The effects of audio and visual distractions on reaction time

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Key Points Summary

- Subjects completed a simple detection task that measured reaction time with distractions of loud music, participating in a conversation, and texting.
- Distractions of participating in a conversation and texting lead to an increase in reaction time and increased heart rate in a simple detection task.
- Participating in a conversation lead to an increase in systolic blood pressure and no change in diastolic blood pressure.
- The distraction of loud music did not lead to an increase in reaction time, heart rate, or blood pressure during the simple detection task.

Abstract

Statistics on the number of car accidents due to distracted driving have been reported; however, little is cited on the severity of distractions other than texting while driving. Thus, in this study, reaction times were measured in response to not only texting, but listening to music, actively engaging in a conversation, and in a control setting where no distractions were present. Reaction times were measured through an online simulator that required subjects to press the space bar of a computer in response to the appearance of a cat on an otherwise blank screen at random time intervals. The cat appeared twice for each of the four conditions (control, music, conversation, texting). During each condition, reaction time, heart rate, and blood pressure measurements were obtained and recorded. Results indicated that average reaction times for the conversation and texting conditions were both significantly different from that of the control (p-values of 0.003469 and 0.029492, respectively). The conversation and texting conditions yielded statistically significant differences in heart rate as compared to the control (p-values of 0.00027 and 0.030278, respectively). There was also a significant change in systolic blood pressure for the conversation condition (p-value=0.031684). There was no significant change in diastolic blood pressure for any trial. These results support the data on the dangers of texting while driving, due to an increase in reaction time.

Introduction

Although distractions are a part of everyday life, they can be deadly while driving a car. A distraction can be defined as anything that renders a person incapable of behaving or reacting in a normal manner. Distractions to a driver can include the use of a cell phone, listening to music, and conversing with others in the car. According to the American Automobile Association, the use of a cell phone while driving increases the risk of crashing fourfold. Other distractions, such as listening to music and conversing with others in the car, can be just as dangerous (1). According to the National Highway Traffic Safety Administration, 5,474 people were killed and 448,000 people were injured in crashes involving distracted driving in 2009 (9). Although cell phones are a popular field of research due to their widespread usage, it is also important to study the effects that other distractions can have on drivers. In fact, all three of these situations (using a cell phone, listening to music, and conversing with others) distract a driver both visually and cognitively (6). This suggests that when distracted, one's physiological state is altered.

Over the past two decades there has been an explosion in the widespread use of cell phones and other electronic devices. At the end of 2009, there were approximately 4.6 billion cell phones being used around the world (7). Although a common part of everyday life, the use of cell phones while driving has proven dangerous and even deadly. In 2009, estimates from the Department of Transportation indicated that 16% of fatal crashes involved reports of distracted driving. Of those killed in distracted driving related crashes, 18% of the fatalities involved the use of cell phones (9). As a result of these findings, there has been a growing awareness of the potential safety risks associated with cell phone use while driving. Recent data demonstrating impairment to reaction time while driving has driven legislators to enact laws banning cell phone usage while operating a motor vehicle. As of February 2012, talking on hand held cell phones while driving has been banned in 10 states across the United States, and text messaging while driving has been banned in 35 states and the District of Colombia. For example, Wisconsin has no laws restricting the use of talking on a cell phone; however, it does have a law banning all drivers from texting (8).

Increases in reaction time can lead to safety risks on the road. In situations such as the braking response, the reaction time of the driver is not simply a one step process, but rather a sequence of complex reactions. The braking response involves mental processing time, movement time, and device response time. Mental processing time consists of four subsequent components: sensation, perception/recognition, situational awareness, and response selection (2). Movement time is the time required for the muscles to respond to the action potentials sent from the central nervous system. The ability to carry out muscular movements can be dependent on the situation. For example, states of high emotional arousal (such as those created by an emergency) impair fine detailed movements such as accurately steering a car (3). The final segment of the reaction is the device response time. The device response time refers to the time it takes the mechanical device to engage and perform the desired action, such as the time lapse from the time the brakes are applied to when the car comes to a halt. Movement and device response times will remain fairly predictable from one person to another when using the same device in similar situations. The responder's mental processing time, however, is highly subject to change in the presence of distractions that add to his or her cognitive load. The higher a subject's cognitive load, the longer his or her mental processing time is expected to be (2).

