Songklanakarin J. Sci. Technol.
42 (1), 223-229, Jan. - Feb. 2020

http://www.sjst.psu.ac.th

Original Article

Medium fidelity automotive interface prototype testing: A comparison between existing and new designs

Muhammad Syafiq Syed Mohamed[1*], Shamsul Bahri Mohd Tamrin[2], Isa Halim[1],
Radin Zaid Radin Umar[1], and Dian Darina Indah Daruis[3]

[1] *Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka,*
Hang Tuah Jaya, Durian Tunggal, Malacca, 76100 Malaysia

[2] *Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences,*
Universiti Putra Malaysia, Serdang, Selangor, 43400 Malaysia

[3] *Department of Mechanical Engineering, Faculty of Engineering,*
Universiti Pertahanan Nasional Malaysia, Kem Sungai Besi, Kuala Lumpur, 57000 Malaysia

Received: 20 July 2017; Revised: 30 May 2018; Accepted: 16 November 2018

Abstract

The main objective of this study was to evaluate the usability of a newly developed automotive navigation interface design and the existing automotive navigation interface design. Professional and non-professional Malaysian drivers were recruited (N=60). Participants evaluated two types of automotive navigation interface prototypes (new and existing design), using the Kansei usability survey, modified System Usability Scale (SUS) in a driving simulator. Task completion time and number of driving errors were also measured. In the Kansei usability survey, the participants rated the existing and new designs as 3.456 and 3.893, respectively, on a 5-point scale. The SUS scores were 62.625 (existing) and 66.625 (new) and errors made while navigating were 12.85 errors (existing) and 8.15 (new). The task completion time for the new design was less than the existing design (2.34 min vs. 2.59 min). Overall, the new automotive navigation interface design prototype demonstrated higher levels of usability compared to the existing design.

Keywords: automotive navigation, GPS, usability, driver distraction, Kansei, Malaysia

1. Introduction

Interacting with an automotive navigation system is a common task for many drivers when navigating through an unfamiliar route. Drivers often have to juggle between engaging with the navigation system while keeping their eyes on the road. According to Chia (2013), automotive navigation devices, known as Personal Navigation Devices (PND), commanded 93% of the market share, and the trend is expected to continue in the future (Chia, 2013). A popular automotive navigation app, Waze, has over 50 million users globally, with Malaysian and Indonesian users in the top ten list of users (Meisia, 2014). Automotive navigation use is expected to continue in the future, along with the global rise of smartphone sales. The use of an automotive navigation system is expected to be the norm for drivers worldwide but this new phenomenon potentially leads to safety issues concerning driver distraction. Since an automotive navigation system helps in the primary task of driving, the levels of usability for any automotive navigation must be sufficiently high to prevent driver distraction. At the same time, usability issues must be resolved as early as possible during the design stage to avoid a costly redesign.

Drivers often use automotive navigation systems for efficient navigation while driving. Urban drivers in Malaysia

---

*Corresponding author
Email address: syafiq@utem.edu.my

appreciate the benefits of the traffic rerouting features in order to avoid congestion caused by accidents or any other unforeseen events on the road. Apart from navigation, automotive navigation devices also offer traffic information as well as possible speed trap locations and points of interests. Therefore, automotive navigation devices are an indispensable tool for drivers especially in Malaysia where the trend for automotive navigation use continues to rise.

According to a study by Young and Salmon (2012), driving performance is degraded when drivers try to engage with portable multimedia devices. Driver distractions due to in-car entertainment systems is a concern for Malaysians as cars in Malaysia have been equipped with sophisticated entertainment and navigation systems, in accordance with the latest developments in technology. Multimedia and navigation systems in cars are linked to higher accident risks (JPJ, n.d.). In line with the continuing trend of GPS use among Malaysian drivers, the issue of driver distraction has started to become a growing concern.

One of the earliest research studies on the usability of automotive navigation systems was by Nowakowski *et al.* (2003). A standard testing protocol was proposed by Nowakowski *et al.* (2003) to test the usability of automotive navigation systems. Results showed that typical automotive navigation systems have several usability issues related to destination entry and route guidance. Similarly, usability studies conducted by Al Mahmud *et al.* (2009), Dopart *et al.* (2013) and Fok *et al.* (2011) revealed that GPS interface design highly influences usability.

