Interference Between Speaking and Computer Tasks and Their Effects on Physiologic Arousal

Tiana Walker Bateman
Brigham Young University

Follow this and additional works at: https://scholarsarchive.byu.edu/etd

Part of the Education Commons

BYU ScholarsArchive Citation
https://scholarsarchive.byu.edu/etd/9664

This Thesis is brought to you for free and open access by BYU ScholarsArchive. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of BYU ScholarsArchive. For more information, please contact ellen_amatangelo@byu.edu.
Interference Between Speaking and Computer Tasks and
Their Effects on Physiologic Arousal

Tiana Walker Bateman

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

Master of Science

Christopher Dromey, Chair
Garrett Cardon
Tyson G. Harmon

Department of Communication Disorders
Brigham Young University

Copyright © 2022 Tiana Walker Bateman
All Rights Reserved
This study examined the effects of concurrent speech and computer tasks on each other and on measures of physiologic arousal in 30 young adults. Physiologic measures included galvanic skin response, heart rate, and heart rate variability. Participants completed a speech-only task, two computer-based tasks, and combined speech and computer-based tasks. Participants spoke for 60 seconds on a procedural discourse prompt. Acoustic measures included the mean and standard deviation of intensity and fundamental frequency as indices of prosody, speaking time ratio to reflect pausing, and speech rate. The primary computer task (with two levels of difficulty) involved making formatting changes to a paragraph with a word processor. The secondary computer task involved data entry (typing items from a shopping list into categories in a spreadsheet). Errors were tallied for each computer task. Statistical analysis revealed a significant decrease in words per minute in both the data entry and the easier formatting tasks; the proportion of speaking time decreased for all three concurrent computer tasks. Performance on all computer tasks was negatively impacted by speech. There was a significant decrease in the number of words correctly sorted and the number of correct formatting changes. The physiologic changes were limited; it remains unclear whether the heart rate increases during combined computer task and speaking conditions resulted from the addition of cognitive load or the respiratory changes inherent in speaking compared to silent task performance. Findings reflect bidirectional interference between speech and computer-based tasks while multitasking. These findings can help speech-pathologists to create therapy activities that are more like what patients will be experiencing in their everyday lives, such as practicing speech during computer tasks.
ACKNOWLEDGMENTS

I would first like to express gratitude for my husband, Michael Bateman, for never failing to express his unconditional love, for supporting for my dreams, for being a sounding board for my ideas, for providing technical support throughout the process, and for helping me find joy in stressful moments. I would also like to thank our son, Thomas, for his patience and the love and joy he brings into to my life daily while I pursue my education.

I am grateful for the friendships I have built among my cohort. They never failed to provide kindness, support, and they were always there when I needed them most. I would also like to thank my committee members Dr. Garrett Cardon and Dr. Tyson Harmon for their invaluable feedback, ideas, and flexibility.

Finally, I would like to thank my thesis chair, Dr. Christopher Dromey. With his irreplaceable knowledge and experience he helped shape my seemingly small idea into true research. I will forever be grateful for his endless patience in guiding me through each step of the research process and for generously sharing his passion for science with me.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td>i</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>DESCRIPTION OF THESIS STRUCTURE AND CONTENT</td>
<td>viii</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Method</td>
<td>10</td>
</tr>
<tr>
<td> Participants</td>
<td>10</td>
</tr>
<tr>
<td> Instrumentation</td>
<td>10</td>
</tr>
<tr>
<td> Stimuli</td>
<td>11</td>
</tr>
<tr>
<td> Procedure</td>
<td>12</td>
</tr>
<tr>
<td> Data Analysis</td>
<td>12</td>
</tr>
<tr>
<td> Statistical Analysis</td>
<td>14</td>
</tr>
<tr>
<td>Results</td>
<td>14</td>
</tr>
<tr>
<td> Effects of Computer Task on Speech Measures</td>
<td>14</td>
</tr>
<tr>
<td> Effects of Speaking on Computer Task Performance</td>
<td>17</td>
</tr>
<tr>
<td> Effects of Concurrent Speech and Computer Tasks on Physiologic Variables</td>
<td>19</td>
</tr>
<tr>
<td>Discussion</td>
<td>27</td>
</tr>
<tr>
<td> Effects of Computer Tasks on Speech Measures</td>
<td>28</td>
</tr>
<tr>
<td> Effects of Speaking on Computer Task Performance</td>
<td>29</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1  *Descriptive Statistics for the Speech Variables* ...........................................................16

