EFFECTS OF ATTENTION AND COGNITION ON SIMULATED DRIVING

by

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ABSTRACT OF THE THESIS

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Participants performed a primary driving simulation task while concurrently carrying out a secondary cognitive interference task to test for attentional channel overload effects to either the driving or conversational task while performing under both conditions. The simulation involved a moderately difficult driving course and the secondary task required response to a spoken word version of the Baddeley Reasoning Test (1968). The variable manipulated was the spatial location of the Baddeley audio between audio located beside the driver (front seat passenger) and audio located behind the driver (rear seat passenger). The results showed participants made many more driving errors and answered far fewer Baddeley sentences correctly when the audio of the conversation was located to their right versus the behind location and the control condition, suggesting that the location of the conversational audio does play a role in driver distraction. These results are due to overlapping attentional channels. Driving while maintaining a conversation with a simulated front seat passenger demands greater attention and imposes greater risks than driving while maintaining a conversation with a rear seat passenger.

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Note: Figures 2, 3, & 4 are exempt from the Digital Millenium Copyright act (DCMA) as per section 1201 (a) (1)

Introduction

Affects of Attention and Cognition

On Simulated Driving

Currently, 49 countries have a complete ban on operating a cell phone while driving a motor vehicle. As of January 1, 2011 only eight states in the U.S. (CA, CT, DE, MD, OR, NJ, NY and WA) and the District of Columbia included this ban and only 19 states included that same ban for school bus drivers carrying children; 33 states have a complete ban on text messaging while operating a motor vehicle. There is a clear legislative progression aimed at preventing harm to people and damage to property by restricting cell phone usage while driving; however, what is less clear is the exact nature of the distraction to the driver.

A large body of research attempts to pinpoint the specific reasons a cellular phone conversation is distracting to drivers. Researchers have analyzed the ability of the driver to brake properly when conversing (Alm & Nilsson, 1995; Consiglio, Driscoll, Witte & Berg, 2003; Strayer, Drews & Johnston, 2003), to respond quickly to some sort of peripheral stimuli (Collet, Clarion, Morel, Chapon & Petit, 2009; Strayer & Johnston, 2001) or to judge the spatial distance of gaps on the road (Brown, Tickner & Simmonds, 1969). What remains central to the majority of this research is the dual-task modality employed (see Caird, Willness, Steel & Scialfa, 2008 and also Horrey & Wickens, 2006 for a meta-analysis of the dual-task literature). A dual-task scenario involves an operator expected to perform two tasks at the same time, wherein one task is considered primary and the other secondary (Dressel & Atchley, 2008). Dual-task scenarios aim to see if the secondary task interferes with or causes distraction to the performance of the primary task.

Strayer and Johnston (2001) and Strayer, et al. (2003) used dual-task methodology to investigate if conversing on a cell phone (the secondary task) while driving (primary task) would divide attention between the external visual field and the internal cognitive processes associated with a cell phone conversation. The researchers defined their hypothesis as one of *inattention blindness*; that is, performance on a secondary task may blind a portion of attentional capacity once available to attend to and successfully perform a primary task.

Strayer and Johnston (2001) found that participants were more likely to miss simulated traffic signals in a driving simulation while conversing than when not conversing. The movement performance losses were similar for hand-held and hands-free cell phone users. In addition, Strayer et al. (2003) found that participants were less likely to attend to and then recall billboards presented in a simulated driving environment when conversing on a cellular device versus driving alone. These findings mirror investigations by Rosenbloom (2007) and Consiglio et al. (2003) that report dual-task performance losses due to attentional limitations posed from the conversation rather than from any physical manipulation of a phone device such as dialing or answering a call. However, few researchers have investigated the effects to the driver when he or she is conversing and responding to conversational sound sources presented in different spatial locations (Consiglio et al. 2003; Ferlazzo, Fagioli, Di Nocera, Sdoia, 2008). Currently, no one has investigated such differences solely between simulated front and rear seat passenger conversations designed to simulate the attentional differences paid to audio in the beside and behind locations while driving a vehicle.

Utilizing a driving simulation, Consiglio et al. (2003) investigated the cognitive effect of changing the location of the conversation in conjunction with a simple reaction time measure. The researchers had participants respond to the appearance of a simulated brake light that appeared on a screen in one of five conversational conditions: control, listening to the radio, conversing with a passenger, conversing using a hand-held phone, and conversing using a hands free phone. Results showed a 19 percent decrease in reaction time from the control condition to the average of both phone conditions. Reaction times slowed as much as 16 percent when conversing with a passenger, implying that a conversation with a passenger can be a similar source of distraction akin to talking on a cell phone. Although their results support dual-task performance losses, they also illustrate an effect based on the spatial location of the conversation.

Ferlazzo et al. (2008) used a dual-task driving scenario that measured performance by using a peripheral detection task (PDT) as the secondary task. All tasks were performed driving in an on road setting, except for a hand-held phone condition that, for legal reasons, was performed on a driving simulator. The PDT required detecting and responding to a small blinking red LED placed slightly out of foveal view on the rear-view mirror. Results indicated that participants in a condition with a conversation were significantly slower at responding to the LED than those in a condition with no conversation. Conversations that took place in the close personal space, which the researchers defined as the space where the driver directly converses via ear-phone headset or hand-held phone, saw the greatest reduction to driver speed compared to conversations taking place outside of the immediate personal space of the driver via loudspeaker or passenger. The researchers concluded their results may be due to the brain coding space into multiple representations (Weiss, Marshall, Wunderlich, Tellmann, Halligan, Freund, Zilles & Fink, 2000; Just, Keller & Cynkar, 2008) and from attentional limitations attributable to a central bottleneck model of attention (Pashler, Harris, & Nuechterlein, 2008); though, they admit that the exact mechanism(s) of attention engaged in the allocation of resources, across different sensory modalities, and between the personal and extra-personal space remains largely unknown.

One possible explanation for the large performance gaps found when participant's converse on cellular devices, or with passengers, is that of a cross-modal visual/auditory attentional bias (Eimer, 2001; Hiscock, Inch & Kinsbourne, 1999; Eimer & Shröger, 1998). It has been shown that directing attention within auditory conditions can modulate the sensory processing of visual stimuli, and that directing attention within a visual paradigm can modulate the modality specific processing of auditory stimuli resulting in a careful balancing act of attention resources needed to maintain functioning in both realms. Also, a biasing in the ear used to answer and maintain conversation from cellular devices and from passenger conversations may also cause performance decrements as it has been found that stimuli presented to the right ear is often attended better than stimuli presented to the left ear (Mondor & Bryden, 1992).

Furthermore, Longo and Lourenco (2009) found that task performance in either a near (30cm) or far (270cm) space condition may be affected with the addition of simulated stress. The researchers had participants bisect lines with a laser pointer in the near or far space while either wearing or not wearing wrist weights. They found that while wearing no weights participants had a leftward bias at the closest distance and a gradual rightward bias at further distances; conversely, when wearing weights participants had a much stronger rightward bias when bisecting lines in the near space and a gradual rightward bias when bisecting in the far space suggesting the addition of stress to tool use can, especially in relation to the arm, engender bias toward spatial locations (Longo and Lourenco, 2009).

In order to investigate such claims of visual, auditory, or spatial attentional bias the current investigation focused on the attentional difficulties that exist when a driver must safely operate a driving simulation and concurrently respond to attentionally demanding conversation from beside the driver and behind the driver, designed to mimic a conversation with front and rear seat passengers. To this end, greater differences in speed and lap time were expected in the beside condition and more on track driving errors were expected for drivers that responded to a conversation to the right of their personal space versus behind their personal space, with the least amount of interference expected in the control condition. Additionally, it was expected that a greater amount of Baddeley conversational errors would occur in the beside, rather than in the behind location, and that a significant difference in subjective opinion of task difficulty between males and females via the NASA-TLX would be found to match objective performance.

Method

Participants

Twenty-four young adults (11 women and 13 men) were recruited from an introductory psychology class to satisfy a course requirement. Students were given one credit per hour of participation with the average running time of the experiment lasting approximately one hour. Data from one male participant was excluded from the lap time and speed analysis due to a computer glitch that resulted in his data not being recorded; therefore, lap time and speed data analysis consisted of a total of 23 participants (11 women and 12 men). Age was not recorded as all of our subjects were generally in the same age group of approximately 18 to 24. To assure some familiarity with driving, years in possession of a valid driver's license were recorded (Mean = 2.4, S.D = 1.84). Three subjects were in possession of their license for slightly less than one year and a value of one were used for their license possession score.

Pre and Post Experiment Surveys

Before beginning the experiment all participants were required to read and to sign an informed consent form (see appendix A) and to complete a brief survey (see appendix B) indicating vision and hearing status, how long they possessed a valid driver's license and the frequency of time they spent talking and texting on the phone while driving and while not driving (Shinar et al. 2005). Time talking and time spent texting were not included in the current analyses and were collected for possible future comparisons.

