Proceedings Paper:

Hibberd, DL, Jamson, SL and Carsten, OMJ (2012) The existence and impact of the Psychological Refractory Period effect in the driving environment. In: de Waard, D, Merat, N, Jamson, AH, Barnard, Y and Carsten, OMJ, (eds.) Human Factors of Systems and Technology. Human Factors and Ergonomics Society European Chapter, 19-21 Oct 2011, Leeds, UK. Shaker Publishing , 249 - 262. ISBN 978-90-423-0416-1

The existence and impact of the Psychological Refractory Period effect in the driving environment

Daryl Hibberd, Samantha Jamson, & Oliver Carsten
Institute for Transport Studies, University of Leeds
UK

Abstract

Driver distraction from in-vehicle tasks can have negative impacts on longitudinal and lateral vehicle control and brake reaction time. The distraction problem is well-established in the literature, and is increasing due to advances in the functionality, availability, and number of in-vehicle systems. One approach to a solution is managing in-vehicle task presentation to reduce associated distraction. This paper reports a driving simulator experiment, designed to investigate the existence of the Psychological Refractory Period in the driving context and its effect on driver performance. The PRP effect is observed when a surrogate in-vehicle task is presented in close temporal proximity to a lead vehicle braking event. Brake responses are subject to an increasing delay as the interval to an in-vehicle task is decreased. In-vehicle task modality modulates this effect. The impact of the PRP effect on driving performance is quantified and recommendations are made for reducing the driver distraction problem through the management of in-vehicle task timing and modality. The potential impact of these results on driver safety is discussed.

Introduction

Driver distraction

Driver distraction due to interaction with systems inside the vehicle has been the subject of research for nearly half a century (Brown, 1965) and has recently become a topical issue at both the academic and governmental level. Driver distraction is estimated to play a contributory role in approximately 25% of vehicle crashes (Stutts et al., 2001), with in-vehicle systems proving to be a prominent source of distraction (Klauer et al., 2006, Neale et al., 2005). The exact contribution of driver distraction to unsafe driving behaviours is difficult to quantify given widespread inconsistencies in the precise definition of the construct (Regan et al., 2011) and the reporting protocols used following vehicle accidents. Furthermore, the safety costs of distracted driving are likely to be under-estimated in the current statistics (Stutts et al., 2001). However, the negative impact of in-vehicle driver distraction on driving performance is indisputable, with examples of degradation of longitudinal and lateral control (Horrey & Lesch, 2009, Lansdown et al., 2004), reduced event detection

In D. de Waard, N. Merat, A.H. Jamson, Y. Barnard, and O.M.J. Carsten (Eds.) (2012). *Human Factors of Systems and Technology* (pp. 1 - 14). Maastricht, the Netherlands: Shaker Publishing.

(Horrey et al., 2008, McKnight & McKnight, 1993) and slower braking responses (Alm & Nilsson, 1995) prevalent in the literature. In addition, the magnitude of the problem is likely to increase in future vehicles, as the level of technological advancement, availability and uptake of in-vehicle systems continues to rise (Damiani et al., 2009, Young & Regan, 2007). If this is considered alongside demonstrations of poor driver awareness of distracting activities and the associated negative effects (Lerner, 2005), it would suggest that management of in-vehicle tasks is required to reduce the problems that could occur.

Psychological Refractory Period

Two tasks that are presented in close temporal proximity have been shown to impact on each others' performance; termed dual-task interference. The Psychological Refractory Period effect (PRP) (Telford, 1931, Welford, 1952) is an example of this, and results from a fundamental limitation in human task performance, whereby two tasks cannot be processed entirely in parallel (Pashler, 1990, Welford, 1952), regardless of their simplicity. The second of two tasks presented in quick succession is subjected to a delay in its processing due to an immediately preceding task occupying the processing resources that it also requires. This is postulated to occur due to limited capacity processing resources at the response selection stage of task processing (termed the Central Bottleneck), which prevents people selecting responses to two tasks at the exact same moment (perceptual and response execution processes are hypothesized to proceed in parallel, Pashler, 1984, Smith, 1967, Welford, 1952). The enforced 'queuing' of one task at this stage of processing ensures that it experiences a concomitant increase in reaction time. The delay in the performance of the second task (relative to its performance in isolation) varies in a manner that is dependent on the interval or stimulus onset asynchrony (SOA) between the two tasks. The effect manifests itself as an increase in the reaction time to Task 2 with decreasing SOA between Task 1 and Task 2.

