2017-04-01

Effects of Conversational Modalities on Driving and Speaking Performance

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

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The purpose of this study was to examine the bidirectional effects of simulated driving and conversations using different speaking modalities. Participants included 30 males and 30 females with no history of speech, language or hearing disorders. The participants were divided into three age groups: 20s, 40s, and 60s. They completed a driving simulation task in isolation and also while speaking on a hand-held or hands-free cell phone or with a passenger in the car. Speech measures included speaking time ratio, mean, and standard deviation of intensity, as well as mean and standard deviation of fundamental frequency in semitones. Driving measures included standard deviation of lane position, mean, and standard deviation of speed, standard deviation of steering wheel position, and the average number of steering wheel turns. There were significant effects of speaking while driving on mean intensity, speaking time ratio, standard deviation of steering wheel position, and the number of steering wheel turns. There were significant gender effects for speaking time ratio, standard deviation of intensity, and mean intensity, with the females having higher speaking time ratios, and the males having a higher standard deviation and mean of intensity. There was a significant age effect for mean fundamental frequency, standard deviation of lane position, and the standard deviation of steering wheel position. For mean fundamental frequency, the 60s group were lower than the 20s group. The 60s group had a higher standard deviation of lane position and standard deviation of steering wheel position. These findings reveal effects on both speaking and driving performance when speaking and driving concurrently. This has potential clinical implications for planning therapy activities that will help individuals generalize their learned skills from quiet, distraction-free clinic rooms to more realistic situations with distractions and background noise.

Keywords: driving, speech acoustics, divided attention, bidirectional interference

ACKNOWLEDGMENTS

Thanks are due to many people for helping me through this process. I would first like to thank my thesis chair, Dr. Dromey, for his time and effort in helping me complete this thesis project. His patience and extensive knowledge on this topic helped me not only have a positive experience doing research but increased my knowledge on our topic as well. Without his dedication and persistence this thesis would not have been possible. He constantly took time out of his busy schedule to meet with me and edited countless drafts every step of the way. His unwavering enthusiasm and encouragement has been invaluable and I could not have finished this project without him.

I would also like to thank all the other people who assisted in any way to complete this project. Kelsey Simmons for helping with data collection, my committee for their support and feedback, Garrett Porter for his programming expertise and of course all the participants for giving their time and energy to help further our research endeavors. I would also like to give a huge thank you to the members of my cohort for their friendship, encouragement, and generosity. I am indebted to them for staying positive and cheering me on even during the hard moments. I never could have made it through grad school without them.

Finally, I would like to thank the most important people in my life, my family. I owe an enormous debt of gratitude to each member of my family for their constant love and support of me and my dreams. None of this would have been possible without their love and encouragement. I am so grateful for their support and reassurance during the tough times and their enthusiasm and praise during the good times. Pursuing my dream of getting my master’s degree would never have been possible without their help and support.

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DESCRIPTION OF THESIS STRUCTURE

This thesis, *Effects of Conversational Modalities on Driving and Speaking Performance,* was generated as part of a research study and is written in the format of a journal article. The content may be used for publishing in future articles. An annotated bibliography is included in Appendix A and an informed consent form is included in Appendix B.

Introduction

For many years researchers have studied divided attention tasks involving two or more concurrent activities. In the field of cognitive psychology there has been significant research examining what takes place when we attempt to perform more than one task at the same time. The performance of everyday tasks can involve complex cognitive, linguistic, or motor processes. When these tasks are performed by themselves (often referred to as isolated tasks), an individual can devote all their cognitive resources to performing each task optimally. However, when two or more tasks are performed concurrently, a person is required to divide their neural resources across all of the tasks.

Many divided attention studies have examined performance on a main task while participants complete a distractor task that is not measured. This can be described as a *unidirectional* study, because the effects of the two tasks on each other are not considered, only the impact of a distraction on a main task. In one such study by Boiteau, Malone, Peters, and Almor (2014) the researchers examined the effects of conversation on a visual tracking task. They found that when participants were talking, their performance on the tracking task significantly decreased compared to when they were listening and performing that same tracking task. The results were not different for a conversation with either an unfamiliar conversational partner or a familiar friend. In addition, the experimenters found that when the difficulty of the tracking task increased, conversational interference increased. Interference is defined as the decline in performance that takes place when an individual is performing more than one task at the same time (Bailey & Dromey, 2015). In the study by Boiteau et al. the researchers were able to determine the effects of the distractor task, talking or listening, on the main measured task, visual tracking task performance.

In a study by Amado and Ulupinar (2005), the experimenters examined the effects of different types of conversation on attention and peripheral detection while driving. They found that the percentage of correct answers given for the attention and peripheral detection tasks was significantly lower during the divided attention conditions, using hands-free and passenger conversations, compared to the no conversation condition. This study showed that different types of conversations have a negative impact on driving performance.

Another example of a unidirectional divided attention study is Dromey and Benson (2003). These authors examined the effects of a concurrent cognitive, linguistic or motor task on speech movements. Lip movement data showed a decrease in displacement and velocity during the motor task. During the linguistic and cognitive tasks, there was an increase in spatiotemporal variability and an increase in the negative correlation between upper and lower lip displacement. This study showed that the distractor tasks had a negative impact on kinematic speech measures, and that the type of task determined the nature of the kinematic change.

In contrast to a unidirectional study, *bidirectional* studies measure the extent to which two different tasks influence one another. In a dual task study completed by Dromey and Bates (2005) the researchers examined lip movements in speech tasks completed concurrently with linguistic, cognitive, and visuomotor tasks. They found that the speech tasks influenced and were also influenced by the linguistic, cognitive, and visuomotor tasks. This study provided evidence for the suggestion that tasks performed concurrently can have an influence on one another in either direction. Bailey and Dromey (2015) evaluated the bidirectional interference between speech and cognitive, motor or linguistic tasks in three different age groups. They found that there was significant interference between speech and non-speech measures when performing linguistic and cognitive tasks along with speech tasks, as well as a significant interference during the concurrent speech and motor tasks – providing further evidence that when certain speech and non-speech measures are performed concurrently, the interference takes the form of a decline in performance of both measures.

Speaking and the ability to perform the necessary operations to drive a car each require significant cognitive resources. For a typical speaker, speech is the result of finely tuned and coordinated actions of multiple subsystems. Correctly articulated speech, while often taken for granted, is actually a very complex process involving a combination of processes including language, memory, articulation, and even breathing in a rapid and precise fashion. Drews, Pasupathi, and Strayer (2008) discussed the idea that in speaking, people bring together multiple elements to create a meaningful conversation. These can include, "monitoring the topic and content, coordinating turn taking and so on" (Drews et al., 2008). These authors suggested that because typical conversations require significant attention, any type of conversation while performing another task should cause a decrease in the performance of that task (Drews et al., 2008). Similar to speaking, driving a car also involves multiple processes. As Beede and Kass (2006) noted, "Driving alone, without engaging in distracting activities, requires the successful time-sharing of concurrently performed tasks" (p. 415). These authors discussed multiple tasks that must be performed concurrently while driving. They separated the tasks into immediate tasks and peripheral tasks. According to Beede and Kass, immediate tasks can include such actions as maintaining forward motion, staying on the roadway, and reacting to changing events that can impact the driver. They listed processing static signs or objects in the periphery, viewing both inside the car and the surrounding environment, and monitoring speed as peripheral tasks. An individual must bring together all of these immediate and peripheral tasks in order to avoid collisions and be a successful driver. Through focused attention and repeated practice of the same motor movements, experienced drivers are able to acquire the skills necessary to drive a car.

When considering interference between conversation and driving, one must also consider the different types of conversations that take place in typical driving situations. With today's technology there are several options for holding a conversation with someone while driving. First, the conversational partner may be a passenger who is physically present in the vehicle. Or they might be participating in the conversation via a hands-free cell phone using Bluetooth or speaker phone capabilities found in many late model vehicles. Lastly, conversations can also take place with the driver holding a mobile phone in one hand and steering the vehicle with the other hand. Several research studies have examined the impact that different types of conversations have on driving safety (Charlton, 2009; Crundall, Bains, Chapman, & Underwood, 2005; Drews et al., 2008). All three of these studies found that cell phone use while driving resulted in a decrease in driving performance compared with in-car passenger conversations. These studies provide evidence that driving while talking on a cell phone negatively impacts driving performance. However, the current study will take this one step further and examine the bidirectional interference between driving and three types of conversations – in-car passenger, hands-free cell phone, and hand-held cell phone – by measuring speech variables in addition to driving performance.

Cognitive function typically decreases as a person ages. Even without neurologically damaging diseases that are more common in older individuals, the available cognitive resources are more limited (Salthouse, 2009). In discussing the effects of aging on dual task performance specifically, Kramer and Larish (1996) noted that, "one of the best exemplars of a mental activity in which large and robust age-related differences have been consistently obtained is dual-task processing” (p. 106). The influence of age has also been observed in speaking and driving dual task conditions because younger people are more familiar with technology, specifically cell phones, but older generations have a greater number of years of driving experience. This idea is discussed more fully by Drews et al. (2008). In this study the researchers examined the effects of using a hands-free cell phone while driving in younger and older drivers. They found that talking on a hands-free cell phone had a negative impact on all 4 areas of driving performance. However, the experimenters found no significant difference in the driving performance of younger versus older drivers.