Table 2  *Descriptive Statistics for the Data Entry Computer Tasks With and Without Discourse* ....................................................................................................................18

Table 3  *Descriptive Statistics for the Level 1 and Level 2 Formatting Computer Tasks* ....19

Table 4  *Descriptive Statistics of Physiologic Variables* ........................................................21

Table 5  *Significant ANOVA Main Effects of Speech and Data Entry on the Physiologic Measures* ..................................................................................................................22

Table 6  *Significant Contrast Analyses of the Physiologic Variables for Each Computer Task Alone Compared to the Computer Task While Speaking Condition* ........23

Table 7  *Significant ANOVA Main Effects of Speech and Level 1 Formatting on the Physiologic Measures* ........................................................................................................26

Table 8  *Significant ANOVA Main Effects of Speech and Level 2 Formatting on the Physiologic Measures* ........................................................................................................27
LIST OF FIGURES

Figure 1  Means and Standard Deviations of Speaking Time Ratio Across the
Experimental Conditions .................................................................17

Figure 2  Means and Standard Deviations of Number of Words Correctly Sorted in Data
Entry Only Compared to Data Entry With Discourse ..........................18

Figure 3  Means and Standard Deviations of Number of Correct Highlights With and
Without Discourse ...........................................................................19
DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, *Interference Between Speaking and Computer Tasks and Their Effects on Physiologic Arousal*, is written in a hybrid format. The hybrid format brings together traditional thesis requirements with journal publication formats required for the field of Communication Disorders. The preliminary pages of the thesis reflect requirements for submission to Brigham Young University. The literature review is included in Appendix A, Appendix B includes the consent/institutional review board approval letter, and a list of procedural discourse prompts used in the study is included in Appendix C.
Introduction

Divided attention, or performing multiple tasks at once, is a skill that, for better or for worse, humans use every day. While driving to work, one might be listening to music or talking on the phone. While listening to a recorded lecture, a student could be scrolling through emails, looking up future assignments, or checking the most recent update on social media. While cooking dinner, a person may be reading the recipe on their tablet, turning the oven on, and ensuring whatever is in the pan on the stove does not burn. Having one’s attention divided between multiple tasks is inevitable. Because of this, it is important to understand the impact that this has on performance of each task. The aim of the present study was to investigate the interference that occurs during concurrent speech and computer tasks.

Multitasking may involve many types of attention. Divided attention is the ability to concentrate on two or more tasks simultaneously (Fish et al., 2017). This can include tasks such as paying for your groceries while chatting with the cashier and talking on the phone while driving. It is generally known that performance in most tasks suffers when attention is divided, a phenomenon called interference (Bailey & Dromey, 2015). Divided attention is different from task-switching, or switching attention, which is the ability to change focus quickly and effectively between two or more tasks (Fish et al., 2017). An example of this includes checking a text message while writing a paper. Two other important types of attention include sustained and selective attention. Sustained attention is the ability to attend to a specific goal-oriented task, whether it is a preferred task or not (Fish et al., 2017). This type of attention is observed when reading a textbook, learning a new skill such as riding a bike, and listening during a work meeting. Finally, selective attention is the ability to tune out distractions while performing a goal-oriented task (Fish et al., 2017). Some examples of this include reading the menu in a loud
restaurant and completing work at home while children play in the background. While each kind of attention is essential to complete daily tasks, divided attention during speech will be the focus of this study because of how often most people, including those served by speech-language pathologists, speak while performing other tasks in their everyday life.

