
Potential Benefits and Costs of Concurrent Task Engagement to Maintain Vigilance: A Driving Simulator Investigation

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Précis

Monotonous driving conditions lead to decrements in driving performance. Furthermore, engagement in a concurrent task, such as conversing on a cell phone while driving has been found to be detrimental. This study investigates the potential of a strategically employed concurrent task to mitigate the decrement.

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Objective: The objective of this study was to investigate the nature of concurrent task interference during a vigilance task and to determine whether a concurrent task improves performance with decreased vigilance. Background: Research has repeatedly shown that engaging in a cell phone conversation while driving increases the risk of getting into crashes. At the same time, it has also been found that task monotony could lead to an increase in crash risk. There is evidence which suggests that engaging in a secondary task reduces the effects of monotony, leading to an improvement in vigilance task performance. Method: A monotonous simulator drive was used to investigate the effects of a secondary verbal task. Three task conditions were used: No Verbal Task, Continuous Verbal Task, and Late Verbal Task. Results: When engaged in a secondary verbal task, drivers showed improved lane keeping performance and steering control when vigilance was lowest. Conclusion: A strategically placed concurrent task can improve performance when vigilance is at its lowest. Application: There is potential for the design of a countermeasure system that can be strategically activated by an automated system monitoring driver performance.

Key Words: countermeasures, monotony, vigilance, concurrent task, attention
Results from the 2008 National Motor Vehicle Crash Causation Survey conducted by the National Highway Traffic Safety Administration (NHTSA) reported that approximately 62,000 non-performance related crashes were due to drivers feeling fatigued, or physically falling asleep behind the wheel (NHTSA, 2008). Drivers can recognize these risks (Nordbakke & Sagberg, 2007) and take steps, such as listening to the radio, or engaging in a stimulating concurrent task, such as talking on a cellular phone, to increase their alertness when driving in long and monotonous situations. However, the 2008 NHTSA study also reported that approximately half a million performance related crashes occur annually due to “inadequate surveillance” or “inattention”. The goal of this study was to investigate whether engaging in a concurrent task can help reduce declines in performance associated with declines in vigilance. We examined this problem by looking at two potential scenarios: one in which someone engages in a concurrent task for the duration of the primary task and one in which a concurrent task was introduced toward the end of their primary task, when vigilance declines are reaching their peak.

For the present study, we used talking as the concurrent task. Talking on a cellular phone is a popular, though occasionally illegal, task for drivers. Wogalter & Mayhorn (2005) reported about 81% of drivers talk on the phone while driving and Nelson, Atchley and Little (2009) report it is as high as 99% in college students. However, the research on the negative effects of cellular phone conversations on driving performance has been unequivocal. Drivers who are engaged in a cell phone conversation while driving are over four times more likely to get into crashes than drivers who are not (McEvoy, et al., 2005; Redelmeier and Tibshirabi, 1997). They are more likely to miss signals, exhibit slower reaction times (RTs) (Strayer and Johnston, 2001),
and exhibit poorer speed maintenance and headway distance (Kubose et al., 2006; Rakauskas, Gugerty & Ward, 2004).

One reason for these decrements is that conversing has a negative impact on visual attention. Atchley and Dressel (2004) found that participants who engaged in a conversational task exhibit narrowed the extent of visual attention. Strayer and Drews (2007) found that drivers were likely to exhibit inattentional blindness when engaged in cell phone conversation, as indicated by poorer recall of objects that were presented during a simulated drive, even when drivers were looking at these objects as indicated by eye-tracking information (see also Strayer, & Drews, 2007; Strayer, Drews & Johnston, 2003).