Neurological response mechanisms are dependent on the type of stimuli. Music is associated with responses to passive listening, person to person conversations are associated with responses to active listening, and texting and driving is associated with responses to physical and cognitive distractions. Passive listening results in the stimulation of the primary auditory cortex, a region of the brain in the temporal lobe that is responsible for processing auditory inputs (5). Thus, the stimulation of the primary auditory cortex may add to the cognitive load and cause a subsequent decrease in neural activity in the areas of the brain responsible for the completion of driving tasks. Active listening is comprised of three elements: comprehending, retaining, and responding. Recent studies have shown that engaging in secondary tasks, such as participating in a conversation, may disrupt driving performance (4). Driving performance may be decreased in response to active listening because auditory processing (as a result of the conversation) can decrease activation of the parietal lobe, a region of the brain responsible for the motor movements involved with driving tasks. The physical distraction involved with texting comes from the synchrony of writing a text message and steering the car. The cognitive distraction from a text message is similar to active listening; the person must comprehend the message, retain its information, and develop a response. The goal of this experiment was to study the effects that auditory distractions (such as listening to music or having a conversation) and visual/cognitive/motor distractions (such as texting on a cell phone) can have on a person's reaction time. We hypothesized that distractions of listening to music, person to person conversations, and texting would be associated with an increase in reaction time, with texting having the greatest increase in response time and listening to music having the lowest increase in response time. The reaction time tester animation found on flashscience.com (10) was used to measure reaction time (in milliseconds) of participants tested.

Materials and Methods

Students enrolled at the University of Wisconsin-Madison voluntarily participated in the experiment after signing a consent form. All participants had normal hearing and normal or corrected normal vision. 7 males and 10 females ranging in age from 19 to 22 participated in the study for a total of 17 volunteers.

Participants were asked to sit in front of a computer while researchers attached a pulse oximeter (Nonin Model 9843, Minneapolis) to the index finger of their non-dominant hand and a sphygmometer to that same arm. Blood pressure was recorded using the BIOPAC Systems, Inc. (California) sphygmometer, stethoscope, and software on a separate computer not visible to the participants. Baseline resting heart rate was taken for comparison. Participants rested between each test until their heart rates matched baseline. Reaction times were recorded via an online reaction time simulator with a simple detection task (10). In the online simulation, subjects looked at a white screen, and at random time intervals an orange cat appeared on the otherwise blank screen. Subjects were asked to press the space bar with their non-dominant thumb as quickly as possible after first spotting the cat, and the simulator calculated the reaction time in milliseconds. Two trials were run in succession for each distraction condition, with the order of conditions being: control, passive auditory distraction, active auditory distraction, and cognitive/visual/motor distraction. Reaction time and heart rate were recorded immediately after each trial. For the control and each distraction condition, blood pressure was recorded only after the second trial.

Control

Subjects were asked to complete the simulation with no added distractions. Heart rate, reaction time, and blood pressure were recorded.

Passive Auditory Distraction

In the second condition, participants listened to the song “Shots” by LMFAO through headphones at 70% of the maximum volume of an iPod Nano (Mac, California). They were again told to press the space bar as soon as they saw the cat appear on the screen. Heart rate, reaction time, and blood pressure were recorded.

Active Auditory Distraction

In the third condition, subjects were asked to participate in a conversation with one of the researchers. Subjects were asked a series of questions (Table 1) and told to respond with their answer choice along with an explanation, all the while still looking at the screen and waiting for the cat to appear. Once they saw the cat and pressed the space bar, heart rate, reaction time, and blood pressure were recorded.

Cognitive/Visual/Motor Distraction

In the final condition, subjects were asked to use their own cell phones to type the phrase, “How much wood could a woodchuck chuck if a woodchuck could chuck wood?” with their dominant hand until the cat appeared on the screen. They then pressed the space bar, and heart rate, reaction time, and blood pressure were recorded.

Results

P-values were obtained using a paired two sample t-test for means when comparing distraction treatment groups (Table 2). Average values for all physiological measurements for each trial can be seen in Figures 2, 4, and 6. The motivation level for all participants was assumed to be high, as subjects participated voluntarily for this study.

Effects on Reaction Time

All three distraction conditions invoked an average increase in reaction time as compared to the control condition (Figure 1). The music condition had the lowest percent increase (1.58%) and the texting condition had the highest percent increase (94.94%). The conversation condition had a percent increase of 13.84%. A paired two sample t-test for means compared: control and music conditions (p-value=0.34927), control and conversation conditions (p-value=0.003469), and control and texting conditions (p-value=0.029492).