However, all of the previous studies on automotive navigation interface design used a fully functional system (Al Mahmud *et al.,* 2009; Curzon, Blandford, Butterworth, & Bhogal, 2002; Dopart *et al.,* 2013; Fok *et al.,* 2011; Noel, Nonnecke, & Trick, 2005). A fully functional product allows proper usability testing to be conducted. Almost all of the interface design issues can be resolved since usability testing consists of carrying out all of the typical tasks associated with the product. For example, the task of destination entry and following route guidance are the two typical tasks to be carried out in an automotive navigation system (Nowakowski *et al.,* 2003). In a partially complete prototype of a product, not all tasks can be carried out since the product is still at the design stage.

Addressing usability problems during the design stage is often the most practical way of preventing costly redesign. Designers and users can work closely to iron out all the possible issues related to the interface design. Engineers typically perform design analysis using a computer simulation tool like CAD software. Virtual reality tools have been employed by some researchers in order to make product evaluations as realistic as possible (Jung *et al.,* 2009; Kuutti *et al.,* 2001; Whitman *et al.,* 2004).

A fully functional system can enable the designers to conduct proper usability testing; however, developing a fully functional prototype can be costly and time consuming. Usability issues should be identified early during the design stage to minimize the need for a costly redesign of an interface. The level of fidelity when testing user interfaces is often debated by researchers (Lim *et al.,* 2006; Sefelin *et al.,* 2003; Virzi *et al.,* 1996; Walker *et al.,* 2002). Usability testing during the design stage is usually conducted using paper prototypes to simulate the actual workings of a product or an interface. According to Walker *et al.* (2002), usability problems can be detected no matter what the fidelity levels are. Even though the level of prototype fidelity may not have a significant influence in discovering the number of usability problems, computer based prototypes were found to be more preferable than paper based prototypes since it offers a more realistic view of how the interface behaves (Sefelin *et al.,* 2003).

Therefore, the objective of the study was to evaluate the usability of a new automotive navigation system and compare it with existing systems. The prototype with a medium level fidelity in the form of a short animation was carefully designed to uncover a good number of usability problems, while keeping the prototype development cost at a reasonable level. Hence, the use of a medium level fidelity automotive navigation interface prototype was deemed to be a cost effective solution for the purposes of this study.

2. Materials and Methods

2.1 Overview

In this study, a new automotive navigation interface design was developed based on the principles of Kansei Engineering and the relevant design requirements for usability were covered in a previous publication by the author (Mohamed *et al.,* 2016).

The automotive navigation interface design prototype was evaluated by Malaysian professional and non-professional drivers using survey instruments that consisted of the Kansei usability survey and modified System Usability Scale (SUS) as well as two objective performance measures: task completion time and the number of driving errors.

2.2 Participants

A sample size calculation was done via MINITAB. Given an effect size of 0.437 and a sigma of 0.8 (values obtained from pilot study data), the sample size calculation in MINITAB revealed a power of 0.803 for a sample size of 54. Therefore 60 participants were selected for this study. A total of 30 professional drivers and 30 non-professional drivers were recruited for the usability testing. Professional drivers in the context of this study were defined as those who were employed to drive passengers, while non-professional drivers were those with valid driver licenses but were not employed to drive passengers. All participants were Malaysian males aged 18–60 years old and all of them had previously used an automotive navigation device.

2.3 Performance measures

2.3.1 Task completion time

Participants were instructed to drive from point A to point B according to Figure 1. The time was measured as soon as the participants started to drive the car until they stopped at point B. Task completion time was captured using screen recorder software.

