental conditions, with the constraint that each condition have an approximately equal number of participants and an approximately equal ratio of males and females. Fourteen participants (9 males, 5 females each) were assigned to each of the identification landmark and distance conditions; 13 participants (9 males, 4 females) were assigned to the preview landmark condition. The participants ranged from 18 to 29 years in age, with a mean of 21 ($SD = 2.5$). Participants signed up on the Psychology subject pool and on signup sheets that were given to two undergraduate Psychology courses and one Industrial Engineering course. Participants received course credit or were paid $15 for their participation.

Design

The study examined the effects of type of in-vehicle information on navigation performance. The study used a between-subjects design, with each participant completing a simulated driving task in one of three conditions: identification landmark, preview landmark, or distance only. During the driving

task, navigation performance, driving error, and vehicle control data were collected. After the driving task, participants' recognition-memory data were collected. The driving route (including turns), the location of the landmarks, and the timing of the IVIS prompts was the same in all the conditions.

Materials

Driving Simulator

A GlobalSim, Inc. driving simulator was used in this study. The simulator had four 50° (horizontal) by 40° (vertical) display channels, which created a 150° (horizontal) by 40° (vertical) field of view for forward viewing and 50° (horizontal) by 40° (vertical) field of view for rear viewing. The use of the rearview mirror and left side view mirror allowed for rear viewing. The vehicle cab in which participants sat in was a Mitsubishi, however the vehicle model simulated the dynamics of a Ford Taurus. The car possessed functioning steering wheel, brake and accelerator pedals, and left side view and rear-view mirrors.

Driving Scenario and Attention Assessment

The driving scenario for the study consisted of residential two-lane roads with medians. The oncoming traffic contained a moderate to high traffic flow. The driver's lane contained a low traffic flow and this traffic did not interfere with the driver. The same landmarks were present in all of the conditions, regardless of whether they were referred to as such by the guidance prompts. During the scenario, there were numerous intersections throughout the driving scene,

however the driver was only required to turn at 10 of them. Therefore, there were

intersections and possibilities to turn before the required turns. The driving

scenario lasted roughly 15 minutes. During the scenario, there were events

displayed on the right of the driver's lane and in the median. These events

included: static accident scenes, construction markings/cones, bicyclists, animals,

and pedestrians. None of the events occurred in the driver's lane or the oncoming

lane; therefore, the driver did not have to make a driving maneuver to avoid them.

The events were used to measure the driver's attention to events in the driving

scenario. The order and content of the events was the same in all conditions and

for all participants.

After they completed the driving scenario, participants were shown 30

pictures. The pictures contained 15 pictures of events that occurred during the

driving scenario and 15 pictures of events that did not occur (foils) in the driving

scenario. Each picture completely filled an 8 ½ x 11 inch sheet of paper. For each

participant, the stack of pictures was randomly ordered. The pictures were stacked

on a table and participants flipped through them one at a time, verbally indicating

"yes" or "no" as to whether they saw the picture of the event in the driving

scenario they just completed.

IVIS display and textual and auditory guidance prompts (see Appendix B)

Drivers were given textual and graphical prompts on the IVIS and

auditory prompts in all conditions. There were three guidance prompts given

before each required turn. The identification landmarks were placed at the

intersection at which drivers were supposed to turn, 20 m from the side of the road, similar to the procedure in May and Ross (2006). In the identification landmark condition, textual prompts (on the IVIS) and auditory prompts displayed and said, for example, "Turn right at the Hampton Inn." Whenever a textual prompt was displayed, the IVIS also displayed an appropriate direction arrow (right or left). After being displayed, the textual prompt and arrow remained visible until just before the turn was reached. The textual and arrow prompts were initially displayed at ½ mile; and auditory prompts were given at 800 m (½ mile), 400 m (¼ mile), and just before the turn at 152 m. At 152 m, the auditory and textual prompt was "Make the next right/left." These distances are consistent with current Honda and Acura navigation systems. No distance information was given to the driver in this condition. A blank screen was shown in between turns in this condition as well as the other two conditions.

Preview landmarks were placed at 700 m and 300 m before a turn (20 m from the side of the road). In the preview landmark condition, textual prompts (on the IVIS) and auditory prompts displayed and said, for example, "A hospital will be on the right, keep going." Along with the textual prompts, the IVIS also displayed the appropriate direction arrow (right or left). Prompts were given at 800 m (½ mile), 400 m (¼ mile), and just before the turn at 152 m. The first prompt (800 m) referred to the landmark at 700 m and the second prompt (400 m) referred to the landmark at 300 m. At 152 m, the auditory and textual prompt was "Make the next right/left."

