# Dynamic Speedometer: Dashboard Redesign to Discourage Drivers from Speeding

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## ABSTRACT

We apply HCI design principles to redesign the dashboard of the automobile to address the problem of speeding. We prototyped and evaluated a new speedometer designed with the explicit intention of changing drivers' speeding behavior. Our user-tests show that displaying the current speed limit as part of the speedometer visualization (i.e. the dynamic speedometer) results in safer driving behavior. Designing with the intent to achieve a particular behavior can be an effective approach for increasing the safety of mission-critical systems. This is an area in which HCI designers can have a significant impact.

### Author Keywords

Dynamic Speedometer, Automobile Interfaces, Automobile Cockpit Design, Persuasive Technology, Captology, Speeding, Designing for Safety, Mission-Critical Systems.

### ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## INTRODUCTION

Speeding increases the risk of a crash and the severity of the crash. Speeding was a contributing factor in 31% of all fatal motor vehicle crashes in the United States in 2003, resulting in 13,380 lives lost and $40.4 billion – $76,865 per minute – in associated costs [1]. A 1 mph increase in average speed results in a 5% increase in injury accidents [2]. Drivers often do not know the speed limit – 19% of drivers either do not know the speed limit, their own speed or if they were within the speed limit [3].

We surveyed 25 drivers about their awareness of the speed-limit. 84% of drivers reported that they are sometimes unaware of the current speed limit. 40% reported that they are sometimes surprised that the speed limit is different from what they thought. 68% of drivers reported that they sometimes catch themselves inadvertently exceeding their desired speed. We found the disconnect between speeding related crashes and drivers' awareness of the speed limit alarming.

Speeding is a problem related to driver behavior. If we hope to save lives, reduce the number of accidents, associated costs, or even just the number of speeding tickets, we need to affect a change in the drivers' behavior by making them more aware of the speed limit and assisting them in realizing when they are speeding. Our goal for this research was to redesign the automobile dashboard to discourage drivers from speeding by appealing to their self-motivation to drive safely.

## RELATED WORK

The most common example of a system that encourages drivers to slow down and follow the speed limit is the Speed Monitoring Awareness and Radar Trailer (SMART). The SMART speed trailer shows the driver the posted speed limit and the driver's current speed. If the driver is driving faster than the posted speed limit, the sign flashes in order to attract the driver's attention. The speed trailer causes drivers to slow down, albeit, temporarily [4, 5].

There is active research in the area of Behavior-Based Safety (BBS) sponsored by the Federal Motor Carrier Safety Administration [6, 7]. BBS focuses on performance monitoring and providing feedback to the driver. To the best of our knowledge, no BBS system has explicitly addressed the problem of speeding behavior.

The Intelligent Speed Adaptation project [8] comes closest to the work we present here by presenting drivers with the current speed limit information. However, their visualization was not integrated as part of the speedometer display and showed the speed limit on a separate display.

## DESIGN DEVELOPMENT

We applied the principles of persuasive technology [9] to brainstorm 20 different approaches[1] that could be used to achieve this behavior change. The domains covered in the idea space included foregrounding of information to increase awareness, visual and audio notification (Figure 1),


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[1] For a full report on the ideas developed please see the project website at http://hci.stanford.edu/research/speedometer.html

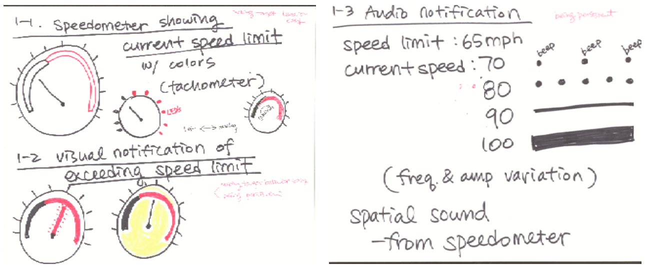


**Figure 1: Ideation sketch for the dynamic speedometer which displays the current speed limit as part of the speedometer visualization. In addition, visual and audio notification cues may be used to alert the driver when he/she exceeds the limit by an arbitrary threshold over the speed limit.**

providing haptic feedback (accentuating real-world effects), reputation systems (publicizing driver reputation / behavior), offering trade-offs (gas consumption, speeding tickets), rewards and incentives (insurance incentives for monitoring), and playing on emotions.

Figure 1 shows the ideation sketches for the approach we chose to prototype and evaluate after considering the level of annoyance and the effectiveness of the ideas.

## DYNAMIC SPEEDOMETER

We designed the dynamic speedometer using a visualization similar to that of the tachometer – visually distinguishing the regions of the speedometer which are higher than the current speed limit (Figure 2). As the speed limit changes, the visualization on the display updates accordingly. This relieves the driver of the task of waiting/searching for a speed limit sign on the road to determine the current speed limit in effect.

The dynamic speedometer can be instrumented to provide visual cues such as making the speedometer needle glow, changing the color / luminosity of the over-the-speed limit region of the speedometer, or changing the background of the dial itself when the driver exceeds a certain threshold over the speed limit. Audio notifications such as beeps of varying frequency and amplitude may also be used.