Effects on Heart Rate

All three distraction conditions invoked an average increase in heart rate in the subjects as compared to the control condition (Figure 3). The music condition had the lowest percent increase (1.37%) and the conversation condition had the highest percent increase (12.90%). The texting condition yielded a percent increase of 3.89%. A paired two sample t-test for means compared: control and music conditions (p-value= 0.35849), control and conversation conditions (p-value=0.00027), and control and texting conditions (p-value=0.030278).

Effects on Blood Pressure

All three distraction conditions produced a percent increase as compared to the control in systolic blood pressure as follows: music (2.34%), conversation (5.36%), and texting (2.26%) (Figure 5). For diastolic blood pressure, the music condition yielded a 3.89% increase, the conversation condition yielded a 6.05% increase, and the texting condition yielded a 0.32% decrease (Figure 5). A paired two sample t-test for means compared: control and music conditions for systolic blood pressure (p-value=0.123537), control and conversation conditions (p-value=0.031684), and control and texting conditions (p-value= 0.239965). The p-values for t-tests comparing the music, conversation, and texting conditions to the control condition for diastolic blood pressure were 0.111448, 0.062856, and 0.367233, respectively.

Discussion

According to the averages of the percent increase in reaction time, the texting condition had the greatest percent increase within each individual subject, followed by conversation and then music (Figure 1). This supports the hypothesis of increased reaction time due to increasing cognitive load because texting requires a larger amount of mental processing than conversation or passively listening to music. Both the conversation and texting conditions had statistically significant differences in reaction time as compared to the control condition. It should also be noted that the music condition had a slightly lower overall average reaction time than the control condition, though within each individual subject a net percent increase in reaction time was observed. However, the difference in averages was not significant (Figure 2). This could be due to subjects that had particularly low reaction times during the music condition, yet still had a percent increase from their control condition.

There was a positive percent increase in heart rate for all three experimental conditions, with conversation having the largest percent increase. The average heart rates for each of the three conditions were also greater than that of the control condition, suggesting stronger and quicker sympathetic nervous system input to cardiac tissue in response to the distractions. Only the conversation and texting conditions were significantly different from the control. This could be a result of the movement of the skeletal muscles involved in speech and texting, which could have increased the subjects' heart rates. Furthermore, another explanation for the significant increase is that heart rate varies with emotion. The types of questions asked during the conversation condition and the difficulty of the texting task could have caused the subjects to become more emotional or anxious, and therefore have an elevated heart rate.

The only significant difference in blood pressure from the control was the systolic blood pressure for the conversation condition. This was also most likely because of an increased emotional response due to the thought-provoking nature of the questions. None of the other experimental conditions for systolic or diastolic blood pressure proved to be significantly different than the control condition (Figures 5 and 6). This could be due to the fact that epinephrine has a delayed sympathetic effect on skeletal muscles. Epinephrine eventually causes vasodilation and increased blood pressure after a delay because it has to travel long distances through the blood from the adrenal medulla to reach the β2-adrenergic receptors on target cells. The blood pressure measurements in this experiment could have been taken during the delay of the onset of sympathetic epinephrine effects. Increased heart rates may have been seen in the subjects due to a more immediate onset of norepinephrine binding (which is also sympathetically released) to α1-adrenergic receptors.

Although the data appeared to yield significant results, a number of limitations may have existed in the experimental design. One limitation of the design was the use of an online simulator and a computer mouse to measure reaction time, instead of a steering wheel and foot pedal. Although a wheel and foot pedal would be ideal to more accurately replicate driving conditions, a more plausible option, due to the limited amount of supplies in the lab, would be the use of a dynamometer to generate a force measurement. The time required for each subject to pick up the dynamometer and generate 50% maximum tension could be measured. The inclusion of a force measurement would be a more accurate representation of the process of pressing an automobile brake. However, there is no accurate way to measure the small amount of time it would take to produce this force. Additionally, driving a car requires a higher cognitive load than a simple detection task. It could be hypothesized that if the reaction time task were more difficult (e.g. a discrimination task or driving simulator), the reaction times would have been slower and may more accurately predict reactions in a driving situation. This could be an area for future investigation.