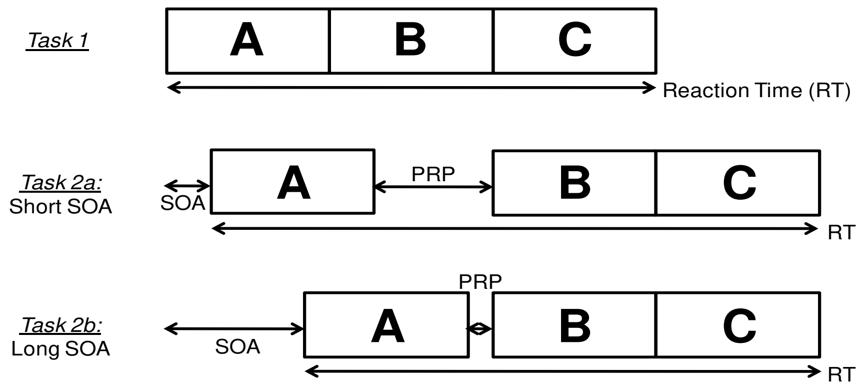

Figure 1. Illustration of the PRP effect. Task processing consists of three serial stages (A = perception, B = response selection, C = response execution). The response selection stages of two tasks cannot overlap hence the longer delay to reaction time when the second of two tasks is presented at short stimulus onset asynchrony (SOA) (Task 1 and 2a) compared to long SOA (Task 1 vs. 2b)

This interference effect is typically observed in simple laboratory studies for SOA up to 350-500 milliseconds (Pashler, 1994, Van Selst et al., 1999), and is resistant to variations in task modalities (Brebner, 1977, Pashler, 1990), task difficulties (Glass et al., 2000, Hein & Schubert, 2004, Karlin & Kestenbaum, 1968) and extent of prior task practice (Dutta & Walker, 1995). Outside of this range, there is little impact of a preceding task on subsequent task performance.

The need for vehicle drivers to multi-task during driving means that it is necessary to investigate this form of dual-task interference in the driving context. There has been a prior investigation of the existence of the PRP effect in the driving environment. Levy et al. (2006) found that brake reaction time slowed with decreasing interval to a preceding surrogate in-vehicle task (presented in the visual or auditory modality). The greatest delay to braking performance was observed when the distracter task was presented simultaneously with the brake lights of a lead vehicle. This study considers the impact of an in-vehicle task on performance of the driving task. Estimating the delay to braking performance caused by the PRP effect could offer potential methods for minimizing the slowing effects of in-vehicle tasks on brake reaction time.

Multiple Resource Theory

Dual-task interference effects can depend on the similarity of two concurrent tasks, in addition to their temporal proximity. It has been proposed that humans possess distinct processing resource channels in the brain, which are specialized to deal with particular types of information, and are each capacity-limited. The theory contends that dichotomous resource supplies exist at the perceptual, central, and response execution stages, meaning that tasks that do not share common processing modalities or codes provide less competition for each others' resources (Wickens, 1984, 2008). Multiple Resource Theory predicts that two visual stimulus tasks will interfere more and cause greater delays to the others' processing than one visual stimulus and one auditory stimulus task. Two differing tasks are less likely to produce a processing resource demand that exceeds the supply available from any single channel. This theory is relevant to the study of interference effects in the driving context due to the largely visual nature of the driving task, and the need to explore alternative presentation methods in the search to reduce the interference effects from in-vehicle tasks.

Current study

The literature identifies driver distraction from in-vehicle tasks as a key causal factor in the degradation of driving performance and the increase in crash risk, both currently and in the future. One approach to mitigating the effects of driver distraction is to ensure that in-vehicle tasks are not presented in a way that can impair performance of safety-critical aspects of the driving task. This study considers the possible methods to manage in-vehicle task presentation to minimize the chance of negative distraction-related effects. The impact of an in-vehicle task on the braking response is assessed, with the interval between the two tasks being varied systematically.

Method

Participants

Participants were recruited at the University of Leeds. 48 participants were tested (30 males, 18 females). Their mean age was 27.5 (SD = 8.2) and mean time since passing a driving test was 7 years 3 months (Min. = 6 months). All participants took part in a single 80-minute testing session and received £10 honorarium. Participants with difficulty detecting the visual, auditory and tactile stimuli selected for the experiment were not considered for further study.