Following all experimental driving trials participants completed the NASA-TLX subjective task inventory to gather data on total subjective workload experienced while performing the simulation (Hart & Staveland, 1988). The NASA-TLX is a multi-dimensional rating procedure that provides an overall subjective workload score based on a weighted average of ratings on six subscales: mental demands, physical demands, temporal demands, own performance, effort and frustration. The subjective data was ultimately used in gender comparisons and to compare to the objectively obtained simulator data to see if subjective accounts of task difficulty coincided with the obtained objective results.

Apparatus & Stimuli

GTR 2: Realism Redefined by Viva-Media (2006) served as the driving simulation. The simulation was controlled by a Logitech MOMO Racing Force Feedback steering wheel, complete with accelerator and brake pedal. Driving data from the simulation was automatically logged to the computer and analyzed via the program Motec *i2* Analyzer (2009). The Motec program ran simultaneously to the driving simulation and automatically logged all chosen driving variables for easy display in chart or graph format following driving.

The simulation was performed on a Dell OptiPlex GX270, Pentium IV 3GHz CPU with 512 MB of RAM. GTR: 2 possesses an intense graphic interface so an NVIDEA GeForce 9500 GT aftermarket graphics card was installed to improve 3D rendering capabilities; the card possessed 1 GB of dedicated video RAM. The simulation was displayed on a Dell computer monitor with a normal refresh rate of 60 Hertz.

Three pairs of external computer speakers were used: one for the beside audio condition, one for the behind audio condition and one to produce only the audio from the simulation, located directly behind the monitor. For the beside audio condition the speakers sat elevated approximately at ear height (three feet), two and one half feet to the right of the seated participant. For the far audio condition the speakers sat at the same height as the close condition but were located approximately 3 feet behind the participant.

To ensure equal sound levels between the two spatial audio conditions a Blue “SnoBall” microphone, a small personal recording microphone, was affixed to the participant’s driving seat at head level and digital levels (dBFs) were taken via Steinberg

Wavelab. The microphone had a frequency response of 40 – 18 kHz and the cardiod pickup pattern was used to control for background interference noise possible from using an omni-directional pickup pattern. The volume of each set of speakers was either raised or lowered until both were in average unison of -28.05 dBFs.

A calibrated analogue dB SPL meter would have been a better choice to reach uniform sound levels between speaker conditions as there is no real way to accurately compare dB and dBFs. Also, it would have been advantageous to control for the actual way sound levels are perceived at the physical location of the human ear on the head by utilizing a dummy head with miniature binaural recording microphones placed inside of each ear to account for any biasing from the way the ear perceives sound from the right or from behind. Contrary to the above limitations, each participant was asked if the conversation was loud enough to perceive in either location; each agreed that it was, indicating that conversational levels were relatively close to 55-65 dB, the average level of basic human conversation (Daniel, E., 2007).

Located out of sight and behind the participant were two researcher controlled second generation iPod Touch's (Apple, 2008); one iPod controlled the audio for the beside condition and one controlled the audio for the behind condition. An Edirol R-09 portable digital recorder (EDIROL by Roland, 2010) was used to record the audio responses of the participant conversational stimuli; it was located directly behind the participant and out of sight along with the two iPod's.

Variables and Design

The independent variable was the spatial location of the audio signal of the conversation; with two levels of presentation: beside and behind. Participants drove 12 total laps: 4 laps in the beside audio condition, 4 in the behind audio condition and 4 control laps with no spatial audio manipulation. A within subjects design was used with the control and two conversational conditions counter-balanced via Latin square across all 12 laps for each participant such that each condition was always followed by a different presentation of one of the three spatial audio manipulations. The speaker conditions were designed to simulate conversation between the driver and a front seat passenger and the driver and a rear seat passenger. The dependent variables consisted of average lap times and average speeds across all 12 laps, instances of driver error, correct answers to the Baddeley sentences, total amount of Baddeley sentences answered and NASA-TLX scores.

Individual lap times were recorded by the Motec program in minute, second and millisecond format. Each final lap time for each of the 12 laps driven by each participant was converted to seconds and a total average lap time across all 12 laps was calculated to serve as each participant's final average lap time score.

Individual average lap speeds for each participant were recorded in miles per hour (mph) by the Motec software for each of the 12 laps driven and a total average speed score across all 12 laps was calculated to serve as each participant's final average lap speed score.

Driver error was defined as any instance of the driver veering off of the designated driving course during each of the 12 laps. To manually record driver error, as well as to keep track of which condition to present to participants, the experimenter possessed a sheet of paper for each participant with 12 boxes labeled across with each of the counterbalanced conditions of beside, behind, or control, labeled in one of the boxes. Each time a participant veered off of the track a check mark was made in the box that corresponded to the participant's current condition.

Conversational Task: Baddeley Reasoning Test

The Baddeley Reasoning Test (1968), as used in Brown et al. (1969), served as the conversational dependent variable. The task required participants to perform grammatical transformations of simple sentences and respond if the sentence read to them was true or false based on a letter pairing presented following the sentence. For example, when the driver was presented with the sentence "B precedes A," and then presented with the letter pairing "AB," the driver should respond with "false," as B does not precede A in this case. Two scores were obtained from the Reasoning test: the total number of attempted items and the total number of correctly answered items.

Creating the Baddeley Reasoning Test

A spoken word version similar in design to Baddeley's initial test was required, though digital recording techniques and audio editing were used to aid in randomization and uniform presentation of the stimuli. In order to randomize the stimuli each of the different Baddeley sentences was first numbered from 1 to 32 and input into an Excel spreadsheet. Next, three random sequences of numbers from 1 to 32 were created by using a random number generator (Haahr, 2011). Each of the 32 sentences was then attached to the random number it was given. Three additional versions of the 32 sentences were created by reversing the original three randomizations.

Six different randomized versions of the original 32 Baddeley phrases now existed in the Excel spreadsheet. Each phrase list of 32 sentences was then recorded via Steinberg Wavelab with four seconds of silence inserted between each sentence to produce six distinct waveforms, each with duration of four minutes and thirty seconds. Next, three new sets of random numbers from 1 to 6 were generated and the newly created six waveforms attached to the random number they were given. The three final randomizations that contained each of the 6 random combinations of the original 32 sentences were then mixed-down via multi-track in Adobe Audition to create the three final waveforms to be presented to participants, each with a total of 192 random Baddeley sentences and a total duration of 27 minutes and 2 seconds.

The reason for the final longer combination was for ease of switching between each condition (beside/behind) for each participant. With only one long waveform to present during each condition, randomized between version's 1, 2 and 3, it was easy to have one iPod control each conditional audio source. Generally, blocks of 3 participants were run, one after the other, with random presentations of one of the three final waveforms for each participant chosen by the random number generator.

Selecting the Vehicle and Driving Course

Donington Park Raceway (Figure 1) was chosen as our racetrack as it is a moderately difficult track, defined by the number of turns (12) the driver needed to make to complete the track. There was a large selection of simulation vehicles to choose from; however, we wanted to keep it simple; all participants were assigned to drive the car with the least amount of horsepower and torque (see Figure 2 for vehicle specs).

GTR: 2 is a racing simulation designed for driving vehicles at high speeds on closed courses. In order to appeal to casual first time users – our participants – the simulation offered a complex menu of options to enable or disable many different driving aides to make the experience less of a racing adventure and more like an everyday driving experience. Automatic transmission, traction control, anti-lock brakes, computer assisted braking and steering aides were all enabled to assist the driver in similar fashion as those aides assist drivers in their real vehicles. The auto-reverse feature and auto-crash recovery feature were disabled because they were completely computer controlled (think "auto-pilot") and could potentially disrupt the normal flow of each participant's experience. Tire wear and other wear associated with vehicle damage were also disabled so that participant's could continue driving all twelve laps even if they happened to skid around a turn, run over an obstacle, or veer off the track. If participants did veer off the track or crash into an obstacle their session would not end as it might in real world driving, they were simply told to get back onto the track and continue driving and answering the Baddeley stimuli as soon as they felt best able to do so.

Procedure

Upon arrival, participants were greeted and then seated to the left of the simulator. They were asked to read and sign informed consent and if they had any questions. The intake survey was then handed to them, filled out and handed back to the researcher. Following the intake, a brief explanation of the task and initial instructions were given. Of importance to the instructions presented in the quoted paragraph below was the final sentence instructing participants to give priority to the driving task.

In an attempt to create a more realistic driving simulation the experiment followed Levy and Pashler (2008) and instructed participants to ignore the concurrent task (conversation) all together on dual-task trials and assign maximum priority to the driving task if they felt overwhelmed answering the Baddeley sentences. Despite this specific instruction, Levy and Pashler (2008) found that responses to their secondary task often preceded the driving response and that driving performance suffered as a result. In other words, telling participants to ignore the secondary task is nearly impossible to enforce in an experimental setting with only two tasks and a strong desire to perform well in the eyes of the experimenter. These instructions were included to encourage more realistic levels of attention were paid to the driving environment.

