Finding Directions to a Good GPS System

A Comparative Analysis and Development of a Predictive Model

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Abstract. GPS devices have become commonplace today, almost as common as cell phones, especially for the developed and emerging economies. In this research paper, the development of a predictive model for selecting a GPS system for use based on the analysis of the interface design is described. The research presents subjective data from user interaction surveys, and objective data using the Keystroke Level Model (KLM). After comparison, inferences or predictions are made based on the analysis of available data. The research makes valid contributions to the GPS interface design field, and the GPS market. A higher level of accuracy can be achieved with data from a larger user survey group, and use of additional models, and an automated tool such as CogTool.

Keywords: GPS, Garmin, TomTom, Magellan, GoogleMaps, DeLorme Street Atlas, KLM, user survey, predictive model.

1 Introduction

This research was conducted determine which GPS system was the most user friendly and effective. Five GPS systems were selected for evaluation, including Garmin, Magellan, TomTom, Google Maps, and DeLorme Street Atlas. Three of the five units were well-known brand name GPS systems: Garmin, Magellan, and TomTom. These three systems are small and portable with a touch screen. Google Maps on a smartphone, and DeLorme Street Atlas, a built-in GPS system included in selected car models, were also included in the selection. With these five models serving as the research set, the GPS marketplace was well represented.

The problem which users have is determining which GPS system is best suited for them. There are many choices available, but there are no real directions or guidance on how to choose a GPS. This research will bridge the gap between what the users want and finding the most suitable device to meet their needs. The comparative analysis will also help determine how different or similar these GPS systems really are. As a result, it will be possible to predict what kind of GPS device best serves the user's need. This will provide new direction on how to choose a GPS system for the next generation of users.

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2 Prior Work

Prior work, conducted on smartphones [1], identified a range of subjective factors which are used when individuals purchase new mobile phones. A survey of users was made to determine how the general public regards cell phones and identify the major design factors that prompted individuals to select their new smartphone model. The application of HCI principles such as keystroke-level modeling (KLM) and Fitts' Law to provide additional, objective data was combined with survey results. With this information, a predictive model was developed to provide consumers with more information about the different models of cell phones analyzed, as assistance help them decide on the best one for them [1].

The research presented here performs HCI and survey analysis on consumer GPS systems. All members of the research team have used and/or own a GPS.

3 Methodology

In the research methodology, five GPS units were used. Three of the five GPS were brand name units, with a touch screen and virtual keyboard. These small, thin, lightweight, and portable units have become a necessity for many users worldwide. The fourth GPS was a smartphone with the application of Google Maps. Google Maps on smartphones was included because so many users own smartphones and the widespread availability of that tool. The fifth GPS unit selected was the DeLorme Street Atlas, a built-in GPS in the car of a research team member. This range of devices provides a diversified and unbiased result.

With the five GPS units defined, a user-friendly survey was developed and used to collect data. The survey consisted of three parts: a pre-assessment, tasks, and a post-assessment. The first part, the pre-assessment script, consisted of collecting all the demographics of the sample size of 50 test subjects.

The second part of the survey included tasks that the user had to perform and rate for each GPS. All of the tasks were rated on a scale of 5 (easiest) to 1(most difficult). The third survey part, the post-assessment, was a continuation of the second part where the task results were collected and few more questions were asked of the user.

A keystroke-level model (KLM) was also used to analyze the GPS devices in this experiment. The KLM model was used to predict task execution time from the specified task scenario. The product descriptions of the five GPS systems tested follow.

3.1 Garmin

The first of the five GPS systems included in this analysis was a Garmin Nuvi 40 LM. Garmin is one of the best in the portable navigation business. This model was released in 2011 with three interesting features, which are junction view, speed limit display, and lane assistance. The layout is clear and easy to follow. It connected to the GPS satellites quickly, taking less than a minute and sometimes just a few seconds if the device has been recently used [2].

3.2 Magellan

The second of the five GPS systems included in this analysis was a Magellan Road-Mate 1212 including a QVGA 3.5” color touch screen with built-in maps of two North American countries and of Puerto Rico. The user may select six million points-of-interest, they may also select Fastest-Time, Shortest-Distance, Least-Or-Most used Motorways, or Avoid Toll-Roads. The GPS features an Address Book, Auto Day-Night view, and SD card memory.