Materials

The study was conducted on a desktop computer driving simulator. All elements of the simulation, including the vehicle dynamics model, the graphical subsystem and the presentation of the various stimuli were provided by a Dual-Core Toshiba laptop with an nVidia workstation-class graphics card. The simulator software consisted primarily of freely available OpenSceneGraph for the rendering process and programs developed by staff at the University of Leeds. The laptop was connected to an Acer 19" flat-panel display 1.0m in front of the driver. A real-time, fully textured and anti-aliased, 3-D graphical scene of the virtual world was displayed. The display was a single 1280x1024 channel with a horizontal field of view of 50° and a vertical field of view of 39°. The simulator was equipped with a Logitech G25 force-feedback steering wheel and spring-loaded foot pedals (accelerator, brake and clutch). There was no gear lever. The steering wheel provided force feedback to simulate the aligning torque of the wheel. Manual response paddles were located on the upper rear-side of the wheel. Vocal responses were recorded using an Olympus WS-321M Digital Voice Recorder attached to a Griffin Lapel Microphone. Vocal reaction times were manually measured using Praat; spectral analysis software.

Simulator environment

Participants drove on a single-carriageway, straight, rural road (maximum length = 1km). The road was centrally-divided with a dashed white line. In addition to the participant vehicle, there was one vehicle present in the driving scene. This vehicle was a black Mitsubishi Shogun, which drove with a fixed speed (40mph) and headway (1500ms) in front of the participant vehicle. Participants were required to operate the simulator using their right foot on the accelerator and brake pedal only. The accelerator pedal activated a controller system that maintained the speed of the participant vehicle. The participant had no control over vehicle speed, but was required to depress the accelerator pedal (>50%) to ensure that all braking responses involved a foot movement between the two pedals. The participant had full lateral control. Throughout the experiment, background vehicle engine noise was presented via the laptop speakers. A simulated vehicle dashboard was visible to the participants – including functional speedometer and tachometer.

Figure 2. Simulator screenshot showing the participants forward field of view. Speedometer and tachometer functioned realistically

Tasks

Braking task
Participants completed a simple, car-following task. The lead vehicle braked with fixed deceleration (-5 ms^{-2}) and duration (3 seconds) on random trials (57.1% of total trials). The braking event occurred after a variable foreperiod (Range = 8-23s). The braking event involved illumination of the two lead vehicle rear side-lights and a centre high-mounted stop light (CHMSL). The correct response involved immediate depression of the brake pedal to stop the vehicle. The braking task was selected for its precisely measurable onset and the high incidence, economic and human cost of rear-end collisions (McIntyre, 2008).

In-Vehicle task
Participants were presented with a two-choice, speeded response task, acting as a surrogate in-vehicle task. Participants were randomly allocated to one of six groups defined by the stimulus modality and response modality of the surrogate in-vehicle tasks.

Table 1. The stimulus modality and response modality combinations for the surrogate in-vehicle task used

Group	**Stimulus Modality**	**Response Modality**
1	Visual	Manual
2	Visual	Vocal
3	Auditory	Manual
4	Auditory	Vocal
5	Haptic	Manual
6	Haptic	Vocal

All tasks involved a discrimination decision followed by a simple, single-action response (International Organisation for Standardisation, 2002). The ease of discrimination was confirmed via pilot work and the necessary procedural checks demonstrated no difference in reaction time to the six types of in-vehicle task. Stimulus duration was short and response actions were distinct and common in the driving environment. Stimulus-response relationships were trained before the experimental phase of the study.

Table 2. Summary of the in-vehicle task stimulus parameters and the responses required

Stimulus Modality	***Stimulus Presented***
Visual	One of two colour rectangles (blue or yellow) presented centrally on the simulated dashboard for 400ms (128 x 235 pixels)
Auditory	One of two sawtooth wav files (300 or 900Hz) presented for 200ms at 75dB
Haptic	One of two steering wheel vibrations (0.8 or 0.4Nm amplitude) presented for 200ms with fixed period (100ms)
Response Modality	***Response Required***
Manual	Single press of a manual response paddle: left or right
Vocal	Single word vocalization: ‘one’ or ‘two’

Design

Participants were asked to perform the braking and in-vehicle tasks under single-task and dual-task conditions. In the dual-task condition, the in-vehicle task was presented before (or at the same time) as the braking event. On such trials, the SOA between the onsets of the two tasks was varied. A mixed ANOVA, three-factorial design (8x3x2) was used. The first factor was manipulated within-subjects and represented the eight levels of SOA that could be presented on dual-task trials (0, 50, 150, 250, 350, 450, 850 and 1000ms). This range was selected based on prior experimental work (Levy et al., 2006, Van Selst et al., 1999). The levels were spread unevenly within the range to ensure high data collection around the intervals likely to elucidate information about the duration of the PRP effect (300-500ms) (Van Selst et al., 1999, Pashler, 1990, Levy et al., 2006, Allen et al., 1998). The second and third factors were between-subjects factors relating to the stimulus modality and response modality of the in-vehicle task. These variables had three (visual, auditory and haptic) and two levels (manual and vocal) respectively.