Another limitation to the experiment was the small sample size of 17 subjects. An increased sample size could decrease experimental error and uncertainty. In addition, the small age range of the participants (ages 19-22) could have affected the results, perhaps biasing the average of some physiological variables. Furthermore, the surrounding environment of the classroom, which was composed of a large group of students performing experiments, could have presented additional auditory and visual distractions that may have altered the results.

Future experiments could include testing a greater number of subjects with a wider age range and isolating the participants in a room without distractions other than those being tested.

There were several possible limitations to the design of the music and texting conditions. The phrase “How much would could a woodchuck chuck if a woodchuck could chuck wood?” was chosen because it is complex and novel. It could be hypothesized that subjects would have shorter reaction times if they texted a message that they typed frequently. Also, the music distraction could have been more than a passive auditory task if the listener was straining to understand the lyrics, identify instruments, etc. However, the distraction was most likely passive in this study, as the subjects were not asked to make any observations about the song.

The data showed that cell phone usage and actively participating in a conversation increased reaction time. This demonstrates the potential dangers that these distractions may be to drivers. Additionally, all participants, excluding two females, reported using a cell phone while driving at any time in the past. With such widespread dangerous driving habits, this issue merits further investigation.

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Tables

Table 1. Questions asked during the active auditory distraction test. The subject was asked to respond to a random sampling of the questions below for the conversation condition. The subject was asked to list their choice along with an explanation.

Would you rather….
1. Eat a five course meal in front of 10 starving children OR steal the bucket from 5 salvation army santas?
2. Lick peanut butter off of a hobo's foot OR lose $250 in the stock market?
3. If there was no risk of injury would you rather hug a panda bear OR a polar bear?
4. Be allergic to babies OR be allergic to elderly people?
5. Drool abnormally in public OR audibly moan during each conversation you have?
6. Always know when people are lying OR always get away with lying?
7. Have the voice of PeeWee Herman and dress perfectly OR have the voice of Morgan Freeman and dress terribly?
8. Have narcolepsy OR chronic insomnia?
9. Shrink to 1 inch tall OR grow to 3 stories tall?
10. Steal an elderly woman's purse OR tell 10 orphans that Christmas is cancelled?
11. Lose your preferred hand OR lose your preferred foot?

Table 2. P-values for each condition. P-values were calculated from a paired two sample t-test for means for each of the 3 conditions: 1) music, 2) conversation, and 3) texting, as compared to control. Results indicated significant changes ($p\text{-value}<0.05$) in: 1) reaction time for music and texting, 2) heart rate during conversation and texting, and 3) systolic blood pressure during conversation.

Condition	Music	Conversation	Texting
Reaction Time	0.349274	0.003469	0.029492
Heart Rate	0.35849	0.00027	0.030278
Blood Pressure - Systolic	0.123537	0.031684	0.239965
Blood Pressure - Diastolic	0.111448	0.062856	0.367233

Figures

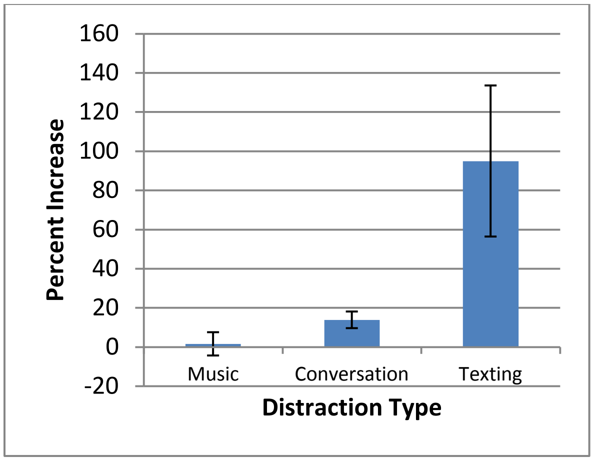

Figure 1. Average percent increase in reaction time as compared to control. Reaction times were recorded during each of three conditions with distractions of music, conversation and texting. The percent increase in reaction time for each condition for each subject was calculated, and these percent increases were averaged for each distraction type. Error bars represent standard error.