> "You are about to perform a driving simulation. You will drive a set number of laps, some of which will require you to verbally respond quickly to sentences spoken to you from the speakers located directly to your right and from those located directly behind you. The sentences are not typical of normal conversation but are designed to serve as a secondary attentional task while you operate the driving simulation. Your job during the experiment and the main goal you should keep in mind the entire time you are performing is to drive as safely as possible so that you stay on the driving track at all times and to correctly answer as many of the conversational stimuli as you can while driving. If you veer off the track simply get back on and continue driving. If you feel over-whelmed or unable to attend to the conversational stimuli give priority to the driving task and resume answering the sentences when you feel you are best able."

Practice Phase

Following intake and initial experimental explanation, participants were told to have a seat at the simulator and were given instructions on how to operate the physical simulation equipment and guidelines to safely perform in the simulated driving environment. Participants were told that during the practice session they would have driving aides available on screen to suggest proper acceleration, breaking and cornering points. One of these aides, the "driving line," (see Figure 3) consisted of a colored line present on the driving track: blue represented a need to accelerate; red represented a need to apply the brakes and white implied application of neither brake nor acceleration. The driving line was only present during the practice phase of the experiment. It was stated that the hardest part of correctly performing the simulation would be navigating turns and that proper acceleration, breaking and coasting techniques should carefully be followed.

The second driving aide was a colored arrow (see Figure 4) that would briefly pop up in the center of the screen when approaching a turn. The arrow varied in color from yellow, which represented an easy slight turn, to orange, a more difficult and sharp turn, to red, which represented a sharp and difficult turn. Along with the color of the arrow a number was always simultaneously presented inside the arrow; the number was the amount of seconds before the turn to come. Participants were told that whenever they saw the arrow it was a basic indication to slow down in order to safely navigate an upcoming turn.

Following the verbal instructions, participants completed a number of preliminary practice driving sessions from the "driving school." In the driving school subjects had to complete trials in three different categories: acceleration, breaking, and cornering.

Before performing any practice trial each participant watched a demo of the computer complete that specific trial. All participants were given five chances to complete each trial without veering off of the track and all 24 participants successfully accomplished that goal. Participants generally did not achieve the GTR: 2 mark of "success" during the practice trials, but they were told that they did not need to as long as they could complete the trials without veering off of the track.

Following the practice trials, before the experimental portion, all participants were asked if they felt comfortable driving the simulation and if they felt they needed any further practice. All participants indicated they felt comfortable and needed no additional practice. It was verbally emphasized many times that the main goal to keep in mind during the entire experiment was to safely navigate the course by staying on the road at all times and to correctly answer as many of the conversational sentences as possible while maintaining a safe speed that enabled staying on the course.

Experimental Phase

Following the practice phase participants were reminded of the conversational stimuli they would need to respond to while driving and were given examples of the sentences in varying degrees of difficulty to better prepare them for the task. They were not told if the answers they gave to the Baddeley practice sentences were correct or incorrect; the experimenter merely nodded after reading the sentence and letter pairing, replied with an "o.k." after hearing their answer, and then read another example. The examples were given to familiarize participant's with the task, not to dissuade or encourage performance before they began the driving task. Each participant drove 12 laps on the Donnington Park track, 4 laps for each condition of beside audio, behind audio and control that contained no spatial audio manipulation. The participant's task during the simulation was to drive as accurately and as safely as possible and to respond to the conversational stimuli as quickly and as accurately as possible while driving.

During driving, participants were presented with the Baddeley stimuli in either the behind or beside speaker location in a calm and slow manner. Switching between conditions was performed by the experimenter pushing pause on one iPod that controlled the beside audio and play on the other iPod that controlled the behind audio and vice versa. Before driving began on the experimental trials the Edirol R-09 voice recorder was started to record the vocal responses of each participant in the beside and behind audio conditions. Following the 12 laps, participants were instructed to return to the "garage" and that their session was complete. Participants were then instructed to return to their initial seat to the left of the driving apparatus and were handed the NASA-TLX subjective inventory. After completing the NASA-TLX each participant was given a debriefing statement (see Appendix C) to help answer any questions they might have had and to outline the purpose and methodology of the experiment.

Results and Discussion

Lap Speed Analyses

Table 1 shows all raw Motec speed data and all means and standard deviations by gender and by condition. A mixed design ANOVA was used to analyze average lap speed as a within subjects variable and gender as a between subjects variable. Mauchley's test of sphericity had been violated, [X^2 (2) = 8.249, p < .05] therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .747). The conservative correction for sphericity just narrowly missed statistical significance for lap speed, *F* (1.495, 42) = 3.555, p = .053.

Upon further examination utilizing paired samples t-tests, a statistically significant relationship was revealed between the behind (M = 104.171, S.D. = 15.918) and control conditions (M = 107.688, S.D. = 19.261), *t* (22) = -2.604, p = .016. Mean differences for beside and behind average lap speeds did not reach statistical significance, *t* (22) = 1.593, p = .126, nor did the difference between beside and control conditions, *t* (22) = -1.338, p = .194. Gender analyses revealed a statistically significant interaction between male and female average speeds, *F*(1, 21) = 22.764, p < .001. Males were on average 24 mph faster in the beside condition, 22 mph faster in the behind condition and 26 mph faster in the control condition.

Greater speeds were initially expected in the beside, behind, and then control conditions. If the close personal cognitive space directly surrounding the driver conflicts with the directional processing of the conversation locations then greater usage of and competition for attentional channel resources will occur in the beside rather than in the behind condition based on attentional bias toward the beside condition. On average, within all participants, there was a difference of a few miles per hour faster from the control condition to the beside and behind conditions and a slightly faster, though insignificant, speed increase in the beside over the behind condition. These results are in line with our hypothesis because participants drove faster in the control condition with no interference to attention that could distract them from properly maintaining higher speeds. The speed differences between conditions are too close to tell if participants were really slightly faster in the beside, than the behind condition because of the additional distraction of the conversation or if the slight increase was only due to chance. Though, it may be the case that the speed results are due to an over-arching speed/accuracy tradeoff such that the few miles an hour faster participants drove in the beside condition were sufficient to push drivers into the realm of attentional overload and exponentially increase road and conversational error.

Lap Time Analyses

Table 2 presents all Motec lap time data and all means and standard deviations by gender and condition. Lap time data were analyzed using a mixed design ANOVA with Lap time as a within subjects variable and gender as a between subjects variable. Mauchley's test of Sphericity indicated that sphericity had been violated [X^2 (2) = 12.481, $p <.05$] therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .683$). There were no significant main effects of Lap time among the different conditions, F (2, 42) = .493, $p = .545$; however, tests of gender effects revealed a statistically significant interaction between male and female average lap times with males finishing much quicker than females, F (1, 21) = 17.502, $p < .000$.

Driver Error Analysis

All driver error data, means and standard deviations by gender and condition are presented in table 3. In total, drivers made 197 on track errors in the beside condition versus 100 in the behind condition and 155 in the control condition suggesting the overall difficulty of staying on the track while simultaneously responding to conversational audio in the beside versus behind and control conditions. A mixed design ANOVA was employed to better analyze the effects. Driver error served as the within subjects variable and gender as the between subjects variable. Mauchley's test of Sphericity was not violated so sphericity was assumed. There was a significant main effect of driver error, $F(2, 34) = 7.352$, $p = .002$; participants made nearly double the amount of errors in the beside (M = 10.37, S.D. = 6.906) versus behind (M = 5.26, S.D. = 5.258) audio condition. It was much more difficult to drive error free and maintain proper vehicle performance with the additional conversational load and interference to driving – more so in the beside than behind spatial locations. Further examination via pair-wise comparisons clarified the significant effects: beside and behind errors differed significantly, $t\,(18) = 3.654$, $p = .002$ as well as behind and control errors (M = 8.16, S.D. = 7.034), $t\,(18) = -2.480$, $p = .023$; the difference between beside and control errors did not reach statistical significance, $t\,(18) = 1.437$, $p = .168$.

There were no statistically significant differences between the beside, behind or control error conditions for male and female drivers, $F\,(1, 17) = .110$, $p > .7$. This result was surprising because there were also no gender differences in errors for the baddeley stimuli suggesting that although there are large gender differences in driving performance (speed and lap times) those performance differences do not result in road error or conversational error differences between gender. At first, it was thought these results were indicative of a speed/accuracy tradeoff between males and females, but it seemed as if the only reason males answered less sentences was because they drove much faster than the females and thus, were quicker at completing laps.