The risks involved when driving and conversing on the cell phone present convincing evidence against doing so. Yet, when a driver exhibits a performance decrement due to the monotony of the drive (Thiffault & Bergeron, 2003), a cell phone conversation might aid in relieving the monotony. Taking a break from the task appears to be the best choice (Nguyen, Jauregui, & Dinges, 1998) but individuals may instead choose to engage in other countermeasures such as a cell phone conversation to break the monotony. For example, Oron-Gilad and Shinar (2000) found that military truck drivers perceived that engaging in a cell phone conversation was an effective countermeasure in breaking the monotony of long drives. Drory (1985) reported that a short secondary verbal task of having to periodically report odometer readings improved driver performance when they were fatigued and under-aroused. More recently, Gershon, Ronen, Oron-Gilad, & Shinar (2009) reported that an interactive cognitive task had positive effects on driver performance when the task was introduced as a countermeasure against roadway monotony and driver fatigue when driving long distances.
The decline in observer efficiency with increased time on task (Mackworth, 1948) has been the dominant finding in the history of vigilance research (although Fisk & Schneider, 1981 suggest that given sufficient practice, tasks are less likely to suffer a vigilance decrement due to automaticity). Many theories including response inhibition and habituation (Galinsky, Warm, Dember, Weiler, & Scerbo, 1990; Mackworth, 1968; Parasuraman, 1985; Posner, 1978), physiological arousal (Duffy, 1957; Erwin, Wiener, Linnoila, & Truscott, 1978), and motivation (Bevan & Turner, 1965; Levine, 1966; Wiener, 1969) have been used to explain the vigilance decrement. Yet there is no clear factor that fully accounts for the vigilance decrement (Davies & Parasuraman, 1982). These views of the vigilance decrement suggest that performance decrement in most observers is likely due to the under-stimulating nature of the task.

The present work focused primarily on the effects of monotony on driver performance rather than the interaction of fatigue and monotony (this interaction is discussed elsewhere (see Desmond, Hancock, & Monette, 1998; Lal & Craig, 2002)), therefore we used a task lasting twenty five minutes. Three measures of driver performance from the driving simulator were chosen to assess vigilance declines: the ability to quickly avoid dangerous events, the ability to maintain stable lane position, and the ability to maintain stable vehicle control. As vigilance declines, reaction time to events decreases as does lane keeping and vehicle control.

To examine the effects of a concurrent task, we investigated changes in vigilance by comparing performance of drivers not engaged in an interactive concurrent task to drivers engaged in the concurrent task continuously and drivers who performed the task only in the last time block where vigilance was lowest. This allowed us to examine potential arousing (Drory, 1985; Gershon et al., 2009; Oron-Gilad & Shinar, 2000) or disruptive effects of a concurrent task.
(Kubose et al., 2006; Rakauskas et al., 2004; Strayer & Johnston, 2001). We hypothesize that the introduction of an interactive verbal task component may arouse drivers and maintain sustained attention by reducing monotony, resulting in reduced vigilance declines over time and potentially improve performance. This arousing effect is hypothesized to be most pertinent in the Late Verbal Task condition where monotony would likely cause a decrease in vigilance.

METHOD

Participants (Drivers)

Forty-five undergraduate students from the university’s undergraduate research pool, 16 males and 29 females (M = 20.03 years, SD = 1.58), participated for course credit. All drivers had an average of 4.77 years of driving experience (SD = 1.62). One driver was disqualified and replaced for not having any prior driving experience. Almost all drivers reported English as their primary/native language. Failure to meet this requirement did not disqualify participation in the study. Drivers were randomly assigned into one of three conditions: No Verbal Task, Continuous Verbal Task, and Late Verbal Task. A Snellen Visual Acuity Chart was used to test for visual acuity in drivers to ensure normal or corrected to normal vision.

Materials and apparatus

Driving simulator. The driving scenario was designed using STISIM Drive (Systems Technology Inc. Hawthorne, CA) simulator software (Version 2.08.02). A fixed-base cockpit with force-feedback steering was used. The vehicle was set on automatic transmission. Drivers viewed the simulated roadway on a single 17 inch LCD display. A Fresnel lens was placed between the LCD display and driver.
Scenario. The roadway was a four-lane rural highway, separated by a median. The width of each lane was 3.66 meters, and visibility was set at 457.2 meters under clear conditions. There were occasional curves and hills on the roadway, but the roadway was generally flat, and monotonous, with sporadic traffic from both directions. The scenario was designed to be under-stimulating to mimic the driving conditions that most motorists encounter when driving on a rural highway. Such driving conditions have been likened to a vigilance task (Papadelis, et al., 2007; Thiffault & Bergeron, 2003). Traffic in the driver’s lane always travelled at speeds slower than the driver’s speed to ensure that passing could occur. The total distance of the drive was 42.67 km. Drivers were instructed to fully depress the accelerator to achieve and maintain the specified speed of 65 mph (104.6 kmh) so that all drive times were approximately equal. Data for analysis was recorded between the 1.52 km and 41.76 km points. Data collection was broken into 5 blocks of 8.05 km. Random wind gusts lasting 30 sec were introduced within each block except the penultimate block to ensure driver engagement.