Displaying the current speed limit as an integral part of the speedometer visualization is a key element of the design of our dynamic speedometer. 50% of drivers determine their speed by looking at the speedometer [3]. Furthermore, the above design represents a natural mapping since the speed limit information is presented on the speedometer – where it makes the most sense.

It is our expectation that making drivers constantly – yet subtly – aware of the speed limit while driving will have an impact on the driver's behavior and will reduce the instances of speeding.

### Technical Feasibility

The dynamic speedometer relies on the automobile knowing the current speed limit at any point in time and space. This is not too far in the future, considering:


**Figure 2: a) Standard speedometer, b) Dynamic speedometer showing 25 mph speed limit, c) Dynamic speedometer showing 40 mph speed limit**

- Companies that provide GPS digital map databases have information on speed restriction[2], which can be included in vehicle's on-board database.
- Construction zones or other exceptions with a new speed limit can be "beaconed" to provide the new information by using the DSRC[3] spectrum or a system such as the TMC[4].

## PROTOTYPING

We developed two prototypes of the dynamic speedometer – a simulation-based prototype and an in-car prototype.

The simulation prototype implemented the visualization component of the dynamic speedometer (i.e. no audio/visual notification cues). The prototype was developed by modifying a driving simulation environment[5]. We modified the cars in the driving simulator to include a dynamic speedometer and added Wizard-of-Oz controls to set the current speed limit used for the visualization in the dynamic speedometer. Figure 3 shows the simulator immediately before and after driving past a speed limit sign. The dynamic speedometer (bottom right) updates to indicate the change in speed limit from 40 mph to 25 mph.

The in-car prototype uses the OBD-II (On Board Diagnostics) interface which is present in all new cars sold in the US after 1996. The ELM-323 chip translates the OBD-II interface to an RS-232 serial interface. We used a PocketPC/laptop computer connected to the ELM-interface box in order to read the vehicle velocity in real-time from the OBD-II and display visualization of the dynamic speedometer (Figure 4).

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[2] NAVTEQ's database offers not just road geometry, but up to 160 attributes such as addresses, signage, and speed restrictions. (http://www.navteq.com/data/database_about_ENG_HTML.html)

[3] DSRC is a block of spectrum in the 5.850 to 5.925 GHz band allocated by US FCC to enhance the safety and the productivity of the transportation system (http://wireless.fcc.gov/services/its/dsrc/)

[4] The Traffic Message Channel (TMC) is a specific application of the FM Radio Data System (RDS) used for broadcasting real-time traffic and weather information (http://www.tmcforum.com/tmc/what_is.htm)

[5] Racer is a free cross-platform car simulation project (for non-commercial use), using professional car physics papers to achieve a realistic feeling.(http://www.racer.nl)

**Figure 3: The dynamic speedometer shown on the right of the screen changes from 40 mph to 25 mph as soon as the driver goes past a speed limit sign in the driving simulator.**


**Figure 4 - In-car prototype showing the OBD-II interface and the visualization used for the dynamic speedometer.**

## EVALUATION

To evaluate the effectiveness of the dynamic speedometer we conducted user-tests with our simulation prototype. The following hypotheses were posed:

H1. (Awareness) Subjects may understand the functionality of the dynamic speedometer without explanation.

H2. (Subconscious Effect) There may be a subconscious effect of the dynamic speedometer on the driving behavior of drivers who are not aware of its functionality.

H3. (Unintentional Speeding) The dynamic speedometer may help reduce unintentional speeding.

H4. (Persuasive Efficacy) The dynamic speedometer may change the driving behavior by reducing speeding.

### Method

*Participants*: 25 university students participated in our study (14 males, 11 females). The subjects' age ranged from 19 to 32 years old. A majority of the subjects had been driving for 4-7 years and currently drove between 2-4 days a week. 50% of the subjects reported having at least one traffic violation or accident. 55% of the subjects had prior experience with driving games.

*Setup:* The simulation prototype was used for conducting the user-tests. We modified an existing car in the simulator to add the dynamic speedometer visualization. The driving route was modified to include traffic road signs such as speed limit signs, stop signs and direction signs. Since the experiment was designed to test speeding behavior, we did not include any additional traffic or hazards on the route. However, the route did contain challenging driving conditions (turns, negotiating stop signs and curves). The route contained three changes in the speed limit, starting with an unknown speed area, changing to a 25 mph zone, then a 40 mph zone followed by a 25 mph zone.

*Procedure*: Subjects were told that the user-study was designed to test the feasibility of using a simulation environment for a DMV (Department of Motor Vehicles) test[6]. They were instructed to drive "normally" observing all traffic rules and regulations. Subjects were allowed to complete a practice round on the simulator for them to become familiar with the route, driving conditions, the feel of the steering wheel, pedals and the handling of the car.