As for the aspect of accuracy, there were no differences between males and females with respect to driver error and correctly answered Baddeley sentences. Speed and Laptime analyses taken together with the error analyses suggest that although there is a speed tradeoff between males and females there is not an accuracy tradeoff based on any speed or location of audio signal. These results are consistent with Ferlazzo et al. (2008) and their failure to find any sort of speed/accuracy trade-off between manipulations of spatial locations of the conversation; although, as mentioned above, a speed/accuracy tradeoff, though not found via gender, may exist overall and serve as a sufficient source of attentional overload to account for the increased amount of errors in the beside over the behind and control conditions.

Error Movement Analyses

There were no significant gender differences in amount of on track errors between conditions, but it was important to try and find out why participants made more errors in the control condition than they did in the behind condition. The following analysis was conducted to delve a bit deeper into the data and see if there existed any patterns in movement from condition to condition. The argument can get convoluted at times, but it is merely meant as an attempt at determining the variations in data results found.

To accomplish the error movement analysis, participant error was re-analyzed to gather data on the difference in amount of errors each participant made when transitioning from one audio condition to another. For example, it was now possible to look at the difference in errors made when a participant moved from a condition of beside to behind audio and compare it to the errors made when they moved from a condition of control to behind, or any other combination of movement between beside, behind and control conditions.

Table 4 presents all raw error movement data and all means and standard deviations by gender and condition for comparison of movement from condition to condition. A mixed design ANOVA was performed with error movement as a within subjects variable and gender as a between subjects variable. Mauchley's test was not violated so sphericity was assumed. A main effect for error movement was found, $F(5, 85) = 5.177$, $p < .001$ suggesting that there was indeed an overall participant effect and a statistically significant difference in driving errors when switching from one condition to the other, but further investigation was needed into the specific differences when moving from control to audio conditions and vice versa.

Table 5 shows all pair-wise comparisons with all significant interactions. The comparisons from the ANOVA showed that there were significant differences when comparing movement of beside to behind (Total Errors = 112, M = 5.89, S.D. = 4.288) to movement from control to beside (Total Errors = 64, M = 3.27, S.D. = 3.515, $p < .01$) and behind to control (Total Errors = 54, M = 2.84, S.D. = 2.651, $p < .01$). This result shows first that many more errors are made in movement between conditions with audio manipulations and second, that the most errors are made when moving from a condition of behind spatial separation of the audio from the driver to one that is beside, and in attentional conflict with the right hand space of the driver which may have a greater effect on safe driving and attending to the road environment. The only exception exists in the similar mean error movements between behind to beside compared to movement between beside to control ($p = .36$.) The similar difficulties in driver error found between these movement comparisons could be attributed to the inability of the attentional system to immediately regain maximal functionality in the control condition following the attentionally demanding beside condition.

Pair-wise comparisons from the RM-ANOVA revealed that the main significantly different movement among conditions appeared when moving from beside to behind (M = 1.42, S.D. = 1.644) compared with moving from behind to beside (M = 5.89, S.D. = 4.228), ($p <.001$). This result supports our hypothesis that the greatest mean differences of driving errors would occur in conditions within spatial audio manipulations and that most errors would occur in the beside audio condition over the behind, as the majority of average errors are found when a participant moves from a condition of behind to a condition of beside spatial audio.

Baddeley Correct Analyses

Refer to table 6 for all raw Baddeley correct answer data, means and standard deviations broken down by gender and condition. A mixed design ANOVA was performed with Baddeley correct answers as the within subjects variable and gender as the between subjects variable. No correction for sphericity was needed as only two levels of the Baddeley Correct variable were tested. There was a significant main effect of correctly answered Baddeley beside sentences (M = 39.63, SD = 12.877) and behind sentences (M = 44.5, SD = 13.092), $F(1, 23) = 9.713$, $p = .005$. Participant ability to maintain attention to complex conversational stimuli while operating a simulated vehicle does differ greatly based upon the spatial location of the conversation. It is more difficult to correctly maintain a complex conversation while operating a simulated vehicle when the conversation occurs in the beside space (simulated front seat passenger) rather than in the behind space (simulated back seat passenger). The interaction between subjects for gender and correct Baddeley beside and behind scores did not reach significance, $F(1, 22) = .934$, $p = .344$, showing that there is no great attentional difference in performance between males and females when it comes to correctly answering the sentences while driving the simulated course.

Baddeley Total Attempted Sentence Analyses

Table 6 presents all raw Baddeley total attempted sentence data, means and standard deviations by gender and condition. Effects were analyzed via mixed design ANOVA: total attempted sentences were the within subject's variable and gender was the between subject's variable. Sphericity was assumed, but there was no significant main effect of beside (M = 66, SD = 11.69) or behind (M = 67, SD = 11.30) total sentences attempted, $F(1,22) = 1.168$, p = .292. This result illustrates that on average there is no participant difference in the amount of total conversational stimuli each could handle while driving. Participants could equally maintain lengthy complex conversation, but simply maintaining a lengthy conversation is no guarantee that the stimuli are attended or properly responded to, as was revealed from the analysis of Baddeley correct scores.

Gender tests revealed a significant interaction between total amount of Baddeley sentences attempted, $F\ (1, 22) = 15.664$, p = .001. Women were able to answer many more sentences indicating ability to handle lengthier conversations over their male counterparts. When the Baddeley total results were taken together with the Baddeley correct score analyses the results reveal that lengthier conversations do not improve any ability for women to correctly answer the Baddeley stimuli any differently than their male counterparts.

NASA-TLX Analysis

It was not feasible to ask participants to complete three separate versions of the NASA-TLX to gather subjective data for each separate audio condition as each subject served as his or her own control. Therefore, the general focus was on the between subjects gender differences of perceived total workload and the individual break down of all six subscales that made up the survey within all participants. Table 7 presents all raw NASA-TLX data, means and standard deviations including a breakdown of the data by gender**.** Table 8 presents pair-wise comparisons from an RM – ANOVA conducted on the individual workload components with all significant interactions are marked. Figure 5 shows the normal distribution of workload across all six dimensions of the NASA-TLX.

A uni-variate ANOVA was conducted with gender as the independent variable and the NASA-TLX scores as the dependent variable. Women (N = 11; M = 79.818; S.D. = 12.890) rated the task as significantly more difficult on the six axes of the NASA-TLX their male counterparts (N = 13; M = 66.846; SD=14.882), $F(1,22) = 5.107$, p = .034.

It is not clear if the greater subjective difficulty reported by women actually *caused* them to perform any differently on the driving simulation, but within all participants the beside, $r\,(21) = .443$, $p < .05$, far $r\,(21) = .476$, $p < .05$ and control $r\,(21) = .555$, $p < .01$ lap times positively correlated with the NASA-TLX scores suggesting that as the perceived subjective difficulty rises, so does the time it takes to complete a lap on the course. Average lap speed scores somewhat negatively correlated with the workload components, but only the control lap speed returned a significant result, $r\,(21) = -.474$, p

< .05. The beside, *r* (21) = -.359, p = .092 and behind *r* (21) = -.410, p = .052 lap speed results narrowly missed significance. There were no statistically significant correlations between the NASA-TLX, Baddeley correct scores, Baddeley Total sentences attempted or driving errors.

To analyze the individual components of workload a mixed design RM-ANOVA was used to compare the six NASA-TLX factors as within subjects variables and gender as a between subjects variable. Mauchley's test was not violated so sphericity was assumed. There was a significant gender effect of workload difference within all participants for the six factors of the NASA-TLX, F (5, 110) = 10.056, p < .000.

Pair-wise comparisons from the ANOVA were examined in order to understand the individual differences among the workload components. There were no mean differences among temporal demands (Total = 66, M = 2.75, S.D. = 1.59) effort (Total = 67, M = 2.79, S.D. = 1.31), frustration (Total = 58, M = 2.41, S.D. = 1.76) and performance demands (Total = 49, M = 2, S.D. = 1.21) suggesting that trying to respond while driving similarly involves great time and effort that can simultaneously frustrate and affect driver opinion of his or her own performance.

All scales differed largely from mental demand (Total = 97, M = 4.04, S.D. = .954) as it was the greatest source of subjective workload next to effort. This suggests that the more mentally challenging the conversation and driving scenario, the more combined effort participant's will have to expend to perform successfully and that in doing so they will similarly require more time to react, become less confident in their own performance and increase their level of frustration. As mental demand rises, attentional overload increases from switching attention between close and far sound sources while maintaining safe driving. Attentional overload is further perpetuated by the accompanying effort, frustration, temporal demands and opinions of own performance that results in the degradation of total attentional resources available and eventual decreased performance to the driving and conversational task. Though, it is possible that the reason for these results may be the participant inability to judge their own impairment; even though mental demand may be high, they may incorrectly judge their own performance, or effort used, because they do not correctly understand they they are indeed under the influence of a highly involved and attentionally demanding process.