To investigate whether drivers were paying attention during the drive, critical events occurred in the first and last block of the drive. A parked car on the road’s shoulder (intruder car) pulled out onto the road when the driver’s vehicle was one second away. To minimize anticipation during the last block, two stationary cars that did not pull onto the road were placed in the second and fourth blocks of the drive. Secondly, we presented billboards of popular North American fast food restaurants (single billboards with a different restaurant in each block) on the right shoulder within each driving block. This served as a memory test and additional evidence of concurrent task costs during the drive (see Strayer and Drews, 2007). Drivers were not warned of the memory test to ensure that attention to the billboards was not artificially elevated.
Interactive Verbal Task. Typical, real world, conversations are free to vary in ways that might interact with fluctuations in primary task demand and level of vigilance. An interactive verbal word association task was used in the current study to control the workload of the secondary task as closely as possible. As with real conversations, drivers had to listen for comprehension and formulate a meaningful response. 71 prerecorded words with positive valence and low arousal, spoken by a male native-speaker of English, were chosen from the ANEW wordlist (Bradley, & Lang, 1999) to serve as stimuli for the verbal task. The words were presented to the right ear of the driver via a Panasonic hands-free kit. E-prime (Version 1.0) was programmed to randomly select words without replacement until the list completed its cycle; following which, the wordlist was recycled. Drivers were informed at the start of the study that there were no correct or incorrect responses, and their task was to free associate using one-word responses to the stimulus word. Words were presented at an inter-stimulus interval (ISI) of four seconds. If drivers failed to respond within the ISI, E-prime would automatically continue with the next word. This rate of presentation was decided upon informal pilot testing where it was noted that four seconds was sufficient for drivers to generate a response. All verbal responses from the driver were spoken into the attached microphone on the hands-free kit. Drivers in the Continuous Verbal Task drove in the simulator and engaged in the verbal task for the entire duration. Drivers in the Late Verbal Task only engaged in the verbal task at the last time block.

Procedure

Upon completion of consent and a demographic data sheet that queried cell phone usage behavior, the experimenter asked drivers to turn their cell phones off to minimize potential disruptions. Following which, drivers engaged in a practice drive that lasted approximately three
minutes. This practice drive allowed drivers to familiarize themselves with the simulator and the handling of the steering controls. Drivers were instructed to fully depress the accelerator pedal to achieve the specified speed. At the end of the practice drive, the experimenter asked all drivers to equip a hands-free kit by placing the headphone over their right ear, and extending the microphone over their mouth. The experimenter informed all drivers that they might be engaged in a verbal task. A second computer, responsible for the interactive verbal task, would be activated remotely once the drive began. The experimenter remained in the same room for the entire duration of the study to ensure that the driver was actively involved with the task. The experimenter did not converse with the driver during the experiment. Upon completion, drivers completed an electronic version of the NASA-TLX (Hart & Staveland, 1988), and were subsequently given two minutes to freely recall as many billboards they had seen during the drive. The entire experiment lasted approximately 30 minutes and was conducted in a darkened room with no ambient light source.

Performance measures

Lane keeping & lane infractions. Lane keeping refers to the ability of drivers to maintain a stable lane position. This value was computed as the standard deviation of lane position (SDLP), where greater values are associated with poorer lane keeping. This increase is attributed to task-induced fatigue, especially under monotonous driving conditions (Desmond & Matthews, 1997), and is associated with an increased risk in collisions with vehicles in adjacent lanes (Ranney, Harbluk & Noy, 2005). Lane and road shoulder intrusions also indicate poor lane keeping. These were assessed by taking into account the number of times a driver straddles the lane divider when there was no vehicle to pass and instances where the driver drove off the
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roadway. Liu & Wu (2009) suggested that an increase in the number of intrusions and an increase in the duration of intrusions indicate decreased attention.