There are multiple theories of divided attention and its potential impact on task performance. One model suggests there is a “bottleneck” that occurs during information processing. According to this theory, at some point while performing multiple tasks simultaneously, one task uses the brain’s capacity for attention, causing interference in the other task (Navon & Miller, 2002; Wickens, 1980). Another early theory addressed by Kahneman (1973) and Norman and Bobrow (1975) suggested that our attention is a finite resource that must be shared between tasks when attention is divided, causing interference in both tasks. This theory could explain why both tasks can be negatively impacted when multitasking (Bailey & Dromey, 2015; Dromey & Bates, 2005); however, it does not fully account for the varying amount of impact different kinds of tasks can have on each other. This can be better explained by Navon and Gopher (1979), who provided an alternate theory suggesting that there are multiple kinds of attention that can be directed toward tasks, explaining why some tasks are more greatly impacted, or show more interference than other tasks. This theory would predict that two cognitive tasks would have more interference with each other than a cognitive and a motor task. Similar to this theory is the functional space or functional distance model of attention. This model focuses on the structures, suggesting that when performing two tasks that rely on the same structures in the brain (such as performing two language tasks at once), more interference will occur than for unrelated tasks (Kinsbourne & Hicks, 1978).
In the field of speech pathology, much interest regarding divided attention has been focused on how performing tasks while speaking impacts speech. People perform speaking tasks while multitasking on a regular basis, including things like talking with a passenger while driving or performing a task at work while talking to a customer. Cognitive tasks, motor tasks, language tasks, and visuomotor tasks have all been shown to impact speech. Studies by Bailey and Dromey (2015) and Dromey and Bates (2005), showed that performing cognitively taxing tasks during speech can reduce the stability of speech movement patterns, impacting older adults more than younger adults. For instance, young adults experienced a decline in utterance length, grammatical complexity, and information content while performing motor tasks such as carrying groceries. While participating in these kinds of motor tasks, older adults' speech rate and utterance length decreased as the complexity of the task increased (Kemper et al., 2005). When performing visuomotor tasks, young adults spoke at an increased speed, and decreased their lip displacement during speech (Dromey & Bates, 2005; Kemper et al., 2005; Kemper et al., 2009). Older adults also tended to add more fillers such as “um” to their speech when distracted by the motor task (Kemper et al., 2005; Kemper et al., 2009). Other tasks including complex language tasks and visuomotor tasks have been shown to negatively impact speech (Dromey & Bates, 2005; Kemper et al., 2009; Kemper et al., 2011). Additionally, when speaking while driving, both tasks are negatively impacted to some degree (Dromey & Simmons, 2019; Glenn, 2017).

In general, more difficult speech tasks are more highly impacted by multitasking than automatic speech (Vogel et al., 2014). This is important because many of the clients that speech-language pathologists encounter will have difficulty speaking, with or without their attention being divided. This could mean that having their attention divided during speech could more severely impact their ability to get their message across in the way they would like. In some
cases, it could impact naturalness and intelligibility as speaking rate, lip displacement, and utterance length are impacted to accommodate performance of a non-speech task. Knowing the impact of multitasking during speech is important to help clinicians better understand the efficacy of treating patients’ speech in quiet clinic rooms with limited distractions. Research by Dromey and Simmons (2019) showed that divided attention negatively impacts speech. Therefore, participating in speech tasks while attention is undivided (in a quiet therapy room) may not generalize to the level of difficulty that everyday multitasking during speech involves. If treatment is more closely aligned with the challenges clients face in their everyday life (in this case including divided attention during speech), it could lead to more effective therapy. This would ideally increase generalization of tasks performed in speech therapy.

While concurrent speech tasks have been studied in the past, many experiments have involved repetitive speech stimuli that allowed researchers to measure the same speech targets for each participant and across conditions (Bailey & Dromey, 2015; Dromey & Bates, 2005). While repetitive speech tasks allow for detailed data analysis across conditions, they do not validly reflect the type of communication in which a client would naturally participate. A more ecologically valid alternative to rote speech tasks is discourse. Discourse, when related to linguistics, is a general term used to describe written or spoken language that proceeds longer than a sentence (Dipper & Prichard, 2017). There are many kinds of discourse, some of which include expository discourse, explaining or describing a specific topic in great detail; narrative discourse, describing an event/telling a story; descriptive discourse, giving a detailed description of something or someone, often including one or more of the senses; and procedural discourse, giving instructions for the process by which a task is accomplished (Boyle, 2011). Most adults use unstructured combinations of each kind of discourse in their everyday conversation.
Unscripted conversation samples from the participant’s daily life would allow for the greatest ecological validity; however, they would not provide a speech sample that could be measured and compared in a straightforward way. For this reason, more structured discourse tasks were considered, such as asking a participant to produce a specific kind of discourse using a provided topic. After consideration of each kind of discourse task, procedural discourse tasks were chosen, for the present study, to allow for topics that will provide enough speech output in every participant to have a measurable sample while still providing more ecological validity than repeating rote phrases. This will also maintain some topic constraints that allow for a comparison of data across conditions.