General Discussion

A number of studies have investigated the abilities of participants to perform in a dual task situation requiring operation of a vehicle while simultaneously carrying on a conversation (Alm & Nilsson, 1995; Brown et al. 1969; Collet et al. 2009; Consiglio et al. 2003; Strayer et al. 2003; Strayer & Johnston, 2001; see Caird, Willness, Steel & Scialfa, 2008 and also Horrey & Wickens, 2006) for a meta-analysis of the dual-task driving literature). The majority of these studies, however, failed to focus on whether the spatial location of the in-vehicle conversation might serve as a significant source of driver distraction.

The present study specifically addressed this dilemma by having participants perform in a dual-task scenario. Participants had to safely operate a driving simulation (Task 1) while simultaneously maintaining and correctly answering complex conversation (Task 2) in one of two spatial locations: beside the driver, simulating conversation with a front seat passenger and behind the driver, simulating conversation with a rear seat passenger. It was hypothesized that drivers would make more driving errors and more incorrect answers to the Baddeley stimuli in the beside rather than the behind audio condition. The hypothesis was based on the notion that attentional channel overlap would increase as the conversation increases in directional location to the right of the driver. When the conversation invades the driver's personal space it can blind part of the attention the driver previously reserved to attend to aspects of the driving realm. The attentional blindness often results in reduced driving quality and an eventual degradation in ability to answer the conversational stimuli. Conversely, maintaining a rear seat passenger conversation occurring outside of the direct locational attentional channel realm of the driver causes less attentional blindness, resulting in better performance on the simulated road environment and producing higher scores on the conversational measure.

The results from the present study support our hypotheses, add to the body of knowledge and support previous findings from Consiglio et al. (2003) and Ferlazzo et al (2008) that reported distractive driving effects when conversing with a simulated rear seat passenger and found a reduction in driving performance when conversing with a loud-speaker located on the center dashboard of a vehicle. The inattention blindness hypothesis of Strayer and Johnston (2001) and Strayer et al. (2003) was also confirmed; attention to our auditory task blinded some portion of attention available to the driving scene, just as attention to the driving environment blinded portions of attentional resources the participant might normally use to successfully process the conversational task.

The most important finding from this study was that the directional spatial location of the conversation does matter when operating a simulated vehicle. Participant driving ability was significantly more impaired when the conversation occurred in the beside versus the behind space; drivers made nearly double the amount of on road errors when they attended to and answered the conversation in the beside location. The conversational conditions added extra attentional strain to driver ability to maintain proper safe road behavior; essentially, conversing negatively affected the driving abilities of the conversant. On the other hand, the driving environment added extra attentional strain to participant ability to simultaneously answer our conversational stimuli; in essence, driving also negatively affected the conversational abilities of the driver. These results are similar to what Eimee (2001), Hiscock, Inch & Kinsbourne (1999) and Eimer & Shröger (1998) found in relation to cross modal visual auditory attentional bias existing such that directing attention within auditory conditions can modulate the sensory processing of visual stimuli, and that directing attention within a visual paradigm can modulate the modality specific processing of auditory stimuli.

Criticisms, Applications and Suggestions for Future Research

Even though the results were interestingly significant, this sort of research is not without its fair share of criticisms. Of issue in the dual-task driving research is the belief that the conversation and driving elements of these experiments do not accurately represent real world conditions; when presented with real-world obstacles versus a phone conversation precedence will most likely be given to the real world situation in order to avoid an accident because of a conversation (Levy & Pashler, 2008; Dressel and Achtley, 2008). If the previous statement were true, then there would not be nearly the amount of phone and vehicle related accidents and damage to property as has occurred and continues to occur (Redelmeir & Tibshirani, 1997). The participants in the current experiment were repeatedly told that the goal of the experiment was to drive as error free as possible and concurrently answer the Baddeley sentences. They were also told that if they felt overwhelmed by the conversation they should stop answering and focus on the driving task and only resume answering when they felt best able. Even with these instructions participants made more on track errors and answered less accurately when in the beside versus behind audio condition.

Also of issue is whether or not the driver, passenger, or caller adjusts their conversation and/or driving performance based on the difficulty of the road environment or the conversation. To some extent I'm sure this does occur as no sane individual *wants* to get into a car accident. A driver would hopefully rather throw the phone down or ignore the caller or passenger completely than hit an obstacle, but, it *is* an accident, and they occur because of complacency and often of a feeling of superiority and the "it won't happen to me" attitude (Alm & Nilsson, 1995). A meta-analysis of the literature done by

Horrey and Wickens (2006) found in-vehicle passenger conversations to be as similarly distracting to drivers as cell phone conversations, adding that passengers do not moderate their conversations any differently than they would if they called from a cell phone outside of the vehicle driving environment. Redelmeier and Tibshirani (1997) have shown that the chance of having a collision while driving and conversing quadruples with the addition of a cell phone conversation. The results of the present study clearly show that conversing while driving causes errors on the road, but specifically, those errors almost double when the driver/ passenger conversation occurs in the beside space of the driver versus the behind space. Accounting for correct participant sound perception of the Baddeley stimuli between the beside and behind condition might have resolved some biasing issues, but, the behind condition may have only seemed less distracting toward driving because it was less audible. Though, the error data suggests otherwise as participants were more accurate in the behind over the beside conversational condition implying they could adequately hear the behind audio and generate more correct responses while driving. Additionally, inclusion of eye tracker apparatus might have helped to control for a possible auditory attentional bias that may have cause participants to divert greater attentional resources to the beside condtion over that of the behind condition.

Participant age was also a critical limitation to the large-scale population generalization of the current research. Time, budget constraints and feasibility of acquiring participant's outside of the university subject pool was simply not an option for the present study. In the future it would be advantageous to collect data from populations consisting of middle aged drivers, elderly drivers and children under the age of 16.

Conducting investigations with these populations would expand the current knowledge base not only because of their age differences, but for the certain differences in consumption of cellular devices. Does increased usage and familiarity, or lack thereof, with cellular devices affect driving performance? Might younger individuals that have little to no driving experience, but huge amounts of cellular experience conversing and texting perform better on the road than those with less cellular experience but more real on road experience?

If the above were true, it would benefit new and old drivers alike to take part in practice conversing and driving in a similar environment to the driving simulation used in the present research. How, exactly to do this is still in deliberation, but it is entirely possible to set up the driving simulation in a public space and allow individuals of all age and experience levels to take part. It could even be made fun and competitive by allowing high scores and comparisons between friends and family as well as marketing and advertising possibilities if set up in a public shopping space.

The results of this study suspect that maybe it is easier for drivers to maintain a conversation while driving if the spatial audio location of the conversation comes from the rear of the car's cabin rather than directly in front of or to the right of the driver. It would benefit drivers greatly if they had an option to enable the audio of their in-vehicle phone conversations to occur in a centrally located speaker location in the rear of the vehicle. Having this option might reduce attentional channel overload between the close personal space of the driver, the conversation, and the driving realm, hopefully also reducing driver fatigue, driver error and driver caused fatalities.

Future studies would benefit from trying the same spatial audio approach but with more realistic and personally tailored conversation. Though, doing so can be difficult and time consuming, with the drawback of the subjective nature of what constitutes a realistic or demanding conversation. A between subjects design would also add the benefit of a specific control group and allow for comparisons of subjective workload via the NASA-TLX between audio conditions. Adding track difficulty as another independent variable would advance understanding of how drivers handle conversation from different spatial locations under different driving conditions such as in the rain, at night, or complex versus easy roadways.

In summary, this study was largely a success. It was shown that the spatial location of the audio from the conversation does have an effect on participant driving ability and participant ability to answer correct conversational stimuli – all more so in the beside space (simulated front seat passenger) than in the space behind the driver (simulated rear-seat passenger). The exact attentional mechanisms of why this result was obtained remain largely unknown at this time. Though, generally it is accepted that the inattention blindness hypothesis and the central bottleneck theories of attentional overload are sufficient, on the surface, to explain the current results. To fully answer the question of what and where attention resides and how and why it is allocated under different circumstances will demand the attention of researchers for decades to come.

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Table 1.

Motec Speed Data expressed in mph (miles per hour) and Means and Standard Deviations by Condition and Gender

	Beside Speed	*Behind Speed*	*Control Speed*
Mean	105.605	104.171	107.688
S.D	16.492	15.918	19.261

Male				Female			
Subject	*Beside*	*Behind*	*Control*	*Subject*	*Beside*	*Behind*	*Control*
1	108.225	100.850	114.875	1	105.050	105.225	112.125
2	126.675	126.550	131.600	2	100.425	93.725	91.800
3	126.425	127.500	130.825	3	92.925	88.775	100.975
4	124.150	124.400	130.850	4	107.825	106.650	110.000
5	126.450	116.850	130.450	5	107.250	109.525	106.550
6	97.500	98.200	97.325	6	70.275	68.800	60.625
7	108.600	110.000	117.300	7	102.250	107.850	113.375
8	120.725	119.850	126.375	8	82.750	84.150	97.025
9	114.325	106.000	105.600	9	88.250	89.125	91.475
10	123.775	119.950	124.225	10	81.750	85.750	79.325
11	102.100	107.225	113.425	11	86.225	80.600	72.625
12	125.000	118.400	118.075				
Mean	116.995	114.647	120.077		93.176	92.743	94.173
S.D.	10.460	9.947	11.033		12.349	13.162	17.240

Note. A total of 23 participants were used in the speed data analysis as a result of a computer recording error. Mean comparisons between behind and control reached statistical significance, $p = .016$., however, comparisons between beside and behind and beside and control did not reach significance, $p > .12$ in all cases. All mean comparisons of gender by condition reached statistical significance at the $p < .001$ level.