Table 3. Summary of the four possible trial types, randomly selected on each trial

Trial Type	**Description**
Dual-task	Surrogate in-vehicle task followed by lead vehicle braking task – SOA counterbalanced
Single-task (braking)	Lead vehicle braking task only
Single-task (in-vehicle)	Surrogate in-vehicle task only
Catch task	No task to perform; included to ensure that a response was not required on all trials, which could foster artificially high driver vigilance.

Dependent variables

Data was collected from both the braking task and the in-vehicle task. Braking response data included the brake reaction time (measured from the onset of the lead vehicle braking event until brake pedal depression), maximum deceleration, minimum time-to-collision, and minimum distance headway. Analysis focused on brake reaction time due to possible confounding of the remaining measures by the instruction to brake as harshly as possible. Each trial was tagged with the trial type and the SOA used (dual-task trials only). All parameters were measured and recorded by the simulator system at a sampling rate of 60 Hz. In-vehicle task performance was assessed through the collection of task reaction time and response accuracy measures.

Procedure

Participants were permitted a short practice session to familiarize themselves with the simulator controls and its operation. The surrogate in-vehicle task was demonstrated and then repeated until ceiling level performance was reached (12 consecutive correct responses). Braking responses to the lead vehicle braking event were practiced both in isolation and in combination with the selected in-vehicle task. One participant was omitted from the study at this point due to difficulties controlling the simulator vehicle.

In the experimental phase, participants were presented with 112 trials. A four-identical block design was used to allow rest periods to reduce fatigue effects. Participants experienced 32 versions of each trial type (except catch trials). The dual-task trial was presented four times for each SOA level. The order of presentation of SOA levels was partially counterbalanced across participants to reduce potential order effects. Trial type and task onset were randomized on each trial (max. trial duration = 29.5s). One task or task combination was presented on each trial. Inter-trial interval was participant-controlled and was accompanied by a black screen on the simulator.

Instructions

Participants were requested to follow the lead vehicle and maintain their position in the left-hand lane. All tasks required an urgent response, and response performance was requested in the order that the tasks were presented. The braking event was described as the lead vehicle approaching a traffic jam, and collision avoidance was emphasized. Constraints were placed on participant behaviours to minimize confounding of manual response times by individual differences in movement speed (hold response paddles throughout) and to prevent lack of detection of haptic stimuli (maintain a loose grip on the steering wheel).

Results

Reaction time data for both tasks was collected for up to 3500ms after task presentation. Dual-task brake reaction time data was analyzed from correct in-vehicle task response trials only. Brake reaction times were accepted for further analysis if they exceeded 200 milliseconds. 93.8% of the data was included in the statistical analyses. All data were subjected to the Kolmogorov-Smirnov test for normally-distributed data and the Levene's Test of Equality of Error Variances. Brake reaction time data produced significant results in both cases and as such the analyses were performed on reciprocal-transformed data. A split-half analysis of possible trial exposure effects on brake reaction time showed no significant effect thus confirming that brake reaction time data from the experimental phase could be pooled across all trials.

Braking task

Consideration of the impact of SOA on brake reaction time data involved analysis of dual-task data only. Mean brake reaction time data was subjected to mixed ANOVA with SOA as a within-subjects variable and in-vehicle task stimulus modality and response modality as between-subject variables. When violations of sphericity were present in the data, the Greenhouse-Geisser correction was applied to the degrees of freedom used in the ANOVA. The effect of SOA on brake reaction time was highly significant, [$F(5.187, 217.857) = 51.239$, $p = .000$, $\mu^2 = .550$]. The plot of brake reaction time vs. SOA shows the typical PRP curve, with increasing brake reaction time as SOA decreases, for SOA within the 0-350ms range. The longest brake reaction time (1096ms) was observed with coincident presentation of both tasks (0ms SOA). For SOA above 350ms, there is a plateau on the graph, with brake reaction time remaining relatively constant. Post-hoc Bonferroni-corrected pairwise comparisons support these trends, with a pattern of significant effects between brake reaction time for short-short SOA and short-long SOA comparisons, but not long-long SOA comparisons.