In the preview landmark condition, two different landmarks were referred to, whereas in the identification landmark condition, only one landmark was referenced. It is believed, however, that it is not the number of landmarks but the placement of the landmarks that will affect navigation performance. Therefore and as stated above, it is hypothesized that those in the identification landmark condition will have better navigation performance than those in the preview landmark or distance conditions.

In the distance only condition, no landmarks were mentioned even though they were visible in the driving scenario. Textual prompts (on the IVIS) and auditory guidance prompts for this condition displayed and said, for example, "Turn right in half a mile." Along with the textual prompts, the IVIS also displayed the appropriate direction arrow (right or left). Prompts were given at 800 m (½ mile), 400 m (¼ mile), and just before the turn at 152 m. At 152 m, the auditory and textual prompt was "Make the next right/left."

<center>Procedure</center>

Upon signing up for the study, the sign-up website and sign-up sheets informed students of the possibility of motion sickness during the simulation and those with a history of migraines and motion sickness were asked to not sign up. Once participants arrived for the experiment, they were told that if they felt uncomfortable at any time that they could stop the study with no consequences. Participants were told to voice any discomfort immediately and to not wait until the end of the experiment. If they chose to continue, they signed a consent form,

which notified them again about the possibility of motion sickness. Demographic information, such as age, gender, number of years driving, and history or motion sickness or migraines was collected (see Appendix A).

Participants were given four practice sessions in order to get acclimated with the simulator. Between each session participants were given three minute breaks. The first session lasted two minutes in which participants drove on a straight road. The second session lasted five minutes in which participants drove on a curvy road. In the third session, participants again drove on a curvy road for 5 minutes but this session was used to determine if each participant met baseline requirements. Participants needed to be in the lane 85% or greater and maintain a speed of at least 40 mph. All participants met this requirement.

 The fourth session allowed participants to acclimate themselves with driving on residential roads, other traffic, stopping, and turning. This practice session was similar to the one used in the actual experiment and contained two turns. However, instead of the IVIS administering guidance prompts indicating when to turn, the experimenter told the participants to turn 300 m before the required turn. Upon completing the final practice session, participants were given a break, allowed to ask any remaining questions and then proceeded onto the experimental driving scenario.

To measure incorrect turns, and near navigational and driving errors during the driving scenario, an experimenter sat behind the driver in the back seat of the car, while the participant drove, and wrote down when the participant turned on the turn signal, at which intersection (s) incorrect turns were made and

if any stop signs or traffic lights were missed. If a turn was executed incorrectly, the experimenter told participants that they left the assigned route and the experimenter took note of the mistake and led them back to the course.

The experimental driving scenario included 10 turns, with three textual and verbal guidance prompts for each turn, and lasted about 15 minutes. To start the trial, the car was positioned at a red light and participants drove straight until guidance prompts were administered. After the driving scenario, the recognition memory test was administered to the participants. This test lasted about 3 minutes. Finally, participants were thanked for their time and allowed to leave. The entire session took about an hour.

CHAPTER III

RESULTS

Statistical contrasts were used to test the hypotheses. This type of analysis is used to determine the specific pattern of difference among the conditions. Since there were often three sub-hypotheses for a particular variable (e.g., identification better than distance, preview better than distance, identification better than preview), these three contrasts were tested with three one-tailed, independent-samples t-tests. The improved Bonferroni procedure was used to control for inflation of type 1 error arising from making multiple tests associated with a single hypothesis (Simes, 1986). This procedure is known to be more powerful than the overly-conservative classical Bonferroni procedure. For all dependent variables, the p-critical (alpha) values for the three contrasts were .0167, .0333, and .05. The lowest actual p value from the three contrasts was compared to the p-critical value .0167, the next lowest was compared to .0333, and the highest was compared to .05. In addition, a measure of effect size, Cohen's d, is presented where appropriate (Cohen, 1988).

Navigation Data

The highest-level driving goal pertains to navigation - reaching one's destination. Navigation performance was measured by the number of incorrect

turns or near navigation errors the participant made. A near navigational error was coded when the participant turned on the turn signal prior to an incorrect turn, which was located at least 200 m before the required turn, but did not actually make the incorrect turn.