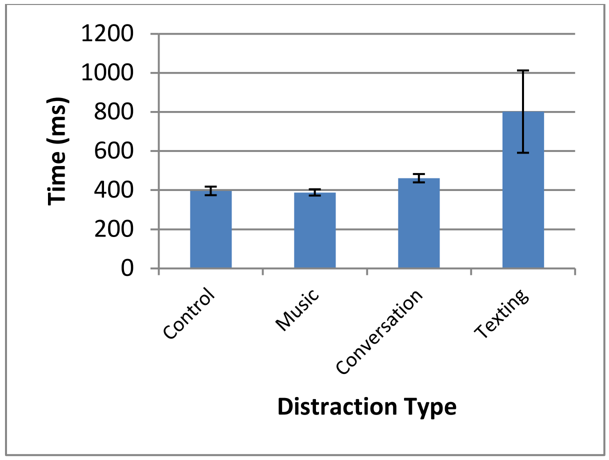

Figure 2. Average reaction time. Reaction times were recorded during each of three conditions with distractions of music, conversation and texting. The reaction times for all subjects were averaged within each condition. Error bars represent standard error.

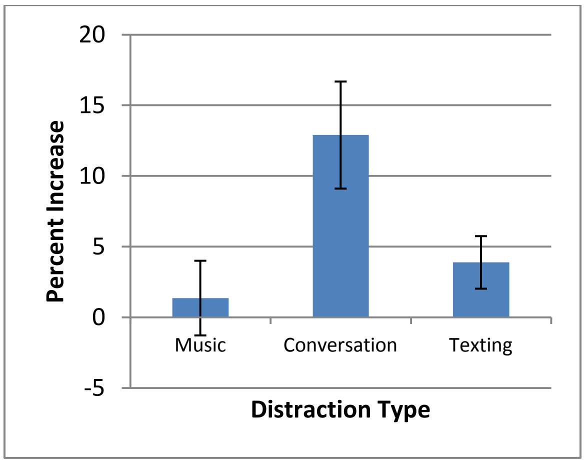

Figure 3. Average percent increase in heart rate as compared to control. Heart rate was recorded during each of three conditions with distractions of music, conversation and texting. The percent increase in heart rate for each condition for each subject was calculated, and these percent increases were averaged for each distraction type. Error bars represent standard error.

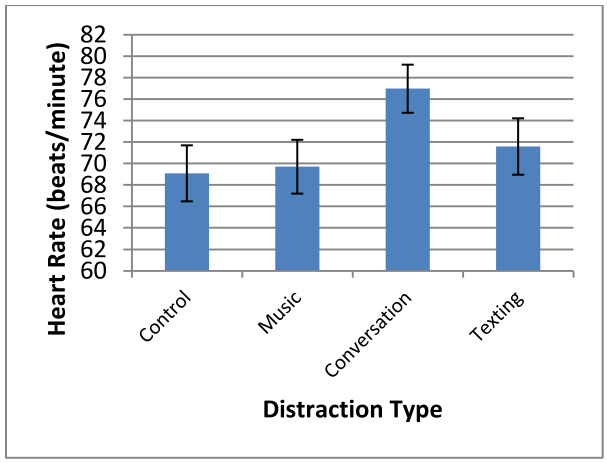

Figure 4. Average heart rate. Heart rate was recorded during each of three conditions with distractions of music, conversation and texting. The heart rates for all subjects were averaged within each condition. Error bars represent standard error.

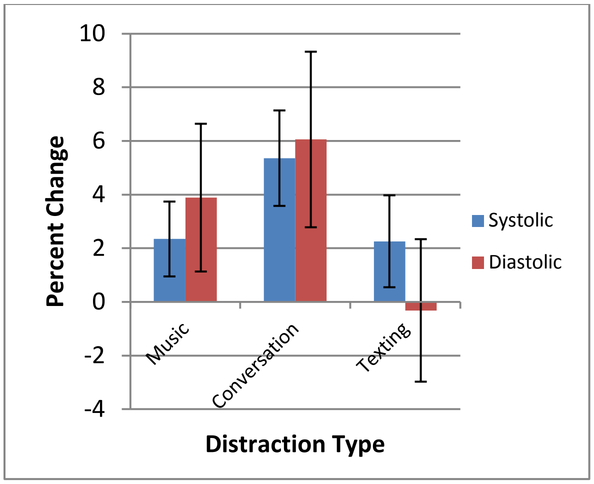

Figure 5. Average percent change in blood pressure as compared to control. Blood pressure was recorded during each of three conditions with distractions of music, conversation and texting. The percent increase in blood pressure for each condition for each subject was calculated, and these percent increases were averaged for each distraction type. Error bars represent standard error.