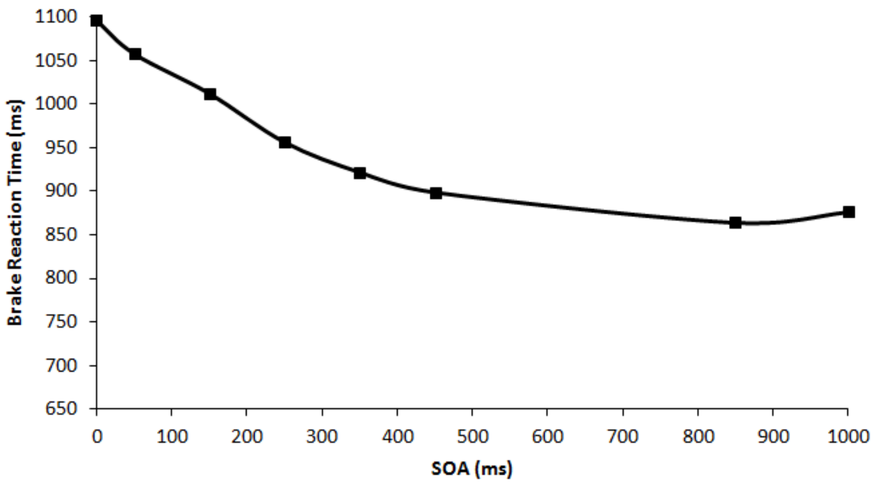

Figure 3. Plot of brake reaction time (dual-task trials only) vs. stimulus onset asynchrony (SOA)

There was a main effect of preceding in-vehicle task stimulus modality on brake reaction time, [F(2,42)=6.070, p=.005]. Braking performance was significantly faster after an auditory [M=921ms, SE=350] or haptic in-vehicle task [M=903ms, SE=350] than after a visual task [M=1052ms, SE=350]. A main effect of preceding task response modality was also observed [F(1,42)=6.890, p=.012], with faster braking responses after a vocal response task [M=909ms, SE=280] than after a manual response task [M=1004ms, SE=280]. Neither the interaction of SOA with stimulus modality or response modality reached significance. In both cases, the significant main effect of modality was present across the entire SOA range.

Performing a similar mixed ANOVA with SOA as a within-subjects variable but with a single between-subjects factor of stimulus-response modality combination, yields a significant main effect of modality on brake reaction time, [F(5,42)=3.906, p=.317]. Post-hoc pairwise comparisons show that braking performance is faster following an auditory stimulus-vocal response or haptic stimulus-vocal response task compared to a visual stimulus-manual response task. A two-way, between-subjects ANOVA using in-vehicle task reaction time data from single-task trials showed neither a significant main effect of stimulus modality or response modality on task reaction time. This finding allows conclusions about task modality effects on brake reaction time to be made without the risk of confounding by differences in the reaction time to each task.

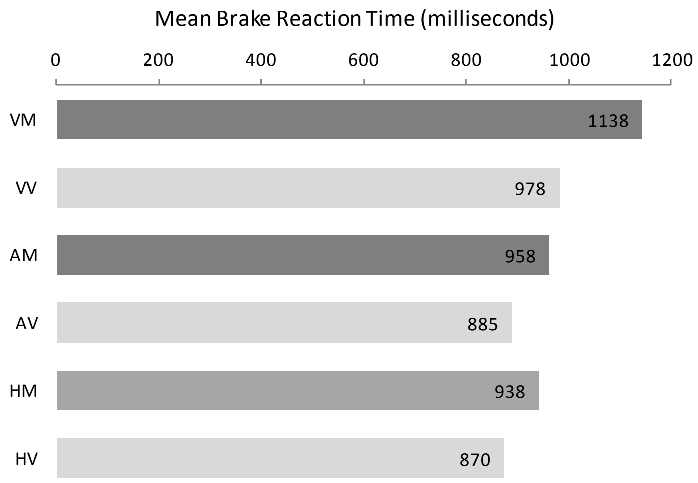

Figure 4. Bar chart shows mean brake reaction time (BRT) on dual-task trials, split by in-vehicle task type (VM = visual stimulus-manual response, VV = visual-vocal, AM = auditory-manual, AV = auditory-vocal, HM = haptic-manual, HV = haptic-vocal)

In-Vehicle task

An 8 (SOA) x 3 (stimulus modality) x 2 (response modality) mixed ANOVA was run on the in-vehicle task reaction time data from correct response trials only. A significant main effect of SOA on reaction time was observed, [F(7,294)=4.557, p=.000, μ^2 = .098].