The distributions of the two navigation-related variables were positively skewed, with a large number of zero values (no errors). Simply looking at the means and medians would not be an appropriate way to understand the data. Transforming the data would also not be appropriate, because a zero would still remain a zero under most transformations (Delucchi & Bostrom, 2004). Because of the skewed distributions with many zero values, a nonparametric test was used to analyze the data, the Mann-Whitney U test. This is a distribution-free method that tests whether or not the shapes of the distribution are different (Delucchi & Bostrom, 2004).

It was hypothesized that navigation performance would be better with identification landmark instructions than with preview landmark or distance instructions, and better with preview landmark than distance instructions. Navigation performance was measured through two variables: incorrect turns and near navigational errors. To test these hypotheses, three contrasts were performed for each variable, comparing identification landmarks to distance, preview landmarks to distance, and identification landmarks to preview landmarks.

For the incorrect turn variable, in the identification and preview landmark conditions, almost all of the participants made 0 errors; while in the distance condition, the number of errors per participant ranged from 0 to 5, with a modal

value of 1 (see Figure 1). These data seem to support the hypotheses that both the

identification and preview conditions would have fewer incorrect turns than the

distance condition, but do not support the hypothesis of fewer incorrect turns with

identification than preview landmarks. These impressions were confirmed by

contrast analyses. The distribution of incorrect turns in the distance condition was

significantly different from the distribution in the identification landmark

condition, $U = 24.5$, $p = .001$, p-critical = .0167, and in the preview condition,

$U = 13.0$, $p = .001$, p-critical = .0333. The distribution of incorrect turns in the

identification landmark condition was not significantly different than the

distribution in the preview landmark condition, $U = 84.5$, $p = .335$,

p-critical = .05. Thus, each of the landmark conditions led to fewer incorrect turns

than in the distance condition, as hypothesized. However, the hypothesis of fewer

incorrect turns with identification than preview landmarks was not supported.

(Refer to Appendix C to see the number of incorrect turns and near navigational
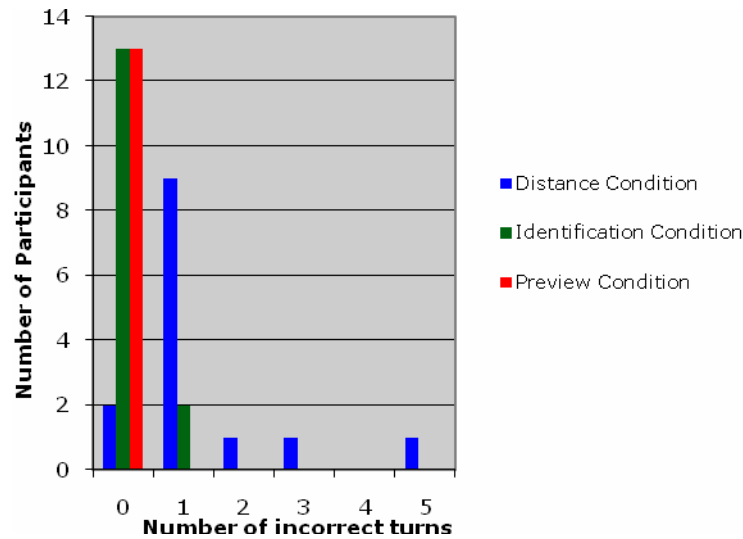
errors for each participant).

Figure 1. Histograms showing number of participants making different numbers of incorrect turns for each IVIS condition.

As Figure 1 shows, almost all the incorrect turns occurred in the distance condition. Also, 14 of the 19 incorrect turns in the distance condition occurred in the first segment of the 10-segment route, and 18 of 19 incorrect turns occurred in the first 3 segments. This pattern suggests that the participants had trouble understanding the distance instructions at first, but they learned how to use these instructions quickly.

For the near navigational errors variable, in the preview condition, all participants made 0 errors. In the identification landmark and distance conditions, almost all of the participants made 0 errors and a few made 1 error (see Figure 2). The distribution of near navigational errors in the preview condition did not differ significantly from the distribution in the distance condition, $U = 58.5$, $p = .019$,

p-critical = .0167, and the identification landmark condition, $U = 58.5$, $p = .020$,