Table 2.
Motec Lap Time Data expressed in seconds and Means and Standard Deviations by Condition and Gender

	Beside Lap Time	*Behind Lap Time*	*Control Lap Time*
Mean	142.794	143.078	140.830
S.D.	26.156	25.782	33.436

Male				Female			
Subject	*Beside*	*Behind*	*Control*	*Subject*	*Beside*	*Behind*	*Control*
1	133.677	143.633	126.241	1	139.469	138.297	129.180
2	113.864	114.306	109.216	2	160.060	154.421	158.583
3	113.891	113.343	110.227	3	156.607	165.849	143.531
4	116.248	116.709	110.972	4	136.018	136.229	132.041
5	114.345	125.237	111.104	5	136.482	133.976	136.878
6	148.600	147.709	149.477	6	215.706	215.768	245.851
7	132.154	121.411	126.263	7	142.448	134.178	128.279
8	119.760	120.431	114.335	8	176.651	173.703	150.392
9	126.571	126.571	137.487	9	166.313	163.899	158.972
10	116.645	120.870	115.733	10	179.527	171.253	187.045
11	142.941	136.854	127.970	11	172.123	182.812	206.174
12	124.164	122.501	123.152				
Mean	125.238	126.701	121.848		161.946	160.944	161.538
S.D.	11.842	11.672	12.461		24.033	25.300	37.211

Note. A total of 23 participants were used in the lap time data analysis as a result of a recording error. There were no significant differences between the beside, behind and control lap times, $p > .5$. All mean comparisons of gender and lap time reached statistical significance of $p < .002$ or less.

Table 3.
Driver Error Data, Means and Standard Deviations by Condition and Gender

	Beside Errors	*Behind Errors*	*Control Errors*
Mean	10.37	5.26	8.16
S.D.	6.906	5.258	7.034
Total	197	100	155

Male				Female			
Subject	*Beside*	*Behind*	*Control*	*Subject*	*Beside*	*Behind*	*Control*
1	1	6	7	1	3	0	9
2	17	22	22	2	6	5	6
3	0	4	2	3	12	11	15
4	25	12	27	4	5	1	2
5	3	2	12	5	21	7	10
6	13	5	2	6	10	1	12
7	4	0	1	7	14	2	7
8	10	3	4	8	14	2	6
9	16	7	6	9	15	4	2
10	8	6	3				
Mean	9.70	6.70	8.60		11.11	3.67	7.67
S.D.	8.084	6.273	9.046		5.71	3.536	4.330

Note. Driving errors from the first 5 participants were mistakenly not recorded. A total of 19 participants were used in the final analysis of driver error.

Table 4.
Error Movement Data, Means and Standard Deviations by Condition and Gender

	Beside to Behind	Behind to Beside	Beside to Control	Control to Beside	Behind to Control	Control to Behind
Mean	1.42	5.89	4.74	3.27	2.84	3.53
S.D	1.644	4.288	5.184	3.515	2.651	4.489
Total	27	112	90	64	54	67

		Beside to Behind		Behind to Beside		Beside to Control		Control to Beside		Behind to Control		Control to Behind	
		M	F	M	F	M	F	M	F	M	F	M	F
		2	0	1	1	6	5	0	2	1	2	4	0
		2	1	8	4	11	4	6	1	11	2	20	4
		2	7	0	9	1	6	0	3	1	7	2	4
		3	1	11	3	23	0	14	0	4	2	7	0
		0	1	2	15	7	6	0	6	5	2	2	4
		2	1	6	5	1	4	7	5	1	4	2	0
		0	0	2	3	1	3	0	6	0	4	0	2
		0	2	5	12	2	3	5	2	2	3	2	0
		2	0	10	9	4	2	2	3	2	0	5	4
		1		6		1		2		1		5	
Mean	Male	1.40		5.10		5.70		3.60		2.80		4.90	
	Female	1.44		6.78		3.67		3.11		2.89		2.00	
S.D.	Male	1.075		3.814		6.945		4.526		3.259		5.685	
	Female	2.185		4.711		1.936		2.147		1.965		2.000	

Note. 10 male and 9 female participants were used in the error movement analyses. Beside and Behind errors differed significantly, $p = .002$ suggesting greater driving difficulty in the beside audio condition. No significant mean differences were found between conditions and gender, $p > .7$. Main effects were found for error movement, $p < .001$. Pairwise comparisons revealed a significant effect when comparing participant movement from behind and beside to movement of control to beside, $p < .01$, and movement from behind to control, $p < .01$. More importantly, the comparison of movement between beside to behind and behind to beside was significant, $p < .001$, supporting our hypothesis that the greatest mean differences of driving errors would occur in the beside audio condition and in movement from a condition of behind to that more attention demanding beside spatial audio location.

Table 5.
Pairwise comparisons of error movement.

	Beside to Behind	Behind to Beside	Beside to Control	Control to Beside	Behind to Control	Control to Behind
Beside to Behind		.000**	.009*	.029*	.021*	.051
Behind to Beside			.360	.010*	.008*	.059
Beside to Control				.124	.084	.290
Control to Beside					.542	.833
Behind to Control						.378
Control to Behind						

Note. ** = Significant at the level $p < .001$; * = Significant at the level $p < .05$.

Table 6.

Baddeley Data, Means and Standard Deviations by Condition and Gender

	Beside Correct	*Behind Correct*	*Beside Total*	*Behind Total*
Mean	39.63	44.50	66.29	67.13
S.D.	12.877	13.092	11.690	11.300

Male					Female				
Subject	*Beside Correct*	*Behind Correct*	*Beside Total*	*Behind Total*	*Subject*	*Beside Correct*	*Behind Correct*	*Beside Total*	*Behind Total*
1	56	56	56	71	1	30	29	63	65
2	41	38	38	56	2	37	35	62	72
3	26	20	54	54	3	30	45	73	78
4	41	39	55	54	4	55	54	65	63
5	44	46	54	58	5	41	37	64	63
6	58	63	69	69	6	57	52	102	100
7	27	27	62	57	7	51	53	66	63
8	13	27	57	57	8	53	65	82	81
9	38	57	61	65	9	32	50	76	75
10	54	65	66	68	10	47	53	83	81
11	45	51	54	57	11	33	45	80	82
12	22	35	68	65					
13	20	26	60	57					
Mean	37.31	42.31	59.62	60.62		42.36	47.09	74.18	74.82
S.D.	14.568	15.140	5.767	6.049		10.557	10.271	12.164	11.383

Note. Mean comparisons between beside and behind correct reached statistical significance, $p < .005$, but comparisons of beside and behind total attempted did not, $p > .2$, indicating that all participants were able to entertain the same relative conversational durations in either condition, but had greater difficulty answering correctly in the beside condition. Total sentences did, however, differ significantly by gender in all cases, $p < .001$. No mean comparisons of beside and behind correct answers by gender reached statistical significance, $p > .3$.

