Navigation Assistance for Drivers

A First-Generation Project and Prototype

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Prototype May be Accessed at:
~~http://www.unc.edu/~jlwaller/257prototype.ppt~~

Conceptual Model

Driving is a task that demands the driver's attention. The addition of global positioning system (GPS) navigation systems to many vehicles, either as factory-installed or aftermarket models, puts additional demands on the concentration of the person sitting behind the steering wheel.

My aim in designing this particular is to propose a safer in-vehicle GPS navigation system that can be used by any driver of a privately owned car or truck, professional delivery vehicle, or eighteen-wheel commercial carrier. Ultimately, the goal is produce a safer system that minimizes the number of distractions a driver must contend with. Keeping both hands on the steering wheel, and the road ahead within the driver's field of vision will go a long way toward improving automobile navigation safety.

Scope/definition of user group

My user group consists of drivers of all types, from business professionals to travelers, truck drivers, and delivery personnel. It is for any driver who needs an intuitive, easy to use tool for navigating unfamiliar areas that also provides a minimal amount of distraction so that attention can be focused on the task of driving. It is not for drivers who consider themselves advanced computer users, or those interested in the inner workings of geographic information systems (GIS).

Checklist of important user characteristics: include summary data for those that are pertinent for design decisions

Psychological characteristics

Attitudes

- Independent
- Self-sufficient
- Safety conscious

Motivation to use the system

- There is a need to easily navigate through unfamiliar areas while safely driving a motor vehicle.
- The user needs a guidance system that will not distract them from the task of driving their vehicle.

Knowledge and experience

Level of education

- High school education and above.

Reading level/native language

- The user must be able to read English and be able to interpret maps and street signs.
- Native language is English.
- A NAAL document literacy level of 3 is required. (See http://nces.ed.gov/naal/defining/measdoc.asp)

Typing skill

- n/a

Level of computer literacy

- The user must be able to use touch-screen menus.

Level of experience/facility in using similar systems or computers in general

- Familiarity with ATMs and other kiosk-style interfaces.
- Familiarity with Windows, Mac, or Linux graphical user interfaces is beneficial, but not required.

Level of experience/expertise with the task

- Experience reading maps.
- A basic knowledge of street signs and their various meanings.

Particular aspects of the task that will be very familiar:

- Stopping
- Starting
- Turning left
- Turning right

Physical characteristics

Perceptual abilities

- Users must be sighted, and must have the visual acuity to drive.
- Users must be able to hear audio cues as well as ambient traffic noises.

Motor skills

- Users must ideally have the use of both hands, though one-handed operation will be possible.

Terry

Age: 39

Occupation: Manager of a Borders Bookstore in Raleigh, NC.

Education: BA in Philosophy from North Carolina State University.

Home Life: Married to Jennifer, age 41, who suffers from epilepsy and cannot drive. Father of two boys, Ian and Trevor, ages 7 and 5. Ian and Trevor have come to the age where they want to go to Disney World. Terry hates Disney World.

Lifestyle, Web Information & User Needs: Terry works odd hours throughout the week. Working retail requires that he spend time in the store over the weekends, and as the manager he is essentially on call 24/7. Though he spends time at his desk dealing with paperwork, he prefers to be out on the sales floor interacting with the customers and the staff. On the job, he is used to using a mouse and windows-based software for title look up and inventory management. He has an older Pentium III computer at home that he picked up second-hand from one of the employees at work. Terry does enjoy surfing the web on occasion, but would much rather read a book or cook dinner for his family while listening to old Delta Blues artists. He has a Yahoo email account at home that he only checks once a week. He checks his work email account approximately three times a day.

His pet peeves include computer programs that nag the user or assume a higher degree of technical skill than Terry himself possesses. He wouldn't call himself a techno-fetishist, but he doesn't consider himself techno-phobic either.