For part 1 of the study (25 subjects), subjects were asked to drive one round in a car equipped with a conventional speedometer (green) and one round in a car equipped with a dynamic speedometer (blue). Subjects were not told about any differences between the two cars, other than the color. In order to counter-balance, we alternated which car the subjects drove first. After completing two rounds, the subjects were asked to fill out a survey.

For part 2 of the study we explained the functionality of the dynamic speedometer to a subset of 14 subjects and asked them to drive the same route in both cars. After completing part 2, the subjects filled out a short survey. Each run was recorded in order to extract speed data from the simulator.

### Results

The maximum speed a subject reached during the second 25 mph zone (chosen from the middle of the course) was used as a measure of their driving behavior. The maximum speed is representative of how much the subject is willing to exceed the posted speed limit. The average speed is not a good measure since it is affected by the individual's negotiation of turns, curves, stop signs and crashes. Furthermore, even though a subject's average speed may be below the posted speed limit there may be instances when the subject exceeded the speed limit. Results were analyzed as a paired sample 2-tailed *t*-test as shown in Figure 5.

**H1. 36% of the subjects understood the functionality of the speedometer without explanation.** After completing part 1 of the study, subjects were asked if they noticed any difference between the two vehicles. 16 out of the 25 (64%) users noticed some difference. 9 subjects (36%) correctly identified the difference and were able to explain the functionality of the dynamic speedometer.

**H2. Subjects that did not understand the dynamic speedometer still drove slightly slower with the dynamic speedometer than with the conventional speedometer (3 mph difference).** For the 16 subjects that did not

[6] The DMV reference was used to encourage subjects to take the driving seriously and not treat it as a game (based on our pilot study).

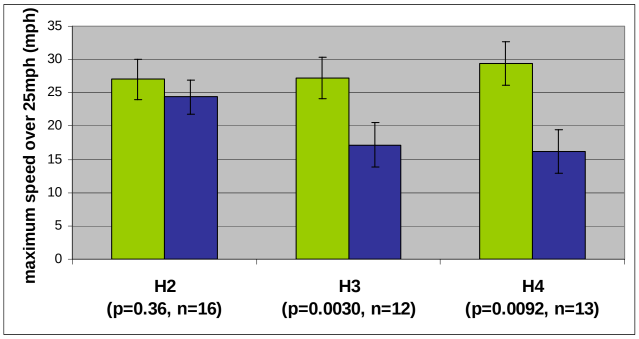


**Figure 5 – H2. Drivers who are unaware of the DS still drive 3 mph slower with the DS than without; H3. Unintentional speeding is reduced in the case of drivers with the DS; H4. DS results in safer driving behavior by reducing the maximum speed drivers drive at.**

understand the functionality of the dynamic speedometer in part 1 of the study, we compared their maximum speed of the run with dynamic speedometer and the conventional speedometer. The maximum speed for these subjects was slightly lower (by 3 mph) for runs using the dynamic speedometer, however, the difference is not statistically significant. ($p$=0.091, n=16).

**H3. The dynamic speedometer assists drivers in reducing instances of unintentional speeding (10 mph difference).** In part 2 of the study (after the subjects were aware of the functionality of the dynamic speedometer and aware that the study is testing the new speedometer) the subjects attempted to stay under the speed limit. The maximum speed with the dynamic speedometer was significantly lower ($p$=0.0030, n=12) than the maximum speed with a conventional speedometer by 10 mph.

**H4. The dynamic speedometer has a significant effect on persuading subjects to drive slower (13 mph difference).** For H4 we compared the maximum speed of the subjects in the conventional speedometer in part 1 with their maximum speed with the dynamic speedometer in part 2 of the study Subjects were aware of the functionality of the DS in part 2; we were careful to use the data of only those subjects who drove with the conventional speedometer first in part 1 in order ensure subjects didn't know we were observing speeding behavior). The maximum speed with the dynamic speedometer was significantly lower ($p$=0.0092, n=13) with a difference of 13 mph.

## CONCLUSION

Within the limits of error for tests conducted in a simulator, our results indicate that showing the current speed limit as part of the speedometer visualization can be an effective approach for discouraging drivers from speeding. If our results generalize to real-world driving situations, the dynamic speedometer can have a significant real-world impact in reducing the number of fatalities, accidents and costs[7].

Designing interfaces for mission critical applications (such as driving) with explicit attention towards encouraging specific safety-related behavior can have a significant impact on reducing the number of accidents. As HCI designers this represents an opportunity for us to use design principles to elicit higher levels of safety by designing for the desired user-behavior.

## FUTURE WORK

Encouraged by our results from the simulation studies, we will be conducting further evaluation with the in-car prototype. The in-car prototype has been enhanced to include audio notification cues to warn drivers when they exceed the speed limit by a certain threshold. Our future studies will test different forms of visual and audio notification methods in order to alert drivers as well as consider longitudinal effects of the dynamic speedometer.


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[7] Our estimates show approximately 1300 fewer fatalities, a 10% reduction in accidents and $4 billion in associated cost savings.