Extensive research has been completed regarding the effects of cell phone use on driving and the safety implications of speaking while driving (Beede & Kass, 2006; Cao & Liu, 2013; Dula, Martin, Fox, & Leonard, 2011; Laberge, 2003; Strayer & Johnston, 2001; Treffner & Barrett, 2004). However, research is more limited regarding the effects of a motor task like driving on the way we communicate. For example, how does talking while driving change our speaking rate, intensity, or pause durations? Drews et al. (2008) compared the conversations of drivers with an in-car passenger versus conversations using a cell phone. They found that the speech rate of the driver decreased with a passenger but increased when using a cell phone. Both the driver and the conversational partner decreased the number of syllables per word they spoke in the dual task condition. The passenger condition had twice as many conversational turns as the cell phone condition. The researchers found a significant difference between cell phone and passenger conversations, both in the effect on driving performance and also in their conversational features. This study measured only basic speech variables during a divided attention task. However, the current study will allow a more detailed quantitative analysis of the effects of driving on speech.

In speech research, experimenters are faced with the choice of focusing on either naturalistic conversation to be able to generalize results to everyday speaking situations or experimental control, which involves having every participant say the exact same words in order to make more straightforward statistical comparisons. In the current study, experimental control was sacrificed in favor of more naturalistic conversations in order to increase ecological validity and allow better generalization to everyday situations.

It is hypothesized that when speaking and driving tasks are performed in the divided attention condition there will be a decrease in performance on each task compared to when either task is performed on its own. Decreased driving performance will be measured by metrics relating to speed and lane maintenance. The level of interference in speech characteristics will be measured using acoustic measures of prosody. While speech therapy typically takes place in quiet rooms with very few visual and auditory distractions, everyday conversations more often take place in busy and distracting environments, where speakers and listeners are required to focus on their speech and block out the background noise. Understanding how speech is affected by dual task conditions can give speech clinicians greater knowledge as to how they can best help their clients succeed in complex, everyday conversational interactions.

Method

Participants

Participants recruited from the local community by word of mouth included 30 men and 30 women in three age groups of 20 individuals each: young adults (ages 20-30 years), middle-aged adults (ages 40-50 years), and older adults (ages 60-71 years). The participants were all native English speakers with no self-reported history of speech, language, or hearing disorders. They had normal or corrected-to-normal vision and a valid driver's license. The participants each signed an Institutional Review Board-approved consent form to be a research subject prior to their involvement in the study.

Equipment

Participants were seated in a sound booth and fitted with a headset microphone to record their speech. The microphone recorded a reference tone that was measured with a sound level meter (Extech 407736) 50 cm away from the speaker in order to subsequently compute the intensity of all recordings in dB. The participants' speech was recorded to a computer using Audacity software (version 2.0.6). The driving simulator used OpenDS software (version 3.5) on a laboratory computer connected to a Logitech Driving Force GT steering wheel and a gas/brake pedal unit.

Procedures

During the study participants engaged in a series of conversations either in the single task condition or while concurrently merging and driving on a simulated freeway. A pilot study completed prior to data collection showed that performance on maintaining a constant speed and consistent lane position plateaued after the fifth out of ten trials the pilot participant completed. Therefore, study participants completed five practice trials to familiarize themselves with the simulator and understand what the task involved. For the first two practice trials they were instructed to familiarize themselves with how the simulator worked and to take the first freeway exit. On the third trial they were given an additional instruction to attempt to maintain a constant speed of 100 km/h while also following previous instructions. Finally, for the fourth and fifth trials, the participants were given the instruction to attempt to stay in the center of the right lane while maintaining the target speed.

Following the practice trials, the participants completed seven tasks involving conversations and driving that were performed in random order. The seven tasks were as follows: a) driving without speaking; b) conversing on a hand-held cell phone without driving; c) conversing on a hands-free cell phone without driving; d) conversing with a passenger in the "car" (sound booth) without driving; e) driving while having a conversation on a hand-held phone; f) driving while having a conversation on a hands-free phone; g) driving while having a conversation with a passenger (the researcher) seated beside the participant. The participants and researcher used the same two phones (one mobile phone and one land-line phone) for each conversational task to ensure overall consistency of equipment across participants. Using the OpenDS software, participants completed the "Motorway" course for each driving trial. It took about two minutes to complete the entire course (including on and off ramps) and the car traveled a distance of 1300 meters on a freeway. The participants were required to merge onto the freeway as soon as they reasonably could, drive in the center of the right lane at a constant speed of 100 km/h, and take the first exit. In addition, there were other cars on the freeway driving a constant speed of 100 km/h.

Data Analysis

The Praat software program (version 5.4) was used to analyze the speech samples. All sounds other than the participant's speech (laughing, coughing etc.) were removed, and also the researcher's speech was deleted prior to the acoustic analysis. The middle 45 seconds of each sample were analyzed.

Speech samples recorded in the single task condition were compared with those in the divided attention condition to assess the effects of driving on the participants' speech. Variability in fundamental frequency and intensity as well as pause durations were calculated to analyze each participant's prosodic performance on each of the six speech tasks (three in the single task condition and three in the divided attention condition). A custom Matlab program (version 9.0) was used to analyze the intensity and speech/pause ratio data; the fundamental frequency variables were exported from Praat.

Driving data from the non-speaking condition were compared with the data from the divided attention condition to assess the effects of speaking on the participants' driving performance. The variables computed for the driving task were the mean and standard deviation of participants' speed, lane position variation, the variation of steering wheel position, and the number of steering wheel turns. The log files created by the OpenDS software were analyzed using a custom Matlab program.

Results

A repeated measures analysis of variance (ANOVA) was performed using SPSS software (version 23) to identify the significant changes in the dependent variables. The within-subject factor was the divided attention versus isolated task condition, and between-subject factors included age group and gender. Results reported in the text below showed a significant effect at $p < .05$. The descriptive statistics for the speech variables of speaking time ratio, mean intensity, standard deviation of intensity, mean fundamental frequency, and semitone standard deviation are listed in Tables 1-5. The descriptive statistics for the driving measures of standard deviation of lane position, mean speed, standard deviation of speed, standard deviation of steering wheel position, and number of steering wheel turns are listed in Tables 6-10.

Effects of Driving on Speech Variables

Hand-held phone: Speaking while driving versus speaking only. As shown in Figure 1, there was a significant main effect for mean intensity, which was higher for the speaking while driving than for the speaking only condition, $F(1, 54) = 4.256$; $p = .044$, $\eta_p^2 = .073$. There were no significant main effects of driving for the variables of speaking time ratio, standard deviation of intensity, mean fundamental frequency or semitone standard deviation when compared to the speaking only condition. The semitone standard deviation was higher for the female participants during the speaking while driving condition compared with the speaking only condition, but this pattern was not found for males. This led to a significant driving by gender interaction, $F(1, 54) = 4.616$; $p = .036$, $\eta_p^2 = .079$. The speaking time ratio across conditions differed significantly between the two genders, $F(1, 54) = 5.789$; $p = .020$, $\eta_p^2 = .097$. As shown in Figure 2, the female participants generally had a higher speaking time ratio than the males. There was a significant gender effect for the standard deviation of intensity, with males having higher values than females across conditions, $F(1, 54) = 8.136$; $p = .006$, $\eta_p^2 = .131$. As would be expected, there was a significant gender effect for mean fundamental frequency, in that the males had lower values than the females, $F(1, 54) = 272.560$; $p < .001$, $\eta_p^2 = .835$.

Hands-free phone: Speaking while driving versus speaking only. ANOVA testing revealed a significant main effect for speaking time ratio. The proportion of time spent speaking was higher for the speaking only versus the speaking while driving condition, $F(1, 54) = 6.384$; $p = .014$, $\eta_p^2 = .106$. There were no significant main effects for mean intensity, standard deviation of intensity, mean fundamental frequency or semitone standard deviation. There was a significant between-subjects effect for gender, in that males had a higher mean intensity than females across conditions, $F(1, 54) = 10.496$; $p = .002$, $\eta_p^2 = .163$. As would be expected, there was a significant gender effect for mean fundamental frequency, in that the males had lower values than the females, $F(1, 54) = 271.912$; $p < .001$, $\eta_p^2 = .834$. There was a significant between-subjects effect for group for the semitone standard deviation, $F(2, 54) = 4.039$; $p = .023$,

η_p^2 = .130. Post hoc testing revealed that the 40s group had a higher semitone standard deviation than the 20s group (p = .020).

Passenger conversation: Speaking while driving versus speaking only. As shown in Figure 2, all participants had a higher speaking time ratio during the passenger conversation speaking-only condition than while driving during the passenger conversation, with the exception of the 60s group males where the speaking time ratio stayed the same, $F(1, 54)$ = 12.197; p = .001, η_p^2 = .184. There were no significant main effects for the mean intensity, standard deviation of intensity, mean fundamental frequency, and semitone standard deviation for driving while conversing with a passenger. As would be expected, there was a significant gender effect for mean fundamental frequency, in that the males had lower values than the females, $F(1, 54)$ = 232.565; p < .001, η_p^2 = .812. There was a between-subjects group effect for mean fundamental frequency, $F(2, 54)$ = 3.426; p = .040, η_p^2 = .113. Post hoc testing revealed that the 60s group had a lower mean fundamental frequency than the 20s group (p = .044).

Effects of Speaking on Driving Variables

ANOVA testing that included both gender and group as between-subjects factors resulted in no gender effects or interactions with gender. Therefore, the results reported are for men and women combined.

Significant main effects. ANOVA testing revealed significant main effects for the standard deviation of steering wheel position, $F(2.198, 125.280)$ = 7.702; p <.001, η_p^2 = .119 and the number of steering wheel turns, $F(2.775, 158.180)$ = 43.177; p <.001, η_p^2 = .431. There were no significant main effects for standard deviation of lane position, average speed, and standard deviation of speed.