Though Terry dislikes Disney World, he thinks it would be fun to watch the kids having a good time there. He's planning a two-week road trip to Florida, including stays in the Florida Keys and Tampa, where Terry's best friend from high school lives. He doesn't consider himself a great map reader, and prefers the step by step directions he finds on MapQuest or Yahoo!Maps. He'd like to try out a GPS navigation unit for the trip, but it must be one that he doesn't have to constantly look at, especially while driving through the major metropolitan areas of Florida. If he gets off the designated route, he would like the system to direct him back to it.

Quote: "I certainly like to take life easy. If it doesn't involve Jen and the boys, then it just isn't anything to seriously worry about."

Celia

Occupation: Corporate Sales Manager for American Electric Power Company

Age: 31

Education: MBA from the University of Virginia.

Home Life: Single, with one cat, Mina. Celia lives in an upscale apartment in Dupont Circle in Washington D.C.

Activities: Likes to go out on the weekends with friends or the occasional date. Right now she considers herself too busy to start a serious relationship.

Work Environment: Celia spends about 90% of her time on the road, visiting various corporate headquarters on behalf of her employer. In addition to a cell phone, she always carries a laptop for presentations and electronic communication with the home office. She loves having the opportunity to travel and see new areas of the country, and when opportunity allows she enjoys driving around the cities she visits to sightsee and get a feel for the local culture.

Computer Proficiency: Since Celia uses a laptop on a daily basis, she feels adequate when it comes to teaching herself new software. She uses the Microsoft Office suite of applications, and though she does not consider herself a "power user", she finds that it meets her basic needs.

Pet Peeves: People who give vague directions, assuming that what makes sense to them will make sense to her.

Attitudes: Celia admits that she takes much of technology for granted, but she isn't afraid of it, and is willing to adapt as new ones are introduced. Nor is she afraid of a little discovery while on the road.

Motivation: Celia would like to try an in-car navigation system as an alternative to the rental car company maps, or the directions usually given by a company representative. In addition to using the GPS system to find her way to meetings, she would like to use it for

exploring during the free time at her destinations. She is also interested in how the system could help her if she were to get lost or confused while driving.

Information-Seeking Habits and Favorite Resources: When preparing to visit a new city, Celia will often buy a guidebook beforehand and research things to do there. She will check travel sites online for current information as well as tips and tricks posted by other users.

Personal and Professional Goals: Celia would like to eventually accumulate enough personal wealth that she can retire early and travel the world. She likes the company she works for, though she is always keeping an eye out for openings at other companies. Should she not leave American Electric Power, she would like to work her way up to a vice-presidency.

Quote: "The journey is the destination."

James

Occupation: Truck driver for Mayflower

Age: 49

Education: High School Diploma; Mayflower Driving Academy

Home Life: Divorced, one daughter Taylor. Lives in a one-bedroom apartment.

Activities: Fishing. Loves baseball and football, and tries to go to at least one professional game of each every year. Plays video games on a PlayStation 2.

Work Environment: James works for Mayflower, a moving company. He drives trucks to the customer's old home, assists with loading the furniture and boxes, and drives to the new home where he helps unload belongings. Due to the nature of his job, he frequently drives in unfamiliar areas and must rely on directions given to him by the company.

Computer Proficiency: James does not own a home computer, though he has some experience with MS Windows via the computers at Mayflower. His PlayStation 2 is all the technology he wants at home right now, but he is comfortable using ATMs and self-service kiosks at grocery stores and airports.

Pet Peeves: Customers who he feels "nag" him.

Attitudes: James wants to get the job done, with as little interference and aggravation as possible.

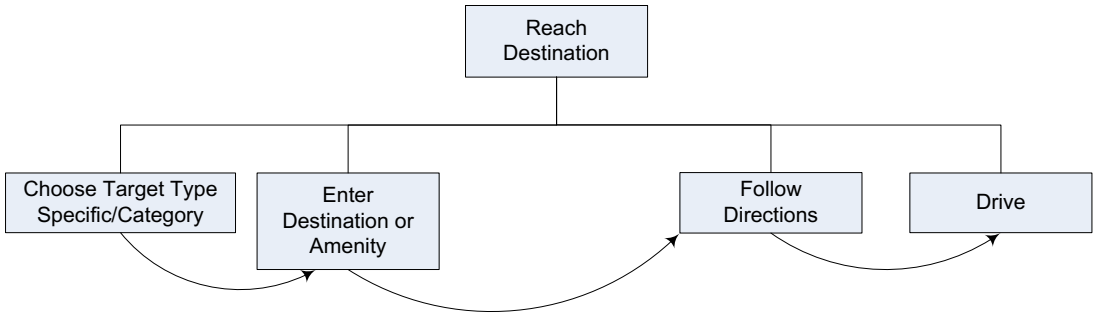
Motivation: James has volunteered to test a GPS navigation system for Mayflower on a cross-country move. He's really intrigued by the idea of the device, and wants to see if it helps out at all.