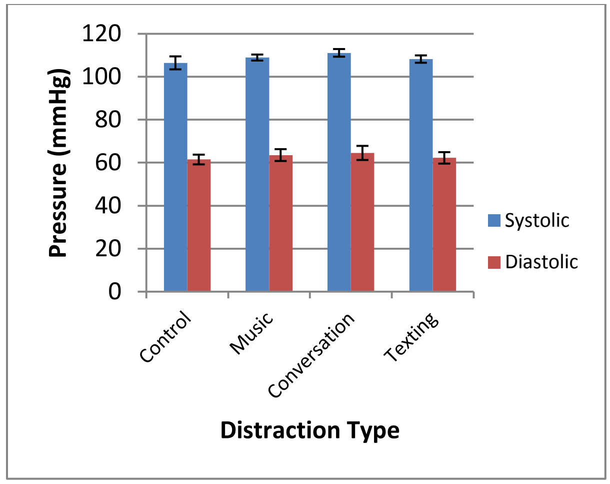

Figure 6. Average blood pressure. Blood pressure was recorded during each of three conditions with distractions of music, conversation and texting. The blood pressures for all subjects were averaged within each condition. Error bars represent standard error.

Appendix

Pilot Test

Due to a concern from a reviewer about the possible presence of "order effects", a pilot test was performed to see if the lack of variation in the order of distraction conditions could have affected the outcomes for reaction time. The pilot test consisted of testing four new subjects, aged 20 to 21, solely for reaction time and ignoring blood pressure and heart rate. The testing order of the conditions was control, music, conversation, texting, music, texting, control, and conversation. Results were graphed (Figures A1, A2) and the general trends seen were the same as in the original study. The texting condition had the largest percent increase in reaction time, followed by conversation and then music. The texting condition also yielded the largest average reaction time, followed by conversation, music, and control conditions, respectively. This suggests that the order in which the conditions were presented likely had no effect on reaction time.

Figures

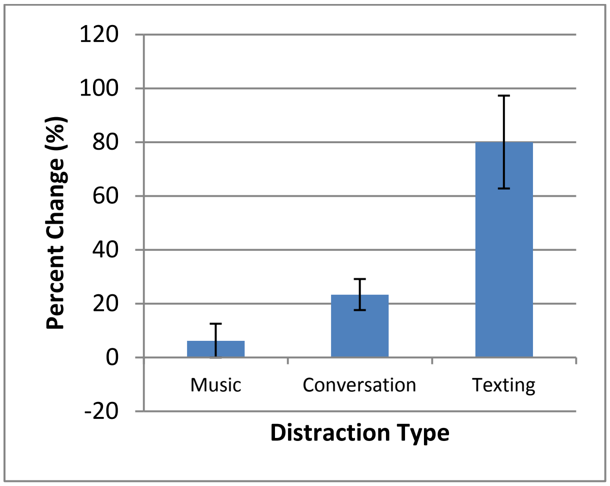

Figure A1. Average percent increase in reaction times as compared to control. Reaction times were recorded during each of three conditions with distractions of music, conversation and texting. The percent increase in reaction time for each condition for each subject was calculated, and these percent increases were averaged for each distraction type. Error bars represent standard error.

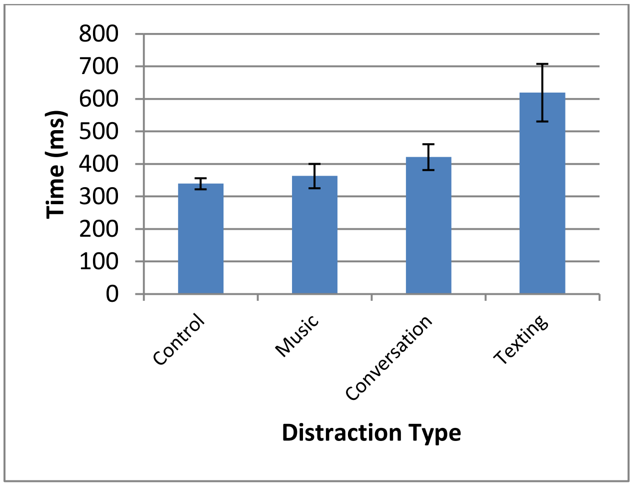

Figure A2. Average reaction time. Reaction times were recorded during each of three conditions with distractions of music, conversation and texting. The reaction times for all subjects were averaged within each condition. Error bars represent standard error.