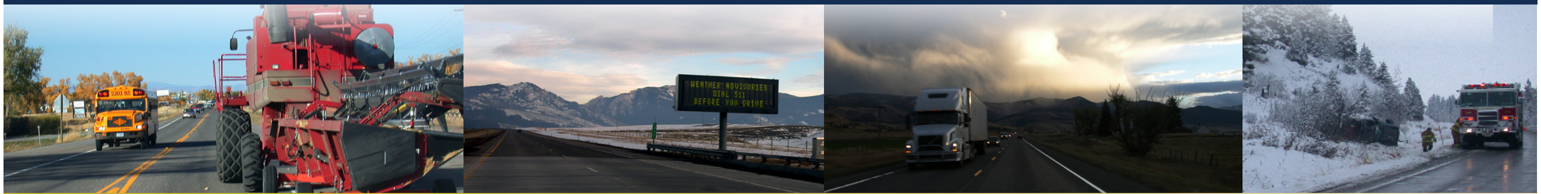


WTI Human Factors Research Facilities

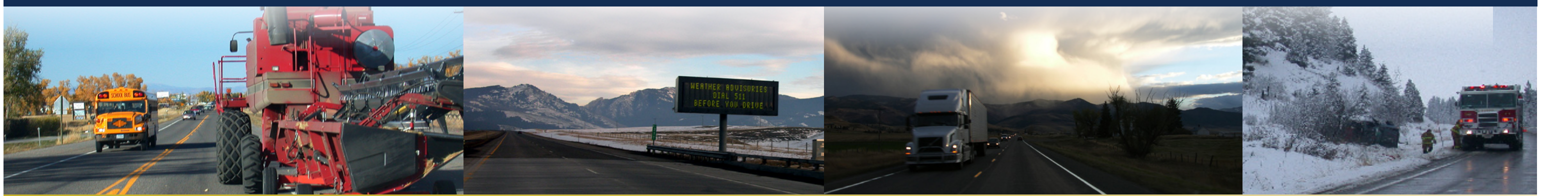
Driving Simulator Optimization: Evaluating Delays in Advanced Driving Simulator

WTI has embarked on a systematic program to optimize and tune its advanced driving simulator so that it provides a realistic research and testing environment capable of yielding results that are transferable to the real world. This tuning and optimization work was completed by Dr. Erwin R. Boer (Entropy Control Inc.) who is an international expert in modeling and optimizing perceptual cues in driving simulators. This involved comparing the response of the simulator including its motion base to driver input (steering, throttle, and braking) with the response of an instrumented vehicle that matched the type of vehicle used to develop the simulator dynamic model (Chevrolet Impala). This press release summarizes the transport delay component of this systematic process completed with the WTI Advanced Driving Simulator (WADS).

For accurate and stable control of any system it is necessary to have minimal delay in the system. Humans are used to compensating for some delays through preview and internal models of the dynamics of the system they control. However, there is a limit to what they can compensate for. If the delay is too long so-called "pilot-induced-oscillations" will occur. In driving this leads to unstable car following and especially unstable lane keeping. Ideally the transport delays should be minimal but in simulators they are unavoidable. Transport delays around 100ms are acceptable under most normal driving conditions but much larger and performance in the simulator will start to show differences from performance in the real world especially in terms of the ability to quickly stabilize evasive maneuvers or stably turn at intersections at normal speeds. Minimal transport delays are critical to being able to drive at high speeds and to stabilize rapid steering control actions. A tradeoff exists between good feedback and transport delays in that more salient multi-modal feedback affords slightly longer delays for the same driving stability. In WADS we strive to optimize response transport delays as well as multi-model cue saliency.

The transport delay in the three primary display modalities of visual, motion, and sound rendering were measured in the WTI driving simulator. To assure accurate measurement, the following procedure was adopted. The first goal was to be able to record activation and the response in each channel on the same computer. A laptop with a PCMCIA National Instruments A/D board was used. The voltage of the brake pedal potentiometer was used, using SimCreator, to activate a movement in the motion base, a shift in the car position, and generation of a sound. The Real Time Technologies SimCreator software offers full access to and control over all modules and signals in the entire simulation.

A 1-DOF linear accelerometer was mounted on the motion base to capture the commanded (i.e. brake voltage triggered) sudden vertical upward or downward movement. When the brake voltage passed the threshold the motion base was jolted up or down depending on whether the voltage increased or decreased through the threshold respectively. A sound was activated or deactivated at the same brake threshold. The sound was picked up directly from the voltage on the speaker; note that the time signal is that of a high frequency amplitude change. The car was visually jumped in the scene such that a white road marking moved on the screen. A photo sensitive resistor was placed in front of the projection screen so that it "saw" white or black depending on the car position in the virtual world; the voltage across the resistor was also recorded on one of the analog channels. The brake pedal was moved up and down slowly three times resulting in three measurements for activation and deactivation



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The calculated transport delays in each of the three display channels are shown in Figure 1. The asterisks show the individual measurements per trigger while the squares show the median transport delay. For each display mode, activation and deactivation are separated as indicated along the abscissa.

The transport delay for the motion base is shortest at around 70ms. The visual display system, with its long display pipeline has a transport delay of about 130ms (i.e. render image, send image to projector, projector takes a few frames of processing before it projects the image). The visual and motion rendering transport delays are not affected by direction of motion of the car. The audio system has a long transport delay of about a 135ms when activating a sound most likely because a wav file is loaded. Deactivating a sound is much faster at about 60ms probably because internally the audio processor simply stops outputting the wav file.

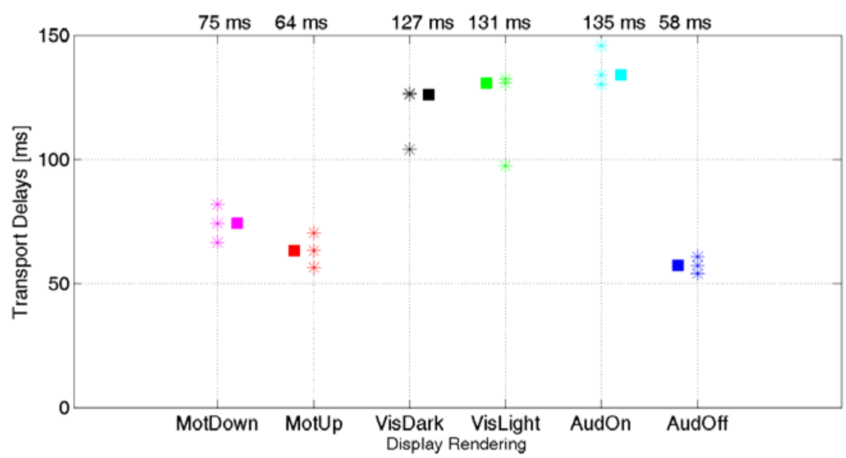

Figure 1. Transport delays for motion, visual and audio display activation. The individual measurements are shown in asterisks and the median in squares. See text for more details.

These motion and auditory transport delays are reasonable as they are well within the range of what humans can compensate for, but the visual transport delay is higher than what is generally considered acceptable. It should be noted that most of the work on acceptable transport delays is performed in fixed base driving simulators. While the visual transport delay should ideally be lowered in the WTI simulator, drivers appear able to control the vehicle in a highly stable fashion in rapid maneuvers without any training indicating that the simulator behaves as they expect. The fact that the motion base transport delay is short is highly beneficial for the driver because this allows for a rapid feedback of changes in vehicle states to changes in steering angles and pedal positions thereby reducing the importance of the slow human visual system to assess vehicle response to control.

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