p-critical = .0333[1]. The distribution of near navigational errors in the

identification landmark condition also did not differ significantly from the

distribution in the distance condition, $U = 95.5$, $p = .891$,

p-critical = .05. To summarize these findings, there were no effects of IVIS

condition on near navigational errors. That is, neither landmark nor distance

information led to fewer near navigational errors.
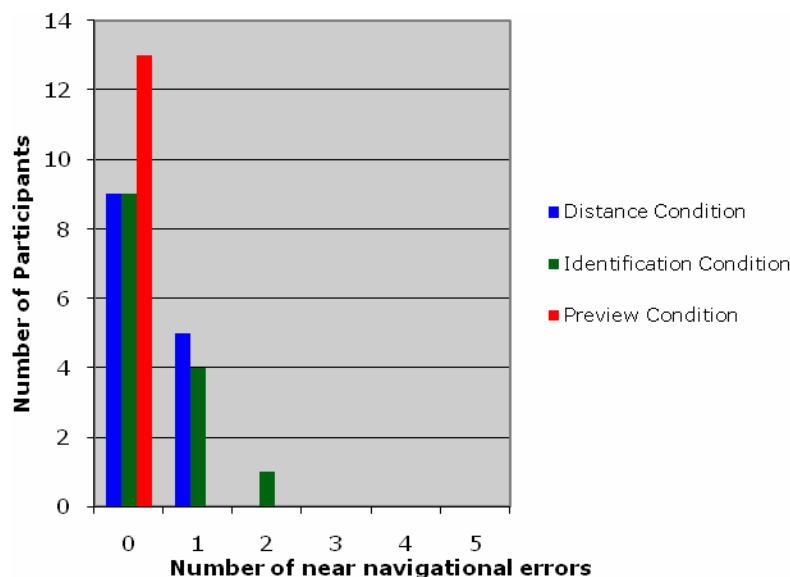
Figure 2. Histograms showing number of participants making different numbers of near navigational errors for each IVIS condition.

Attention Data

The second-level driving goal deals with attending to and avoiding

hazards in the roadway environment. The recognition memory test and driving

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[1] Although it appears that this contrast is significant, it is not. According to the modified Bonferroni alpha procedure, this contrast is not significant because of the requirement that all contrasts after the first non-significant contrast are by default non-significant as well.

errors were used to measure attention to the road. It was hypothesized that

participants in both the identification and the preview landmark conditions would

perform better on the attention measures than those in the distance condition. The

preview and identification landmark conditions were not expected to differ on the

attention measures. Three different contrasts were performed and compared

identification landmarks to distance, preview landmarks to distance, and

identification landmarks to preview landmarks.

The dependent variable used to assess performance on the recognition test

was P(A), which measures a person's sensitivity at discriminating events from

non-events (foils). The formula for P(A) is h+[1 - fa] / 2, where h = hit rate (the

proportion of events detected) and fa = false alarm rate (the proportion of yes

responses to foils). Perfect sensitivity means a hit rate of 1 and a false alarm rate

of 0, which corresponds to a P(A) of 1.0. A P(A) value of 0.5 is the worst,

meaning the person is just guessing and lacks the ability to discriminate between

an object that occurred and one that did not (Macmillan & Creelman, 1991).

The mean sensitivity value was 0.714 (SE = .021) for the identification

landmark condition, 0.749 (SE = 0.020) for the preview condition, and 0.774

(SE = 0.020) for the distance condition. These results suggest that all conditions

were performing at around the same level with small differences in sensitivity

scores between them. Therefore, none of the three P(A) means differed

significantly from each other. Sensitivity with identification landmarks did not

differ significantly from that in the distance condition, $t(26)$ = -2.07, two-tailed p

= .048, p-critical = .0167, d = 0.81. Sensitivity with identification landmarks also

did not differ significantly from that in the preview condition, $t(25) = -1.188$, one-tailed $p = .123$, p-critical $= .0333$, d $= 0.475$, but this was as predicted. Sensitivity with preview landmarks did not differ significantly from that in the distance condition, $t(25) = -0.904$, two-tailed $p = .375$, p-critical $= .05$, d $= 0.36$, contrary to the prediction. These contrasts do not support the hypotheses that both identification and preview landmark conditions would show better recognition memory than performance than the distance condition. They are consistent however, with the hypothesis that the identification and preview conditions would not differ much in terms of recognition memory.

Although the mean sensitivity value for the identification landmark condition seems to show slightly poorer performance than the distance condition, the relatively low mean in the identification condition could be due to an outlier. One participant in the identification condition had a P(A) $= 0.5$, was 2.7 standard deviations below the mean of this group, and 3.1 standard deviations below the mean of all participants. This person's recognition memory was at chance performance; and therefore he or she might have been guessing instead of attempting to perform well on this test. When this person is dropped, the mean sensitivity of the identification landmark condition is 0.73 ($SE = 0.013$), and there is still not a significant difference between the groups, $t(25) = -1.862$, two-tailed $p = .075$, p-critical $= .05$, d $= 0.75$.