Table 1

Descriptive Statistics for Speaking Time Ratio

		Hand-held Drive		Hand-held Only		Hands-free		Hands-free		Passenger		Passenger	
Gender	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female	20	0.81	0.09	0.79	0.09	0.70	0.26	0.79	0.11	0.70	0.10	0.77	0.08
	40	0.75	0.06	0.75	0.08	0.69	0.08	0.76	0.09	0.73	0.07	0.75	0.11
	60	0.78	0.10	0.74	0.08	0.72	0.07	0.74	0.05	0.69	0.07	0.74	0.11
Male	20	0.71	0.11	0.72	0.06	0.68	0.09	0.74	0.08	0.70	0.12	0.75	0.08
	40	0.72	0.06	0.76	0.08	0.73	0.10	0.74	0.12	0.65	0.11	0.71	0.11
	60	0.73	0.06	0.72	0.07	0.70	0.07	0.73	0.05	0.72	0.05	0.72	0.07

Table 2

Descriptive Statistics for Mean Intensity (dB SPL at 50 cm)

		Hand-held Drive		Hand-held Only		Hands-free		Hands-free		Passenger		Passenger	
Gender	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female	20	63.9	4.0	63.3	3.8	64.6	3.2	63.8	3.6	61.9	4.4	62.0	4.2
	40	61.9	1.8	62.7	1.9	63.3	1.8	63.4	1.3	60.8	2.3	61.4	1.9
	60	64.3	2.8	63.1	1.8	64.4	1.9	64.9	1.1	61.8	2.0	62.3	1.9
Male	20	65.0	4.0	63.4	3.3	65.5	2.3	65.5	2.5	62.7	3.5	62.5	2.5
	40	64.7	3.5	64.3	3.0	66.2	2.7	66.5	2.4	62.6	3.2	63.9	3.2
	60	65.0	3.0	64.7	2.6	66.3	2.6	65.8	2.1	62.9	3.4	62.9	3.1

Table 3

Descriptive Statistics for Standard Deviation of Intensity in dB

		Hand-held Drive		Hand-held Only		Hands-free		Hands-free		Passenger		Passenger	
Gender	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female	20	6.3	1.3	6.5	1.2	6.7	0.8	6.8	1.4	6.6	1.0	6.6	1.2
	40	6.7	1.1	6.4	0.7	6.5	1.2	6.6	1.1	6.3	1.1	6.6	1.0
	60	6.3	0.8	6.2	0.8	6.4	0.7	6.4	0.9	6.2	0.9	6.0	0.7
Male	20	6.7	1.0	7.0	1.4	6.9	1.0	7.1	1.4	6.8	1.0	6.9	1.7
	40	7.1	0.8	7.7	0.7	7.2	0.7	7.2	1.0	7.4	1.0	7.0	0.7
	60	6.8	0.8	6.7	0.8	6.3	0.7	6.5	0.7	6.3	0.5	6.4	0.7

Table 4

Descriptive Statistics for Mean Fundamental Frequency in Hz

		Hand-held Drive		Hand-held Only		Hands-free		Hands-free		Passenger		Passenger	
Gender	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female	20	215.3	18.0	213.4	19.5	211.6	18.7	210.9	14.8	211.8	18.8	210.1	19.2
	40	199.4	27.7	198.2	25.7	209.0	22.9	200.2	23.8	192.3	26.7	195.4	27.2
	60	193.1	17.8	187.3	16.1	190.7	11.2	194.8	30.5	186.7	23.7	182.5	17.1
Male	20	120.5	26.2	118.7	26.9	122.8	26.9	121.7	26.2	120.1	27.8	119.0	29.0
	40	112.2	15.1	115.2	14.2	119.8	14.4	120.3	14.0	109.9	12.8	110.4	13.1
	60	117.0	13.7	114.6	13.1	122.4	13.1	121.1	13.2	111.6	14.6	115.2	12.0

Table 5

Descriptive Statistics for Standard Deviation of Fundamental Frequency in Semitones

		Hand-held Drive		Hand-held Only		Hands-free		Hands-free		Passenger		Passenger	
Gender	Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female	20	3.00	0.51	2.72	0.59	2.92	0.67	2.72	0.84	2.94	0.60	2.66	0.74
	40	3.03	0.68	2.79	0.85	3.21	1.04	2.82	0.61	2.78	0.76	2.98	0.68
	60	2.92	0.86	2.68	0.76	2.85	0.64	2.88	0.79	3.06	0.59	2.69	0.48
Male	20	2.21	0.62	2.26	0.78	2.32	0.61	2.24	0.73	2.34	0.73	2.26	0.57
	40	2.79	0.58	3.24	0.58	2.96	0.48	3.25	0.54	3.09	0.66	2.99	0.73
	60	2.73	0.55	2.40	0.48	2.72	0.54	2.40	0.45	2.94	0.60	2.66	0.74

Table 6

Descriptive Statistics for Standard Deviation of Lane Position (Arbitrary Units)

	Driving Only		Hand-held Drive		Hands-free Drive		Passenger Drive	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
20	0.31	0.27	0.23	0.07	0.27	0.15	0.27	0.21
40	0.32	0.09	0.32	0.07	0.39	0.32	0.36	0.29
60	0.39	0.17	0.36	0.10	0.43	0.22	0.42	0.30

Table 7

Descriptive Statistics for Mean Speed in km/h

	Driving Only		Hand-held Drive		Hands-free Drive		Passenger Drive	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
20	99.4	2.3	100.7	2.8	101.0	2.9	100.6	3.2
40	99.3	1.9	98.8	4.0	97.9	3.8	99.0	2.1
60	99.4	2.6	98.2	4.2	97.9	4.6	99.8	4.3

Table 8

Descriptive Statistics for Standard Deviation of Speed in km/h

	Driving Only		Hand-held Drive		Hands-free Drive		Passenger Drive	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
20	3.7	3.2	4.1	2.2	4.6	2.7	4.6	3.6
40	4.5	1.8	5.7	2.4	6.1	3.4	5.3	1.9
60	6.1	2.4	6.2	2.8	7.0	3.5	6.8	2.4

Table 9

Descriptive Statistics for Standard Deviation of Steering Wheel Position (Arbitrary Units)

	Driving Only		Hand-held Drive		Hands-free Drive		Passenger Drive	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
20	13.5	9.0	17.1	5.9	16.6	7.0	15.7	10.9
40	17.0	9.8	29.8	19.3	24.7	15.5	20.3	8.4
60	23.4	14.6	36.1	32.9	35.2	32.6	38.2	40.7

Table 10

Descriptive Statistics for Average Number of Steering Wheel Turns

	Driving Only		Hand-held Drive		Hands-free Drive		Passenger Drive	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
20	24.5	8.1	35.8	18.4	38.6	14.6	36.7	13.7
40	26.2	10.3	44.4	15.7	42.3	12.8	39.8	9.4
60	31.4	13.6	48.1	25.0	49.7	25.7	46.5	22.0

Speaking condition contrasts. Contrast testing revealed that the standard deviation of speed was significantly higher during the hands-free driving condition than during the driving only condition, $F(1, 57) = 6.058$; $p = .017$, $\eta_p^2 = .096$. The standard deviation of steering wheel position was higher for driving while using a hand-held phone, $F(1, 57) = 17.523$; $p < .001$, $\eta_p^2 = .235$, a hands-free phone, $F(1, 57) = 9.364$; $p = .003$, $\eta_p^2 = .141$, and while conversing with a passenger, $F(1, 57) = 5.702$; $p = .020$, $\eta_p^2 = .091$ than while driving without speaking. As seen in Figure 3, the number of steering wheel turns was higher for speaking and driving than while only driving. There were significant contrasts for the hand-held phone, $F(1, 57) = 60.042$; $p < .001$, $\eta_p^2 = .513$, hands-free phone, $F(1, 57) = 90.459$; $p < .001$, $\eta_p^2 = .613$, and passenger conversation conditions, $F(1, 57) = 76.057$; $p < .001$, $\eta_p^2 = .572$, compared to driving without speaking.

Interaction of speaking with group. There was a group interaction with speaking, where the 20s group had a higher average speed in the hands-free speaking and driving condition than while driving only, in contrast to the 40s and 60s groups, who had a lower average speed in the hands-free phone speaking while driving condition, $F(2, 57) = 3.743$; $p = .030$, $\eta_p^2 = .116$.

Between subjects effects. There was a group effect for the standard deviation of lane position, $F(2, 57) = 5.426$; $p = .007$, $\eta_p^2 = .160$.; post hoc testing revealed that 60s group had a higher standard deviation of lane position than the 20s group ($p = .005$). There was a group effect for the average speed, $F(2, 57) = 3.220$; $p = .047$, $\eta_p^2 = .102$, although post hoc testing did not indicate specific inter-group differences. However, a perusal of the descriptive statistics shows higher speeds for the 20s group compared to both older groups for the talking while driving conditions. As shown in Figure 4, there was a group effect for the standard deviation of speed, $F(2, 57) = 7.788$; $p = .001$, $\eta_p^2 = .215$. Post hoc testing revealed that the 60s group had a more variable speed than the 20s group ($p = .001$). There was a group effect for the standard deviation of steering wheel position, $F(2, 57) = 4.840$; $p = .011$, $\eta_p^2 = .145$. Post hoc testing revealed that the 60s group had a greater standard deviation of steering wheel position than the 20s group, ($p = .008$).

