Effects of Guided Arrows on Head-Up Display Towards the Vehicle Windshield

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Abstract **-The concept of head-up display has gained wide acceptance being used for military aviation and has also spread to commercial aviation. Head up display (HUD) is now being used in automobiles to assist with navigation. The advantage of this system is reducing the number and duration of the driver's sight deviations from the road, by projecting graphic information on the windshield. Nevertheless, there has been little study as to how to use the super-imposed graphic such as guided arrows for car navigation system. The aim of the study is to evaluate the superimposition properties between the guided arrow marked on the road and the guided arrow on the center of the driver's field of vision, including the position of arrows. The subjects are assigned to carry out a car simulation test using an eye tracking device. The data was recorded in terms of eye movement and response time from both types of graphics in order to measure the driver's distraction. The results show that though the shape of the graphic has no effect, the location of the arrows does. The guide arrow also did not distract experienced drivers. This study can contribute a guideline for road safety.**

Keywords- Augmented Reality; super-imposed graphic, guided arrow, windshield-based display

I. INTRODUCTION

Since 2008, some vehicles have been equipped with new in-vehicle devices that are embedded in the car such as navigation systems which consist of Bluetooth, personal digital assistants (PDAs), cellular phones, and e-mail. The major contribution of Head up display is to present's information to the driver without his having to look away from his usual viewpoint, the road ahead. As a result, the devices are encouraging people to alternate their driving guidance source. The concept of head-up display has gained wide acceptance being used for military aviation and has spread to commercial aviation. Head up display (HUD) is now being used in automobiles to assist with navigation. The advantage of this system is reducing the number and duration of the driver's sight deviations from the road, by projecting the graphic information on the windshield. Nevertheless, that there is not much study on how to use the super-imposed graphic such as guided arrows for car navigation system is crucial.

The research is focused on exploring human attention associated with head up display on usual events and the reduction of risk of workload management while driving and increasing driver situation awareness by providing information and also to monitor how drivers can maintain their spatial orientation and situation awareness which could reduce when compare to basic Head down display (HDD) with main vision and normal activity. In comparison to the HDD interface, commonly used in the auto industry, the head-up display reduces the number and duration of the driver's sight deviations from the road, by projecting the required information directly into the driver's line of vision. This allows drivers to receive information without lowering their gaze, thus avoiding attention gaps that result from them taking their eyes off the road to look down at the information on a HDD Collins et al.[1], Green[2]. In this way, the driver can more easily keep his driving under control Kiefer[3], and can quickly respond to information relating to the road environment from the in-vehicle communication system Iino et al. [4].

A. HUD and Distraction

One cause of accidents comes from the dual or secondary tasks. Distraction is likely to increase the risk of an accident when driving a car as it may elicit periods of divided attention from the main task, e.g. by glancing away from the road scene. Distraction is attention to irrelevant stimuli or actions, and this implies a definition of what is relevant or irrelevant for a given goal. Boyle and Lee[5] analyze the relationships among three types of accidents (angular collision, rear-end, fixed object) and four types of distractions (cognitive, cell phone, in-vehicle and passenger-related) among young drivers. Recarte and Nunes [6] proposed four types of distraction: visual (searching for a phone number on the cell phone menu or checking a temperature display), cognitive (listening to the radio or searching by touch a button to open a window), activation (low activation, drowsiness or tiredness), and anticipation (knowledge/expectations related). The visual distraction is a main key of study.

B. HUD driving behavior

The primary study of the effects of using HUD on attention demand and driving performance was conducted by Liu et al [7]. From his experiment, he concluded that use of HUD can enable drivers to respond faster to unanticipated road events (i.e. speed limit detection and response tasks designed for his study) under both low and high driving loads. Under low driving traffic load, drivers have improved driving behaviors as evidenced by smaller variances in lateral acceleration and steering wheel angle. These valid indicators of required attention for driving show that drivers need less concentration when using the HUD. On the other hand, Victor et al [8], study the sensitivity of eye movement measure to in-vehicle task difficulty. They found that as the visual task became more difficult, drivers looked less at the road center area ahead, and looked at the display more often, for longer periods, and for more varied durations. Gaze concentration to the road center area was also found as driving task complexity increased. The critical time spent looking away depends greatly on the traffic situation: half a second while following a car at a close distance on a winding road may be more critical than 2 seconds while driving on a straight, wide, and empty motorway. Nevertheless, distraction times over 2 seconds are considered unacceptable as a general criterion for driving NHTSA [9]. Currently, the HUD function is for display only. Driver and system cannot interact fully. This research will try to investigate the interaction techniques on the particular kind of input device. For the output device, the HUD is a new technology that still requires development of the information display.