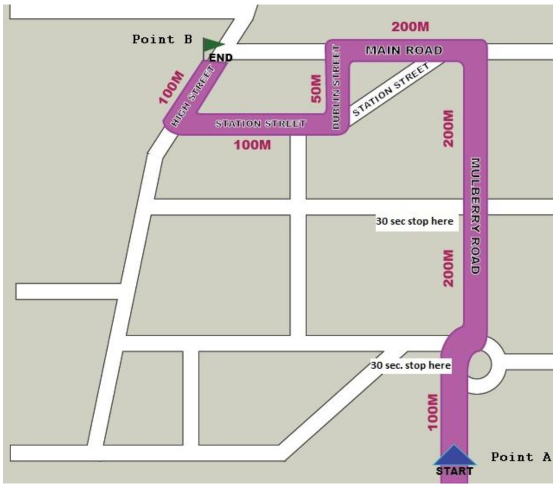


Figure 1. Driving route.

2.3.1 Number of driving errors

Driving errors were classified as traffic violations committed by the participants while driving. The researcher developed a classification of driving errors committed by the participants by studying all of the recorded screenshots of the driving simulator while the participants were engaged with the simulator. Figure 2 shows the classification of driving errors used in this study. During each driving session with the driving simulator, the session was recorded using screen recorder software for the driving error analysis. Each time the participant violated a traffic rule the error was noted. The number of driving errors was counted for the new and existing automotive interface designs.

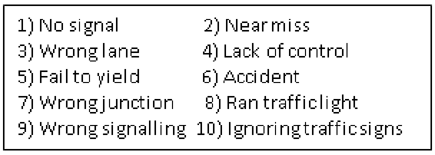

1) No signal
2) Near miss
3) Wrong lane
4) Lack of control
5) Fail to yield
6) Accident
7) Wrong junction
8) Ran traffic light
9) Wrong signalling
10) Ignoring traffic signs

Figure 2. Classification of driving errors.

2.4 Kansei usability survey

The Kansei Usability Survey was initially used in an earlier study (Mohamed *et. al*,. 2015) by the authors to develop the automotive navigation user interface prototype. A total of 11 Kansei words related to usability are listed in the survey (Table 1). Each Kansei word listed in Table 1 was rated using a five-point Likert scale, ranging from strongly agree (5) to strongly disagree (1). Based on a previous study conducted by the author, the Cronbach's alpha for the Kansei Usability Survey was 0.980 which indicated high instrument reliability (Mohamed, Shamsul, & Rahman, 2016).

2.5 Modified system usability scale (SUS)

Apart from the Kansei ratings, a modified System Usability Scale (SUS) was used to assess the usability of the old and improved GPS interface design. The SUS scale is a widely used evaluation tool to evaluate usability for human machine interfaces (Orfanou, Tselios, & Katsanos, 2015). The modified SUS based on a Likert scale questionnaire results in an overall usability score that ranges from 0 to 100 (Table 2). Each item's score contribution ranges from 0 to 4. For items 1, 3, 5, 7 and 9, the score contribution is the scale position minus 1. For items 2, 4, 6, 8, and 10, the contribution is 5 minus the scale position. The sum of the scores is multiplied by 2.5 to obtain the overall value of the SUS (Brooke, 1996).

Table 1. Kansei Usability Survey.

Information and icons
1) Findability: Easily found and located at the expected region?
2) Interpretability: Cannot be confused
3) Guessability: Operation easy to guess
4) Operability: Can be operated quickly, without reading or looking at labels?
5) Legibility: Easily seen and clear?
6) Understandability: Easy to understand?
7) Readability: Easy to read?
8) Usefulness: Useful for the driver?
9) Distinguishable: Easily differentiated?
10) Recognizable: Easily recognized?
11) Noticeable: Can be noticed easily

2.6 Automotive interface navigation prototypes

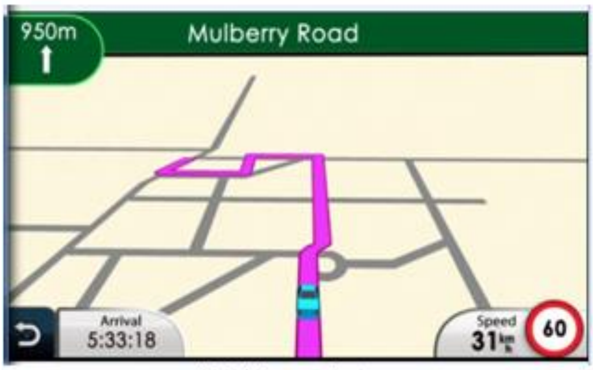
Two automotive navigation interface design prototypes were compared in this study (Figure 3). Both designs were a short animated route in a hypothetical metropolitan city that consisted of odd junction designs, and closely spaced turns. Odd junction designs and closely spaced turnings are common challenges for drivers when navigating using GPS systems (Nowakowski *et al.*, 2003) and therefore should be included in the usability testing protocol for automotive GPS systems.