Information-Seeking Habits and Favorite Resources: Within the past five years, James has made use of his cell phone for calling Mayflower when directions haven't been clear. He always carries a road atlas, and makes it a point to buy a new one every year.

Personal and Professional Goals: James is about 6 years away from retirement, after which he hopes to move to the Florida Keys and work on a charter fishing boat.

Quote: "Yeah, I'll check it out, but it better not get me on the wrong road or going in the wrong direction. That's why I'm taking my road atlas: to be on the safe side."

Task Analysis



Essential Use Case: Choose Destination or Amenity
User chooses between a specific destination such as an address, or an amenity, like a park.

User intention	System responsibility
Begin interaction with system	
	Offer choice of "destination" or "amenity."
Choose "Destination" or "Amenity"	
If "Destination"	
	Offers input for address
If "Amenity"	
	Offers input for amenity type

Scenario: Terry needs to drive to the hotel, so he turns the navigation system on. It prompts him to choose either a destination or an amenity.

Essential Use Case (Option 1): Enter Destination
User proceeds to enter the destination.

User intention	System responsibility
Select "Destination"	
	Prompts for a city name.
	Prompts for a street name.
	Prompts for a numeric address or intersecting street name.
If numeric address:	

	Prompts for numeric address.
If intersection:	
	Prompts for name of intersecting street.
	Plots course from current GPS location.

Scenario (Option 1): Terry selects "Destination." The navigation system prompts him to enter the city name of his destination. When complete, the system prompts him to enter the street name. The system then asks him to choose to enter either a numeric address, or an intersecting street name. Terry selects "numeric address" and enters the four digit number from the street address. The system plots the course from the current location.

If Terry had chosen "Intersection" instead of destination, the system would have asked him to enter the name of the street that intersects the first street he entered. At that point, the system plots the course from the current location.

Essential Use Case (Option 2): Enter Amenity
User chooses from a list of specific amenities.

User intention	System responsibility
Select an amenity from a list.	
	List the options for specific locations (e.g. restaurants, museums, historical landmarks, parks).
Select amenity category.	
	Displays a list of the specific amenity types within a 50 mile radius of current GPS location along with a brief list of each amenity's features/attractions.
Select specific amenity.	
	Plot course from current GPS location.

Scenario (Option 2): Since Celia is in Mountain View, California for the first time, she would like to get out and see some of the nature parks in the area. She selects "Location" from the navigation system's prompt, and it brings up a list of different options. She selects "Parks", and icons representing the parks and showing their locations appears overlaying a map. She sees a park called "Mount Diablo", and selects it on the navigation screen. The system plots the course to Mount Diablo from her current location.

Essential Use Case: Drive and Follow Directions
User follows the specific directions and/or prompts offered by the system.

User intention	System responsibility
Navigation	
	Displays an abbreviated list of step-by-step directions.
Makes a turn.	
	Updates the list of directions with each turn.
	Changes the directional guides based on GPS location.

Scenario: Terry drives the car, following the directions and anticipating upcoming turns. The navigational guides and step by step directions highlight the route he needs to follow in order to reach the destination. As he approaches a turn, the navigation system directions indicate that he should take a right onto Carson Ave. in approximately ¼ mile. After making the turn, the navigation system indicates that his destination is 500 yards ahead on the left. As he pulls into the parking lot of the hotel, the system announces that the destination has been reached.