Table 7.
Raw NASA-TLX Data, Means and Standard Deviations including Gender

		Workload											
		Mental		Physical		Temporal		Performance		Effort		Frustration	
Mean		4.04		1.04		2.75		2.00		2.79		2.41	
S.D		.954		1.23		1.59		1.21		1.31		1.76	
Total		97		25		66		49		67		58	
		Mental		Physical		Temporal		Performance		Effort		Frustration	
		M	F	M	F	M	F	M	F	M	F	M	F
		5	4	0	4	3	0	3	2	2	2	2	3
		5	3	1	1	1	4	4	2	3	0	1	5
		5	4	3	1	4	5	2	1	1	4	0	1
		4	5	0	0	5	3	2	2	1	4	3	1
		4	4	0	2	3	5	1	0	5	2	2	2
		5	5	0	1	2	3	1	0	4	3	3	3
		2	3	1	0	4	1	1	2	2	4	5	5
		5	5	2	0	3	3	1	3	4	3	0	1
		2	4	1	1	3	1	5	2	4	2	0	5
		3	4	0	1	3	5	4	2	1	3	4	0
		5	4	0	4	3	0	1	2	3	2	3	3
		3		0		2		2		3		5	
		4		2		0		3		5		1	
Mean	Male	4.00		.77		2.77		2.31		2.92		2.23	
	Female	4.09		1.36		2.73		1.64		2.64		2.64	
S.D.	Male	1.155		1.013		1.301		1.377		1.441		1.787	
	Female	.701		1.433		1.954		.924		1.206		1.804	

Table 8.
Pairwise comparisons of all six NASA-TLX components

	Mental	Physical	Temporal	Performance	Effort	Frustration
Mental		.000***	.004**	.000***	.001***	.003**
Physical			.002**	.018*	.000***	.011**
Temporal				.113	.949	.572
Performance					.047*	.343
Effort						.525
Frustration						

Note. *** = significance at the level p < .001; ** = significance at the level p < .01.; * = significance at the level p < .05; the table shows that there is no mean difference among temporal demands, effort, frustration and performance demands, suggesting that trying to respond while driving similarly involves great time and effort while often frustrating and affecting drivers opinions of their own performance. All scales significantly differed from mental demand as it was the largest source of subjective workload next to effort. This suggests that the more mentally challenging the conversation and driving scenario, the more combined effort participant's will have to expend to perform successfully and that in doing so they will similarly require more time to react, become less confident in their own performance and frustrate themselves, which can perpetuate the cycle as long as the driving and conversing continues and mental demand continues to rise.

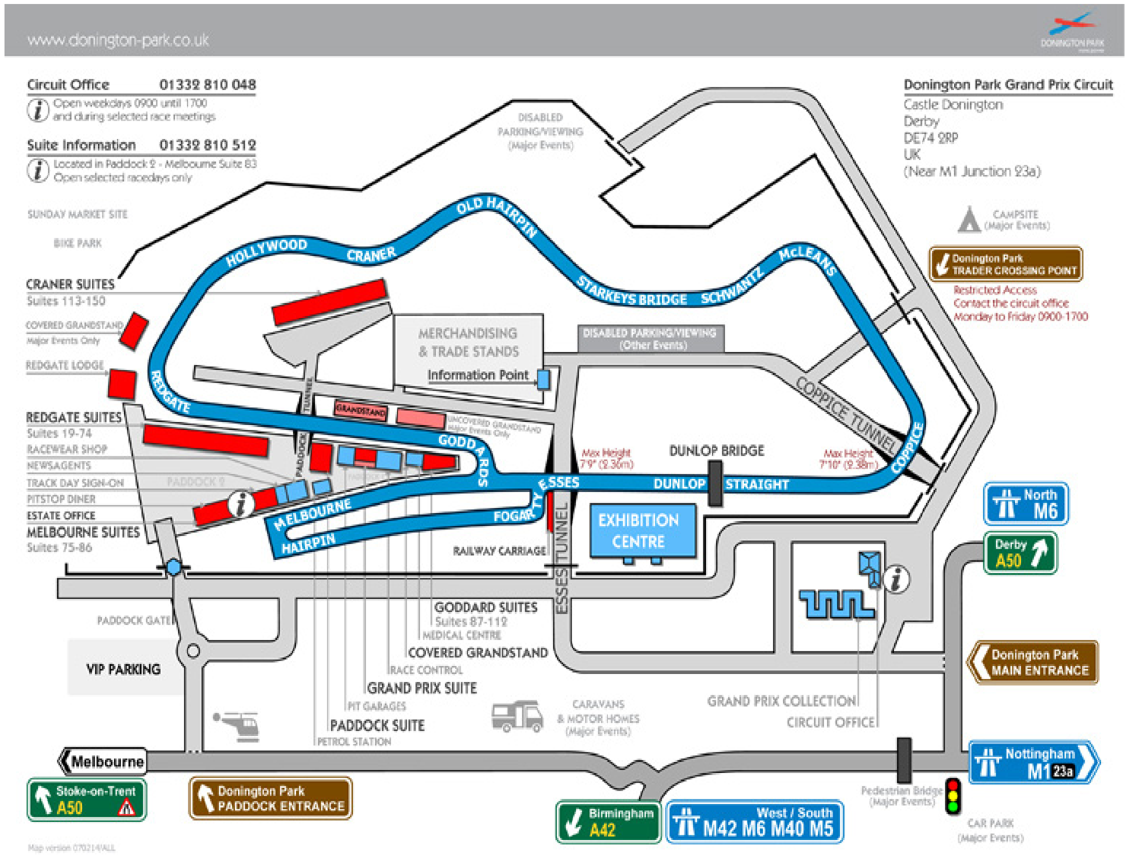

Figure 1. Donnington Park Racetrack. The path marked in blue was the course driven by participants.

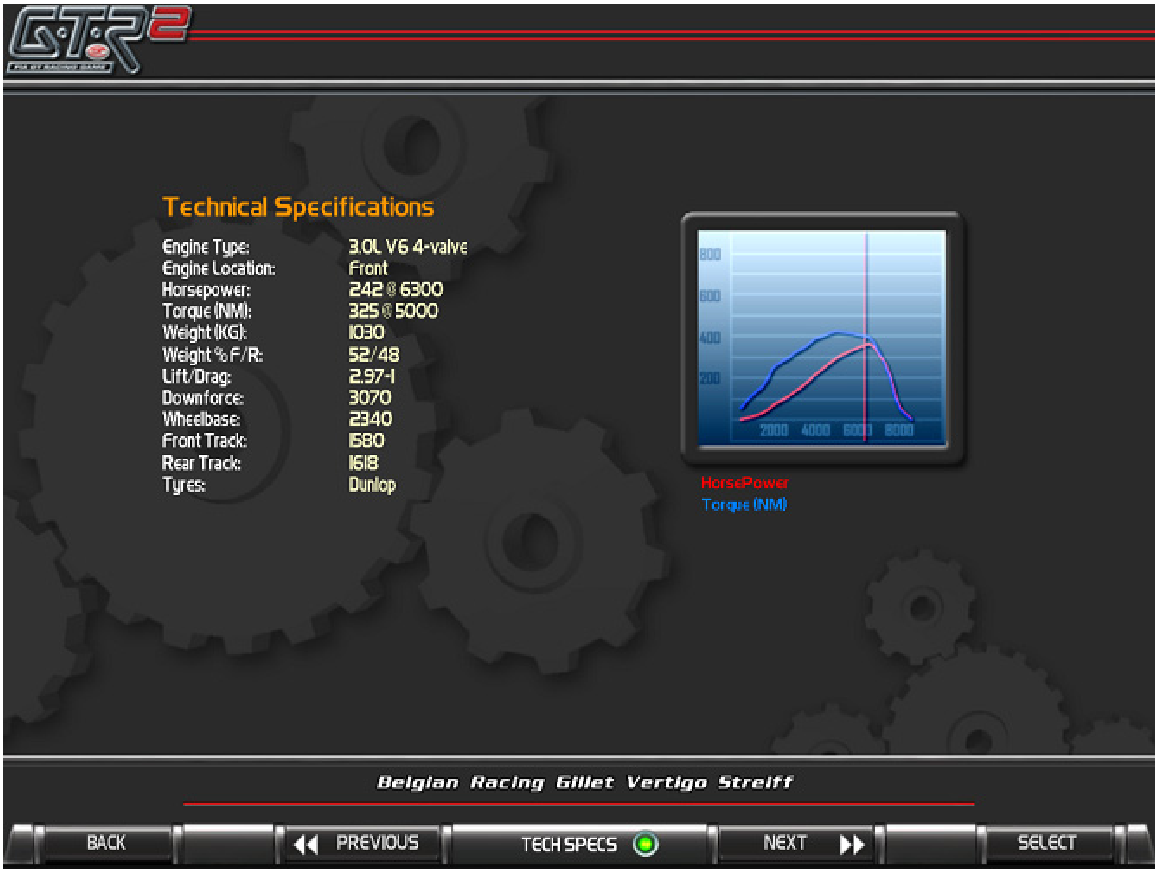

Figure 2. Technical specifications for our chosen vehicle: A Belgian Racing Gillet Vertigo Streiff.

Figure 3. Depiction of the "driving line" available to participants during practice driving sessions. Red indicated a need to apply brakes, blue stressed acceleration and white suggested neither braking nor accelerating.

Figure 4. Depiction of driving aide arrow. This aide was available during practice and experiemental sessions. The figure above shows a Red Arrow pointing to the right containing the number one. This indicates that a difficult right turn is approaching in approximately one second. If the arrow were yellow, pointed to the left and contained a 3 that would mean that an easy left turn was approaching in approximately 3 seconds.