As noted previously, speakers experience interference when speaking and performing other tasks simultaneously. Some measures of interference, such as the impact of background noise on speech, only allow for examining interference effects that impact speech. Others are bidirectional, showing the quantifiable impact of speaking while multitasking on the non-speech task as well. One bidirectional study has shown that speaking while performing a linguistic based task not only causes interference in speech, but also causes interference in the linguistic task (Dromey & Bates, 2005). A later study by Bailey and Dromey (2015) showed that speaking negatively impacted both cognitive and linguistic tasks; it can also negatively impact tasks such as driving (Glenn, 2017). Many tasks must be performed while speaking; therefore, understanding the impact of speech on other tasks is also important.

Another topic of interest related to divided attention is the impact of divided attention on physiological responses. It is possible that stress increases as the number or difficulty of tasks increases. It is widely known that the body’s physiological response to stress can be measured through indications such as galvanic skin response, increase in heart rate, and heart rate
variability (Fernandes et al., 2014; Kim et al., 2018; Kurniawan et al., 2013; Sharma et al., 2016). Another less common measure of stress is changes in speech; however, this is most accurate when a baseline speech measure is acquired (Kurniawan et al., 2013). These measures (galvanic skin response, heart rate variability, and speech) can be detected as a result of the activation of the sympathetic nervous system, when a person’s body is preparing for fight or flight in the case of an emergency. These responses can also occur in stressful, overwhelming, or emotional situations, with or without an actual emergency occurring (Fernandes et al., 2014; Kim et al., 2018; Kurniawan et al., 2013; Sharma et al., 2016). Speech can be used as a measure of stress due to an increase in respiration rate that occurs as the body responds to stressful situations. This change in respiratory rate can raise a person’s fundamental frequency during speech. Articulation is also impacted as increased respiration rate forces shorter sentences and phrases, changing articulation rate (Kurniawan et al., 2013). Sharma et al. (2016, p. 13) defined galvanic skin response (sometimes referred to as psychogalvanic reflex), as “a change in the electrical properties of the skin.” By measuring these electrical changes on a person’s, palms, fingers, and/or soles of the feet, a snapshot of the sympathetic nervous system’s response to stress can be seen. This is due to the relationship between the perspiration caused by the sympathetic response and the electrical conductance measured on the skin (Sherma et al., 2016). Heart rate variability (HRV) can be defined as changes in the length of time between heart beats, which can be impacted by the heart’s response to external and internal events (Kim et al., 2018). HRV is often used in studies to measure changes in the autonomic nervous system using electrocardiography. These measures have been interpreted as an indicator of an individual experiencing stress. Due to the association of HRV with increases in stress, it is considered a reliable measure of stress (Kim et al., 2018). Because of the impact that stress might have on the
performance of divided attention tasks, the current study measured stress levels through heart rate (HR), HRV and galvanic skin response (GSR).

Research has shown that there is a relationship between concurrent speech and cognitive tasks and autonomic arousal (Abur et al., 2016). As mentioned previously, fundamental frequency and articulation can be impacted by physiological response (Kurniawan et al., 2013). These studies both show a relationship between physiological response and speech in general; however, physiological response and speech multitasking have not been studied in depth. Many speech disorders are exacerbated by stress. For example, for people who stutter, research has shown that the number of disfluencies a person experiences increases as the number of daily stressors increase (Blood et al., 1997). Because stress makes communication more difficult for those with communication disorders, it is important to better understand more about how stress is impacting a person’s ability to speak. This is particularly important for those whose speech intelligibility is already negatively impacted by a disorder. With divided attention impacting speech on a daily basis, measuring physiological response will paint a better picture of how stress and divided attention are impacting speech.

While research has shown various impacts of multitasking on speech, little research has been done on the specific impact of computer, tablet, and phone-based multitasking on speech. Every day, new technology is being invented allowing increasing opportunities to multitask using these devices. The clients served by speech-language pathologists are distracted by their devices daily. Because of this, it is important to understand how much of an impact can be found while speaking and using these devices in everyday life.