Table 2. Modified System Usability Scale (Source: Brooke, 1996).

I would like to use this navigation interface frequently.
I found the navigation interface unnecessarily complex.
I thought the navigation interface was easy to use.
I think I would need Tech Support to be able to use the navigation interface.
I found various functions in this navigation interface were well integrated.
I thought there was too much inconsistency in this navigation interface.
I would imagine that most people would learn to use this navigation interface quickly.
I found the navigation interface very cumbersome to use.
I felt very confident using the navigation interface.
I need to learn a lot about this navigation interface before I could effectively use it.

The new automotive interface navigation prototype was developed based on an earlier study by the researcher. The design specifications for the new automotive interface navigation prototype were obtained from the results of a modified Kansei Engineering approach (Mohamed *et al.*, 2016), while the current design was chosen based on the best Kansei evaluation ratings obtained in the previous study by the author.

(a) New Design



(b) Old/Current Design

Figure 3. New Design (top), Existing Design (Bottom).

2.7 Usability testing protocol

Participants were asked to drive using the driving simulator according to the route shown by the animated design prototypes in Figure 1. A randomized repeated measures counterbalanced experiment design was used in the evaluation. The newly developed automotive navigation prototype would be evaluated against a current automotive navigation design. Participants with even numbers would evaluate the new automotive navigation design first followed by the current automotive navigation design while the odd numbered participants would be assigned to the current automotive navigation design followed by the new automotive navigation design.

Before starting the actual driving, participants were told to adjust the driving controls in the simulator. Once the adjustments were made, a practice session was done for at least five min to ensure that the participants were familiar with the driving controls. When the practice session was done, participants would complete two experimental drives. After completing each driving session for one design prototype, the participants filled out the Kansei usability survey and the System Usability Scale. Their driving session was recorded using screen capture software. The usability test followed the criteria set forth by Nowakowski *et al.* (2003). The test involved route-following tasks for the prototype. According to Nowakowski *et al*. (2003) a good test route should include non-standard intersections, closely spaced turns, and hard to see streets. Therefore the usability test conducted on the automotive navigation prototype featured at least one of the criteria described by Nowakowski *et al*.

The route that was chosen in driving the simulator software consisted of several non-standard turns, closely spaced turns (less than 100 m) in a hypothetical metropolitan city. An unfamiliar route was chosen, so that the participants would have to rely totally on the directions provided by the automotive navigation prototypes. The route consisted of several turns, with odd geometric junctions, and closely spaced turns, which were included in the animation for testing and evaluation purposes.

3. Results and Discussion

The Wilcoxon Signed Rank Test was used as most of the data from the Kansei ratings, modified SUS scale, task completion, and driving errors could not meet the assumption of normality for the Student's t-test. The Anderson Darling Test conducted on all datasets (except the System Usability Scores data) showed P-values less than 0.05 which indicated non-normal datasets (Table 3). Therefore, the non-parametric test was used in this analysis. Cronbach's alpha statistics for the Kansei evaluation rating and the modified SUS scores datasets were 0.9285 and 0.9235, respectively, which indicated high reliability of the datasets.

The descriptive statistics results showed that the usability performance of the new design was better in every measure compared to the existing design (Table 4). Task completion times and driving errors were less when the participants navigated using the new design and the modified SUS scores and the Kansei rating were higher than the existing design. Results from the inferential statistics indicated that the new design performed significantly better than the existing design (Table 5).

Table 3. Anderson Darling Summary Statistics (overall data).

Datasets	P-value
Kansei Evaluation Rating (1 to 5 points)	0.019
Modified System Usability Scale scores (0–100 points)	0.15
Number of Errors Made While Navigating	0.033
Task Completion Times (min)	0.005

Table 4. Summary of descriptive statistics of overall data.

