

Development of the Enhanced Peripheral Detection Task: A Surrogate Test for Driver Distraction

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ABSTRACT

Up to now, there is no standard methodology that addresses how driver distraction is affected by perceptual demand and working memory demand - aside from visual allocation. In 2009, the Peripheral Detection Task (PDT) became a NHTSA recommended measure for driver distraction [1]. Then the PDT task was renamed as the Detection Response Task (DRT) because the International Standards Organization (ISO) has identified this task as a potential method for assessing selective attention in detection of visual, auditory, tactile and haptic events while driving. The DRT is also under consideration for adoption as an ISO standard surrogate test for driver performance for new telematics designs. The Wayne State University (WSU) driver imaging group [2, 3] improved the PDT and created the Enhanced Peripheral Detection Task I (EPDT-I) [4]. The EPDT-I is composed of a simple visual event detection task and a video of a real-world driving scene. It is simple, easy to learn and run, and convenient for use in the lab, road, or brain imaging environments [5]. With the success of EPDT-I, the WSU driver imaging group further developed the Enhanced Peripheral Detection Task-II (EPDT-II; also called "Wayne State Enhanced DRT" or "Wayne State EDRT") by adding a number of features to engage participants more with the primary driving task and to assess attentional processes in greater detail. This research also compared performance in the EPDT-II at our lab, EEG, and neuroimaging environments to the open road for validation purposes [6]. In conclusion, the Wayne State EDRT provides a sensitive and up-to-date surrogate test for measuring driver distraction in the lab and on the road.

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INTRODUCTION

Driving is commonly referred to as a single task. However, driving is really complex multitasking, involving sensory, motor, and higher-level cognitive components. These play out over different levels of functional hierarchy, on different timescales, and often concurrently [7, 8]. Multitasking experiments give researchers a unique platform for viewing attention use in one of its most natural forms - in a multi-sensory processing environment. By seeing how the brain allocates resources for a secondary task (such as cell phone conversations) while engaged in the primary driving task, we can better understand the shared and differential neural networks for attention, distraction, speech processing, memory, executive functions, and general perceptual processing.

Driver distraction contribution to a causative factor in crashes varies widely in different crash studies. The 100-car naturalistic driving study showed only 3% (2 crashes out of 69) with cognitive distraction [9]. Other naturalistic driving studies conducted at VTTI have a similarly low involvement

of cognitive distraction [10, 11]. On the other hand, some simulator studies claim that cellular conversation, a major source of cognitive distraction, causes worse driver performance than drunk driving [12]. The National Safety Council [13] estimated up to 50% of "look but fail to see" errors for missing information in their driving environment, according to a presentation by Strayer [14]. Earlier real world crash studies by Treat et al. (1979) [15] and Treat (1980) [16] indicated that about 25% of all crashes involving drivers over 65, and about 12% for drivers younger than 65 who crashed were due to cognitive distraction. However, in the recent case-crossover studies of cognitive distraction while driving [17, 18], the control of bias becomes an important factor in valid estimation of the risk factors for crashes caused by cognitive distraction. A concurrent paper [19] in this SAE issue provides in-depth scientific definitions and analyses of the possible underlying attentional mechanisms for cognitive distraction, as well as a re-assessment of the contribution of cognitive distraction to crash risks.

As for assessment of an individual's driver distraction, there is still no standard methodology that addresses how driver distraction is affected by perceptual demand and working memory demand - aside from the visual allocation. For the first time, the Peripheral Detection Task (PDT) might become a NHTSA recommended measure for driver distraction [1]. In addition, the PDT task was renamed as the Detection Response Task (DRT) in order for the International Standards Organization (ISO) to identify this DRT task as a potential method for assessing selective attention in object event detection across various modalities while driving, such as visual, auditory, tactile and haptic events. Since 2009, the DRT has been under consideration for adoption as an ISO standard surrogate test for driver performance for new telematics designs.

According to the ISO TC22/SC13/WG8, "The DRT method is based on a simple detection-response task where participants respond to relatively frequent artificial stimuli presented with some temporal uncertainty. Detection performance, measured in terms of response time and hit rate, represents the degree to which selective attention is affected by the secondary task under evaluation." The DRT method may be implemented in several different ways in terms of stimulus presentation modality (visual or tactile) and in terms of whether the DRT is performed while driving (dynamic) or not (static), depending on the purpose of the study.

Many investigations into human performance involve the use of driving simulators. What is often lacking is a validation of these simulators using on-road data. In a series of studies, we investigated the effects of conversation on multitasking performance in a validated driving workload paradigm [2, 3, 6], an Enhanced Peripheral Detection Task (EPDT). Behavioral validation studies for predicting event detection on the road from lab data have recently shown excellent results, with correlations of 0.9 for brake response times to visual events [6]. Validation is especially important given the cognitive complexity of real-world driving tasks and the public policy implications of driver performance research. The WSU driver imaging group is the first to apply neuroimaging measures to a validated driving simulation paradigm.

The WSU driver imaging group created the Enhanced Peripheral Detection Task I (EPDT-I) [4] and EPDT-II [2, 3] that provide additional features to the original PDT. These EPDTs are composed of a simple visual event detection task and a video of a real-world driving scene. They are simple, easy to learn and run, and convenient for use in the lab, road, or brain imaging environments. The WSU driver imaging group does not only add a number of features to engage participants more with the primary driving task, but also provides a window to look into more detailed components of attentional processes in driver performance, as well as neural processing networks in the brain. The detection performance of the EPDT-II in the lab has been validated by open road driving. Results of statistical analysis on driver performance

indicated high correlations for detection response times from the lab to the road [6].