C. Super-imposed graphic

This research shows that the graphical user interface (GUI) of the information design could integrate to the HUD in the future. There are several researches that study the HUD and driving performance. To extend the existing HUD technology, Wu et al and Seder from Carnegie Mellon University and General Motor Research & Planning, respectively, invented a prototype of landmark-based car navigation using full-windshield head-up display system [10]. The projected information (text, image and graphics) is distorted on the car windshield because of its non-planar surface. They used the blue laser to draw a border over the signage or point out the landmark that can help the driver in terms of navigation. From this research, the HUD should not be limited to a small size. It could extend to the full-windshield. In this study, the investigation is the superimposition graphic overlaying on the road environment. The overlapping clutter can sometimes hinder the ability to read particular pieces of information on the HUD or, in particular, to see unexpected elements only visible in the outside world through the HUD. The objectives are to evaluate the superimposition graphic in terms of properties, sequential layer, and limitation of information in term of visual distraction with the objects in the driving environment. Many studies have been conducted on Graphing mapping on the HUD such as Second life and visual longitude [11] and Simulated augmented reality windshield display for elder driver navigation [12].

A. AIMS and OBJECTIVES

The aim of these studies is the collection of the resulting cognitive load. Using the HUD for interaction resulted in more efficient operation time, better driving performance (lane keeping) and less cognitive and visual demand (Peripheral Detection Task). However, the type and design for interaction remain crucial for the fixation time duration and several driving performance values. Fixation time means the time the driver concentrates on a single source of information. Thus, prolonged fixation time has to be prevented by using an appropriate information design and reducing interaction complexity to a minimum.

- To observe the effect on GUI shape that could cause some behavior or effects on driving performance during the test.
- To monitor the positioning of GUI on its location and find out the effect on the driver performance and response time.
- To evaluate the superimposition properties between the guided arrow marked on the road and the guided arrow on the center of driver's field of vision.
- To detects the type of shape of GUI that could not distract driver's attention and assist the driver to have immediate response time without creating a nuisance.

II. METHODS

The study focuses on the car driving simulation in the laboratory rather than on the road due to the reason of safety and experiment control. The aim of this research is on the distraction of information display on dual tasks. Data collection from the drivers' behavior will be used to analyze and investigate. The result will show the significant difference, if any, between arrow types of graphics. This study will contribute to future guidelines for road safety

A. Tasks

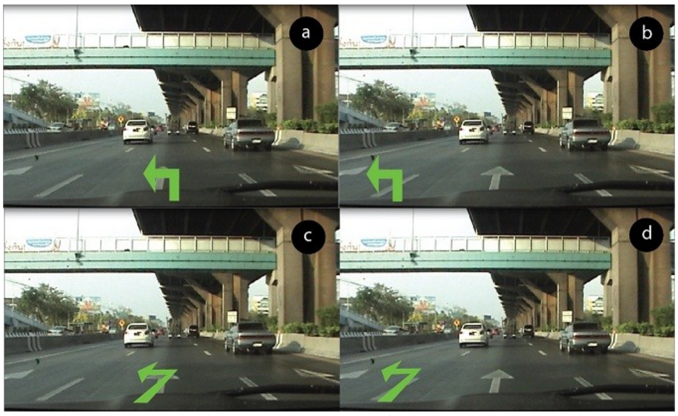

Figure 1. Four types of treatments

The subjects are assigned to test the car driving simulation with the eye tracking device from SMI and analyzed by using Begaze analysis software [13]. The data was recorded in terms of eye movement and response time from both types of graphics in order to find out the driver's distraction. There are four treatments: guided arrow on center of driver's field of vision (Fig. 1a), the guided arrow marked on the road (Fig. 1b), the guided perspective arrow on center of driver's field of vision (Fig. 1c) and the guided perspective arrow marked on the road (Fig. 1d). Subjects were requested to drive the car simulation around 10 minutes before starting the test.