Overall Data	Existing Design Mean (SD)	New Design Mean (SD)
Kansei Evaluation Rating (1 to 5 points)	3.456 (0.979)	3.893 (0.804)
System Usability Scale scores (0–100 points)	62.625 (20.018)	66.625 (21.441)
Number of Errors Made While Navigating	12.85 (7.392)	8.15 (6.305)
Task Completion Times (min)	2.59 min (0.7037)	2.343 min (0.709)

Table 4. Summary of inferential statistics of overall data (Wilcoxon signed-rank test).

	Z Score	P-value
Kansei Evaluation Rating	–2.386	0.017
System Usability Scale (SUS) scores	–0.99	0.322
Number of Errors Made While Navigating	–4.989	0.00
Task Completion Times (min)	–3.015	0.003

When navigating the route, a number of participants made navigation errors as they tried to navigate from the Main Road to Dublin Street and Station Street (Figure 4). The distance between these junctions were less than 100 meters apart, thereby causing some participants to miss the correct turn altogether. High Street and Station Street are both located at a very odd junction angle. Coupled with their proximity, some participants struggled to find the correct turn while navigating on those streets. However, the number of errors committed by participants using the new automotive navigation interface was fewer compared to the existing design (Figure 4).

The findings validate the testing method used in this study which was proposed by Nowakowski *et al.* (2003). Automotive navigation usability testing should include closely spaced turns and junctions which are often weak points for drivers while navigating unfamiliar roads (Nowakowski *et al.*, 2003). Errors such as missing turn signals, entering the wrong junction, entering the wrong lane were frequently committed by the participants while navigating the roads in this study. Despite the fact that the new design performed better in terms of usability, there is one glaring issue that was raised by some of the participants. The design of the buildings in the new design can obstruct the views of important junctions on the map. Some participants encountered a lot of difficulties while trying to navigate the route since the highlighted route was blocked by the tall buildings. This is particularly true when navigating from Main Road to Dublin Street and Station Street. A lot of errors were committed by the participants when they tried to navigate these streets.

Main Road, Dublin Street, and Station Street were all blocked from the view of the participants. This prevented the participants from anticipating the next turn while navigating the route. Participants recommended that some buildings in the new design to be made transparent to prevent blocking the views of important junctions and roads on the map. However, some participants do prefer the presence of buildings to determine their position and plan their journey. According to some, the nearby buildings can also serve as points of interest. It was also very difficult to get lost since the map design was almost the same as the actual environment. The current design had the advantage of no distracting buildings on the map which made the route easy to follow.

According to Wickens (1992) and Abubakar & Zeki (2015), pictorial realism states that any display should resemble the variable or item that is represents as 3D images which helps to convey more accurate spatial data. This is corroborated by Ware (2012) that visualization greatly helps in cognition. The way that 3D objects are represented in GPS navigation systems greatly influences the usability of a navigation system. It is with this view that the new GPS interface navigation was designed. All buildings in the new design were drawn to be as realistic as possible. However, the design of 3D objects in navigational maps in mobile devices remains to be a bone of contention for researchers (Abubakar & Zeki, 2015). A single perfect solution has yet to be found since the design of 3D maps on navigation systems remains to be a complex problem.

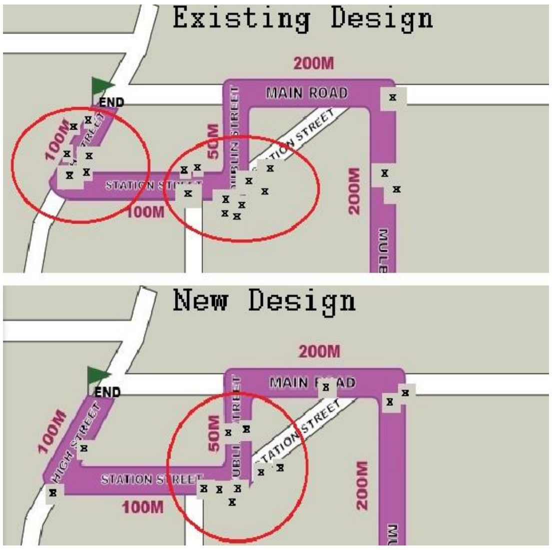


Figure 4. Comparison of errors (existing design and new design). Main Road to Dublin Street and Station Street are circled in red. The dots indicate error locations.