3.3 TomTom

The TomTom GPS brand used in this research is one of the best known GPS brand names. It comes preloaded with maps of the U.S and Canada with both 2D and 3D views. Also, it has built-in turn-by-turn spoken direction, Help Me, Emergency menu, real-time traffic capability, Millions of Points Of Interest (POIs), and the MapShare instant map update.

3.4 Google Maps

Smartphones are widely available and popular in the last 10 years, so it was practical to include a GPS navigation application on a smartphone in the comparative analysis. Google Maps is a very popular app that comes standard on many smartphone models now. It is based on the Google Maps system that people can access on their computers. A new LG Escape P870 with Google Maps loaded onto it was used in this research, running Android 4.0 [3]. It has the ability to know the current location on a map, provide directions to a given address, and the Navigation part provides step-by-step voice guidance along the directed path [4].

3.5 DeLorme Street Atlas

In addition to these handheld units, a GPS system custom built into a car, the DeLorme Street Atlas in a 1997 VW Golf GTI., was included The DeLorme Street Atlas USA 2009 Plus software is known for its flexibility and powerful mapping program. Street Atlas remains one of the most popular mapping software in the carputer world [5]. Unlike other handheld GPS units, Street Atlas gives the user many options on how they would prefer to travel, what system to use it on, and routes to take. Route planning is one of the best features that the software offers as it allows users to set up a destination with only the desired highways to be used, in addition to all the points of interest to visit in between, plus directions to avoid certain tolls along the way [6-7].

4 Testing

4.1 KLM Estimations For Each Model

Keystroke-Level Modeling (KLM) uses estimations of time for actions to produce objective, numerical predictions for how easy it is to perform a given task on a device. Table 1 shows KLM value estimations used to calculate the average time per task.

Table 1. KLM Value Estimates (Seconds)

K (keystroke - type, swipe, etc.)	0.22
P (point to key)	1.1
M (mentally prepare for an action)	1.35
R(t) (system response time)	as needed

The KLM analysis showed that with these estimations it was possible to calculate and measure how long each task execution took. Some of the devices could not perform all of the functions planned to be used in the survey script, so N/A, meaning not applicable, was put down for the tasks which could not be done.

The keystrokes required and estimated completion times for each task by GPS unit tested (Table 2), considered the design usability principle of efficiency [8-10]. The data show that each of the GPS units performed differently on the two metrics of path length and time taken to complete the task. Each GPS was ranked by the shortest path length to task accomplishment and the time needed for a specific task. DeLorme, Garmin, and TomTom GPS units were highly ranked for three tasks each, while GoogleMaps appeared once.

Table 2. Keystrokes and KLM Time Estimates by Task and GPS Unit Tested

	DeLorme		Garmin		GoogleMaps		Magellan		TomTom	
Task	K	T	K	T	K	T	K	T	K	T
Get Directions to Destination (saved)	2	5.89	4	9.78	4	12.68	n/a	n/a	3	5.98
Get Directions to Destination (typing)	2	8.34	10	14.4	10	20.6	14	12.43	16	13.07
Change Routing Method	4	8.78	n/a	n/a	3	10.01	5	15.35	3	10.11
Toggle Voice Navigation	4	7.13	n/a	n/a	3	14.66	6	20.02	3	13.31
Turn On/Off Avoid Highways/Tolls	5	10.95	4	10.72	6	13.17	4	12.68	4	11.72
Create Point of Interest (visible, predefined)	3	9.31	3	10.66	3	8.66	6	19.02	3	8.31
Create Point of Interest (typing dest.)	9	9.95	11	16.6	11	22.92	18	54.06	13	20.07
Reset/Restart GPS	2	10.89	2	3.77	2	5.34	2	5.34	2	4.54
Change/Restore Time Zone	n/a	n/a	n/a	n/a	n/a	n/a	6	12.23	6	5.77
Clear Navigation History	n/a	n/a	3	4.87	4	7.98	8	23.36	4	6.49

K = Keystrokes Required **T = Calculated KLM Time Estimate (seconds)**

4.2 User Test Survey

The second part of the comparative analysis involved a user test. Each team member surveyed 10 subjects using a specific GPS model. The survey consisted of three parts. First was a pre-test assessment to gather demographic information to correlate data into user groups by age and previous experience with GPSs and similar devices. In the second part of the survey, the test subjects performed a series of preset tasks using the assigned GPS. The third part of the survey was a post-test questionnaire to capture the test subjects' impressions of the ease of use and other related factors about specific tasks and the overall experience using the GPS.