B. Driving Simulator

The driving simulation was integrated by using two light sources (see Fig. 2). The signal resource that showed the guided arrow is from plasma TV screen size 50'. The road scene was projected from the back side of screen. The experiment was set up based on the synchronization between animated graphic and road scene. The combiner was a transparent plastic sheet that reflects the graphic on the

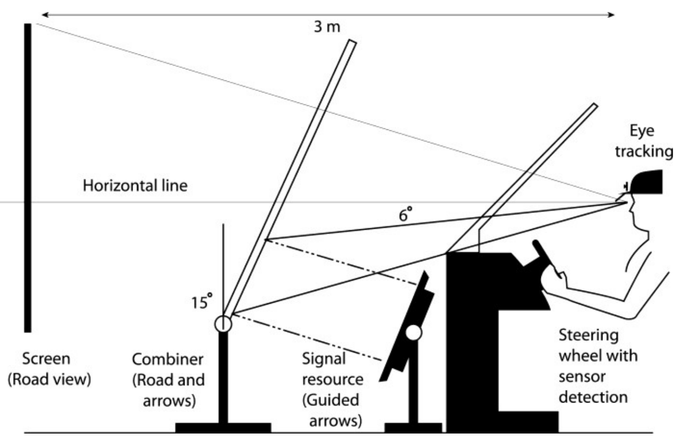

Figure 2. Instruments

Figure 3. Driving Simulator

windshield. The eye tracking was used to capture the fixation duration that reflects to drivers' attention. By marking Areas of Interests (AOI), researchers can understand how much drivers spent time on guided arrow and surrounding cars. A fixation was defined as a minimum of 12 consecutive recordings of 16 ms each or 100 ms. [14]. In this research, AOI was defined into two parts. First is the vehicle ahead and second part is the arrows. The surrounding environment such as bridge and signage were not taken into account.

C. Subjects

Five human subjects participated in this experiment. Two are female. They were predominantly experienced drivers. The experience of driving is range from none to 30 years.

D. Task and Procedure

All participants were required to complete four driving simulations and all were asked to follow guided arrows and a lane change task. In this experiment, the arrows appear all the time rather than pop up when necessary. The reason is to study the effect of distraction when the arrows appear all the time. Time allocation for each member would be around 30 minutes to compete the whole experiment. There were 4 simulated videos for participants. Each video was around 3 minutes long with different GUI. The road scene is three lanes allowing for changing to left and right lanes. Before carrying out the actual test, the driver calibrated their eye tracking device with the system. They were also request to move the steering wheel of the simulator car following the guided arrows.

E. Observation and statistical analysis

Fixation measurements from the eye tracking device were used to measure the quality of the driver's perception. A computer attached to the eye tracking device, recorded driver' eye movement and fixation time after driving. The fixation time was limited at 2 m/s for before being considered to be a distraction. In comparison, the steering wheel activity was also recorded to find out any responses to the task.

III. RESULTS

The result of this study can be described into five parts. Fixation counted number is a frequency of fixation time. It counts from the recorded fixation duration each time. This result shows how much subjects spent time on each AOI. The second result is a comparison on each treatment. This result shows the difference of arrow types based on fixation duration. The third part is the drivers' distraction. In this part, it shows how various arrow displays affects distraction. The fourth part is the response time. This result confirms the response time for each subject. It is a confirmation whether subjects paid attention to the arrow or not. The last part is user satisfaction. It is users' preference on the type of arrow subjects selected.

