Automotive Peripheral Vision Interface

Deliver information to driver while operating an automobile

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Both internal and external factors contribute to the complexity of the driving environment. Traffic conditions, intricate car management systems, a multitude of communication devices, and more demand increased levels of attention from drivers. Furthermore, in-car information displays are becoming cluttered and distracting. To address the distractions introduced by this information overload, we propose a way to display information in the driver's peripheral vision with less distraction. This paper investigates the potential of peripheral vision interface to deliver information to the driver while operating an automobile. Our field and experimental findings suggest that a successful implementation of such an information interface is possible. However, the driver's perception of information from a peripheral vision interface may be reduced due to cognitive load and optic flow stimuli used to present information. The results and possible future developments are discussed from the perspective of car design.

Key words: peripheral vision, interface design, design and sensibility, information design

1. Introduction

In recent years, the computing devices and resources are becoming smaller and ever more available, inevitably influencing how we design cars. In the last decade, car interiors have become more and more complex [4]. The implementation of advanced navigational, communication, entertainment and car management systems allows drivers and car passengers to, for example, access the Internet, telecommunicate, enjoy music and movies or gather extensive information on the car and surroundings [7]. These information technologies are transforming in-car environment.

On the other hand, information provided this way requires more and more driver's visual and cognitive attention. Driving task itself already demands a high degree of visual and cognitive attention [7] and performing secondary tasks generally distracts driver from driving [18]. Secondary visual information urges driver to glance away from the road, causing interference [29] resulting in increased variability in lane position [19], decreased driving performance and increased risk of accident [9]. Road-traffic safety researchers emphasize the need for driver to keep attention on the road and reduce the time spent paying attention to in-car displays [35]. Reducing the visual load alone cannot be a solution if the cognitive load is high [19]. Due to less effective use of environmental cues [25] when under increased cognitive load, driver's reaction time increases [1], while the ability to maintain vehicle control decreases [2]. Some may argue that cognitive load has less impact than visual load [29] but both are capable of reducing the drivers' ability to perform the primary task of driving.

Multiple resource theory (MRT) [36] points out that cognitive interference is highest when tasks are performed using the same cognitive resources [37]. Multiple tasks utilizing the same cognitive resource will interfere with each other more than multiple tasks utilizing different cognitive resources [38].

Based on MRT and cognitive load theory (CLT), a number of in-car applications have been developed that utilize multimodal (e.g. haptic, audio, verbal [3,10,14]) interfaces to help eliminate visual and cognitive load by distributing information over various cognitive resources.

Further implications of MRT show that focal vision and peripheral vision use separate visual processing resources when driving [23,31]. Hypothesis of Mourant And Rockwell based on the analysis of eye-movement suggested that peripheral vision is used for maintaining lane position [21]. That has been confirmed in real-life setting [30] . Recent evidence from a meta-analysis of the effect of cell phone use on driving performance also showed that using focal processing to operate handheld phone had relatively small effect on lane keeping, while using hands-free phones shown to had substantial effect on event detection and response time [8].

Driving is more or less dominated by visual perception; most of the driving related information is received visually. Therefore, displaying information in peripheral vision presents itself as a promising field to deliver information to the driver without dissipating visual attention or causing additional cognitive load. It is hypothesized that it could provide driving related information, improve situation awareness, reduce the need of glancing at in-car information display and enhance driver-vehicle interaction.

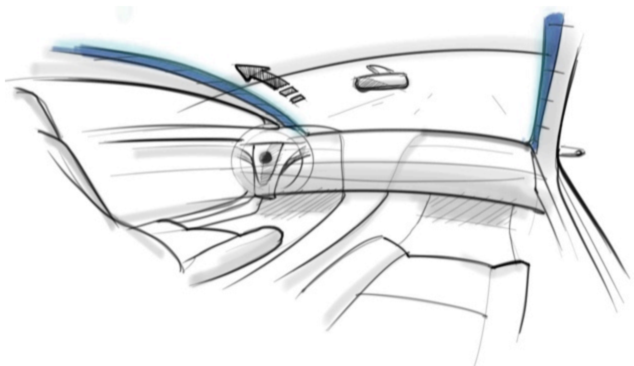

Figure.1 Idea sketch for displaying information in driver’s peripheral vision

2. Related Works

2.1 In-car information display

Although there are many researches and applications concerning visual and mental distraction, we still see challenges remain in the field of in-car information display. Instrument panel display is one of the information elements of a car that occasionally necessitates driver’s visual attention but at the same time increases visual and mental distraction.