To summarize the recognition memory test data, there were no effects of IVIS condition on attention to the driving environment. In other words, the condition one was in did not affect his or her ability to recognize events in the

driving scenario. Given the non-significant results with this attention variable, the questions arise as to: whether the recognition memory test lacked sensitivity to the manipulations, and whether this study provided sufficient statistical power to detect an effect of IVIS condition on recognition memory. Regarding sensitivity, the mean P(A) values were about midway between the minimum (0.5) and maximum (1.0) values, suggesting that this test was sensitive.

Regarding power, one way to assess power to detect differences between means is to look at the 95% confidence interval around the differences between the means. Narrow confidence intervals suggest high power. For the identification and distance conditions, the 95% confidence interval for the difference between the means ranged from -0.119 to -0.0005. For the preview and distance conditions, the 95% confidence interval for the difference between the means ranged from -0.083 to 0.032. For the identification and preview conditions, the 95% confidence interval for the difference between the means ranged from -0.095 to 0.026. These confidence intervals suggest that the maximum differences in P(A) among the three IVIS conditions were less than 0.12; and when the possible outlier in the identification condition is dropped, these differences were less than 0.09. Thus, this study had the power to detect P(A) differences of greater than 0.12 or 0.09 and it did not detect any differences.

Driving errors were also used to measure attention to the road. A driving error occurred when the participant either missed a stop sign or traffic light, or stopped past the white line marking at the intersection. Refer to Appendix C to see the number of driving errors for each participant. Throughout all three

conditions, the majority of the participants did not make any errors, and the distributions of errors did not differ much for the three IVIS conditions (see Figure 3). The distribution of driving errors made in the identification landmark condition is not significantly different than the distribution of errors made in the distance condition, $U = 74.0$, $p = .146$. Nor is the distribution of driving errors made in the preview condition significantly different from the distribution of errors made in the distance condition, $U = 85.0$, $p = .593$. These results do not support the hypotheses that identification and preview landmark information would lead to fewer driving errors when compared to distance information. The distribution of driving errors in the identification landmark condition do not differ significantly from driving errors made in the preview landmark condition, $U = 64.0$, $p = .071$. This finding occurred as predicted.
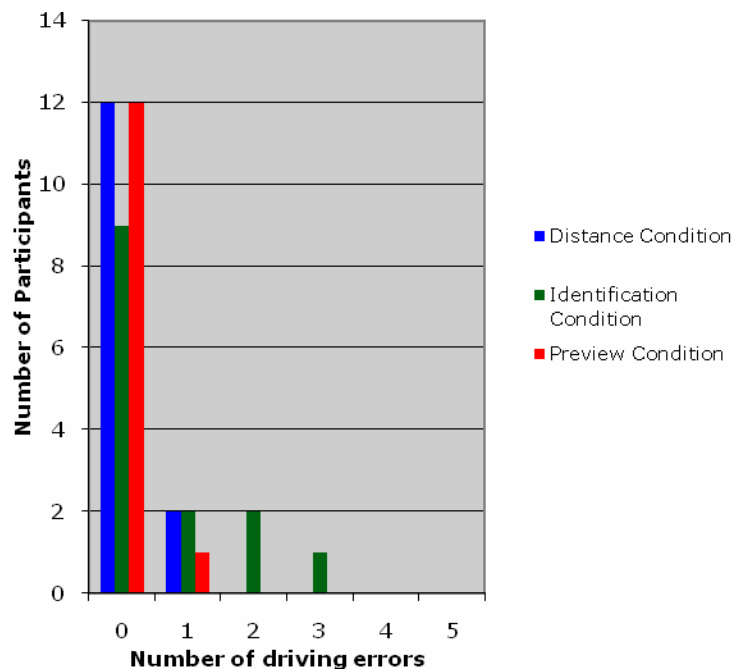

Figure 3. Histograms showing number of participants making different numbers of driving errors for each IVIS condition.

Vehicle Control Data

The lowest-level driving goal is vehicle control. Speed and steering data was collected by the simulator at a rate of 10 times per second. Speed control was measured through speed variability, i.e., the standard deviation of speed. Steering control was measured through lateral speed. Both variables were measured on straight road segments when drivers were up to speed (that is, they were not accelerating away from a stop or decelerating in order to stop). In order to ensure that participants were up to speed (40 mph), only segments that were at least 700 m long were used in the analysis. This means that the distance from start to when participants had to stop at traffic lights or stop signs was 700 m long. There were eight of these segments. To be conservative and after looking at pilot data from several driving segments, it was determined that participants could take 250 m to get up to speed and 300 m to decelerate. Therefore, from starting (or coming off a turn) participants were up to steady speed after 250 m and began decelerating at 300 m before having to stop or make a turn. This left at least 150 m of each segment for data analysis, in which participants were up to speed.