*Steering wheel angle & steering deflections.* Under normal driving conditions, drivers make minor steering adjustments to maintain a steady course on the road. It has been suggested that greater variability in steering wheel angle (SSD) indicates decreased attention (Brookhuis & De Waard, 1993; Oron-Gilad & Ronen, 2007; Thiffault & Bergeron, 2003). It has also been suggested that steering angles greater than 10 degrees indicate decreased attention as the driver has to make sharp and abrupt adjustments rather than minor adjustments to maintain a steady course (Thiffault & Bergeron, 2003).

*Reaction time.* This measure refers to the time taken for the driver to initiate a significant response to avoid an intruder car. A baseline steering wheel angle for each driver was calculated from a 457 meter region of roadway that had no traffic or wind gust. That location was standardized and a significant steering response was defined as a z-score deviation of steering angle greater than ±1.96.

*Workload and attention.* Perceived workload was measured by ratings using the NASA-TLX, administered after the drive. To measure attention, we used a technique similar to Strayer and Drews (2007). As attention declines, drivers encode less information in their environment. Drivers were required to recall as many of the billboards that they saw during the drive as they could despite not being informed explicitly to encode them at the beginning of the study.

RESULTS
All analysis were conducted using a 3 (Verbal Task) x 3 (Time) mixed factorial ANOVA unless otherwise stated. Violations of sphericity were controlled using the Greenhouse-Geisser or Huynh-Feldt corrections when epsilon ($\varepsilon$) was below 0.70 or above 0.70 respectively (Howell, 2002). Planned comparisons (with Holm-Bonferroni corrections) focused on the final time block. Data from the first time block (practice block) were excluded as were data from the fourth time block (no wind gust block), leaving three blocks of equivalent time and procedure.

**Lane keeping (SDLP)**

For this analysis, we also removed instances where the driver was not in either lane due to lane drifting or instances where the driver was passing another car, including intruder car events. SDLP increased significantly over time for all conditions $F(2, 84) = 6.58, p < .01, \eta^2_p = .14$. There was also a significant Time by Verbal Task interaction $F(4, 84) = 14.07, p < .001, \eta^2_p = .40$ (See Figure 1). There was no main effect of Verbal Task ($p = .30$). Paired sample t-tests revealed a significant increase in SDLP between the third and last time blocks for drivers in the No Verbal $t(14) = -2.49, p < .05$, and Continuous Verbal Task $t(14) = -2.74, p < .05$. Conversely, drivers in the Late Verbal Task exhibited a decrease $t(14) = 4.09, p < .001$, in SLDP during the same period. Planned comparisons of data from the last block found a difference between the No Verbal Task and the Late Verbal Task, $F(1, 42) = 17.08, p < .001$. Late Verbal Task drivers exhibited significantly better lane position as compared to No Verbal Task drivers and Continuous Verbal Task drivers $F(1, 42) = 10.57, p < .001$ (see Table 1).
Lane infractions and duration of infractions

There was a significant increase (ε = .75) in lane infractions over time $F(1.49, 62.67) = 4.09, p < .05, \eta^2_p = .09$. There was no main effect of Verbal Task ($p = .96$). There was a significant Time by Verbal Task interaction $F(2.98, 62.67) = 3.24, p < .05, \eta^2_p = .13$ (see Figure 2). Paired sample t-tests found a significant increase in lane infractions for the No Verbal Task $t(14) = -2.79, p < .05$ and a marginally significant increase for the Continuous Verbal Task group $t(14) = -2.07, p = .06$ between the third and last time blocks. Conversely, we found no significant decrease in lane infractions for Late Conversation Task group $t(14) = 1.37, p = .19$ in the same period, though the data appeared to suggest a trend toward a decrement (see Table 2). Planned comparisons revealed a marginal trend toward fewer lane infractions between Late Verbal Task drivers $F(1, 42) = 3.04, p = .09$, and Continuous Verbal Task drivers (see Table 2).

There was a significant increase (ε = .94), in the duration of lane infractions $F(1.89, 79.15) = 18.99, p < .001, \eta^2_p = .31$. There was no main effect of Verbal Task ($p = .43$). Planned comparisons did not reveal any significant differences. Regardless of task type, the duration spent out of lane increased as a function of time (see Table 2).