The current trend of increasing amount of information available in car, lead many car manufacturers to implement dynamic visual displays that can display various information in the same display [4]. This is especially visible in most hybrid and alternative fuel cars, usually equipped with large color LCD displays fit for fuel economy driver interface (FEDIs). FEDI displays information on fuel economy and is intended to guide drivers to improve their driving accordingly. These features too urge drivers to look at the display more often and demand driver’s attention. As more alternative fuel cars enter the market and the cost of in-car displays decreases, it is likely that display providing even more detailed information will be introduced.

The richness of information introduces some safety concerns. For instance, Japan's safety guidelines on in-vehicle display systems [11] reported a 3.1 seconds (total eyes-off-the-road time, including transition time) as a maximum safety allowed when driving in a city and 3.7 seconds on expressway [11]. In another safety report also noted that drivers are unwilling to go without road information for less than 2 seconds [27]. While there is reported that driver may takes approximately 1.26 glances and around 0.78 second fixation time on speedometer [39], we assumed that total eyes-off-the-road time including transition will be close to 2 seconds.

In safety guidelines we learned that when perform driving task only a relatively small amount of information can be conveyed safely to the driver within very limited amount of time. As the result, a driving interface that is designed to reduce the number of glances and fixation times will increase safety [17].

2.2 Peripheral vision

Idea of presenting information in peripheral vision is not new. Thibos & Bradley, 1991 had suggested the idea of shifting visual information from central to peripheral vision [16].

In a computer context, displaying information in peripheral vision even in a single screen has been shown to reduce distraction [20]. Peripheral-vision space around the user is considered a valuable resource for design of awareness and communication systems [12] harvests more of user's visual field can be a key to improve user experience. There has been several experimentations to extend the interface beyond the desktop using peripheral displays, some notable example are a study of wall-sized display [5], studies of using peripheral displays to convey social presence using digital photo frame [22], and research to improve awareness between group of people using projected display [12].

2.3 Endogenous and exogenous control

Visual attention can be guided toward objects in two manners by endogenous control and exogenous control. Endogenous control (goal-driven or top-down control) refers to process that driver intentionally directs attention toward stimuli. Exogenous control (stimulus-driven or bottom-up control) refers to direction of attention guide toward stimuli automatically or unintentionally by characteristic of visual field or stimuli [14,35].

In the case of driving, exogenous cues, such as unexpected movements, can draw attention to a particular object or location without drivers' intention. On the other hand, endogenous control directs attention toward particular features in driving environment when information is relevant to the driver [33]. Cognitive load would be expected to interfere more with endogenous control, which refer to driver's attention toward safety-relevant objects than exogenous control, which regard of paying attention to salient objects.

One concern may rise when displaying information in peripheral vision that peripheral stimuli could impede driver visual attention with the involuntary control of eye movement toward objects, causing distraction. Although, there is research studied the influence of peripheral stimuli in reading showed that readers noticed movement in peripheral vision but the performance of attentive reading does not affected by visual motion in periphery [28]. The effect of exogenous to drivers' attention is critical to distraction and need to be taken into our account in the experiment as well as further design and development process.

Previous studies in computer science may share the same with driving in term of cognitive load where user has to attends to primary task refer as reading or text editing and at the same time perform secondary task in periphery. But the big difference to driving is the optic flow effect generated by car moving through space, this is in great degree a still remains unexplored.