5 Results

Data from the pre-test assessment and the post-test survey was collected and analyzed according to a mix of demographics to see how various subsets of the test population responded to each of the tested GPS units.

5.1 Demographic Breakdown of the Test Subjects

One of the objectives of the GPS usability survey was to gather input from a mix of test subjects. The survey would benefit if the test group was comprised of individuals representing a variety of demographics including gender, age, race, primary language, and level of education. Tables 3, 4, and 5 demonstrate that this success.

Table 3. Distribution of Test Subjects' Age and Gender by GPS Unit Tested

	DeLorme		Garmin		GoogleMaps		Magellan		TomTom	
Age Grp	F	M	F	M	F	M	F	M	F	M
19-35	4	4	2	4	1	1	2	2	1	3
35-47			1	1	1	1	2	1	2	4
>48	1	1	1	1	4	2	1	2		

Table 4. Distribution of Test Subjects' Race and Primary Language by GPS Unit Tested

	First Language	Asian	Black	Caucasian	Hispanic	Indian
DeLorme	English		1		3	
	Japanese	2				
	Spanish				4	
Garmin	English	1		1		2
	Thai	6				
GoogleMaps	Cantonese	1				
	English			9		
Magellan	English			1	3	
	Spanish				6	
TomTom	English	1	7	1		
	Spanish				1	

Table 5. Distribution of Test Subjects' Level of Education and Gender

	DeLorme		Garmin		GoogleMaps		Magellan		TomTom	
Education	F	M	F	M	F	M	F	M	F	M
HS				1			2	3		
Some Col.		2			1	3				
2yr	2						1	1	1	1
4yr	2	2		1	3	1	2	1	1	4
Post Grad	1	1	4	4	2				1	2

In addition to these common demographics, it was important to categorize the test subjects according to some particular characteristics or experiences which could play an obvious role in how well they perform the required tasks.

Test subjects were asked what their level of experience was in using a GPS. A person with little or no GPS experience was not likely to respond to the test in the same way that someone who regularly uses a GPS would respond. Users were also asked what their level of experience was using Internet/computerized map services such as GoogleMaps or MapQuest. A person with this type of experience might have different expectations about what a GPS should do. Since most GPS units employ a touch-screen interface, test subjects were asked about their previous experience with any touch-screen devices such as smartphones, tablets, or touch-screen computers. A test subject who has never used a touch-screen device will likely have some initial discomfort with even the simplest touches and gestures. Finally, users were asked to rate themselves according to their overall technical abilities. A person who routinely delves deeply into the technical aspects of every device they use (i.e., a person who is often asked to "fix" something on someone else's computer) will probably be more successful using a new device for the first time than a person who knows or cares little about the devices they use. Table 6 shows a breakdown of the test subjects.

Table 6. Distribution of Test Subjects' Technical Experience

		Prior Electronic Map Usage								
		Few	Reg.	None	Few	Reg.	None	Few	Reg.	**Grand Total**
	Touch	Never Use GPS		Rarely Use GPS			Regularly Use GPS			
Tech Expert	-	1								**1**
	+					1				**1**
	**				9	2		1	6	**18**
Tech Intermed.	-		1							**1**
	+	3		2	1		1			**7**
	**			3	1	1	3	3		**11**
Tech Novice	+			1						**1**
	**	1			1				8	**10**
	Grand Total	**5**	**1**	**6**	**12**	**4**	**4**	**4**	**14**	**50**

Touch Screen Experience

-	None
+	Limited
**	High

As seen in Table 6, a majority of the test subjects included in this survey had regular touch-screen experience. Relatively few test subjects rated themselves as technical novices. It is not clear whether this is a true assessment or if there was a bias in the way this question was asked that caused it to skew results higher. It is interesting to note that nearly all of the test subjects that rated themselves as novices were surveyed by one member of the research team. There may have been different interpretations of this question among the members of the research team.

5.2 User Test Survey Results

The simplest and possibly most significant overall ease of use measurement is the "overall grade" that each test subject was asked to provide at the end of the test (Table 7). On this metric, the Magellan unit scored the best, DeLorme came in second, GoogleMaps and TomTom tie for third, and Garmin fourth. Breaking down that score by age group shows that Magellan's high score was primarily because of high grades from the >48 age group. Interestingly, the second place unit (DeLorme) earned its ranking by achieving higher scores in the 19-35 age group (Table 8).