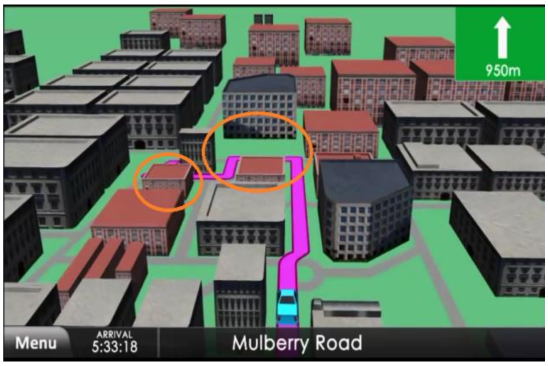


Figure 5. Highlighted route blocked by tall buildings (refer to circled buildings).

A realistic looking navigation map allows drivers to determine their present location with respect to their next planned turnings or exits. Landmarks do assist drivers when navigating an unfamiliar road. According to Kaplan (1976) landmarks are defined as “a known place for which the individual has a well formed representation”. Landmarks have been useful for drivers when navigating roads (Burnett, 2000; Burnett, 1998; Green *et al.*, 1993; Jackson, 1998; Streeter & Vitello, 1986) and landmarks are most highly valued information followed by left and right directions given by passengers (Burnett, 1998; Streeter & Vitello, 1986). Furthermore, Deakin (1996) pointed out that wayfinding errors in an unfamiliar city decrease when landmark information is made available which supports the finding of this study where driving errors decreased when the new automotive navigation interface design was used.

The 3D realistic representation of buildings and landmarks provided users cues and contexts in the display. In turn, this will encourage the sensemaking process. Taylor & Van Every (2000) defined sensemaking as a cognitive pathway leading to a coordinated action. It is an active process where the individual seeks information, gives it an interpreted meaning, and acts based on it. According to Weick (1995), one of the principles of sensemaking is that people extract cues from the context to make sense of the situation. Realistic 3D representation of buildings and landmarks theoretically can provide user cues, assist the sensemaking process, and consequently influence behavioral actions.

The modified System Usability Scale (SUS) scores showed no significant difference between the existing design (62.625) and the new design (66.625). This is due to the fact that the SUS sensitivity towards detecting differences in usability for different interfaces may be low. According to Kortum & Acemyan (2013), the SUS scores for any product does not typically go below 50 even when the product may have significant usability issues. Therefore, Kortum and Acemyan (2013) suggested that the midpoint range (50) should be the point to define the “usability failure” point. A previous study by Sauro (2011) reported that only 4% of 233 studies reviewed had SUS scores less than 40 which supported the findings of Kortum and Acemyan. Despite the findings from Kortum & Acemyan, (2013) and Sauro (2011) on the ability of the SUS scale, the new automotive navigation interface design scored slightly higher (66.625) than the existing design (62.625). This study proved the fact that usability was successfully engineered into the new automotive navigation interface design via the Kansei Engineering approach as explained by the authors of this study in an earlier publication (Mohamed *et al.,* 2016).

In implementing the Kansei Engineering approach, interpretation of certain design elements in an interface design need to be carefully considered. Even though previous studies (Abubakar & Zeki, 2015; Wickens, 1992) suggested that 3D images in an interface may help in the accuracy of visualization, the results from this study showed that the manner of how the 3D images are displayed in an interface is important as well. The design and layout of 3D images in an interface needs further research in terms of how usability can be affected b

4. Conclusions

The newly developed automotive navigation interface showed higher levels of usability compared to the existing automotive navigation interface design in terms of the Kansei usability survey (Z=–2.386, P=0.017), number of driving errors (Z=–4.989, P<0.00), and task completion times (Z=–3.015, P=0.003). Objective and subjective measures of usability were utilized in this study. Due to resource limitations, a full-fledged automotive navigation system could not be developed by the researcher. Developing a prototype with a medium-high level fidelity was deemed to be the best option while minimizing the development cost since both low and high fidelity prototypes are able to uncover usability issues (Walker *et al.,* 2002).