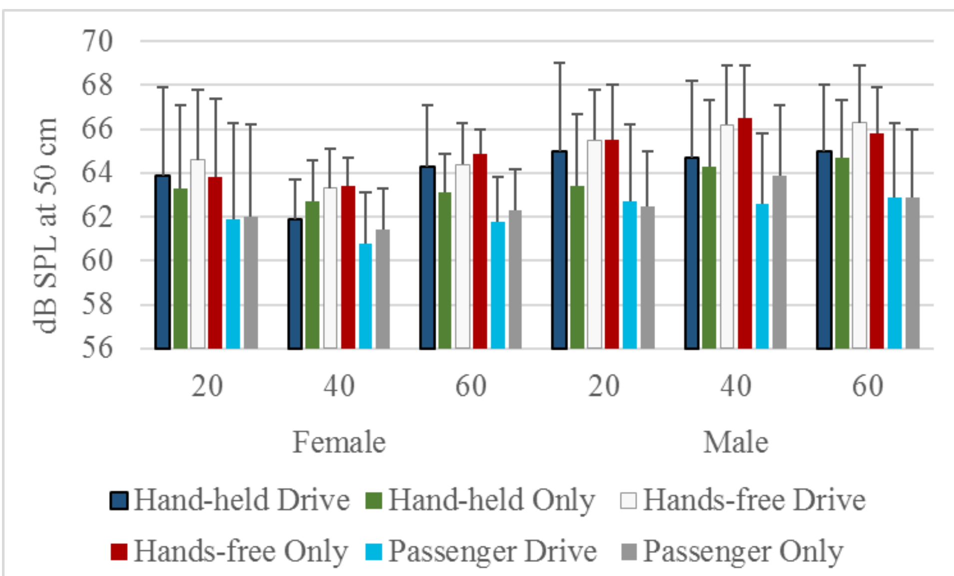

Figure 1. Mean intensity of speech in dB SPL at 50 cm.

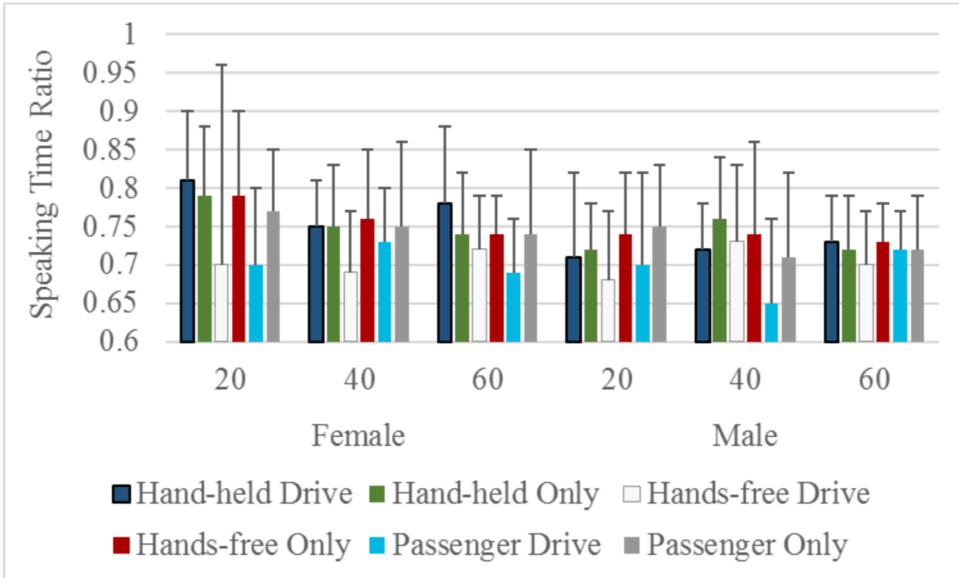

Figure 2. Speaking time ratio.

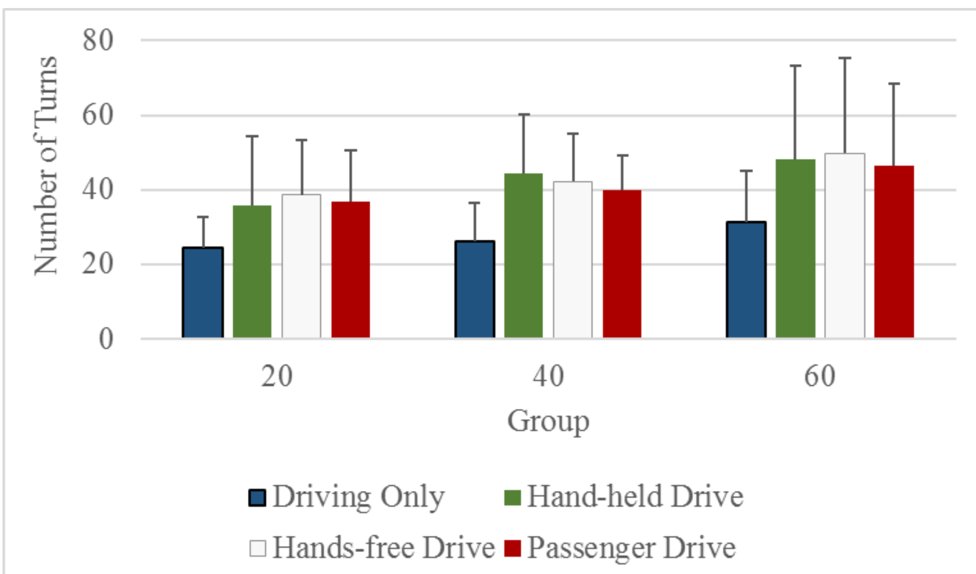

Figure 3. Mean number of steering wheel turns.

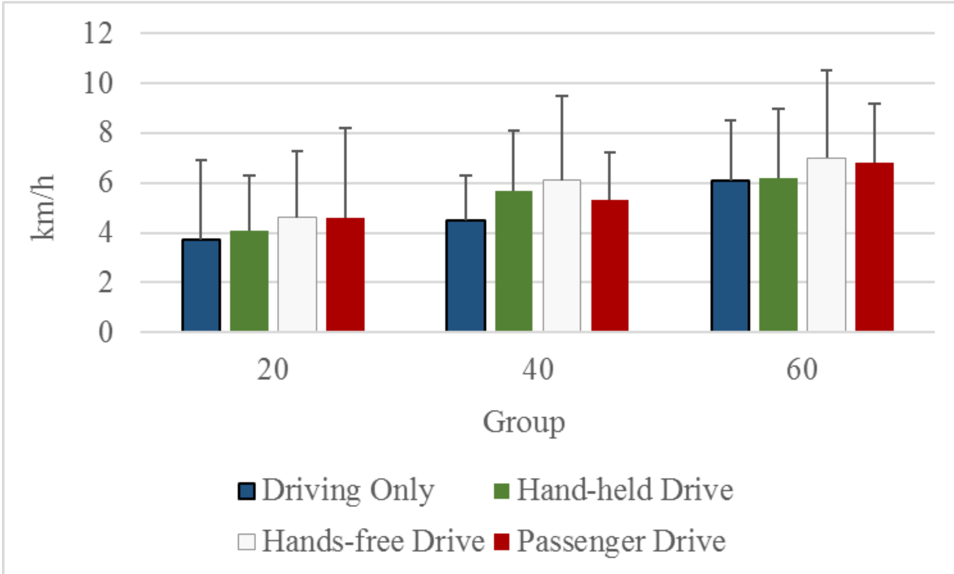

Figure 4. Standard deviation of speed in km/h.

Discussion

The current study was conducted to examine bidirectional interference between simulated driving and conversations using different speaking modalities. The factors of age and gender were included in the statistical analysis to determine their influence on driving and conversation. It was hypothesized that performance on both speaking and driving tasks would decrease when they were performed concurrently, and on a number of measures these effects were found.

Effects of Speaking on Driving Variables

There has been extensive research examining the effects of speaking on driving performance. Studies have been conducted involving cell phone conversations and passenger conversations; both have resulted in poorer driving performance. Drews et al. (2008) found that cell phone use while driving resulted in decreased driving performance compared with in-car passenger conversations. Treffner and Barrett (2004) found that participants performed best on driving tasks when no conversation was taking place. The driving results in the current study were consistent with the findings of previous researchers. Several measures reflected poorer driving performance in the divided attention condition. These included standard deviation of speed, standard deviation of steering wheel position, and the number of steering wheel turns. All three of these variables were significantly higher in the driving while conversing conditions than in the driving only conditions. This may be due to the increased cognitive load required to perform two tasks simultaneously. When participants performed only a driving task, they were able to devote all their cognitive resources to that task. However, when asked to perform the simultaneous tasks of holding a conversation while driving, performance on the driving task decreased. This is likely due to neural resources being devoted to processing and formulating language at the expense of more attentive driving.

Another finding of the current study was a group effect illustrating age differences in driving performance. The 60s group had a higher standard deviation of steering wheel position, a lower average speed, and a more variable speed than the 20s group. This is possibly because older participants were not as familiar with video game systems similar to the driving simulator used. On the other hand, the 20s group adapted more quickly to the simulation hardware. This may be due to an increased familiarity with technology and current video gaming systems which allowed them to maintain a more consistent steering wheel position and speed. This finding differed from that of Strayer and Drews (2004), whose study showed no difference in driving performance between young and older drivers. However, differences in experimental methodology may have contributed to this difference.

Effects of Driving on Speech Variables

Previous research has shown that when a person performs a speech task concurrently with a motor or cognitive task, their speech changes. Dromey and Benson (2003) found a significant decrease in the lip movement variability of participants when performing a speech task concurrently with a motor, linguistic or cognitive task compared to when they performed a speech task alone. In two other studies by Dromey and Bates (2005), and Bailey and Dromey (2015), the researchers found significant interference between a speech task and linguistic, cognitive or motor tasks. These reports are consistent with the current findings that speech and non-speech tasks can have an impact on each other when performed concurrently.