The objective of the research is to provide novel and usable interaction technique for drivers and since for the most part of the research is considerable an unexplored area practically and theoretically. In this research we then decided to conduct two parallel approaches using field experiment and laboratory experiment. The data regarding drivers' feedbacks and preferences along with scientific data were collected and used to guide the experimentation and further development direction.

3. Peripheral Vision Experiment

Findings from pilot study raise the question of how drivers interact with graphics present in their peripheral vision in driving environment. Weather cognitive load and optic flow have effect on ability to detect the data in peripheral vision? We conduct the experiment to examine the interaction between driver and data present in peripheral vision as well as search for general suggestions and principles for further develop of the system.

3.1 Participants

Total of 12 participants (6 men and 6 women) were recruited to take part in the study. All of the participants were students recruited at Kyoto Institute of Technology, Japan. Their ages ranged from 23 to 26 (M = 23.91, SD = 1.08). The criteria for participation were possession of a driving license and either normal or corrected to normal vision.

3.2 Apparatus

Throughout the experiment, participants were seated in the driver's seat of an applied fixed base simulated-driving. A 350 mm by 205 mm driving scene was projected on the screen approximately 80 cm in front of participant. 12.5 mm x 50 mm stimuli were present in black area around the projected driving scene represent A-pillar and area around front-windscreen, see figure 2.

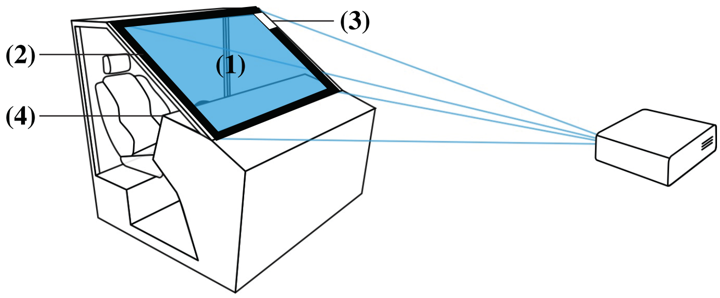

Figure 2. Experiment set-up (1) Driving Scene (2) black area around the driving scene for testing stimuli (3) Stimuli (4) Participants press green button when see stimuli

3.3 Design and Procedure

The participants were randomly assigned to four different test conditions.

3.3.1 Baseline (BL)

In this condition, participants were asked to look at white square dot in front them represent fixation point. Background of the test condition is present in black color. In baseline condition white square dot is fixed throughout the test.

3.3.2 Simulated Cognitive Load (SCL)

In this condition, participants were asked to look at white square dot in front them represent fixation point. Background of the test condition is present in black color. In simulated cognitive load condition white square dot move randomly according to eye movement data we collect from pilot study. The white dot randomly change to green color which participant have to step on gas pedal and red color which participant have to step on brake pedal simulate cognitive load in driving.

3.3.3 Simulated Optic Flow (SOF)

In this condition, participants were asked to look at white square dot in front them represent fixation point. Background of the test condition is present with driving scene of a car taken from driver's perspective in Tokyo. In simulated optic flow condition white square dot is fixed throughout the test.

3.3.4 Simulated Driving (SD)

In this condition, participants were asked to look at white square dot in front them represent fixation point. Background of the test condition is present with driving scene of a car taken from driver's perspective in Tokyo. In simulated driving white square dot move randomly according to eye movement data we collect from pilot study. The white dot randomly change to green color which participant have to step on gas pedal and red color which participant have to step on brake pedal simulate cognitive load in driving.

The experimental protocol proceeded as follows. Participants began by seated in the simulator after adjusted seat position each participant received a brief training session so that they could become familiar with the basic operation of the experiment and know how to operate the test feature. Training included instruction and practice reacting to stimuli by press the green button locate in front of participants.

After training, participants were given a paper that listed 4 different test conditions to choose in random order. All tasks were videotaped and timed, with each experiment lasted approximately 3 minutes with 1 minute interval between the test condition.