It was hypothesized that participants in the two landmark conditions would display lower variations in speed and in lane position (lower lateral speed) than those in the distance condition, and that speed and lane position control will not differ much for the identification and preview landmark conditions. Three different contrasts were performed comparing identification landmarks to distance only, preview landmarks to distance only, and identification landmarks to preview landmarks.

The mean speed variability was 0.613 m/s ($SE = 0.041$) for the identification landmark condition, 0.567 m/s ($SE = 0.050$) for the preview landmark condition, and 0.549 m/s ($SE = 0.051$) for the distance condition. These results suggest that speed variability did not differ much across the three conditions. It was expected that both the identification and preview landmark condition would have lower variations in speed than the distance condition, but this hypothesis was not supported; there was no significant difference between the identification landmark and distance conditions, $t(26) = 1.003$, one-tailed $p = .163$, p-critical = .0167. Nor was there a significant difference in regards to mean speed variability between the preview landmark and distance conditions, $t(25) = 0.295$, one-tailed $p = .385$, p-critical = .05. It hypothesized expected that speed variability would be roughly equal among the identification and preview landmark conditions and this hypothesis was supported, $t(25) = 0.681$, one-tailed $p = .251$, p-critical = .0333.

In regards to the steering control variable, participants in all three IVIS conditions had similar lateral speed movements. Those in the identification landmark condition moved laterally at an average speed of 0.55 m/s ($SE = 0.042$.) and those in the distance condition moved laterally at an average speed of 0.59 m/s ($SE = 0.041$). Participants in the preview condition moved laterally at an average speed of 0.55 m/s ($SE = 0.029$). It was hypothesized that both the identification and preview landmark condition would have lower variations in lane position than the distance condition. This hypothesis was not supported. There was no significant difference found between the identification landmark

condition and the distance condition, $t(26) = -0.651$, one-tailed, $p = .261$, p-critical = .0333. A non-significant difference was also found between the preview landmark condition and distance condition, $t(25) = -0.722$, one-tailed $p = .239$, p-critical = .0167. The results of these contrasts do not support the prediction that those in the identification and preview landmark conditions would display better vehicle control than participants in the distance condition. It was also expected that lane position would not differ much for the identification and preview landmark conditions; and this hypothesis was supported, $t(25) = -0.039$, one-tailed $p = .484$, p-critical = .05.

CHAPTER IV

GENERAL DISCUSSION

This study addressed the question of how three kinds of IVIS information, which highlighted identification landmarks, preview landmarks, and distance-to-turn information, affected drivers' ability to navigate, to attend to the road, and to control their vehicle. Presenting landmark information in an IVIS was predicted to lead to better navigation, attention, and vehicle control than presenting only distance information, because human navigational strategies rely on landmarks and landmarks are valued pieces of information for drivers (Burnett, 2000). Additionally, landmark information was expected to free up cognitive resources that would have gone strictly to navigation, and allow them to be used toward attention to the roadway, hazard avoidance, and vehicle control.

<u>Navigation Effects</u>

To summarize the navigation results, both the identification and the preview landmark conditions led to fewer incorrect turns than the distance condition, as predicted. The hypothesis regarding fewer incorrect turns in the identification than the preview landmark condition was not supported. Additionally, incorrect turns occurred only in the early segments of the route. The high number of incorrect turns in the distance condition occurred mainly in the

first segment of the drive. As noted previously, the first and second prompts were given a ½ mile and ¼ mile before the required turn and told participant to "turn right in a ½ mile" and "turn right in a quarter mile." It is unlikely that participants knew how far a half mile was and thus turned at the first available turn (which was an incorrect turn). Upon hearing the second prompt, it is unlikely that participants knew how far a quarter mile was and turned at the next possible turn after the prompt (which was also an incorrect turn). As Foo et al. (2005) suggested, our spatial knowledge of the environment rarely represents distance information accurately. These results suggest a learning effect for the distance condition; not until participants drove the first full segment and learned that three guidance prompts would be given, did incorrect turns decrease for the majority of the participants. It should be noted that these same learning effects did not occur in the other two conditions, suggesting that when following strictly distance instructions, people might have to make mistakes in order to learn when they are supposed to turn. Therefore, making mistakes such as incorrect turns (which appears to be inherent when following distance instructions) does not aid navigation performance.