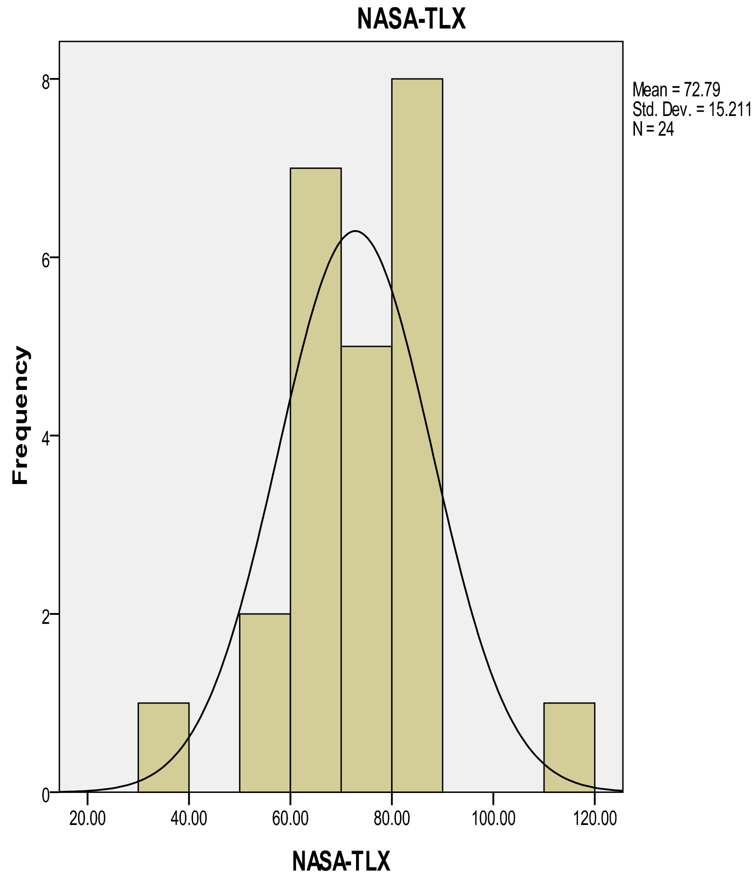

Figure 5. Normal distribution of subjectively perceived difficulty of our task across the six dimensions of the NASA-TLX.

Appendix A

Acknowledgment of Informed Consent

We are asking you to take part in a research study designed to test effects of attention and cognition. In this study you will engage in conversational tasks while performing a computer driving simulation. We anticipate running approximately 50 participants throughout the course of this research. The maximum duration of your participation is two separate sessions on two different days with an approximate length of two hours per session; minimum duration of participation will likely be one session, occurring on one day, for approximately one hour. We kindly ask that you do not divulge the details of the procedures of this experiment with your fellow classmates as this could bias their performance if they too will be participating in our research.

We want you to understand that your participation is voluntary. There is little if any risk or harm that will come to you by participating but you may end your participation at any time without prejudice. If you choose to end your participation early a pro-rated amount of credit will be given. A minimum of one credit hour will be given if you show up as agreed, but decline participation after hearing the full description of the task; the full two hours of credit for the first training session will be given upon completion of this first session *and* upon return for the second session. At that time, four total credit hours will be given. Four hours is the maximum time we expect for your participation; however, as stated above, it could be considerably less. Please understand that you have the option of not participating in this research and may write an approved paper to satisfy your course requirement. The purpose of your participation is to advance the larger body of psychological knowledge concerning attention and cognition and for you to leave the experiment with a greater understanding of the processes involved in conducting a research study.

We want you to know that all of your responses will be kept anonymous; any response made by you will not be able to identify you as the respondent. We want you to also understand that your results will be kept confidential and only released in the aforementioned anonymous fashion in scientific papers and reports.

If you have any questions or comments about this research you may contact Tom Martinez directly at: (856)829-8688; or via email: guitar1@camden.rutgers.edu. You may also contact Dr. J.W. Whitlow, Jr. of the Rutgers Camden Psychology Department at (856)225-6520; or via email: bwhitlow@camden.rutgers.edu. If you have any additional questions about your rights as a research subject, you may contact the IRB administrators at Rutgers University at:

Rutgers University Institutional Review Board for the

Protection of Human Subjects

Office of Research and Sponsored Programs

3 Rutgers Plaza

New Brunswick, NJ 08901-8559

Tel: 732-932-0150 x 2104

Email: humansubjects@orsp.rutgers.edu

Participant

Date: ________________________________

Signature: _______________________________

Investigator

Date: ________________________________

Signature: _______________________________

Appendix B

The following questions were designed to gather basic background information. We ask that you give some response to every statement even if some seem similar. There is no right or wrong answer to any of these questions. If you are unsure how to answer a question, answer as best as you can. When you are finished, please hand the survey to the researcher. Rest assured that all results will be kept both anonymous and confidential and used only for this current research experiment.

When ready, please turn the page and begin answering the statements.

Thank You.

Directions:

For questions 1, 2 and 3, please circle the response that best answers that question for you.

For questions 3 and 4, please write your answer in the blank(s) provided.

1. Are you: **MALE** or **FEMALE**

2. I have normal or corrected to normal vision (via contacts or glasses).

    a. Yes
    b. No

2. As far as I am aware my hearing is normal and I have no problems hearing everyday sounds.

    a. Yes
    b. No
    c. Other (Please explain below)

    ____

3. Please indicate the approximate time in years that you have been in possession of a valid driver's license:

    ____

4. Please indicate the approximate amount of times, over the last month that you have used a cell phone to:

    a. Make or answer a phone call:

    ____

    b. Make or answer a text message:

    ____

c. Make or answer a phone call while driving:

____

d. Make or answer a test message while driving:

____

Appendix C

Debriefing Statement:

The following few paragraphs will summarize the purpose of our study and the manipulations and apparatus that were employed. Please carefully read the statement silently to yourself; it will hopefully answer any questions about your participation. If after reading this statement you have any additional questions, please do not hesitate to ask those questions. Feel free at anytime to use the contact information at the end of this statement to contact myself, Dr. Whitlow, or the Office of Research and Sponsored Programs.

The purpose of the experiment you just took part in was to gather data for additional validation of existing research and to build upon those hypotheses and methodologies with our own manipulations. The methodology of this current experiment is based in part upon Strayer and Johnston's (2001) *inattention blindness* hypothesis. According to the researchers, cell phone conversations can impair or *blind* certain aspects of our attentional capacity needed to safely operate a motor vehicle. This sort of phenomena is often investigated by using a "dual-task" methodology. Our study employed such a methodology by incorporating a driving simulation as the primary task, and conversational stimuli, which was a version of the Baddeley Reasoning Test (1968) as the secondary cognitive interference task.

Building upon the dual-task framework and the inattention blindness hypothesis we became primarily concerned about the location of the audio stream of the conversation and how that may influence performance in dual-task scenarios. The idea for the presentation of what you experienced as a headphone condition and an external speaker condition was inspired by research recently conducted by Ferlazzo, Faioli, Di Nocera & Sdoia (2008). Ferlazzo et al. (2008) hypothesized that a main mechanism of attentional costs during dual-task performance is a shift of spatial attention between near and far spaces. We agree with Ferlazzo et al. (2008) but feel that their sole focus on reaction times as a dependent measure did not adequately sample the realm of variables that could be affected by manipulating independent variables such as ours: the location of the audio stream of the conversation and the difficulty of the driving environment.

We understand that our manipulations may not easily generalize to actual driving and cell phone conversation. That is a trade off often made between real-world on-road driving experiments and in-lab simulation experiments. However, we were afforded greater flexibility in control over our variables and greater safety to our participants; both of these reasons were major motivating factors behind our choice of design. Our goal with this design was to show that when performing a primary task similar to operating a motor vehicle, while engaging in a secondary conversational task, decrements to that primary task will result. It is our hope that upon reading this debriefing statement you come away with some greater understanding of what it takes to create a sound research experiment.

If you enjoyed the experience of this experiment, both the simulation and driving apparatus are easily available for purchase through amazon.com. The simulation used was *GTR 2: Realism Redefined, by Viva Media.* The driving apparatus, including wheel, brake and gas, was a Logitech MOMO Racing Force Feedback driving assembly. The program we used to simultaneously gather real time simulation data was the *i2 Analyzer,* by the company *Motec.* Motec software is freely offered and downloadable from Motec.com by clicking on *downloads* > *software* > *latest releases,* and choosing the latest version of the *i2 pro* software. The program has a surprisingly easy learning curve, but can be as difficult and complex as you choose to make it; it easily interfaces directly with GTR 2 for seamless recording of nearly any user defined driving variable.

Again, if you have any further questions at any time please do not hesitate to contact myself, Dr. Whitlow or the Rutgers Office of Research and Sponsored Programs at the following:

Tom Martinez directly at home: (856)829-8688, or via email: guitar1@camden.rutgers.edu.

Dr. J.W. Whitlow, Jr. of the Psychology Department at (856)225-6520, or via email: bwhitlow@camden.rutgers.edu.

If you have any additional questions about your rights as a research subject, you may contact the IRB Administrator at Rutgers University at:

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