Table 7. Ease of Use Average Grades (1-5) by GPS Unit

	DeLorme	Garmin	GoogleMaps	Magellan	TomTom
Overall	4.2	3.5	4	4.3	4
Task-Task	4.5	3.7	3.9	3.7	4.7
Learning	3.9	3.9	3.9	3.6	3.9
Purchase	3	3	3.3	4.4	3.9

Table 8. Ease of Use Average Grades (1-5) by GPS Unit and Age Group

	DeLorme		Garmin			GoogleMaps			Magellan			TomTom	
Age:	19-35	> 48	19-35	35-47	> 48	19-35	35-47	> 48	19-35	35-47	> 48	19-35	35-47
Overall	4.4	3.5	3.7	3.5	3.0	4.5	4.5	3.7	4.3	4.0	4.7	3.8	4.2
Task-Task	4.8	3.5	3.8	4.0	3.0	3.5	4.0	4.0	4.0	3.3	3.7	4.8	4.7
Learning	4.3	2.5	3.8	4.5	3.5	4.0	4.0	3.8	4.0	3.0	3.7	3.8	4.0
Purchase	3.3	2.0	3.2	3.0	2.5	4.0	2.5	3.3	4.5	4.0	4.7	3.5	4.2

Looking at the overall grade measurement broken down by education level (Table 9) reveals that in most cases, there was no difference in the overall score based on the test subjects' level of education. The Magellan unit did score higher among test subjects with less than a 4-year college degree, but since similar differences, positive or negative, did not appear for the other units, this is probably not a reliable factor for the predictive model.

Table 9. Ease of Use Average Grades (1-5) by GPS Unit and Education Level

	DeLorme		Garmin		GoogleMaps		Magellan		TomTom	
Education Level:	< 4yr	4yr+	< 4yr	4yr+	< 4yr	4yr+	< 4yr	4yr+	< 4yr	4yr+
Overall	4.3	4.2	2.0	3.7	4.0	4.0	4.4	4.0	4.0	4.0
Task-Task	4.5	4.5	3.0	3.8	4.0	3.8	3.7	3.7	5.0	4.6
Learning	4.0	3.8	5.0	3.8	4.3	3.7	3.6	3.7	4.0	3.9
Purchase	3.5	2.7	2.0	3.1	2.3	4.0	4.6	4.0	3.5	4.0

When looking at the test subjects' experience with touch-screen devices (Table 10), the overall ease of use grade changes for certain GPS models, but not others. For the top-scoring Magellan unit, there was no difference in the score from users who regularly use touch-screen devices when compared to users that do not. The same is true for the TomTom unit, tied with GoogleMaps for third. GoogleMaps, on the other hand, had significantly higher scores among users who routinely use touch-screen devices. If the results of this survey were limited only to users who regularly use touch-screen devices, GoogleMaps would have scored the best.

Table 10. Ease of Use Average Grades (1-5) by GPS Unit and Touch-Screen Experience

	DeLorme	Garmin		GoogleMaps			Magellan		TomTom	
Touch Experience:	**	+	**	-	+	**	+	**	+	**
Overall	4.2	3.0	3.6	4.0	3.3	4.8	4.3	4.3	4.0	4.0
Task-Task	4.5	2.0	3.9	4.0	3.5	4.3	3.3	3.9	5.0	4.7
Learning	3.9	3.0	4.0	4.5	3.3	4.3	3.3	3.7	4.0	3.9
Purchase	3.0	1.0	3.2	3.0	3.3	3.5	4.3	4.4	4.0	3.9

Touch Screen Experience

-	None
+	Limited
**	High

There are similar findings when looking at the test subjects' general technical expertise (Table 11). The overall ease of use grade changes for certain GPS models, but not others. For the Magellan and TomTom units, there was no difference in the scores from tech experts compared to intermediate test subjects. Both the DeLorme and GoogleMaps units got higher scores from test subjects who consider themselves technology experts. GoogleMaps, again, would have had the top overall score if the test subjects were limited to being technical experts.