Future research should investigate further the amount of detail required in automotive navigation interface maps. Even though 3D objects in automotive navigation interface may be perceived to be useful for drivers, the results from this study proved that the presence of the 3D objects in a map may have a negative influence on usability.

References

Abubakar, A., & Zeki, A. (2015). Visualisation of a three-dimensional (3D) object’s optimal reality in a 3D map on a mobile device. *Applied Mathematics and Information Sciences*, *9*(6). Retrieved from http://search.proquest.com/openview/cb18f65c6ecba248638aaf403c032faa/1?pq-origsite=gscholar&cbl=1386356

Al Mahmud, A., Mubin, O., & Shahid, S. (2009). User experience with in-car GPS navigation systems. *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services - MobileHCI ’09* (p. 1). New York, NY: ACM Press. doi:10.1145/1613858.1613962

Burnett, G. (1998). *Turn right at the King’s Head; Drivers' requirements for route guidance information*. Loughborough, England: Loughborough University. Retrieved from https://www.researchgate.net/profile/Gary_Burnett/publication/268057025_Turn_right_at_the_King’s_Head_Drivers'_requirements_for_route_guidance_information/links/554c924b0cf21ed2135bbdaf.pdf

Burnett, G. (2000). “Turn right at the Traffic Lights”: The requirement for landmarks in vehicle navigation systems. *Journal of Navigation*. Retrieved from http://journals.cambridge.org/abstract_S0373463300001028

Chia, A. (2013). Car navigation systems market in 3 Asean countries to reach 2.08 million units in 2018 - The Malaysian Insider. Retrieved August 13, 2014, from http://www.themalaysianinsider.com/business/article/car-navigation-systems-market-in-3-asean-countries-to-reach-2.08-million-un

Curzon, P., Blandford, A., Butterworth, R., & Bhogal, R. (2002). Interaction design issues for car navigation systems. *Proceedings of the 16th British HCI Conference, London.* London. England. Retrieved from http://eprints.ucl.ac.uk/16834/

Deakin, A. (1996). Landmarks as navigational aids on street maps. *Cartography and Geographic Information Systems*. Retrieved from http://www.tandfonline.com/doi/abs/10.1559/152304096782512159

Dopart, C., Haggman, A., Thornberry, C., Mehler, B., Dobres, J., & Reimer, B. (2013). A driving simulation study examining destination entry with iOS 5 google maps and a Garmin Portable GPS System. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 57, pp. 1889–1893). SAGE Publications. doi:10.1177/1541931213571421

Fok, A. W., Frischmann, T. B., Sawyer, B., Robin, M., & Mouloua, M. (2011). The impact of GPS interface design on driving and distraction. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 55, pp. 1755–1759). SAGE Publications. doi:10.1177/1071181311551364

Green, P., Hoekstra, E., Williams, M., Wen, C., & George, K. (1993). *Examination of a videotape-based method to evaluate the usability of route guidance and traffic information systems.* Ann Arbor, MI. Retrieved from https://trid.trb.org/view.aspx?id=412282

Jackson, P. (1998). In search of better route guidance instructions. *Ergonomics*. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/001401398186559

JPJ proposal to ban TV monitors draws flak. (2011). *The Star Online*. Retrieved from http://www.thestar.com.my/story/?file=/2011/2/7/nation/8013995&sec=nation

Jung, K., Kwon, O., & You, H. (2009). Development of a digital human model generation method for ergonomic design in virtual environment. *International Journal of Industrial Ergonomics*, *39*(5), 744–748.

Kaplan, S. (1976). Adaptation, structure and knowledge. In G. Moore & R. Golledge (Eds.), *Environmental knowing: Theories, research and methods* (pp. 32–45). Stroudsburg, PA: Dowden, Hutchinson and Ross.