The task of evaluating peripheral vision interaction comprised of observing stimuli, which, at different times, appeared randomly in the peripheral vision. When participant recognized the stimuli, participant react by pressing a green button locates in front of them. Each test condition generated 24 random position impulses, 6 of which appeared to the left area of the driving scene, 6 to the right area, 6 to the upper area, and 6 to the below area. We use 3 different types of stimuli that we summarized from previous pilot study - static, moving, and blinking.

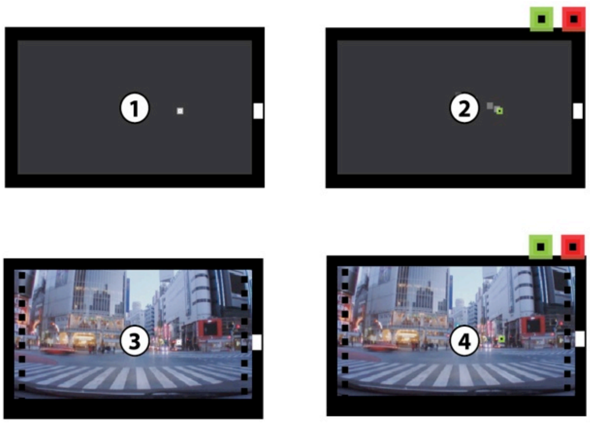

Figure 3. Test conditions (1) Baseline Condition. (2) Simulated Cognitive Load Condition. (3) Simulated Optic Flow Condition. (4) Simulated Driving Condition.

3.4 Performance measure

For each task, the following performance measures were recorded:

3.4.1 Task Reaction Time

Reaction time after each stimulus appeared and the time participants pressed the green button was recorded with a computer program.

3.4.2 Task Completion

A task was considered “Complete” if the participant was able to press the green button after saw the stimuli. If the participant was not able to press the green button the task was considered “Not Complete”.

4. Result

4.1 Task Reaction Time

The results showed a significant main effect in test conditions ($F(3,96) = 30.739$, $p< .001$**, see figure 4.), stimuli types ($F(2,96) = 6.880$, $p< .01$, see figure 5.), however, there is no significant interaction between test condition and stimuli types.

4.1.1 Test Conditions

As expected, the reaction time in simulated cognitive load condition, simulated optic flow condition, and simulated driving condition are significantly higher ($p< .001$**) than baseline. Simulated optic flow condition and simulated driving condition also significantly higher ($p< .001$) than simulated cognitive load condition. While the effect was less significant ($p< .05$) between simulated optic flow condition and simulated driving condition.

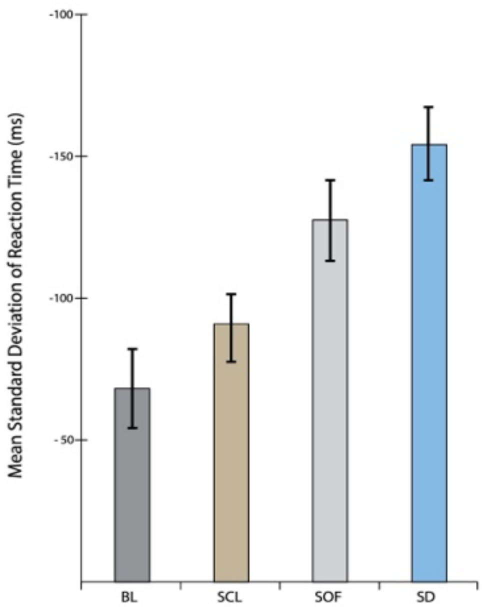

Figure 4. Mean Standard Deviation of Reaction time by test conditions. (1) Baseline Condition (BL). (2) Simulated Cognitive Load Condition (SCL). (3) Simulated Optic Flow Condition (SOF). (4) Simulated Driving Condition (SD)

4.1.2 Stimuli type

In figure 5, blinking stimuli is rated the fastest reaction time in comparison to all stimuli types and the difference is significant between static stimuli ($p < .001$) and between moving stimuli ($p < .05$). The similar result shows in simulated driving condition where blinking stimuli also show the fastest reaction time with significant difference to static stimuli ($p < .05$) and moving stimuli ($p < .01$), see figure 6.