Steering wheel angle

There was a significant increase in SSD (ε = .57) over time $F(1.13, 47.59) = 14.70, p < .001, \eta^2_p = .26$. There was a significant interaction between Time and Verbal Task $F(2.27, 47.59) = 3.18, p < .05, \eta^2_p = .13$. There was no main effect for Verbal Task ($p = .16$). Paired sample t-tests between the third and last block found a significant decrease in SSD for drivers in the Late Verb Task group $t(14) = 2.99, p < .01$. Drivers in the No Verbal and Continuous Verbal Task did
not show a significant change in their SSD (all p's > .10). Planned comparisons found a difference between the No Verbal Task and the Late Verbal Task, $F(1, 42) = 6.64, p < .05$. Late Verbal Task drivers exhibited significantly better steering control compared to No Verbal Task drivers (see Table 1).

**Steering deflections greater than 10 degrees**

Steering counts increased significantly ($\epsilon = .85$) over time $F(1.69, 71.26) = 8.97, p < .001, \eta^2_p = .18$. Furthermore, there was a significant Time by Verbal Task interaction $F(3.39, 71.26) = 2.64, p < .05, \eta^2_p = .11$. Analysis of drivers in the No Verbal Task showed a marginal trend toward an increase in abrupt steering behavior $t(14) = -2.05, p = .06$, between the third and last time block. Conversely, drivers in the Late Verbal Task, showed a marginal trend toward fewer abrupt steering behavior between the third and last time block, $t(14) = 1.84, p = .09$. Planned comparisons found that drivers in the Late Conversation Task made fewer abrupt steering maneuvers $F(1, 42) = 7.04, p < .01$, than drivers in the No Conversation Task (see Table 3).

**Reaction time to intruder car**

3 (Task type) x 2 (Event) mixed factorial-ANOVA found a significant main effect of reaction time to the intruder car $F(1, 42) = 41.6, p < .001, \eta^2_p = .49$. In general, drivers were quicker to respond to the intruder car at the second event ($M = 475.33$ ms, $SD = 438.47$), as compared to the first event ($M = 1000$ ms, $SD = 406.03$). The task type by event interaction approached significance $F(2, 42) = 2.63, p = .08, \eta^2_p = 11$. There was no main effect between
task types ($p = .84$). Planned comparisons did not reveal differences between tasks (all $p's > .05$).

**Workload and Attention**

One-way independent ANOVA did not find significant differences between Verbal Tasks for perceived global workload (average TLX = 59.18, SD = 12.94). However, the billboard recall data showed that the concurrent task conditions did reduce attention for non-roadway events. One-way independent ANOVA found a significant difference between tasks, $F(2, 42) = 6.58, p < .01; \eta^2_p = .24$. Post-hoc analysis with the least significance difference adjustments indicated that the drivers in the Continuous Verbal Task recalled fewer billboards ($M = 1.87, SD = 1.19$), than drivers in the other conditions (No Verbal Task = 3.13 billboards recalled, SD = 0.92, $p < .01$; Late Verbal Task = 3.13 billboards recalled, SD = 1.19, $p < .01$).

**DISCUSSION**

The current study sought to investigate potential performance gains for a verbal task when drivers had declining vigilance. The data present an interesting answer to the question of whether a concurrent verbal task can spare performance losses due to declines in vigilance. The short answer suggests that there is evidence for the application of a strategic concurrent task as a means of mitigating decrements to performance.

Overall, lane position became less stable over time, consistent with a decline in vigilance (Desmond & Matthews, 1997). Drivers in the Late Verbal Task condition were better able to maintain lane position later in the drive than the other groups. This suggests a strategically
placed concurrent task can aid drivers in maintaining road position. This finding corroborates with studies of postural stability (Stoffregen, Pagulayan, Bardy, & Hettinger, 2000) and driving (Brookhuis, De Vries, & De Waard, 1991; Cooper, Medeiros-Ward, Seegmiller, & Strayer, 2009; Knappe, Keinath, Bengler, & Meinecke, 2007) suggesting that a concurrent task improves stability and extends those findings by showing the effect becoming strongest as vigilance declines under monotonous driving conditions. Recently, Becic et al., (2010) suggested that decreased variability in a dynamic environment does not necessarily imply improved performance. Instead, a lack of variability may indicate a driver in a static rather than dynamic state. Such a state may lead to a poorer response from the driver should an adverse event occur. However, we find that SDLP for drivers in the Continuous Verbal Task worsened over time, and their performance was similar to drivers not engaged in the concurrent task for the duration of the drive, while the Late Verbal Task drivers showed an improvement in the last time block. It is hard to imagine that the No Verbal Task drivers are improving in performance over time, and thus the similarity of the No Verbal Task and Continuous Verbal Task data argue for SDLP as a marker of declining performance. It was only the presence of a concurrent task in the last time block that lead to increased stability indicating that a concurrent task, per se, is not the cause of increased stability, but perhaps it is due to the participant’s level of engagement with the task that matters. This is worth further investigation in future studies.