In the current study, the participants spoke with greater intensity while driving and speaking on a hand-held phone than in the speaking only condition. It could be speculated that this increase in intensity resulted because the individual was required to hold the phone while talking and driving which required more effort and motor control. In other words, the participants may have been more distracted while talking and driving because they had to focus on an additional motor task. This finding is consistent with previous reports of an increase in vocal intensity during a divided attention task involving a manual motor activity and a speech task performed together (Dromey & Bates, 2005).

In both the hands-free and passenger divided attention conditions the participants had more pauses in their speech than in the speaking only conditions, with the exception of the 60s group males, where the speaking time ratio was the same. This could be due to additional attentional demands while driving, which caused the participants to pause more in formulating conversation.

In addition to the effects of driving on speech measures, there were also significant interactions involving age and gender. In the hand-held condition female participants had a higher semitone standard deviation during the speaking while driving condition, whereas this pattern was not observed for males. This could be a result of the female participants exhibiting greater effort when challenged by the driving task and thus more variability of their intonation was observed while they were driving. The standard deviation of intensity and mean intensity were higher for the males than the females for the hand-held and hands-free driving conditions. The reason for this is unclear; however, it may have resulted from a gender-based difference in mechanisms of prosody.

In the hand-held driving condition, the female participants' speaking time ratio increased and the males' speaking time ratio decreased. This finding is similar to several other studies where researchers have shown that women are superior multitaskers to men. One example is a study by Dromey and Benson (2003), who found that men deteriorated more in their performance on some divided attention speaking tasks than women.

There was also a significant group effect for the hands-free driving condition, in that the 40s group had a higher semitone standard deviation than the 20s group. The reason for this effect is unclear.

As would be expected, there was a significant gender effect for mean fundamental frequency across conditions and groups, in that the males had lower values than the females for fundamental frequency. This is consistent with the typically lower fundamental frequency ranges of men due to their larger vocal folds.

Limitations of the Current Study and Directions for Future Research

The current study was limited by several factors that could be addressed in future studies. First, the driving task was extremely simple and only required the participants to maintain a specific speed and lane position, but did not allow for a very realistic overall driving experience. In addition, the software and hardware used for the driving simulator were consumer-grade, including an inexpensive steering wheel and pedal system. The driving simulation did provide participants with a certain level of challenge, but it could have been more effective in giving a realistic driving experience if the system had been more sophisticated. The software allowed for a few simple measures to be taken; however, these measures were rudimentary and showed only basic levels of driving performance. In future studies researchers could include measures of reaction time to unexpected stimuli, measures of following distance, and other metrics to more subtly evaluate driving performance.

Another limitation was that the steering wheel system was highly sensitive to movements made by the participants, and this may have been the cause of discomfort reported by several of the older participants. Two participants withdrew due to dizziness and motion sickness that might have been avoided if the steering hardware had been less sensitive.

While the current study focused on the changes in each participant's speech, future studies could measure changes that take place in the experimenter's speech while communicating with participants. This would allow a better understanding of whether both conversational partners' speech patterns were affected similarly by the selected conversational modality.

Conclusion

The current study provides insights into the effects of using different modalities to engage in conversations while driving. Previous work has shown how communication can have a negative impact on driving performance. However, this study provides additional information about how driving can impact speech performance. The results show that driving significantly impacts several speech measures and that speaking while driving also negatively impacts driving performance.

The clinical implications of the current study have relevance for the environment in which a person receives speech and language therapy services. Conversations in everyday life will typically take place in distracting environments, often in contexts where dividing one's attention is necessary. Clients must learn to communicate while also eating, walking, driving, and performing other necessary activities of daily living. The findings of the current study can help clinicians understand how to help their clients generalize their successful communication skills from quiet, distraction-free clinical offices into everyday environments requiring focus and the division of attention.

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Cao, S., & Liu, Y. (2013). Concurrent processing of vehicle lane keeping and speech comprehension tasks. *Accident Analysis and Prevention, 59*, 46-54. doi:10.1016/j.aap.2013.04.038

Charlton, S. G. (2009). Driving while conversing: Cell phones that distract and passengers who react. *Accident Analysis and Prevention, 41*(1), 160-173. doi:10.1016/j.aap.2008.10.006

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APPENDIX A: Annotated Bibliography

Amado, S., & Ulupinar, P. (2005). The effects of conversation on attention and peripheral detection: Is talking with a passenger and talking on the cell phone different? *Transportation Research part F: Traffic Psychology and Behaviour, 8*(6), 383-395. doi: 10.1016/j.trf.2005.05.001

Objective: The purpose of this study was to analyze the effects of different types of conversations on attention and peripheral detection while driving. *Method*: The participants included 24 men and 24 women who were undergraduate students from Ege University in Turkey. The students ranged from 20 to 25 years of age. The participants were given a test trial for each task prior to collecting data for that task. This study used the Vienna Test System to measure attention and concentration as well as a driving task requiring them to steer a car straight on a road while evaluating lights on the left and right side. These tasks were performed in isolation and also while answering simple and complex questions from a list (In which hemisphere is our country located? etc.) and doing arithmetic problems. Questions were given "in person" by the experimenter sitting in the same room as the participant and also via a loud speaker from outside the room. *Results:* Experimenters found that the percentage of correct answers was higher in the "no conversation" condition. Also the two conversation conditions resulted in slower overall reaction times when performed together with the attention and peripheral detection tasks. However, the conversation type did not have a significant effect on the number of correct answers and difficulty level of the speech task also had no effect. Experimenters also measured basic features of the conversations and found that the participants answered fewer complex questions during the divided attention condition and that the number of complex questions answered significantly decreased during the "in person" condition. *Conclusion:* The researchers found that performance on the attention and peripheral detection tasks decreased significantly in the divided attention condition. The findings of this study suggest that conversation has a negative impact on attention and peripheral detection which are both essential cognitive processes during driving. *Relevance to the current work:* This study addresses the bidirectional effects of different types of conversations and driving performance. However, one limitation of this study that the current study will address is the limited analysis of the speech samples and the effects of driving on speech. This study mainly focuses on the negative safety implications of conversations on driving performance.

Bailey, D. J., & Dromey, C. (2015). Bidirectional interference between speech and nonspeech tasks in younger, middle-aged, and older adults. *Journal of Speech, Language, and Hearing Research, 58*(6), 1637-1653. doi:10.1044/2015_JSLHR-S-14-0083

Objective: The purpose of this study was to observe the bidirectional interference between speech and cognitive, motor, and linguistic tasks in young, middle-aged, and older adults. *Method*: The participants included 10 men and 10 women in each of the three age groups. All were native speakers of English. Participants were seated in a sound booth to ensure the audio recordings would be clear and no auditory distractions would disrupt the study. Each participant was fitted with a head mounted system to measure lip and jaw movement. A head mounted microphone was used to record speech and was calibrated using a sound level meter. Each participant completed a linguistic task, a cognitive task and a motor task in isolation. A 30 second practice period was given prior to beginning each task. Each task was then also performed while repeating the sentence, "I saw Patrick pull a wagon packed with apples." During the linguistic task the participants were presented two words on a screen and instructed to determine if the words were semantically related. During the cognitive task the participants were given two numerical values in fraction form and they were asked to determine if the quantity comparison was correct or not correct. Participants were given 60-seconds for each of these tasks. During the motor task participants were given 60-seconds to place as many pegs in the Purdue Pegboard Test as they could. Measurements of the non-speech tasks were taken in isolation and compared with measurements taken in the divided attention condition. The cognitive and linguistic tasks were scored as the total number of responses, number of correct responses and the accuracy of responses. The motor task was scored as the number of pegs placed in the 60-second time period. *Results:* This study focused on the dependent measures of utterance duration, lower lip displacement, and velocity along with a measure of movement consistency across repetitions (spatiotemporal index). The researchers found that there was a condition (isolated versus dual task) main effect for all speech measures except velocity. Each of the three concurrent tasks impacted speech kinematics differently, which may be due to the attention required for each of these three different tasks. Utterance duration, negative upper-lower lip correlation, and lower lip spatiotemporal index were all significantly higher during the combined linguistic and speech task compared with the speech-only condition. The same result was observed for the cognitive task combined with the speech task versus the speech only condition. However, the linguistic task appeared to interfere more with speech than the cognitive task did. There was a significant condition effect on lower lip displacement and vocal intensity for the combined motor and speech task versus the speech task alone. This study also showed that concurrent cognitive and linguistic tasks with speech do negatively impact cognitive and linguistic performance. However, the researchers found that concurrent speech and motor tasks do not have an effect on motor performance. *Conclusion:* The researchers found a significant interference between speech and non-speech measures when performing linguistic and cognitive tasks combined with speech tasks as well as significant interference during the concurrent speech and motor task. They also found significant age effects in the area of utterance duration. *Relevance to the current work:* This study addresses the bidirectional effects of speech and non-speech tasks, taking into account the factors of age and gender. However, one limitation of this study that the current study will address was the highly constrained speech task that did not generalize to typical speaking situations.