A. Fixation Counted Number

TABLE I. MEAN OF FIXATION COUNTED NUMBER

AOI	Subject no.1	Subject no.2	Subject no.3	Subject no.4	Subject no.5	Mean
Right arrow	29	19	23	46	1	23.6
Left arrow	32	21	25	66	1	29
Straight arrow	144	164	36	205	130	135.8
Car objects	358	598	408	252	162	355.6

The result shows that the highest average frequency of fixation counted number were car objects, straight arrow, left arrow and right arrow respectively (see Table I). Car objects were the highest at 355.6 times, whereas the total counted arrows were 188.4 times. The mean of fixation numbers on straight arrow against other arrows were high as 135.8 times, whereas right and left arrows count as between 23-29 times. The reason for straight arrows being higher than other arrows is that they were shown more than others. The numbers of left and right arrows are quite equal. The cumulative number of all arrows is around 52.9% comparing with the car objects. Many subjects moved their eyes between car objects and arrows quite often especially for the intermediated and inexperienced drivers. Inexperienced drivers move their eyes to the straight arrow more than 200 times in the experiment (subject number 4). The ratio of all arrows is more than the car. On the other hand, the experienced driver (subject number 5) who has driven more than 30 years did not glance at the arrows much. He looked the car ahead and used his corner of eye to look instead. He did not spend much time on arrows. As a result, it is concluded that eye movements are less in experience drivers. After interview, experience driver revealed that he must look at in cars in front of him not less than 400 meters at least to avoid collision.

B. *Comparison of Treaments*

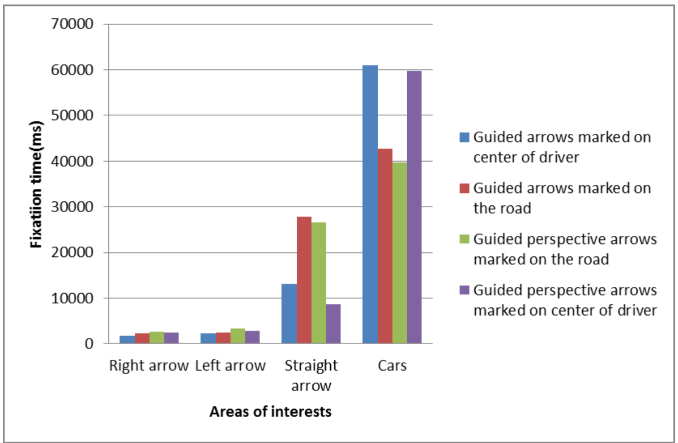

Figure 4. Fixation time mean of each AOI on four treatments

The result of four treatments shows that subjects pay attention on the cars in their field of view the most (see Fig. 4). Comparing between the time that they spent on the cars, it appears that subjects gave more attention when all arrows were in the center of driver's field of vision than the arrows marked on the road. If the arrows are not in the center of the driver's view, they paid less attention on the cars around by 20 seconds. The reason might be that subjects cannot move their eyes to many locations at the same time. This should be kept in consideration when designing a graphic user interface on a large screen as a full windshield. Fitts' law could be used to explain the movement time and distance with the eye movement [15]. On the other hand, subjects paid attention on the straight arrow more when all arrows are not in the center of driver. They spent time on the straight arrow of guided arrows marked on the road more than the center of drivers around 20 seconds. There is not much difference on the right and left arrow, since the time that they spent is less than 2.6 seconds. The arrow shapes in 2D and perspective do not affect the driver attention.

C. *Distraction*

Figure 5 shows an example of distraction of guided arrow on the center of driver's field of vision. This type of distraction is eyes off the road (visual). The distraction is on the straight arrow 2 times and left arrow 1 time. This is a result from inexperienced driver (subject number 4). The result shows that there were three occasions that a period of distraction was more than 2 seconds. Nevertheless, the number of not distract is more than distract. For intermediate and experienced drivers, the arrows did not distract them much. Moreover, it did not appear that other subjects spent more time than 2 seconds on arrows. For other treatments, there is no visual distraction based on time measurement. The inexperienced drivers effect distraction, while the rate of distraction for male and female is not significant difference [16].