Further evidence of performance enhancement from strategic vigilance countermeasures was also observed in a trend toward Late Verbal Task drivers exhibiting fewer roadway infractions in the last time block compared to drivers in the No Verbal Task condition. Due to large variability between individual drivers, we were unable to achieve statistical significance.
We also observed that drivers in the No Verbal and Continuous Verbal task groups showed a significant increase in infractions, whereas drivers in the Late Verbal task were relatively unaffected. This provides some evidence that a strategically employed verbal task may lead to improvements in driver performance with respect to maintenance of lane position. We also raise the possibility that although these results suggest improvements in driving performance, there is still a degree of risk involved. This risk is evidenced by the finding that regardless of task type, all drivers exhibited an increase in the duration of infractions over time. This may indicate that although a strategically initiated verbal task may indeed arouse the driver such that lane keeping improves, the driver still incurs a cost of being less attentive due to the concurrent task.

Consistent with this notion, steering variability worsened over time, but drivers in the Late Verbal Task showed an improvement when compared to drivers in the No Verbal Task condition. This result further supports the view that a strategically placed concurrent task may aid drivers who are experiencing a decline in vigilance (Gershon et al., 2009; Oron-Gilad & Shinar, 2000). The increase in abrupt steering behavior also lends support to the increase in lane infractions. As drivers become less attentive, they are likely to overcorrect. As predicted, we find that drivers who engage in a late verbal task exhibit a decrease in abrupt steering behavior, giving further evidence that a strategically placed verbal task can arouse the driver.

However, we must be cautious suggesting that use of a strategic concurrent is without cost, despite data showing benefit to some performance measures. The first point to consider is the RT data for the intruder car. We found that RT to the intruder car improved over time but we suggest that this was not due to our experimental manipulations but was a strategic effect due to drivers becoming more cautious after experiencing the first intrusion event. Secondary analysis
found that drivers in the Continuous Verbal Task group showed a trend toward slower RT to the intruder car $F(1, 42) = 3.67, \ p = .06$, as compared to the no verbal task group for the first event. Though these results failed to achieve statistical significance, it should be noted that the slower RT was likely due to interference from the concurrent task, which is consistent with the literature (Strayer and Johnston, 2001). Thus, a concurrent task itself is potentially costly. A second point to consider is a similar effect found with the billboard recall data. Distracted (concurrent task) drivers showed poorer recall of incidental information, consistent with Strayer & Drew’s (2003; 2007) report of inattentive blindness, or Atchley and Dressel (2004) who reported a decrease in functional field of view due to dual-tasking. This implies that distracted drivers are more likely to miss objects in the roadway. Whether this inattention effect is greater than declines due to a loss of vigilance in the case of strategic use of concurrent tasks (such as the Late Verbal Task) must be pursued in future work.

CONCLUSION

To conclude, we find some evidence that a strategically employed concurrent task does improve vigilance when considering the arousing effects of the task. However, we have also found that there are obvious costs associated with performing a concurrent task. While drivers can learn to mitigate or better allocate their resources over time, their performance is unlikely to improve due to the additional cognitive load from the concurrent task. Future work will need to consider additional factors that may reveal potential benefits for a concurrent task under monotonous conditions. Furthermore, as noted, we focused primarily on the effects of a
monotonous driving condition in a relatively short drive, rather than the interaction of fatigue and monotony. To better investigate the energizing effects of an interactive task, future studies should examine longer, more fatiguing scenarios, and employ techniques that measure physiological responses. This would allow us to observe relationships between performance and physiological arousal. It may be possible that different, more personalized, conversations may lead to a stronger energizing effect as compared to a simple verbal task.
Key points:

- Monotony leads to vigilance decrements
- There is evidence that a concurrent task may mitigate the effects of the vigilance decrement
- Presence of a concurrent task may be detrimental to primary task performance
- Some evidence that a strategically employed concurrent task may help alleviate vigilance decrements.
- Benefits of these improvements are debatable as there is still a cost incurred.
- Future studies should investigate concurrent tasks of varying difficulty, while employing additional measures such as physiological recordings.
References


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Table 1

Deviation of Lane Position (in meters) and Deviation of Steering Wheel Angle (in degrees) as a function of time.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation of Lane Position</td>
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<td></td>
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<tr>
<td>No Verbal Task</td>
<td>0.39 (.19)</td>
<td>0.43 (.19)</td>
<td>0.45 (.18)</td>
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<tr>
<td>Continuous Verbal Task</td>
<td>0.36 (.22)</td>
<td>0.38 (.23)</td>
<td>0.43 (.23)</td>
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<tr>
<td>Late Verbal Task</td>
<td>0.40 (.27)</td>
<td>0.42 (.26)</td>
<td>0.35 (.20)</td>
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<th></th>
<th>Deviation of Steering Wheel Angle</th>
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<tr>
<td>No Verbal Task</td>
<td>2.11 (.52)</td>
<td>2.51 (.59)</td>
<td>2.96 (1.33)</td>
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<td>Continuous Verbal Task</td>
<td>1.84 (.37)</td>
<td>2.33 (.33)</td>
<td>2.51 (.74)</td>
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<tr>
<td>Late Verbal Task</td>
<td>1.98 (.49)</td>
<td>2.49 (.62)</td>
<td>2.09 (.46)</td>
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*a Numbers in parenthesis are standard deviations

*b Each time block is approximately 5 mins in duration
Table 2

Total Lane Infractions and Duration of Infractions (in milliseconds) as a Function of Time

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<th>Condition</th>
<th>Time(^b)</th>
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<td></td>
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<td>Block 3</td>
<td>Block 5</td>
</tr>
<tr>
<td></td>
<td>Lane Infractions</td>
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<tr>
<td>No Verbal Task</td>
<td>2.27 (2.91)</td>
<td>2.33 (2.61)</td>
<td>4.27 (3.49)</td>
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<td>Continuous Verbal Task</td>
<td>1.86 (2.13)</td>
<td>2.13 (2.03)</td>
<td>5.00 (5.55)</td>
</tr>
<tr>
<td>Late Verbal Task</td>
<td>3.07 (3.81)</td>
<td>4 (3.81)</td>
<td>2.53 (1.41)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Duration of Lane Infractions</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No Verbal Task</td>
<td>1039.69 (818.66)</td>
<td>1466.82 (1324.49)</td>
<td>2241.36 (1406.76)</td>
</tr>
<tr>
<td>Continuous Verbal Task</td>
<td>1134.78 (1128.66)</td>
<td>1697.17 (1703.89)</td>
<td>3210.81 (1801.78)</td>
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<tr>
<td>Late Verbal Task</td>
<td>1323.56 (1506.33)</td>
<td>1894.95 (1446.86)</td>
<td>3025.57 (2335.15)</td>
</tr>
</tbody>
</table>

\(^a\) Numbers in parenthesis are standard deviations

\(^b\) Each time block is approximately 5 mins in duration
Table 3a

Total number of Steering Wheel Angles > 10 Degrees, as a Function of Time

<table>
<thead>
<tr>
<th>Condition</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Verbal Task</td>
<td>2.07 (1.83)</td>
<td>3.47 (2.59)</td>
<td>5.80 (5.05)</td>
</tr>
<tr>
<td>Continuous Verbal Task</td>
<td>1.27 (1.33)</td>
<td>2.27 (1.44)</td>
<td>3.60 (1.44)</td>
</tr>
<tr>
<td>Late Verbal Task</td>
<td>1.67 (2.55)</td>
<td>3.80 (3.19)</td>
<td>2.27 (1.22)</td>
</tr>
</tbody>
</table>

a Numbers in parenthesis are standard deviations

b Each time block is approximately 5 mins in duration
Figure 1
Standard deviation of lane position (± 1 SE) over time, greater values indicate greater degree of weaving.
Figure 2
Number of roadway infractions (± 1 SE) over time.
Biographies

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