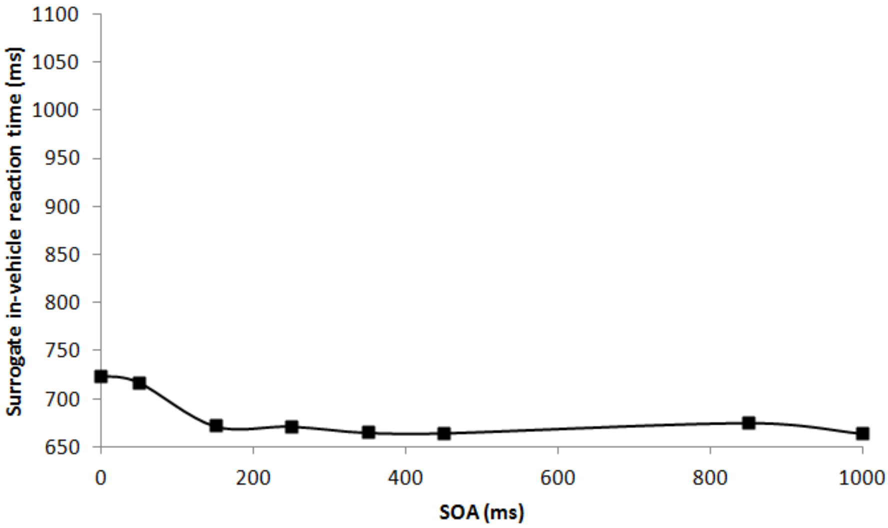

Figure 5. Plot of in-vehicle stimulus reaction time against SOA (dual-task data only)

Discussion

The PRP effect has been demonstrated in the driving environment. This study has shown that an in-vehicle task interferes with the performance of a subsequent braking event in a way that is dependent on the interval between the two tasks. For stimulus onset asynchronies (SOA) in the 0-350ms range, decreasing temporal spacing of the two tasks causes a slowing of the braking response. For SOAs outside of this range, the effect of task temporal separation on braking performance diminishes.

This study extends the work of Levy et al. (2006) by using post-hoc pairwise comparison analysis – rather than inspection of the brake RT graph – to identify the SOA at which an in-vehicle task ceases to impair a braking response. The outcome is similar to previous work in that the PRP effect seems to exist for SOA in the range 0-350ms. Furthermore, the delay to the braking response across this range is identical in this and the aforementioned study (174ms). To quantify this effect, for a vehicle travelling at 70mph, a 174ms increase in brake reaction time would equate to an increase in stopping distance of approximately 5.45 metres. It would seem reasonable to suggest that this effect could have a noticeable impact on driver safety, either in increasing the likelihood of a collision with the lead vehicle, or increasing the severity of a collision that is unavoidable. These figures lead systematically to the conclusion that there are potential safety benefits to be obtained through the prevention of concurrent presentation of in-vehicle task stimulus with lead vehicle braking, with a gradual decrease in this advantage until an inter-task interval in excess of 350ms.

The modality of a preceding in-vehicle task affects dual-task brake reaction time and modulates the magnitude of the PRP effect. Unlike the prior study of the PRP in the driving domain (Levy et al., 2006), there are significant main effects of both in-vehicle task stimulus and response modality on subsequent braking performance. There was no interaction of either modality with SOA, however, the mean trends show that the delay caused by the PRP effect is longer for tasks that share greater stimulus or response modality overlap with the braking task. This fits with Multiple Resource Theory predictions(Wickens, 1984, 2008) showing increased dual-task interference between similar tasks. However, it should be noted that while the main effect of SOA was present within each in-vehicle task modality group, the pattern of pairwise comparisons did not show a strong PRP effect for either the auditory-vocal or haptic-vocal groups.

Table 4. The impact of preceding in-vehicle task modality on the brake reaction time delay caused by the PRP effect. The PRP effect delay is calculated by subtracting mean brake reaction time on 0ms SOA trials from the same variable on 350ms SOA trials.

In-Vehicle Task Modality	PRP Effect Delay (ms)	+ Stopping Distance at 70mph (m)
Visual-Manual	291	9.106
Visual-Vocal	223	6.978
Auditory-Manual	257	8.042
Auditory-Vocal	96	3.004
Haptic-Manual	163	5.101
Haptic-Vocal	95	2.973

A surprising result was found for braking performance on long SOA dual-task trials (450-1000ms), where braking responses were more rapid than single-task braking responses. This suggests a beneficial effect of an additional in-vehicle task on driver safety. It could be that the presence of an in-vehicle stimulus primes for faster responses to subsequent tasks. However, it is likely that this effect is an artifact of the methodology employed. The frequency of in-vehicle task-braking task co-occurrence is much greater in this experimental study than would be expected in real-world driving, and as such, the provision of an in-vehicle task stimulus may have been associated with a subsequent braking event, thus priming for a rapid response. This learned association would not be possible in the more unpredictable on-road driving environment, and the authors would predict that this effect would therefore not be observed.