Beede, K. E., & Kass, S. J. (2006). Engrossed in conversation: The impact of cell phones on simulated driving performance. *Accident Analysis and Prevention, 38*(2), 415-421. doi:10.1016/j.aap.2005.10.015

Objective: The purpose of this study was to examine the effects of various cognitively distracting tasks on driving performance. *Method*: The participants included 36 undergraduate students from the University of West Florida. The students ranged from 20 to 53 years of age. All participants had a valid driver's license. Experimenters used STISIM driving software by Systems Technology Incorporated for the driving task. The driving simulation operated on a desktop computer with a steering wheel mounted to the desk and gas and brake pedals on the floor. Participants filled out a driving history questionnaire and completed a practice driving trial prior to beginning data collection. During the study pre-recorded questions and statements began automatically when participants reached a certain location along the driving course. The recordings were comparable to a hands free cell phone condition and required various responses from the participant. The experimenters analyzed driving data in the areas of speed, adherence to stop lights and signs, and how well the participant stayed in the correct lane. *Results:* Experimenters found a significant increase in traffic violations and lapses in attention while driving and responding to the recordings than when driving in isolation. The experimenters reported that data from this study suggest that when drivers were overloaded with cognitively demanding conversations they coped by overlooking peripheral areas of the driving task. *Conclusion:* The researchers found a significant negative impact on driving when participants were engaged in the hands-free cell phone conversation. The implications of this study are that cell phone use while driving negatively effects driving performance even when the cell phone is hands-free and not only when it is hand-held. *Relevance to the current work:* This study addresses the effects of conversation in the hands-free condition on driving performance. However, one limitation of this study that the current study will address is analysis of the effects of driving on speech characteristics. While this study focuses mostly on the effects on driving, the current work will focus on the effects on speech when attention is divided between conversations and driving. Additionally, the current work will look at hands-free, hand-held, and passenger conversations.

Boiteau, T. W., Malone, P. S., Peters, S. A., & Almor, A. (2014). Interference between conversation and a concurrent visuomotor task. *Journal of Experimental Psychology: General, 143*(1), 295-311. doi:10.1037/a0031858

Objective: The purpose of this study was to analyze how dividing attention between a conversation and a visual tracking task affects performance on either task. Participants completed two experiments during the study and the results were compared. *Method*: For experiment number one the participants included twenty-four University of South Carolina undergraduates, fourteen female and seven male with a mean age of 19.62 years. The participants performed a visual tracking task on the computer while also conversing with an unfamiliar designated speaker. For experiment number two the participants included 26 females and 10 males with a mean age of 18.97 years. 20 of the participants from experiment number one were again given the visual tracking task but this time they completed the task while conversing with a familiar friend. *Results:* Experimenters found that the divided attention condition when participants were talking led to more significantly decreased performance on the tracking task than in the divided attention condition when they were listening. Similar results were obtained when participants were speaking with an unfamiliar conversation partner versus with a familiar friend. In addition, experimenters found that when the difficulty of the tracking task was increased, conversational interference also increased. *Conclusion:* The researchers found that performing a visual tracking task while also having a conversation does in fact negatively impact the participant's performance. Also they found that using natural conversations in divided attention tasks is a more reliable procedure because the data gained can be generalized to real life conversational situations. *Relevance to the current work:* This study addresses the effects of conversations with familiar versus unfamiliar partners on a visual tracking task. However, one limitation of this study that the current study will address is the effect on the participants' speech characteristics. This study focuses on the effects on a person's visual performance but does not address the changes in speech when performing a motor task while speaking.

Cao, S., & Liu, Y. (2013). Concurrent processing of vehicle lane keeping and speech comprehension tasks. *Accident Analysis and Prevention, 59*, 46-54. doi:10.1016/j.aap.2013.04.038

Objective: The purpose of this study was to examine the negative impacts of conversation on driving performance and specifically to analyze the implications for safety with the use of in-vehicle information systems and mobile devices while driving. *Method*: The participants included twenty-four native Mandarin Chinese speakers recruited in China (seventeen males and seven females) with a valid driver's license and normal or corrected-to-normal visual and auditory abilities. Participants completed a driving task where they attempted to stay as close to the center of the lane as possible. Participants were then given sentence materials and asked to judge if the sentences had the same meaning by pressing buttons on the steering wheel as quickly as they could. These tasks were evaluated in isolation and in a dual-task condition as well. *Results:* Experimenters found that performing a speech comprehension task for small amount of time may not have an immediate impact on the participants' ability to stay in the center of the lane. However, as the participant continues to perform this task there is some evidence that their performance will decrease over a longer period of time. *Conclusion:* The researchers found no significant decline in participants' ability to stay in the center of the lane even when measured in the dual-task condition. However, the rate of response to the speech comprehension questions was reduced in the dual-task condition compared with the isolated task condition. Mental workload was increased in the dual task condition compared with the isolated task condition. Experimenters listed the increase in mental workload as a problem only after a significant amount of time performing both tasks concurrently. The safety implications of this finding are relevant to a driver who performs driving with another task concurrently for extended periods of time on a regular basis. *Relevance to the current work:* This study addresses the effects of divided attention on driving performance when the participants are listening and responding to sentences. However, one limitation of this study that the current study will address is the generalization to real world situations. The current study will use real time conversations to assess the effects of speaking but also listening and processing incoming information in real time.

Charlton, S. G. (2009). Driving while conversing: Cell phones that distract and passengers who react. *Accident Analysis and Prevention, 41*(1), 160-173. doi:10.1016/j.aap.2008.10.006

Objective: The purpose of the study was to evaluate conversational characteristics, specifically conversational suppression, and driving performance when measured in a dual-task condition. The drivers engaged in conversations with passengers in the car, over a cell phone, and with a remote passenger who could see the driving simulation through a window but was not physically in the car. The experimenters then evaluated the effectiveness of using an alerting cell phone to warn the conversational partners when the driver was approaching a hazard. *Method*: The study included 112 participants, 56 male and 56 female who were recruited via newsletters, bulletin boards, and newspapers locally in Waikato, New Zealand. The participants ages ranged from 17 to 59 years of age with the average being 27.65 years. Participants all had a current New Zealand driver's license and were asked to wear any corrective lenses they required to see when driving. Each participant was randomly assigned to one of four experimental groups. There was a no conversation control group, a passenger conversation group, a hands-free cell phone conversation group, and a remote passenger group where the conversational partner talked to the driver via a hands-free cell phone but could also see the participant's driving performance via a window. The participant pairs were able to self-select who would be the driver and who would be the conversational partner and they were able to converse about any topic. Experimenters measured safe driving parameters for the participants as well as a number of conversational measures for each of the groups. Participants were then recruited to drive a route with hazards while also using the alerting cell phone. *Results:* Experimenters found that participants in the control and passenger groups had generally reduced speeds when they approached a hazard whereas participants in the cell phone and remote passenger group decreased their speed only slightly or not at all. Overall experimenters found that participants in the control and passenger groups had faster response times and were safely able to navigate the hazards in the simulation compared with the cell phone and remote passenger group. In addition, experimenters found significant differences in the conversations of the different groups involved. Specifically, they found that for both the driver and the converser the mean length of utterance was less in the passenger condition than in the cell phone or remote passenger condition. Also there was a significant decrease in number of pauses and a significant decrease in situation awareness (discussing the current driving situation) during the cell phone conversation condition versus the passenger and remote passenger condition. Experimenters then found that the alerting cell phone condition had similar results to the no conversation condition in speech characteristics and with driving safety. *Conclusion:* The researchers found a significant difference in both the driving performance and conversational characteristics of all groups involved in the study. When the drivers were in the no conversation condition they were the safest on almost all parameters. In addition, drivers were more safe in the passenger condition than in the cell phone condition. Experimenters reported that their analysis is that when drivers have a passenger in the car with them they feel more responsibility to drive carefully. Also conversational partners riding in the car are able to cater their conversations (pausing, questions etc.) to the situations happening on the road. However, when the driver is conversing on a cell phone the partner does not see the situations that are occurring and therefore cannot adjust the conversation accordingly. On the other hand experimenters found no difference between the no conversation condition and the alerting cell phone condition. This study give evidence to support the claim that passenger conversations are not as dangerous as cell phone conversations. However, there is also evidence to support the use of signals via cell phones, radio, and GPS units to alert drivers to oncoming hazards. *Relevance to the current work:* This study addresses the safety parameters and conversational differences involved when speaking with different types of conversational partners while also driving. The study gives basic principles that the current study also addresses. However, the current study looks at driving on a road with typical driving parameters instead of hazards and will give a more in depth analysis of speech characteristics rather than focusing on safety parameters when driving.

Crundall, D., Bains, M., Chapman, P., & Underwood, G. (2005). Regulating conversation during driving: A problem for mobile telephones? *Transportation Research part F: Traffic Psychology and Behaviour, 8*(3), 197-211.

Objective: The purpose of this study was to test the hypothesis that one reason cell phone use while driving is linked to distraction and an increase in accidents is that the person on the other end of the phone cannot pace the conversation based on what is happening on the road. On the contrary a passenger in the car is hypothesized to be less distracting because they can pause or stop talking altogether when hazards appear on the road. *Method*: There were 20 participants (18 female) in this study. The mean age was 25.7 years. The participants were placed in pairs and randomly assigned to the role of driver or conversational partner. The participants engaged in conversation while driving an experimental route of approximately 20 miles around Nottinghamshire, England. The conversation took place by way of a game. Each pair was asked to pick one of seven envelopes with words of a given category in each one. To encourage continuous conversation, driver and conversational partner scored individual points for the number of times they said a target word. The drivers completed the trials in their own car. There were 3 types of conversation evaluated: the in-car passenger condition, the blindfolded in-car passenger condition, and a remote partner via a hands-free cell phone. There were also four types of roads used: rural (least demanding), dual carriageway, suburban, and urban roads (most demanding). Half the participants drove the route in one direction while the other half drove the route in the opposite direction. Each pair was given practice with the word game and the driver was instructed to drive as they normally would. *Results:* Experimenters found that drivers and passengers each produced the largest number of utterances on the rural road type in the mobile phone condition. In most measures the urban roads reduced the conversational amount suggesting that the driver and conversational partners noted the increased driving demands and adjusted their conversation accordingly. The experimenters found a significant difference between the in-car passenger condition versus the hands-free cell phone condition. The hands-free cell phone condition prevented the conversational partner from adjusting to the on road demands and thus increased the number of utterances made by the driver. *Conclusion:* Experimenters concluded that hands-free cell phone use is more dangerous while driving due to the increase in conversation needed by the drivers. On the other hand, when conversing with an in-car passenger the driver and passenger are both able to adjust the conversation to oncoming hazards and difficult driving circumstances. *Relevance to the current work:* This study addresses the difference between in-car passengers and remote partners with regards to their speech and driving performance. However, the current study will address the speech and driving differences when using a hand-held cell phone as well. The conversation of the current study was also more realistic talking about the driver's family, interests, and hobbies as opposed to being given words and topics to discuss.