The other measure of navigation performance was near navigational errors, i.e., incorrect signaling. Contrary to the predictions, IVIS condition did not affect near navigational errors. Although most participants made no signaling errors, there were still 11 errors of this type, and about half of these were in the identification landmark condition. These errors could have occurred because the identification landmark was placed right at the intersection where participants

were supposed to turn; however, 200 m before the required turn, there was another intersection. Upon driving up to this first intersection, the participant could at most times clearly see the landmark mentioned in the auditory prompts. If the landmark was fairly large, like the Hampton Inn building, it was sometimes hard to tell which intersection the landmark laid closest to. Therefore, some participants might have turned on their turn signals as they approached this intersection before the required turn, realized that the landmark was that the next turn and then turned off their signal. Some of these errors therefore, might simply be due to the lack of space between the intersection before the required turn and the required turn, as there was only 200 m available. However, this situation could occur in the real world, perhaps in an urban setting, when using this type of landmark but turning on a turn signal too soon hardly seems like a major mistake (such as driving errors).

<div align="center">Attention Effects</div>

To summarize the attention results, there was no effect of IVIV condition on attention to the driving environment, as measured by the recognition memory test. However, it was expected that those in the two landmark conditions would be better able to attend to the driving environment than those in the distance condition. This result was predicted because it was believed that those in the distance condition would be paying particular attention the IVIS and thus cognitive resources would not be available for road monitoring or hazard avoidance. Landmark information was expected to free up cognitive resources

that could then be directed toward the driving environment. However, only a few participants mentioned even looking at the IVIS while driving, and if they did it was not more than 2 or three times. It appears that the participants relied heavily on the auditory guidance prompts to know when to turn. This was probably because the IVIS offered no new information regarding when to turn and thus participants did not need to look at it.

Although the recognition-test findings did not support the hypothesized advantage for the landmark conditions, this negative result is still informative. A power analysis suggested that, in the context of a maximum possible difference between conditions of 0.50 on the recognition measure (P(A)), this study could have detected any P(A) difference between conditions of greater than .12; but it did not detect any such differences. This suggests that any effects of IVIS condition on attention to road events were small.

The other measure of attention was driving errors, such as running a red light or stop sign. Contrary to predictions, IVIS condition did not affect driving errors. However, there were nine driving errors in the identification landmark condition, and only one or two in the preview landmark and distance conditions. One possible reason for the slightly higher number of driving errors in the identification landmark condition might be because participants were preoccupied with looking for the landmark and thus missed what was directly in front of them. Especially on the first segment of the drive, the first prompt was given a ½ mile before the required turn and participants might have been expecting to see the landmark earlier than ½ mile down the road. These mistakes could potentially be

very dangerous in the real world if someone misses a stop sign or traffic light. Crashes with other vehicles, and hitting pedestrians or animals could occur if this mistake occurs. This was an unforeseen result of this condition and might be one of the drawbacks of just using identification landmark information when following directions.

Although only one driving error occurred in the preview landmark condition, there were many instances where participants almost made these types of errors. Because the guidance prompts told the participants to keep going, many of them would keep driving, then realized that there was a red light or stop sign and have to slam on the brakes in order to stop before the white intersection line. Some participants mentioned that they noticed that some of the guidance prompts were given very close to an intersection. Because they heard the "keeping going" and did, this command might have caused them to almost run a red light or a stop sign. The wording of the auditory and textual prompts could be a drawback with this type of landmark information, but future research should investigate the proper wording so as to lessen potential mistakes that could occur when following this type of information.

<div align="center">Vehicle Control Effects</div>

IVIS condition was also predicted to affect vehicle control. Past research has found that IVISs degrade drivers' vehicle control (Fox, 1998). IVIS users frequently drove outside the lane boundaries and lacked good lateral placement (Fox, 1998). Additionally, greater variations in speed and in steering wheel

control were also exhibited by those using an IVIS (Liu, 2001). More specifically, display of distance information was associated with poor vehicle control (Fox, 1998; Liu, 2001). Therefore, for vehicle control it was hypothesized that those in the two landmark condition would display lower variations in speed and in lane maintenance than those in the distance condition.