The main effect of SOA on in-vehicle task reaction time of dual-task trials is a surprising result. Prior studies of the PRP effect tend to show forward interference effects on the second task, but little impact of the second task on speed of performance of the first (Levy et al., 2006, Van Selst et al., 1999). The effect of SOA would suggest that the first task is not always winning the race to gain access to the limited-capacity central processing resources. However, post-hoc analysis revealed that the only significant pairwise comparisons involved the 0ms SOA condition. This trial type might be expected to produce slower in-vehicle task performance because the braking task is presented simultaneously, and thus may be perceived as the first task to arrive, subsequently delaying the ‘second’ in-vehicle task. This does not suggest a backwards interference effect on the in-vehicle task or the PRP effect for the first task presented in the dual-tasking scenario.

It is interesting to note that a comparison of brake reaction time on single-task and dual-task trials (no division by SOA level) produced a non-significant result. Brake response was as fast on dual-task trials as single-task trials, due to an improvement in braking speed at long SOAs relatively to single-task performance. The authors would suggest that this effect could be the result of a high frequency of in-vehicle task/braking task combinations (28.6% of all trials), allowing the in-vehicle task to be a relatively accurate predictor of a subsequent braking event (50% hit rate). This could produce pre-emptive brake responses; a response strategy that would not be possible in more realistic driving scenarios, where an in-vehicle task stimulus would not be as intrinsically linked with a following braking stimulus.

The application of these results is currently limited by the inability to predict the exact onset timing of lead vehicle braking events. However, a conservative application of these findings still offers potential improvements to driver safety. For example, braking events at certain road geometry features (motorway off-ramps, intersections, traffic control signals) or in heavy congestion could be approximately predicted using forward sensing technology and GPS data. Furthermore, a 1998 study (Koter, 1998) showed that harsh vehicle braking manoeuvres tend to be preceded by a specific accelerator release profile. The communication of this information between leading and following vehicles could allow the management of in-vehicle task presentation in following vehicles within the SOA range identified in this study.

Further work should be conducted to determine whether the PRP effect is observed across a range of braking scenarios, with more accurate in-vehicle task simulations. Real in-vehicle task stimuli would be beneficial. Also, this study considers brake reaction time to repeated, highly-expected braking events. Expectancy is a variable that has a significant impact on braking performance (Engström et al., 2010), and therefore recommendations about in-vehicle task presentation would be more reliable if considered with more realistic levels of braking task expectancy. Presentation guidelines may also need to be tailored to driver age, due to the generalized increase in brake reaction with age (Glass et al., 2000, Hein & Schubert, 2004).

References

Allen, P.A., Smith, A.F., Vires-Collins, H., & Sperry, S. (1998). The Psychological Refractory Period: Evidence for Age Differences in Attentional Time-Sharing. *Psychology & Aging, 13*, 218-229.

Alm, H. & Nilsson, L. (1995). The effects of a mobile telephone task on driver behaviour in a car following situation. *Accident Analysis & Prevention, 27*, 707-715.

Brebner, J. (1977). The Search for Exceptions to the Psychological Refractory Period. In S. Dornic (Ed.) *Attention & Performance VI, Proceedings of the Sixth International Symposium on Attention and Performance.* Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Brown, I.D. 1965. Effect of a car radio on driving in traffic. *Ergonomics, 8*, 475 - 479.

Damiani, S., Deregibus, E., & Andreone, L. (2009). Driver-vehicle interfaces and interaction: where are they going? *European Transport Research Review, 1*, 87-96.

Dutta, D. & Walker, B.N. (Year). Persistence of the PRP Effect: Evaluating the Response-Selection Bottleneck. In EDITOR BOOKTITLE LOCATION:PUBLISHER *(Not conference date/location)* ~~36th Annual Meeting of the Psychonomic Society, Nov 1995 1995 Los Angeles, CA. 4~~.

Engström, J., Aust, M.L., & Viström, M. (2010). Effects of Working Memory Load and Repeated Scenario Exposure on Emergency Braking Performance. *Human Factors, 52*, 551-559.

Glass, J.M., Schumacher, E.H., Lauber, E.J., Zurbriggen, E.L., Gmeindl, L., Kieras, D.E., & Meyer, D.E. (2000). Aging and the Psychological Refractory Period: Task-Coordination Strategies in Young and Old Adults. *Psychology & Aging, 15*, 571-595.