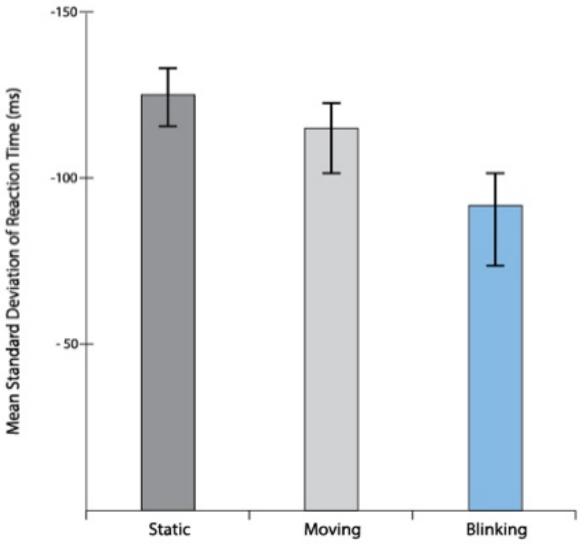

Figure 5. Mean Standard Deviation of Reaction time by stimuli type

The interesting result is, in baseline condition there is no significant difference between blinking stimuli and moving stimuli while in simulated driving condition the reaction time is significantly higher ($p < .01$) between blinking stimuli and moving stimuli.

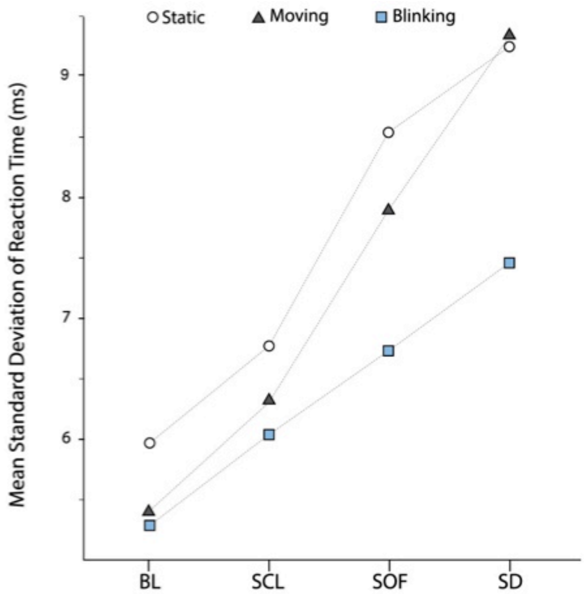

Figure 6. Mean reaction time of stimuli in difference test conditions.

4.2 Task Completion

The results showed a significant main effect of test conditions (F(3,96) = 2.793, p< .05), stimuli types (F(2,96) = 8.756, p< .001), however, there is no significant interaction between test condition and stimuli types.

4.2.1 Test Condition

A pairwise comparison analysis revealed no difference in task completion rate between baseline condition and simulated cognitive load condition. Only marginally difference between simulated optic flow condition and simulated driving condition (p< .05). There is no significant difference between simulated optic flow condition and simulated driving condition. The percent participants completed the task (detect stimuli in peripheral vision) in baseline condition is 98.9% compare to 89.58% in simulated driving condition.

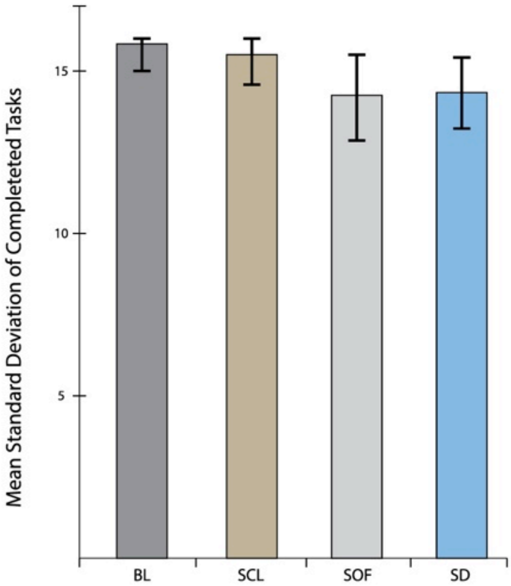

Figure 7. Mean completed task in each test conditions.