Drews, F. A., Pasupathi, M., & Strayer, D. L. (2008). Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied, 14*(4), 392-400. doi:10.1037/a0013119

Objective: The purpose of this study was to determine how conversations with a passenger versus conversations using a cell phone differ while driving. These parameters were also compared with a driving only condition. *Method*: The participants included 47 females and 49 males, with an average age of 20. Participants were recruited in friend pairs and completed the study with a familiar conversational partner. All participants had normal or corrected-to-normal vision and a valid Utah driver's license. Participants were given a 15-minute driving practice after which they completed a driving only condition, a cell phone and driving condition, and a passenger and driving condition using a freeway road simulator. *Results:* Experimenters found that the number of errors was significantly greater in the cell phone and driving condition including lane maintenance, and task completion. Drivers showed a pronounced tendency to drift and were four times as likely to fail to complete the task when in the cell phone condition versus the passenger condition. On the other hand, experimenters found no difference in driving speed and found a greater following distance in the cell phone condition. For the speech parameters, the most references were made to the traffic during the passenger condition as well as twice as many turns compared to the cell phone condition. When analyzing the production rate and complexity of speech experimenters found that in moderately demanding driving conditions, the production rate of the driver decreased when in the passenger condition but increased in the cell phone condition. Both driver and conversational partners responded to increasing demands in the driving simulator by decreasing their number of syllables per word. *Conclusion:* The researchers found a significant difference between cell phone and passenger conversations which they attributed to the fact that the traffic and driving conditions are more likely to become a topic of conversation in the passenger condition leading to increased safety and awareness of what is going on around the driver. Also because the conversation is affected by the driving situations that the passenger can see and respond to. *Relevance to the current work:* This study addresses the differences in speech and driving performance between passenger and cell phone dual task driving situations. The current study will continue to expand on this work by adding the component of hands-free versus hand-held cell phones and increasing the amount of analysis focusing on speech parameters such as intensity, pause duration, and fundamental frequency.

Dromey, C., & Bates, E. (2005). Speech interactions with linguistic, cognitive, and visuomotor tasks. Journal of Speech, Language, and Hearing Research, 48(2), 295-305. doi:10.1044/1092-4388(2005/020)

Objective: The purpose of this study was to observe the bidirectional effects of cognitive, linguistic, and visuomotor tasks when performed concurrently with speech tasks. *Method*: The participants included twenty college age speakers of English, 10 males and 10 females with no history of speech, language or hearing disorders. The participants were seated in a sound booth and lip and jaw movements were measured using a head-mounted strain gauge system with an attached microphone. Upper lip, lower lip, and jaw kinematic signals were recorded and analyzed. Seven tasks were performed by each participant including a speech only task, a linguistic only task, a cognitive only task, and a visuomotor task along with an additional combined task for each of the three divided attention conditions. *Results:* Experimenters found that spatiotemporal variability of lip displacement increased when measured with linguistic tasks. Motor tasks resulted in rapid speech with smaller lip displacement. Vocal intensity increased for all concurrent task conditions compared with the speech only condition. *Conclusion:* The researchers found that performing motor, cognitive, and visuomotor tasks concurrently with speech tasks has a significant effect on several labial kinematic measures including lip displacement, velocity, and spatiotemporal variability. They also found an increased negative correlation between upper and lower lip displacements. *Relevance to the current work:* This study addressed the bidirectional effects of cognitive, linguistic, and visuomotor tasks on speech performance. However, one limitation of this study that the current study will address is the effects of age on these effects. This study only evaluated these effects for college age participants, while the current study included individuals in the 20s group, 40s group, and 60s group.

Dromey, C., & Benson, A. (2003). Effects of concurrent motor, linguistic, or cognitive tasks on speech motor performance. Journal of Speech, Language, and Hearing Research, 46(5), 1234-1246.

Objective: The purpose of this study was to determine the effect of three different types of tasks on speech performance. *Method*: The participants included twenty young adults, ten males and ten females who were all native English speakers with no speech, language or hearing disorders. Participants were seated in a sound booth and speech measurements were taken using a head-mounted strain gauge system. The study had four conditions, including a speech only task and three additional speech tasks performed with either a motor, linguistic or cognitive task. The researchers recorded upper and lower lip movements, which they then segmented and analyzed. *Results:* They found that displacement and velocity decreased during the speech with motor task condition while spatiotemporal variability and the strength of the negative correlations between upper and lower lip displacements increased during the speech with linguistic and speech with cognitive task conditions. *Conclusion:* The researchers found that performing another cognitive, motor or linguistic task along with a speech task can have an impact on the movements of speech articulators and that different types of task being performed can have different effects. *Relevance* *to the current work:* This study demonstrated that significant effects can be observed in speech measures when performed with linguistic, motor or cognitive tasks, as is addressed in the current work. However, one limitation of this study that the current study will address is the bidirectional effects that can take place between speech measures and other cognitive, linguistic, or motor tasks. The current study examines the effects that can take place when these tasks are performed together.

Dula, C. S., Martin, B. A., Fox, R. T., & Leonard, R. L. (2011). Differing types of cellular phone conversations and dangerous driving. *Accident Analysis and Prevention, 43*(1), 187-193. doi:10.1016/j.aap.2010.08.008

Objective: The purpose of this study was to examine the effects of differing types of cell phone conversations on driving safety. Experimenters hypothesized that more emotional cell phone conversations would increase dangerous driving behaviors compared with mundane conversations and no phone conversations at all. *Method*: The participants included 75 undergraduate students with a mean age of 21.74 years old. Participants were randomly assigned to one of three experimental conditions: no phone call, mundane phone call, and emotional phone call. In the control condition participants were given instructions on the driving task and told to drive carefully as though the car were their own. They drove the course through and didn't use the phone at all. In the mundane task condition participants drove the same course and at some point during the course an experimenter called them on the phone and talked to them about various pieces of basic personal information such as hobbies, daily activities or music interests. In the emotional condition participants drove the same course and an experimenter called them to discuss emotional subjects rated by the participant as the least to the greatest emotional importance to them. *Results:* Experimenters found that in four out of five measured variables there were significantly more dangerous driving behaviors in the emotional condition compared to the other two conditions. In addition, for two parameters of driving performance there was a significant difference between the mundane phone call condition and the no phone call condition. The experimenters concluded that the results suggest that talking on the phone in any condition has a negative impact on driving performance. In addition, emotional cell phone conversations have a greater impact on driving performance than mundane cell phone conversations. *Conclusion:* The researchers found a significant difference in the level of distraction of different types of cell phone calls. Experimenters found that emotional conversations produce more distractions and pose greater risks than mundane conversations or no conversations at all. This study adds additional information to the already well supported idea that talking on the cell phone while driving is dangerous. Now there is evidence to support the idea that different types of conversation can be even worse than just talking on the cell phone while driving in general. *Relevance to the current work:* This study addresses the safety concerns of different types of cell phone conversations on driving tasks. However, one area this study does not address which will be discussed in the current study is the effect that speaking and driving has on various speech characteristics.

Kramer, A. F., & Larish, J. L. (1996). Aging and Dual-Task Performance. In W. A. Rogers, Fisk, A. D. & Walker, N. (Ed.), *Aging and skilled performance* (pp. 83-112). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publisher.

Objective: The purpose of this chapter was to review current literature in the area of dual task performance. *Relevance to the current work:* This chapter reviews how aging impacts dual task performance. This is relevant to the current work because aging is included as a factor that may impact dual task performance with speaking and driving. This chapter summarizes evidence from numerous other research studies that dual task performance is affected by aging.

Laberge, J. (2003). *The effect of passenger and cellular phone conversations on driver distraction.* Unpublished master's thesis, University of Calgary, Calgary Alberta

Objective: The purpose of this study was to determine the effects of cell phone and passenger conversations on driving tasks when performed in a dual task condition. *Method*: The participants included 80 students from the University of Calgary, 46 men and 34 women. They ranged in age from 18-27 years, had normal or corrected-to-normal vision, and all had a valid driver's license. Each participant drove a practice trial prior to beginning data collection. This allowed them to familiarize themselves with the various characteristics of the driving simulator. Each participant was then randomly assigned to one of 3 groups: cell phone, passenger or driving alone. Drivers and conversational partners completed a word game while driving. The experimenter gave them a word and then the driver and conversational partner took turns saying a word that began with the final letter of the last word. Each participant was asked to drive 50 km/h and observe all rules of the road. Each driving scenario was 4000 m in length and lasted around five minutes. *Results:* Experimenters found that participants generally did not modulate their conversations as driving demands changed. Also, lane and speed maintenance were influenced by increasing the driving demands during the simulation. Responses to a pedestrian were slower when performed in the dual task condition of speaking and driving. *Conclusion:* The researchers found a significant decrease in driver performance when participating in the dual task condition. *Relevance to the current work:* This study addresses the effects of divided attention tasks on driving performance when speaking and driving at the same time. However, one limitation of this study that the current study will address is that in this study participants were only involved in one experimental group out of three. In the current study participants performed each of the driving and speaking conditions. In addition, the conversation of this study lacked the ecological validity of real conversations, whereas in the current study conversations were completely naturalistic, and the results may be generalized to real life speaking situations.