Table 11. Ease of Use Average Grades (1-5) by GPS Unit and Technical Expertise

	DeLorme			Garmin		GoogleMaps		Magellan			TomTom	
Technical Experience:	-	+	**	-	+	+	**	-	+	**	+	**
Overall	3.0	4.0	4.4	3.6	3.0	3.4	4.6	4.0	4.3	4.3	4.0	4.0
Task-Task	3.0	4.0	4.9	3.9	2.0	3.4	4.4	4.0	3.0	4.0	4.6	5.0
Learning	2.0	3.0	4.4	4.0	3.0	3.4	4.4	4.0	3.0	3.8	3.9	4.0
Purchase	1.0	2.0	3.6	3.2	1.0	3.2	3.4	4.0	4.3	4.5	3.9	4.0

Technical Experience:

-	Novice
+	Intermediate
**	Expert

The overall grades based on the test subjects' experience with computerized map services like MapQuest (Table 12) were also examined. Based on this criterion, it was found, once again, that the overall ease of use grade changes for certain models, but not others. The most significant change was noted with the Garmin unit, which had its overall grade rise from 2.5 to 3.8 between test subjects with little experience with map services and those that use them regularly. However, the DeLorme unit performed the best among users who regularly use map services.

Table 12. Ease of Use Average Grades (1-5) by GPS Unit and Experience with Computerized Map Services

	DeLorme		Garmin		GoogleMaps		Magellan		TomTom		
Electronic Map Experience:	+	**	+	**	+	**	-	+	-	+	**
Overall	4.0	4.5	2.5	3.8	4.0	4.0	4.3	4.3	4.0	4.0	4.0
Task-Task	4.2	5.0	2.5	4.0	3.8	4.0	3.3	4.0	4.7	4.5	5.0
Learning	3.5	4.5	4.0	3.9	3.8	4.0	3.3	3.8	3.8	4.0	4.0
Purchase	2.3	4.0	1.5	3.4	4.0	2.6	4.3	4.5	3.8	4.0	4.0

Electronic Map Experience:

-	None
+	Limited
**	High

Upon examination of the average grade for likelihood of purchase in Table 7, the test subjects said they would be most likely to purchase the top-scoring Magellan unit after trying it. Interestingly, it had the lowest average rating for learning how to perform the tasks, and for navigating from task to task, tied with the Garmin unit.

The final set of questions for the test subjects asked them to rate how the units performed and whether it provided appropriate feedback and had the features they expected. They were asked if the unit produced results quickly enough, and if it provided informative feedback. They were asked if they considered the routes calculated by the GPS to be good choices or not. Responses for these three questions revealed nothing of value for the survey. All five units received perfect or near perfect scores for all three and are excluded from further discussion. Since affordance is an important concept but is not easily explained in a user survey, they were asked if they felt that the interface made all the actions and options clear to them. Users were asked if they felt that they could easily remember how to perform the tasks they just completed if they needed to do them again at a later date. The final two questions asked them to rate the completeness of the feature set relative to their expectations, and if they preferred the unit they tested over one they had used before. Table 13 shows the percentages of positive responses to these questions by GPS model.

Table 13. Percentages of Positive Responses to Post-Test Questions by GPS Unit

	DeLorme	Garmin	GoogleMaps	Magellan	TomTom
Interface Clarity	30	100	40	100	100
Step Memory	80	60	70	100	100
Feature Set	100	65	70	90	65
Unit Preferred	33	50	80	50	80

Overall, the DeLorme and GoogleMaps units scored poorly for interface clarity relative to the other units. Looking at the demographic breakdowns for these scores produced no noticeable pattern or explanation. Age, education, and previous technological experience made no difference in the scores. Responses to the question about how easy it would be to remember how to perform these tasks in the future were noticeably affected by the age of the test subjects. The Magellan and TomTom units got perfect scores, but the lower scores for DeLorme, Garmin, and GoogleMaps clearly show that scores went down as the test subjects got older (Table 14).

Table 14. Percentages of Positive Responses to Post-Test Questions by GPS Unit and Age Group

	DeLorme		Garmin			GoogleMaps			Magellan			TomTom	
Age:	19-35	> 48	19-35	35-47	> 48	19-35	35-47	> 48	19-35	35-47	> 48	19-35	35-47
Interface Clarity	38	0	100	100	100	50	50	33	100	100	100	100	100
Step Memory	88	50	83	50	0	100	100	50	100	100	100	100	100
Feature Set	100	100	75	50	50	75	100	58	100	83	83	75	58
Unit Preferred	38	0	60	50	0	100	100	50	50	33	67	100	67

An interesting anomaly in the scores for how easy it would be to remember how to perform these tasks is seen when the results are broken down by the users' experiences with online map services like MapQuest (Table 15). For DeLorme and Garmin, the test subjects who use online map services regularly gave them a higher score, but for GoogleMaps, they gave it a lower score. It is possible that a test subject's previous experience with online maps could have altered their expectations of the units they were testing, but it is not clear why this would skew results in opposite directions.