General description of task characteristics

The frequency or timing of the task

How frequently do users perform the task?

- Users will typically only perform the destination/location entry once per trip.

What are the time constraints on the task?

- There are no time constraints on the task, though the user should not attempt to enter data while driving. This would defeat the purpose for a safer navigation system.

The complexity and difficulty of the task

- The task is fairly simple as long as the user has specific information (address, intersection, street name) for their destination. The task becomes even easier for choosing locations (gas stations, banks, restaurants) that have been previously stored in the system. The task is highly structured, with the system automatically narrowing choices as the user inputs data, as well as determining location and prompting the user when and where to turn as well as what roads to follow.

The relationship of the task to other user tasks

Is system use mandatory or discretionary?

- System use is discretionary. The user does not have to turn the system on at all, they may use it in conjunction with a map, or they may choose to turn it off/on at any point during their drive.

How important is the task?

- Arriving at the correct destination is very important.

What is the relationship between the users and the data?

- The users only input limited amounts of data. The system should make data entry as easy as possible by offering suggestions based on current and/or future location.

The physical environment of task performance

Where is the task performed?

- Inside a motor vehicle.

What other tools does the user have?

- The user should have supplemental maps.

The social and cultural environment of the task

Relationships with other people in the workplace or on the work team

- The task should only be entered by the driver when the vehicle is at rest. Otherwise, a passenger can manipulate the system en route.

The organizational culture and its effects

- n/a

National or ethnic cultural effects

- None that I am currently aware of.

Planning for learning and breakdowns

What training will be provided? How is the task learned?

- The user is advised to first use the system in area they know well. This will give them the opportunity to get a feel for how the system behaves, and familiarity with the system is very important when using it in unfamiliar areas.

What happens when things go wrong?

- The system will feature an optional "breadcrumb" feature that shows the exact route taken by the user. In the event the user gets lost or off-track, they only have to retrace their steps by following the digital breadcrumbs.
- In the event the user gets lost and they have not utilized the breadcrumb feature, the system will offer a "deus ex machina" function, that either allows them to call a service for assistance, or automatically plots a course for the user's home or another pre-determined destination.
- If a destination or location is not featured in the system, it will determine the nearest possible coordinates based on street intersections, a list of which the system will offer the user.

Design Decisions

Design Decision 1: How should the information be displayed?

Criteria:

- Reduce the time spent looking at a center-console display, and increase the time spent looking at the road.

Method selected:

- Two separate displays for information. One Heads Up Display (HUD) and one console display.

Alternatives considered:

- Increasing the size of the display.

Evidence:

- "Indeed, the purpose of a navigation system (to provide guidance at route decision points) means that it frequently will provide information at points of high attentional [sic] demand." (Ross 2001).
- "Increasingly, navigation systems are becoming part of an 'integrated' console that includes other in-vehicle functions…." (Ross 2001)
- "…the control interface for many navigation systems is largely based on the desktop computing paradigm and therefore requires the user to engage in highly visually oriented tasks, such as scrolling and selecting items from lists, menu orientation, choosing individual characters from a large array, and so on." (Burnett 2004).
- Accidents whereby vehicle navigation systems were considered causal: "Detailed analyses were conducted for the year 1999, in which it was revealed that the majority of crashes (63%) involved collisions with a lead vehicle. A further analysis of the data from Japan for the year 1999 attributes 22% of accidents to 'operating' tasks, and 74% to 'looking' tasks." (Green 2000, cited in Burnett 2004).
- "Visual directions with *overhead map* were the most interruptive which had significantly more lane deviations than audio with map and visual, higher user perception of distraction than visual, and longer total time than audio and audio with map." (Moldenhauer 2003 emphasis mine)

Evidence:

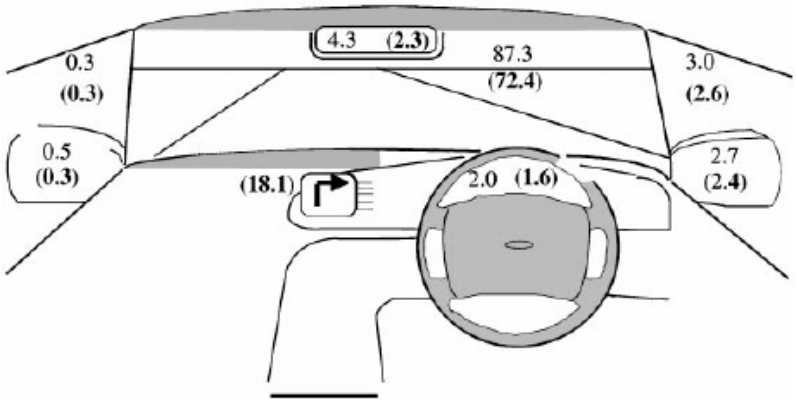


FIGURE 4. Percentage of journey time spent glancing towards different areas of the visual scene when using instructions given by a passenger (normal font) or a turn-by-turn vehicle navigation system (bold font in parentheses) (Burnett & Joyner, 1994).

(from Ross 2001)

Discussion of evidence:
As illustrated in the above diagram, the amount of time drivers spend looking at the road drops from 87.3% to 72.4% when a vehicle navigation system is present (Ross 2001). Additionally, of five people who responded to my unofficial, informal survey, three specified the necessity of focusing on the road or eliminating distractions from the GPS screen:

- "Screen is somewhat cluttered and small, hard to read while driving…. [L]arger display…easier to read display, less clutter on display…less hands and eyes on device while driving, driver needs to stay focused upon driving, devices divert your attention, safety concerns with that."
- "...big text so you wouldn't have to focus too hard on it [GPS] and could focus more on the road.
- "…but GPS units I have seen are small screen & harder to interpret sometimes (esp driving.. and who is really going to /*pull over*/ all the time, right?!)"

Design Decision 2: How should directions be presented to the driver?

Criteria:

- provide the option for speech synthesized directions.
- a means for turning it off or on and that does not require the driver to take his or her eyes off of the road.

Method selected:

- Text-to-speech based turn-by-turn directions with a simple means of enabling/disabling the option.

Alternatives considered:

- no audible directions.

Evidence:

- "In some cases, a range of menus must be navigated just to turn off the voice messages." (Burnett 2004)
- "If I had my choice I would rather have a GPS based map that gives you turn by turn instructions…" (informal email survey response)
- "most helpful, is the feature that show landmarks, etc… and tells you to turn right, etc…" (informal email survey response)
- "…audible directions in addition to a scaled map." (informal email survey response)
- "I do *not* like the idea of relying on some canned female voice in my car that calmly says /"Turn left here please" /or something creepy like that." (informal email survey response)
- "Audio directions caused the highest level of reaction [time]…." (Moldenhauer 2004)

Discussion of evidence:
Moldenhauer (2004) demonstrated that audible directions gave a higher reaction time than looking at a list of directions or a map. Most survey respondents (with one notable exception) preferred that the system give audible turn-by-turn directions. Because enough users will not want this function, or will want to disable it in familiar environments, users should have the option of disabling it at will.

Design Decision 3: How will the user input information into the system?

Criteria:

- Keeping hands away from the console and as close to the steering wheel as possible.

Method Selected:

- A steering-wheel mounted gesture interface.

Alternatives considered:

- A touch-screen interface for the console unit.

Evidence:

- "The major potential safety benefit of this new interface is decreased driver inattention. More specifically, this may be achieved in the following ways. (A) Faster interaction with secondary controls, resulting in a reduction in the amount of time in which the driver's eye-gaze is not on the forward scene. (B) The ability to situate the computer display in a position much closer the driver's normal line of sight, increasing the ability of the driver to use peripheral vision whilst operating the secondary controls…. (D) The interface can be operated with both hands still on the wheel. Note that, with traditional, physical, secondary controls, involuntary steering is sometimes initiated when reaching for controls." (Cairnie 2000)
- "…gesture interfaces can be used as safely as a physical radio." (Alpern 2003)
- "Through our initial quantitative findings, we've shown that gesture interfaces are a viable option for secondary tasks." (Alpern 2003)

Discussion of evidence:

- As stated by Cairnie above, "decreasing driver inattention" is the primary goal of the interface for inputting information. This is achieved, in part, by allowing the driver to keep both hands on the wheel. Should the driver need to activate any optional service of the navigation system, the combination of both hands on the wheel with keeping the driver's attention on the forward scene (utilizing the HUD) minimizes potential distractions and keeps the road ahead in the line of sight.