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging*, 30(4), 507-514. doi:10.1016/j.neurobiolaging.2008.09.023

Objective: The purpose of this study was to examine the effect of age on cognitive performance. *Method*: All of the participants were between the ages of 18 and 60 and rated their health as "very good" or "excellent". The participants were given a battery of 12 tests and then given those same tests again in the longitudinal and short-term retest studies. The battery of tests evaluated performance based on 4 criteria: reasoning, speed, memory, and spatial visualization. *Results:* Experimenters found some evidence of age-related cognitive decline. They also found that cognitive decline can occur before age 60 even in healthy, educated adults. *Conclusion:* The researchers found that aging does exhibit some effects on cognitive functioning. *Relevance to the current work:* This study, like the current work, addresses the effects of age on cognitive performance. However, this work examines how age interacts with cognitive decline in areas of memory, reasoning, speed, and spatial visualization, whereas the current work examines how age interacts with modalities of talking while driving.

Strayer, D. L., & Drews, F. A. (2004). Profiles in driver distraction: effects of cell phone conversations on younger and older drivers. *Human Factors, 46*(4), 640-649.

Objective: The purpose of this study was to examine the effects of using a hands-free cell phone while driving. *Method*: The participants included 20 younger adults, ages 18-25 years old and 20 older adults, ages 65-74 years old. All participants were in good health, had normal or corrected-to-normal vision and a valid driver's license. Participants were given a 20-minute practice trial. During the driving simulator participants drove four 10-mile sections of a highway. Half of the driving trials were used in an isolation condition and half were used in the dual task cell phone condition. Participants were instructed to follow a pace car in the right-hand lane of the highway. The following distance of the participants was analyzed to determine their reaction time when cars slowed down in front of them. Then during the dual task condition the participant spoke with an experimenter about topics they selected prior to beginning data collection. No manual manipulation of the cell phone was necessary and any effects on driving were due to the actual conversation and not manipulation of the cell phone itself. Brake onset time, following distance, speed, and half-recovery time were measured to assess driving performance. *Results:* Experimenters found that talking on a hands-free cell phone did in fact still have a negative impact on all 4 areas of driving performance. They found that participants may have tried to compensate for their lack of attention by maintaining a greater following distance from the vehicle in front of them. Experimenters also found that the effects of cell phone use were consistent across the age ranges suggesting that younger drivers are not more capable of driving and using a cell phone because of their increased familiarity with technology. The conversations used in this study were more naturalistic in their form than in previously performed studies. This allowed the researchers to generalize their results to everyday driving and talking situations. *Conclusion:* The researchers found a significant difference in driving performance between driving with no conversation and driving while also talking on a hands-free cell phone. They found no difference in the driving performance of younger versus older drivers. *Relevance to the current work:* This study addresses the impact of hands-free cell phone use on driving performance. However, limitations of this study that the current study will address is the use of hands-free as well as hand-held and passenger conversations while driving. Also the effects of gender on dual task driving and talking performance will also be examined. One other limitation of this study is that the experimenters looked only at driving performance and did not assess the effects that driving had on conversation or speech characteristics.

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: dual-Task studies of simulated driving and conversing on a cellular telephone. *Psychological Science, 12*(6), 462-466.

Objective: The purpose of this two-part study was to determine the effects of cell phone use on driving performance and also to determine the impact of the difficulty level of the course. *Method experiment 1*: The participants included 48 undergraduates, 24 male and 24 female, from the University of Utah. Their ages ranged from 18 to 30, with an average age of 21.3 years. All participants had normal or corrected-to-normal vision. They were randomly assigned to one of three groups: radio control, hand-held phone, and hands-free phone. Participants performed a tracking task using a joystick and cursor to follow a moving target. They first participated in a practice trial. Then they performed the tracking task with no conversations or radio involvement. Lastly they participated in the dual task condition where they performed the tracking task while also talking to an experimenter on the two types of phones or listened to a radio broadcast of their choosing. *Results experiment 1:* Experimenters found that the probability of missing the simulated traffic signals more than doubled during the dual task conditions using cell phones. Preliminary analysis showed no significant difference between the two cell phone groups. However, there was no significant difference between the isolated driving condition and the radio control condition. *Method experiment 2:* In the second experiment the participants included 24 undergraduate students from the University of Utah, 12 male and 12 female. Their ages ranged from 18-26, with an average age of 20.5. All participants had normal or corrected-to-normal vision. The procedure was similar to that of the first experiment using a joystick and cursor to follow a moving target. However, different dual task conditions were used with participants hearing four and five letter words every three seconds and being required to either repeat those words back to the examiner or generate a new word from the final letter of the given word. Added insight was available from this experiment due to an additional parameter of the difficulty level of the course: easy or difficult. *Results experiment 2:* Experimenters found that tracking errors increased when participants performed the word-generation task but not when they simply repeated the words back to the experimenter. *Conclusion:* The researchers found a significant decrease in driving performance when performing the driving trials concurrently with speech tasks. They suggested that cell phone use impacts performance by pulling cognitive resources away from the driving task at hand. *Relevance to the current work:* This study addresses the effects of dual task conditions on driving performance when completed with conversations concurrently. However, one limitation of this study that the current study will address is the analysis of the effects driving has on speech characteristics.

Treffner, P. J., & Barrett, R. (2004). Hands-free mobile phone speech while driving degrades coordination and control. *Transportation Research part F: Traffic Psychology and Behaviour, 7*(4-5), 229-246.

Objective: The purpose of this study was to determine the effects of using a hands-free cell phone on various measures of driving performance using real driving tasks. *Method*: The participants included nine novice drivers, with an average age of 18.4 years. Their average driving experience was 19 months. Each participant performed a driving task using an instrumented vehicle on a closed circuit driving track while also talking on a hands-free cell phone. A control condition of no conversation was also completed. A 2002 automatic Holden vehicle with instrumentation was used to measure vehicle position, speed and 3D acceleration, and accelerator and brake depression. Three driving tasks were completed including cornering, controlled braking and obstacle avoidance. The participants completed two laps prior to collecting data to familiarize themselves with the course. There were also three levels of conversational complexity. *Results:* Experimenters found that on all three measures of driving performance, the participants performed the best with no conversation taking place. The experimenters stated that perception and awareness of road conditions were significantly decreased when using a hands-free phone while driving. *Conclusion:* The researchers found a significant correlation between the cell phone conversations and decreased driving performance. They discussed the implications of safety concerns involving cell phone use while driving. *Relevance to the current work:* This study addresses the effects of using a hands-free cell phone while also driving. However, one limitation of this study that the current study will address is the naturalistic conversations that would occur in real life situations. In this study the conversations that were used were contrived and mostly mathematical calculations rather than actual realistic conversations.

APPENDIX B: Informed Consent

Consent to be a Research Subject

Introduction
This research study is being conducted by Dr. Christopher Dromey of the Department of Communication Disorders at Brigham Young University to determine how driving and talking simultaneously impact each other, as well as how age and gender are factors in performing multiple tasks at once. Katy Glenn and Kelsey Simmons, who are both graduate students studying speech-language pathology, will assist with this research. You were invited to participate because you are a native speaker of English, with no history of speech, language, or hearing disorders.

Procedures
If you agree to participate in this research study, the following will occur:

- the study will take place at the BYU John Taylor Building in Room 110 at a time convenient for you
- you will be given 15 minutes to practice and become familiar with a computer-based driving simulator
- you will be given a list of topics and asked to select 10 topics that are most interesting to you; during the experiment you will be asked to speak for approximately 60 seconds about one or more of those topics
- you will be asked to drive the simulator for 15 minutes
- separate from the driving task, you will be asked to answer 3 questions presented by the researcher
- you will then be invited to answer questions or participate in a conversation using a cell phone or with a passenger, all while driving at the same time
- you will be compensated with $10.00 in cash for your time at the end of the study
- total time commitment will be 1 hour

Risks/Discomforts
There no known risks of participation in this study; however, it is possible that you may experience mild fatigue by the end of the experiment. The researchers will provide you with a break whenever you need one during the study.

Benefits
There will be no direct benefits to you. It is hoped, however, that through your participation researchers may learn about attentional processes and may be able to eventually assist speech-language pathologists in improving their therapy techniques.

Confidentiality
The research data will be kept with subject codes instead of names on a password protected computer and only the researcher will have access to the data. At the conclusion of the study, the non-identifiable data will be kept in the researcher's locked lab.

Compensation
As a token of our appreciation, you will receive $10.00 for your participation; compensation will not be prorated.

Participation
Participation in this research study is voluntary. You have the right to withdraw at any time or refuse to participate entirely.

Questions about the Research
If you have questions regarding this study, you may contact Dr. Christopher Dromey at dromey@byu.edu or at 801-422-6461 for further information.

Questions about Your Rights as Research Participants
If you have questions regarding your rights as a research participant contact IRB Administrator at (801) 422-1461; A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu.

Statement of Consent
I have read, understood, and received a copy of the above consent and desire of my own free will to participate in this study.

Name (Printed):____________________ Signature:______________________ Date:________