Kortum, P., & Acemyan, C. (2013). How low can you go?: is the system usability scale range restricted? *Journal of Usability Studies*. Retrieved from http://dl.acm.org/citation.cfm?id=2817707

Kuutti, K., Battarbee, K., & Sade, S. (2001). Virtual prototypes in usability testing. *Proceedings of the 34th Annual Hawaii International Conference on IEEE*. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=926545

Lim, Y., Pangam, A., Periyasami, S., & Aneja, S. (2006). Comparative analysis of high-and low-fidelity prototypes for more valid usability evaluations of mobile devices. *Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing roles.* Retrieved from http://dl.acm.org/citation.cfm?id=1182506

Meisia, C. (2014). Waze touches 50M users globally; Malaysia, Indonesia in top 10 list. Retreived from https://e27.co/waze-touches-50m-users-globally-malaysia-indonesia-in-top-10-list/

Mohamed, M. S. S., Rahman, R., B. M. T., S., Abdul Jalil, N. A., & Mat Said, A. (2015). Determination of salient variables related to automotive navigation user interface research survey for Malaysian consumers. *Advanced Science Letters*, *21*(7), 2089–2091.

Mohamed, M., Shamsul, B., & Rahman, R. (2016). Integrating usability in automotive navigation user interface design via kansei engineering. *Modern Applied*. Retrieved from http://www.ccsenet.org/journal/index.php/mas/article/view/56859

Noel, E., Nonnecke, B., & Trick, L. (2005). Evaluating first-time and infrequent use of in-car navigation devices. *Proceedings of the 3rd International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.* Retrieved from http://drivingassessment.uiowa.edu/DA2005/PDF/55_noelformat.pdf

Nowakowski, C., Green, P., & Tsimhoni, O. (2003). Common automotive navigation system usability problems and a standard test protocol to identify them. *ITS-America 2003 Annual Meeting.* Retrieved from http://umich.edu/~driving/publications/ITSA-2003-Christopher.pdf

Sauro, J. (2011). *A practical guide to the system usability scale: Background, benchmarks and best practices*. Denver, CO: Measuring Usability.

Sefelin, R., Tscheligi, M., & Giller, V. (2003). Paper prototyping-what is it good for?: A comparison of paper-and computer-based low-fidelity prototyping. In *CHI'03 Extended Abstracts On Human Factors In Computing Systems* (pp. 778-779). New York, NY: ACM Press. doi:10.1145/765891.765986

Streeter, L., & Vitello, D. (1986). A profile of drivers' map-reading abilities. *The Journal of Human Factors:* Retrieved from http://hfs.sagepub.com/content/28/2/223.short

Taylor, J. R., & Every, E. J. V. (1999). *The emergent organization: Communication as its site and surface*. London, England: Psychology Press.

Virzi, R. A., Sokolov, J. L., & Karis, D. (1996). Usability problem identification using both low- and high-fidelity prototypes. *Proceedings of the SIGCHI conference on Human factors in computing systems common ground - CHI '96* (pp. 236–243). New York, NY: ACM Press. doi:10.1145/238386.238516

Walker, M., Takayama, L., & Landay, J. (2002). High-fidelity or low-fidelity, paper or computer? Choosing attributes when testing web prototypes. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Retrieved from http://pro.sagepub.com/content/46/5/661.short

Ware, C. (2012). *Information visualization: perception for design*. Retrieved from https://books.google.com/books?hl=en&lr=&id=UpYCSS6snnAC&oi=fnd&pg=PP1&dq=,+Information+Visualization:+Perception+for+Design.+Morgan+Kaufmann&ots=32Az0d0Kkg&sig=Nfbpyf9VoDHL6FIv10C2iF8GLlo

Weick (1995). Sensemaking in organizations (Vol. 3). Sage.

Whitman, L. E., Jorgensen, M., Hathiyari, K., & Malzahn, D. (2004). Virtual reality: its usefulness for ergonomic analysis. *Proceedings of the 36th Conference on Winter Simulation* (pp. 1740–1745).

Wickens, C. (1992). *Engineering Psychology and Human Performance.* Retrieved from http://psycnet.apa.org/psycinfo/1992-97502-000

Young, K. L., & Salmon, P. M. (2012). Examining the relationship between driver distraction and driving errors: A discussion of theory, studies and methods. *Safety Science*, *50*(2), 165–174. doi:10.1016/j.ssci.2011.07.00