Design Decision 4: What kind of menu structure will the system use?

Criteria:

- The menus must be easy for the user to navigate quickly and safely, with minimal time spent looking for options.

Method Selected:

- Radial and marking menus.

Alternatives considered:

- Linear popup or pulldown menus.

Evidence:

- "Reducing the amount of occlusion created by a pop-up menu is based on the hypothesis that the graphic occludes a user's visual focus and causes the user to lose the context, forcing the user to send time re-acquiring the context after the menu disappears." (Tapia 1995)
- "…menus appearing and disappearing on the screen can be visually disruptive—a menu may obscure objects on the screen that are the focus of attention." (Kurtenbach 1994).
- "Unlike linear menus, marking menus can be operated 'eyes free' because selection is based on direction of movement, not position. Hence, they are especially suited to tasks that require attention on other matters…." (Kurtenbach 1994)
- "When a user is familiar with the layout of a menu, selection from a radial menu will be faster than selection from a linear menu…. [E]ven when menu items have a natural linear ordering, selection using a radial menu is still faster and less error-prone than selection using a linear menu." (Kurtenbach 1994)
- "Users reported that marking was relatively error free and empirical data showed marking was substantially faster than using the menu." (Kurtenbach 1994)

Discussion of evidence:

- Any menu that exists in the driver's field of vision should continue the theme of minimal distraction. Once a driver has become accustomed to the radial menu layout and the proper sequence on the steering wheel-mounted gesture interface for command input, he or she will no longer need to look at the menu in order to access the desired features.

Design Decision 5: Besides turn-by-turn directions, what other information will the system provide the user to aid in navigation?

Criteria:

- Visual points of reference, other than street names, that aid in driver navigation.

Method Selected:

- The turn-by-turn directions will include landmarks.

Alternatives considered:

- Intersection names.
- Topographical features.

Evidence:

Table 3. Criticality assessment while driving, for IRANS.

IRANS	
Information Requirement	**Criticality Assessment**
Trip Planning	
Current criteria for automated trip planning	neither required nor desired
Time to get to each destination from previous destination	desired
Cost of each toll along the route	desired
Total toll charges along the route	desired
Total time for trip	desired
Estimates of mileage	desired
Locations of attractions and points of interest	desired
Forecast weather information	desired
Historical traffic information	desired
Street or roadway names on the route	required
States, regions, communities, and districts along the route	neither required nor desired
Landmarks or topographical features along the route	desired
Number of turns or roadway changes required	neither required nor desired
Types of roads used on the route (interstate, highway, etc.)	desired
Distance to each destination from previous destination	desired
Distance to specific attractions	desired

(Hulce 1998)

Information Requirement	Criticality Assessment
Cost of completing route	neither required nor desired
Notification of a more optimal alternative route	desired
Preview of proposed alternative route	neither required nor desired
Historical congestion information	desired
Real-time congestion information	desired
Location of tolls	desired
Weather forecast information	desired
Regions, communities, and districts the route will traverse	neither required nor desired
Landmarks along route	desired

(Hulce 1998)

Information Requirement	Criticality Assessment
Location of major landmarks (to aid in identifying turns)	desired

(Hulce 1998)

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Location of major landmarks (to aid in identifying turns)	visual	in transit	Partial-route video map Partial-route video map with text description

(Hulce 1998)

Discussion of evidence:

- Landmarks are an easy way to help guide the driver. Since street names change, may be hidden or otherwise obscured, drivers can make use of additional information when it comes to gauging the correct places to make turns. Most auto GPS systems already have amenities such as restaurants and banks featured in their databases. Incorporating these as landmarks would be a fairly simple operation.

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