The results failed to support this hypothesis. One reason for these negative findings could be that the only visual information given on the IVIS in this study was a direction arrow and distance to turn (1/2 mile, ¼ mile), whereas, in the Fox (1998) study, more visual information was displayed on the IVIS, such as a direction arrow, distance to turn, and distance to destination. Additionally, auditory prompts were given in conjunction with the visual display in this study, which repeated the displayed information. Less information on the IVIS display, coupled with the auditory prompts therefore likely resulted in less dependence on the IVIS. In other words, participants did not have to direct as much attention to the IVIS in order to know when to turn, unlike the participants in the Fox (1998) study. As previously noted, only a few participants even looked at the IVIS in the current study.

Additionally, maintaining control of one's vehicle is very much an automated process. Not a lot of conscious thought is required to keep one's vehicle in the lane or to maintain speed. All of these reasons could help explain why low variations in vehicle control occurred across conditions in this study.

Conclusions

Although this study hypothesized that providing landmark information in an IVIS would improve drivers' ability to navigate, attend to the road, and control their vehicle, the main area where landmark information affected driving was in navigation. In particular, drivers made fewer incorrect turns with landmark information than with distance information.

When looking at the two navigation error measures and the one attentional error measure (driving errors), the preview landmark condition stands out in that only a single error was made by a single participant. This could be due to the nature of the directions given in the preview condition. Auditory and textual prompts mentioned landmarks along the route and told the participant to "keep going." Therefore, participants simply kept driving until they received the last prompt, which told them to "make the next right/left." Based on the findings of this study, it appears that it would be hard to make an incorrect turn or near navigational error in this condition because participants did not know when to turn until they heard the last prompt. This is a good thing because fewer incorrect turns occurred, thus helping with navigation.

However, the exact phrasing when using preview landmark should also be looked at if this type of information is to be incorporated into guidance prompts. Hearing the "keep going" might cause people to make mistakes (i.e., miss stop signs and traffic lights) or slam on their brakes so as to avoid making those mistakes. Slamming on one's brakes could have grave consequences when other cars come up behind the driver.

Lastly, all of the studies investigating landmark information have been performed in a driving simulator or real environment in optimal lighting conditions. Future studies should examine if landmarks are still useful at night or in other less than optimal lighting conditions.

APPENDICES

Appendix A

Demographic Questions

1. Age

2. Gender

3. Years driving

4. Do you have a past history of motion sickness? (yes/no)

5. Do you have a past history of migraines? (yes/no)

Appendix B

Diagram of when guidance prompts are given and the placement of landmarks for

each condition

54

Identification Condition

Turn
Hampton Inn

152 m

400 m

800 m

Final Guidance Prompt ("Make the next right")

Guidance Prompt (e.g., "Turn right at the Hampton Inn)

Guidance Prompt (e.g., "Turn right at the Hampton Inn)

Preview Condition

Turn

152 m

300 m School

400 m

700 m Fire station

800 m

Final Guidance Prompt ("Make the next right")

Guidance Prompt (e.g., "A school will be on the right, keep going")

Guidance Prompt (e.g., "A fire station will be on the right, keep going")

Distance Condition

Turn

152 m

400 m

800 m

Final Guidance Prompt ("Make the next right")

Guidance Prompt (e.g., "Turn right in a quarter mile")

Guidance Prompt (e.g., "Turn right in a half mile")

Appendix C

Number of incorrect turns, near navigational and driving errors for each

participant

Subject #	Condition	# Incorrect turns	# Near navigational errors	# Driving errors
2	ID	0	1	3
6	ID	0	0	1
13	ID	0	1	0
14	ID	0	1	2
15	ID	0	0	0
16	ID	0	2	0
18	ID	0	0	0
23	ID	0	0	1
25	ID	0	1	0
28	ID	0	0	0
32	ID	0	0	0
35	ID	0	0	0
40	ID	0	0	2
47	ID	2	0	0
3	Preview	0	0	0
9	Preview	0	0	0
10	Preview	0	0	0
19	Preview	0	0	0

22	Preview	0	0	0
26	Preview	0	0	0
29	Preview	0	0	0
31	Preview	0	0	0
34	Preview	0	0	0
38	Preview	0	0	1
41	Preview	0	0	0
43	Preview	0	0	0
45	Preview	0	0	0
1	Distance	1	0	1
4	Distance	0	1	0
8	Distance	0	1	0
11	Distance	2	0	0
12	Distance	3	1	0
21	Distance	1	1	0
24	Distance	5	0	0
27	Distance	1	0	0
30	Distance	1	0	0
36	Distance	1	0	0
37	Distance	1	0	0
39	Distance	1	0	0
42	Distance	1	0	0
46	Distance	1	1	1

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