4.2.2 Stimuli type

Overall, participants can detect significant fewer static stimuli than moving stimuli (p< .05) as well as blinking stimuli (p< .001). While moving stimuli and blinking stimuli show no significantly difference, see figure 8.

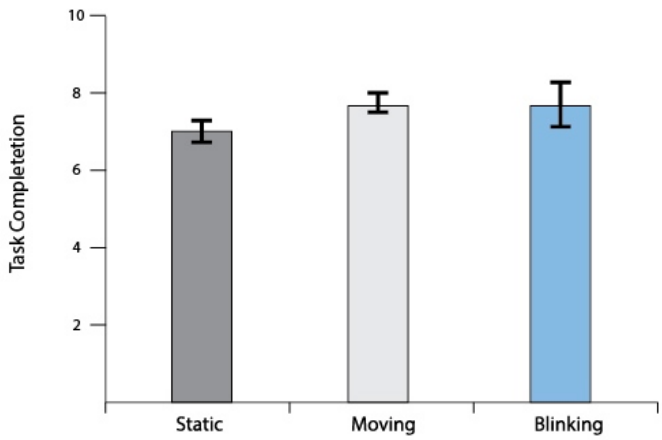

Figure 8. The graph shows task completed by stimuli.

In figure 9, all stimuli were equally detected in baseline condition and simulated cognitive load condition. However, detection rate of static stimuli drop significantly compared to moving stimuli ($p < .01$) and blinking stimuli ($p < .05$) in condition with simulated optic flow. While, moving stimuli and blinking stimuli show no difference in all conditions.

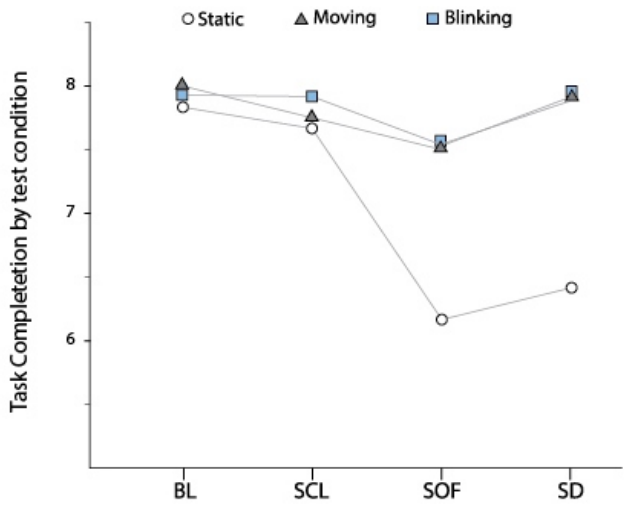

Figure 9. Task completion of stimuli in the test conditions.

5. Discussion

The goal of this experiment is to explore the possibility of presenting information in driver peripheral vision and provide driver with more effective and safe interaction.

We found that it take significantly longer time to detect stimuli present in peripheral vision in driving environment, this mean information that require immediate reaction might not be suit for peripheral vision interface. Nevertheless, this is to a large extent depending on stimuli type. As blinking stimuli overall performance is significantly faster than moving and static stimuli, especially in simulated driving condition where the difference is clearly shown in figure 5. Interestingly, in baseline condition moving stimuli performance is no difference to blinking stimuli whilst in simulated driving condition the difference became significant. One explanation is that moving stimuli blend into background from optic flow therefore makes it harder to detect.

Task-completion is one interesting result show participants successfully detect stimuli 89.6% in simulated condition compared to 98.9% in baseline condition. This again largely depends on stimuli type, as the result shown in figure 7 static stimuli is harder to detect in condition with optic flow.