Hein, G. & Schubert, T. (2004). Aging and Input Processing in Dual-Task Situations. *Psychology & Aging, 19*, 416-432.

Horrey, W.J. & Lesch, M.F. (2009). Driver-initiated distractions: Examining strategic adaptation for in-vehicle task initiation. *Accident Analysis & Prevention, 41*, 115-122.

Horrey, W.J., Lesch, M.F., & Garabet, A. (2008). Assessing the awareness of performance decrements in distracted drivers. *Accident Analysis & Prevention, 40*, 675-682.

International Organisation for Standardisation (2002). Road vehicles – Ergonomic aspects of transport information and control systems – Dialogue management principles and compliance procedures (ISO 15005). Geneva, Switzerland.

Karlin, L. & Kestenbaum, R. (1968). Effects of number of alternatives on the psychological refractory period. *Quarterly Journal of Experimental Psychology, 20*, 167 - 178.

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J.D., & Ramsey, D. J. (2006). *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-Car Naturalistic Driving Study data*. Washington DC: National Highway Traffic Safety Administration.

Koter, R. (1998). Advanced Indication of Braking: A practical Safety Measure for Improvement of Decision-Reaction Time for Avoidance of Rear-End Collisions. In R.K. Jurgen (Ed.) *Object Detection, Collision Warning and Avoidance Systems.* PT-70 ed. Warrendale, Pennsylvania, USA: Society of Automotive Engineers, Inc.

Lansdown, T.C., Brook-carter, N., & Kersloot, T. (2004). Distraction from multiple in-vehicle secondary tasks: vehicle performance and mental workload implications. *Ergonomics, 47*, 91-104.

Lerner, N.D. (2005). Deciding to be distracted. In EDITOR Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design (pp. 499-505) Iowa City: University of Iowa,.

Levy, J., Pashler, H., & Boer, E. (2006). Central Interference in Driving: Is There Any Stopping the Psychological Refractory Period? *Psychological Science, 17***,** 228-235.

Mcintyre, S.E. (2008). Capturing attention to brake lamps. *Accident Analysis & Prevention, 40***,** 691-696.

Mcknight, A.J. & Mcknight, A.S. (1993). The effect of cellular phone use upon driver attention. *Accident Analysis & Prevention, 25***,** 259-265.

Neale, V.L., Dingus, T.A., Klauer, S.G., Sudweeks, J., & Goodman, M.J. (2005). *An Overview of the 100-Car Naturalistic Study and Findings. In International technical conference on the enhanced safety of vehicles* (CD-ROM). Washington DC: National Highway Traffic Safety Administration.

Pashler, H. (1984). Processing stages in overlapping tasks: Evidence for a central bottleneck. *Journal of Experimental Psychology: Human Perception & Performance, 10***,** 358-377.

Pashler, H. (1990). Do Response Modality Effects Support Multiprocessor Models of Divided Attention? *Journal of Experimental Psychology: Human Perception and Performance, 16***,** 826-842.

Pashler, H. (1994). Dual-Task Interference in Simple Tasks: Data and Theory. *Psychological Bulletin, 116***,** 220-244.

Regan, M.A., Hallett, C., & Gordon, C.P. (2011). Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis and Prevention, 43***,** 1771-1781.

Smith, M.C. (1967). Theories of the Psychological Refractory Period. *Psychological Bulletin, 67***,** 202-213.

Stutts, J.C., Reinfurt, D.W., Staplin, L., & Rodgman, E.A. (2001). *The Role of Driver Distraction in Traffic Crashes*. Washington DC: AAA Foundation for Traffic Safety.

Telford, C.W. (1931). The refractory phase of voluntary and associative responses. *Journal of Experimental Psychology: General, 14***,** 1-36.

Van Selst, M., Ruthruff, E., & Johnston, J.C. (1999). Can Practice Eliminate the Psychological Refractory Period Effect? *Journal of Experimental Psychology: Human Perception & Performance, 25***,** 1268-1283.

Welford, A.T. (1952). The "psychological refractory period" and the timing of high-speed performance - A review and a theory. *British Journal of Psychology, 43***,** 2-19.

Wickens, C.D. (1984). Processing Resources in Attention. In R. Parasuraman and D.R. Davies (Eds.) *Varieties of Attention.* London: Academic Press.

Wickens, C.D. (2008). Multiple Resources and Mental Workload. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50***,** 449-455.

Young, K. & Regan, M. (2007). Driver distraction: A review of the literature. In I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter, & J.D. Irwin (Eds.) *Distracted driving.* Sydney, NSW: Australasian College of Road Safety.