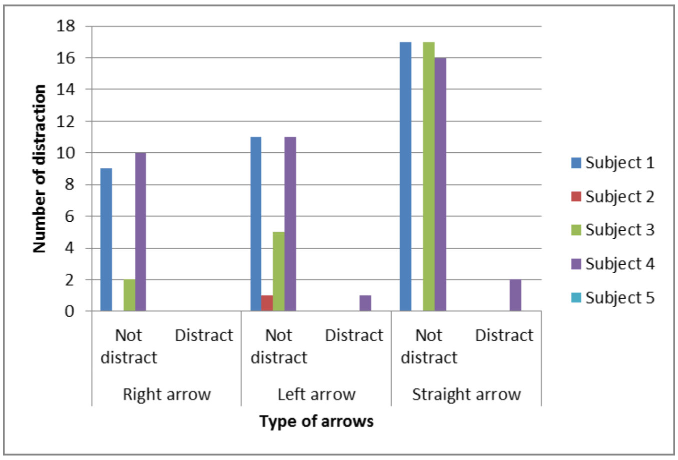

Figure 5. Example of distraction

D. *Response Time*

TABLE II. RESPONSE TIME

Treatments	Left rotation	Right rotation	Error
Guided arrows mark on center of road	3.05	6.05	1
Guided arrows marked on the road	4.71	5.72	0
Guided perspective arrows marked on the road	4.68	4.50	0
Guided perspective arrows marked on center of driving	5.22	4.56	1

Table 2 shows the response time collected from the steering wheel rotation. It shows that the mean of response time is around 3 to 6 seconds after showing arrows. Left and right rotations have a similar result. There were only 2 errors where subjects did not rotate their steering wheel after stimulation by arrows. This error calls action execution (fail to act). A subjects forgot to turn his steering wheel at the first time he met an arrow. This type of error can be categorized as a cognitive distraction (mind off the road). The inexperienced driver also showed that she rotated the steering more than experience drivers. The time of 3 to 6 seconds is an appropriate time that used to inform drivers of information before changing lane.

E. *Satisfaction*

TABLE III. SATISFACTION RESULTS FROM QUESTIONNAIRE

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Experience of driving	2	10	6	0	30
Which shape of arrows would you prefer?	Perspective shape	2D shape	Perspective shape	Perspective shape	2D shape
Do you find any difference between those four tests?	No	No	Yes	No	No
Do you think where arrows/position should be?	Center	Center	Center	Full-windshield	Center
Do you think the arrow sizes on the test are appropriate?	Yes	Yes	Yes	Yes	Yes
Do you think the position of arrows below the horizontal line acceptable?	Yes	Yes	Yes	Yes	Yes

The questionnaire was handed to subjects after testing. The result shows that subjects preferred both perspective and 2D shapes. Many of them did not recognize the difference between these shape types. They would like to have an arrow in the center of driver's field of view instead of full-windshield. The size of arrows and the position were acceptable. The result of questionnaire had a similar outcome to the experiment. For example, subjects cannot distinguish between perspective and 2D shape of arrows. In the experiment, the fixation time has a similar result.

Many subjects mention that the guided arrows are nuisance sometimes and useless. Designing warnings that promote appropriate responses and acceptance is a ubiquitous problem that confronts designers of many systems. An inappropriate response occurs when the driver responds to the situation incorrectly, such as ignoring the collision warning [17].

IV. DISCUSSION

From the experiment, perspective and 2D arrows are not so much different. Other graphic application could be applied for full windshield such as lane departure and traffic signage. The experience of driving also affects the way drivers' glance. Inexperienced and intermediate drivers look often between graphic and the cars ahead, whilst experienced drivers glance at the car further away. He looked at the graphic by looking from the corner of the eye. As a result, higher experience of car driving may be linked to less distraction. A further study could a) examine the eye movement in experience and non-experienced drivers. Curry et al. reported a similar study on teen driver errors that lead to serious motor vehicle crashes [18]. Most of the errors are recognition. The internal distraction including handheld electronic equipment is 13.9%. Suggested measures of internal distraction are based on the concentration of gazes towards the road center area, which is higher when the driver is lost in thought. b) develop technology to be able to measure the current traffic situation and traffic environment.

V. CONCLUSION

Our finding provides evidence to support the design of GUI on windshield as follow:

1. GUI shape did not affect to the drivers' attention.
2. Subjects paid attention on the guided arrow on center of drivers' field of vision more than on the road.
3. Experience driver has less fixation time on arrow but he still responds well.
4. The positioning of GUI effects to the fixation time. The design of full windshield should be kept in consideration.