METHODS

ENHANCED PERIPHERAL DETECTION TEST-I (EPDT-I)

The driving distraction study by the WSU driving imaging group [2,3] used the Enhanced Peripheral Detection Task-I (EPDT-I) [4], comprised of a simple visual event detection task and a video of a real-world driving scene (Fig. 1). The red visual events occurred one at the time in a random order at the central lower position or the left peripheral position. Visual event detection and viewing of the natural driving video occur throughout the task. It was designed to be simple, easy to learn and run, and convenient for use in the lab, road, or brain imaging environments [5].



Figure 1. Participants were instructed to focus on the “primary driving” task (watching the driving video while responding to the lights), while engaging in a secondary task, such as simulated cellular conversations. The visual event detections and viewing of the natural driving video occurred throughout the experiment.

The EPDT-I was designed to be conducted with secondary tasks to assess interference, and the secondary task used in this study was a simulated hands-free cellular phone conversation. In this research, we utilized the EPDT-I with a secondary conversation task while recording neural responses, using functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG).

In this study, the EPDT-I employed a personal computer, monitor, and a driving simulator foot pedal. During the behavioral study, the subject was instructed to focus their attention on activities occurring in a video of a driving scene recorded from a moving vehicle and to respond to target visual events, while engaging in a secondary task (e.g., simulated cellular conversations). The primary driving task required subjects to view the driving scene and depress a

pedal with one's foot in response to small red circles randomly presented below or to the left of the driving scene at frequent and varying time intervals. These targets appeared every four to six seconds, for a duration of 3.5 seconds, unless a participant responded, at which point they disappeared. The same visual event duration and interval were used in previous study [4]. Latencies to respond to the circles, as well as failures to respond to the circles within 3.5 seconds, were recorded by the software presenting the video and circle targets. Participants were instructed to treat this task as a simulation of driving a vehicle.

As for the secondary task, subjects were told to press a mouse button in response to the sound of a ringing phone and then to answer simple pre-recorded questions delivered over a speaker, such as, "Could you tell me your birth date?" This condition included answering the cellular call by pressing a button, carrying on a hands-free conversation, viewing the driving video, and pressing a pedal in response to the appearance of red circles.

Accuracy and reaction time data are collected and analyzed. The EPDT-I was successfully administrated while recording neural responses with both functional MRI and magnetoencephalography (MEG) with secondary conversation tasks [2, 3]

ENHANCED PERIPHERAL DETECTION TEST-II (EPDT-II)

With the success of EPDT-I, the WSU driver imaging group continued to develop the Enhanced Peripheral Detection Task-II (EPDT-II) by adding a number of features to EPDT-I to better engage participants with the primary driving task and to assess attentional processes at a greater level of detail [6, 20, 21, 22, 23, 24]. Like EPDT-I, it is designed to be simple to learn, simple to run, and convenient for use in neuroimaging environments. The EPDT-II is still at its core based on event detection, but instead of only presenting red circle targets, the task also presents green circle non-targets, to which they are instructed not to respond. The visual targets lasted for 2.5 seconds until the participant responded with a stimulus interval of every 3-5 seconds. The green targets provide a means to measure subjects' abilities to inhibit a response, which other research has indicated reduced attention to the primary task. The EPDT-II paradigm allows sufficient target and non-target events that provide additional events in response to the red lights, which help improve statistical power in investigation of subcomponents of cognitive attention and distraction. Besides watching a driving video as in EPDT-I, in EPDT-II participants are asked to keep tracking the lane that the vehicle is traveling by moving an on-screen arrow as close as possible to the center of the lane, providing additional driving metrics. We have also successfully replicated the design during in-vehicle road-testing and established cross-site validity for its principle measures. It is a flexible tool, permitting simple modification to include all varieties of demand.

The EPDT-II provides a platform to explore the nature of the event detection performance associated with the secondary task as well as the ability to inhibit responses to non-targets, a necessary and key component to investigating driver distraction. Contrasting accuracy and response time performance of non-targets to targets permits researchers to explore the nature of the demand associated with the secondary task as well as the ability to inhibit responses to stimuli, which can also be important for driving safety. Therefore, EPDT-II could be a powerful tool for making inferences about cognitive processes in the attention networks.

In our research, while performing the event detection task during driving, participants were also asked to respond to simulated hands-free incoming calls, which could involve pre-recorded messages with two speech tones (i.e., neutral vs. angry speech tones). For example, a 9-minute task, consisting of event detection, video watching and lane tracking, was divided into experimental conditions of single tasking (the EPDT-II alone) and multi-tasking (the EPDT-II plus hands-free cell phone conversations). This method allows for behavioral contrasts between single- and multi-tasking conditions. While our work has focused on evaluation of the impact of cellular conversations, additional secondary tasks (such as audio, visual, manual, tactile, haptic, emotional or cognitive tasks) can be readily incorporated into this EPDT-II design with minimal adjustment. Our research also compared participants' performance in the EPDT-II at numerous sites, including our WSU lab, neuroimaging environments, and on the road (see below), for validation purposes. By comparing response times, errors, and lane tracking, task performance can ensure the validity of this task across testing sites and across multiple demand task conditions [6].



Figure 2. Enhanced Peripheral Detection Test-II (also called Wayne State EDRT) design