Reaction time and task-completion results point in the same direction at “non-critical information” which is not require immediate reaction or not critical to safety if driver fail to detect. This also match participants’ feedback from our prototyping session in pilot study that they feel more comfortable to voluntarily “pull” information present in peripheral vision because they can control the amount of information and timing. In contrast, “push” information which likely to distract attention from driving.

However, stimuli used in this experiment were limited to only 3 types further investigate with larger variety and properties (e.g. moving speed, blinking speed, size) could reveal more interesting results.

6. Conclusion

Even though driving task requires a lot of visual and cognitive attention, modern in-car information displays are attempting to display more and more information. As a result, driving scene becomes cluttered and distracting. In this research we proposed the possibility of displaying information in driver's peripheral vision, providing necessary information for driver while allowing driver to keep attention on the road.

The experiment findings show that it is possible to perceive information using peripheral vision in driving environment. However, driver's perception of information on peripheral vision interface is reduced due to cognitive load and optic flow generated in driving. Driver's perception varies depending on type of visual stimuli used to display information. Based on the results, we propose using peripheral vision interface to display non-critical driving related information to driver without risk of interfering with driving mechanism.

In future development of this concept, there are challenges that need to be considered. i) Only low-level information can be perceived in peripheral vision. Considering this limitation, information should be carefully designed to ensure information delivery. ii) Driver's attention is critical to driving. The information displayed in peripheral vision should not at any cost negatively interfere with performance of driving task.

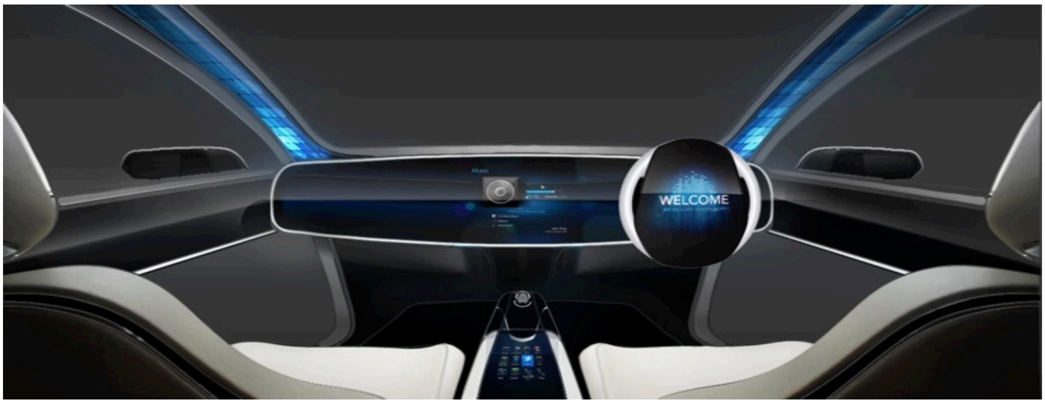

Figure 10. An illustration of an idea of utilizing peripheral vision display in A-pillar of car.

In regard to the mentioned challenges some example of using peripheral vision interface can be envisioned.

1.) Speedometer - Speed of the car can be display in peripheral vision by positioning of a graphic indicator in relation to A-pillar.

2.) Supplementary Navigation interface - Looking at navigation screen can be distracting [15]. A supplementary navigation interfaces could help driver focus on the road by providing path-finding indication.

3.) Supplementary Warning System - Despite the fact that pushing visual information into driver's peripheral vision can cause distraction, in some cases, for example collision warning system, this can effectively be used to draw driver attention. Combine with audio and/or haptic information could render the warning even more effective.

4.) Ambient Information Interface - Driver can voluntary see the information in peripheral vision interface but when returning attention back to the road, information in peripheral vision blends into background. The information in peripheral vision still can be perceived subliminally. Thus, there is a potential to use peripheral vision interface to create ambient information and subliminally influence driving behavior [26].

What kind of information is appropriate to display in peripheral vision and the costs of attention need further examination. In future research we intend to explore a larger variety of graphical elements and their informative properties as well as their effect on distraction.

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