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REFERENCES

[1] Collins, D.J., Biever, J.W., Dingus, T.A., Neale, V.L., "Development of human factors guidelines for advanced traveler information systems (atis) and commercial vehicle operations (cvo): an examination of driver performance under reduced visibility conditions when using an in-vehicle signing and information system(isis)". Publication No. FHWA-RD- 99-130, US Department of Transportation Federal Highway Administration,1999.

[2] Green, P., "The 15-second rule for driver information systems". Proceedings of the Intelligent Transportation Society of America Conference (CD-ROM), Intelligent Transportation Society of America, Washington, DC., 1999.

[3] Kiefer, R.J., "Effect of a head-up versus head-down digital speedometer on visual sampling behavior and speed control performance during daytime automobile driving". Paper 910111, Society of Automotive Engineers, New York, 1991.

[4] Iino, T., Otsuka, T., Suzuki, Y., "Development of heads-up display for motor vehicle". Paper 880217, Society of Automotive Engineers, Warrendale, 1988, pp. 15–23.

[5] Boyle, LN., Lee, D.J., Using driving simulators to assess driving safety, Accidental Analysis & Prevention, Vol. 42, Issue 3, May 2010, 2010, pp.785-787.

[6] Recarte, M. A., and Nunes, L. M, "Mental load and loss of control over speed in real driving: Towards a theory of attentional speed control", Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 5, Issue 2, June, 2002, pp. 111-122.

[7] Liu, Y. C., and Wen, M.H., "Comparison of head-up display(HUD) vs.head-down display (HDD): driving performance of commercial vehicle

operators in Taiwan", International Journal of Human-Computer Studies, Vol. 61 (5), Nov 2004, pp. 679-697.

[8] Victor, T. W., and Harbluk, J. L., Engstrom, A.J. Sensitivity of eye-movement measures to in-vehicle task difficulty, Transportation Research, Part F, Traffic Psychology and Behaviour, Vol.8, Issue 2, 2005, pp. 167-190.

[9] National Highway Traffic Safety Administration (NHTSA). The impact of driver inattention on near-crash/crash risk, 2006. Available at: http://wwwnrd.nhtsa.dot.gov/departments/nrd-13/810594/images/810594.pdf

[10] Wu, W., Blaicher F., Yang, J., Seder, T., and Cui, D. "A prototype of landmark-based car navigation using full-windshield heap-up display system", AMC'09, Beijing, China, Oct 2009.

[11] Tonnis, M., Lange, C., and Klinker, G., "Visual longitudinal and lateral driving assistance in the head-up display of cars". IEEE, 2007.

[12] Kim, S. J., and Dey, K. A., "Simulated augmented reality windshield display as a cognitive mapping aid for elder driver navigation", CHI 2009, Boston.

[13] SensoMotoric Instruments, Eye & Gaze tracking system, http://www.smivision.com. Last Accessed on 25 March 2012.

[14] Caird, J K., Chisholm, S L., and Lockhart, J., "Do in-vehicle advanced signs enhance older and younger drivers' intersection performance? Driving simulation and eye movement results", International Journal of Human-Computer Studies, Science Direct, 14 Feb 2007.

[15] Vertegaal, R., "A Fitts' law comparison of eye tracking and manual input in the selection of visual targets", IMCI'08 : Proceedings of the 10th international conference on Multimodal interfaces, Oct 2008.

[16] Sullman, J.M., "An observational study of driver distraction in England", Transportation Research, Part F 15, 2012, pp. 272-278.

[17] Lee, D. J.,Hoffman, D.J. Hayes, E., "Collision warning design to mitigate driver distraction", CHI 2004, April 24-29,Vienna,Austral, 2004, pp. 65-72.

[18] Curry, E.A., Hafetz, J., Kallan, J. M., Winston, F.K., Durbin, R.D., "Prevalence of teen driver errors leading to serious motor vehicle crashes, Accidental Analysis and Prevention, Vol. 43, pp. 1285-1290, 2011.