While the Garmin and GoogleMaps units' scores about their feature sets were lower than the other units' scores, there is no identifiable demographic breakdown that identifies a pattern or a reason for this.

Table 15. Percentages of Positive Responses to Post-Test Questions by GPS Unit and Online Map Service Experience

	DeLorme		Garmin		GoogleMaps		Magellan		TomTom		
Electronic Map Experience:	+	**	+	**	+	**	-	+	-	+	**
Interface Clarity	33	25	100	100	40	40	100	100	100	100	100
Step Memory	67	100	0	75	100	40	100	100	100	100	100
Feature Set	100	100	50	69	70	70	88	92	67	50	75
Unit Preferred	40	25		50	100	67	50	50	83	50	100

Electronic Map Experience:

-	None
+	Limited
**	High

For the question about which unit a user would prefer (the one they just tested or a unit they had previous experience with), there is not enough data to form conclusions about the results. Not all test subjects had prior GPS experience, and the matrix of unit tested versus unit with experience is too large a result set to satisfy with only 50 test subjects.

5.3 Predictive Model

Based on the user responses to the survey and the tasks performed on each of the GPS devices, a predictive model was developed to provide consumers with a method to improve their initial experience with a new GPS by picking one that is likely to work well for them (Figure 1). The overall scores for the GPS models tested indicate that there is no single best choice for all users. Instead, demographics such as age, technical experience and previous use of online map services can be used to predict which units are likely to be a good fit for certain users. It should be noted that there are no paths in this predictive model that suggest choosing a Garmin GPS. It is possible that another test sample or more consistent data collection procedures would produce different results, and therefore, alter this predictive model.

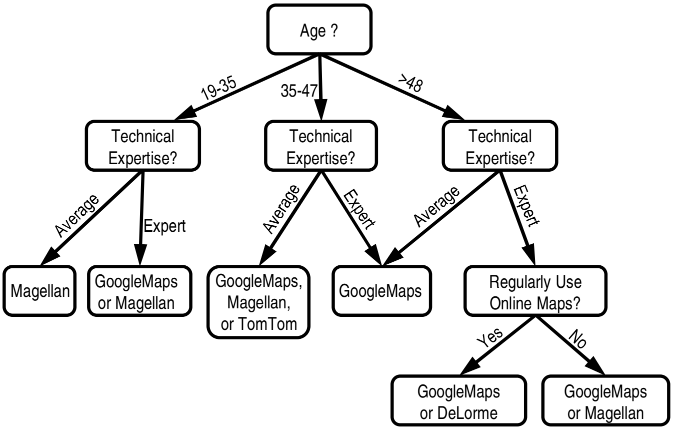

Fig. 1. Predictive Model Flowchart

6 Conclusions

In this research paper, steps taken to develop a predictive model that can be used by anyone for selecting a GPS system for use have been described. This was based on both subjective user interaction survey data, and an objective interaction measurement from a Keystroke Level Model (KLM).

The research has many practical implications. Developers can use these findings to create simple applications to help potential GPS buyers decide what suits them best. GPS interface designers can easily determine how, and where to focus their energy based on what users they are designing for.

This potential application would also serve as a cost-saving mechanism for GPS manufacturing companies, as they would know what to produce and for whom.

Additional test data from more measurement models e.g. Fitts' Law, and from a larger user sample pool, as well as using CogTool [11] to analyze the interfaces of the different GPS models could be done in the future. The results of additional analysis could serve as a tiebreaker for preliminary data from the other models, especially for tasks with no clear performance distinction. A higher level of accuracy will be guaranteed for every prediction.

7 Future Work

This work validates KLM on interfaces of GPS devices. GPS is a relevant part of daily lives. People use GPS for several reasons in their daily life and its role is increasing. The most common use for GPS remains retrieval of driving directions.

With a higher survey data sample pool, a clearer pattern should emerge, and a more consistent prediction will be possible. This could form the basis for the development of a simple web/mobile application for predicting a specific GPS choice given inputs such as ethnicity, level of education, experience with GPS and touch screen devices, computer, and experience with use of GPS device.

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