Much of the previous research on multitasking while using these devices involves the term media multitasking, which has been used to refer to a number of different things including
texting or talking on the phone while reading or performing other tasks (Bowman et al., 2010; Steinborn & Huestegge, 2017), switching between windows/activities on a laptop while performing other tasks (Deng, 2020; Yeykelis et al., 2014), and general use of devices while performing daily tasks, including things such as watching television or listening to music (Ophir et al., 2009; Ralph et al., 2015; Wiradhany et al., 2019). In general, studies have shown that divided attention during media multitasking negatively impacts performance in both the media related task and other tasks (Bowman et al., 2010; Deng, 2020; Glenn, 2017; Ophir et al., 2009; Steinborn & Huestegge, 2017; Wiradhany et al., 2019; Yeykelis et al., 2014). Some researchers have studied media multitasking from a broader perspective, by focusing on how different levels of multitasking impact the overall ability to selectively attend. Studies have yielded conflicting evidence, including one study reporting that people who have high levels of media multitasking in their daily life have more difficulty with selective attention (Ophir et al., 2009) and two studies suggesting that high levels of media multitasking do not impact ability to attend on a general level (Ralph et al., 2015; Wiradhany et al., 2019). While the evidence is equivocal that high levels of media multitasking impact selective attention, it is clear that media multitasking can greatly decrease the speed at which a task is performed (Bowman et al., 2010). These studies are useful in understanding the impact that media tasks can have when performing another task concurrently. Most studies use the term media multitasking to describe tasks switching between the media-based task and another task. The current study will focus on true multitasking while using computers (performing the computer-based tasks and speaking simultaneously). This will allow a better understanding of the impact of each task on speech and vice versa.

Very few studies have been performed regarding the impact of computer or phone-based multitasking on speech. While performing a motor tracking task on a computer, speakers who
were planning utterances that contain a lot of information had more difficulty with pursuit motor tracking as a dual task combined with speech than they did performing the computer-based motor tracking task alone. Speech during computer use (motor tracking) was more difficult, with the participants showing more pauses after utterances, longer utterances, or utterances spoken more quickly (Kemper et al., 2011). While most studies like these were not focused specifically on the computer use aspect of the motor tracking tasks, and instead were measuring motor-based tasks, this suggests that there could be an impact of computer use on speech. This study shows that there could be negative consequences in both speech and other media tasks when attempting to perform both tasks at once (Kemper et al., 2011).

Many technology-based tasks are performed every day both professionally and personally. Some professional tasks include entering data into a spreadsheet, formatting word processor documents, and sending emails. Personal tasks include sending messages, online shopping, playing games, and spending time on social media. Often these tasks are completed while speaking and the impact of multitasking on the technology-based task and speaking are unknown. It is also unclear how much stress is impacting the ability to multitask well.

The purpose of the current study is to examine the interference between speaking and performing technology-based tasks. It also aims to help us better understand the relationship between stress and divided attention, specifically with speaking and technology-based tasks. It is hypothesized that because of the interference between tasks, the performance on both tasks will decrease in the concurrent as opposed to the isolated task conditions. It is also hypothesized that stress (measured through HR, GSR and HRV) will increase as difficulty of the computer task increases.
Method

Participants

The participants were recruited via word of mouth from the local community. They included 30 younger adults from 18-30 years of age (15 men and 15 women). The participants were all native speakers of Standard American English who reported no history of speech-language or hearing disorders, with one exception—a male participant with a mild stutter. The participants all passed a hearing screening at 30 dB HL and had normal or corrected to normal vision. Each participant signed an informed consent document that had been approved by the Brigham Young University Institutional Review Board.

Instrumentation

The participants wore a head mounted microphone (AKG C420) while seated in a sound booth. The participants’ speech was recorded to the computer at a sample rate of 44,100 Hz with a Focusrite Scarlett 2i2 USB analog to digital converter and Adobe Audition software. Physiologic measures including galvanic skin response (GSR), heart rate, and heart rate variability (HRV) were measured using the NeXus-10 system with BioTrace+ software (Version 2018A; Mindmedia, 2018). Physiologic measures included galvanic skin response; heart rate mean, minimum and maximum; measures of HRV including HRV low frequency range, HRV high frequency range, HRV low/high ratio; root mean square of the successive differences in heartbeat intervals, and standard deviation of heartbeat intervals. These measures were taken and recorded to the computer during all task conditions. Before participating in each task, the participant was instructed to place three heart rate sensors—one below each clavicle, and one just below their lowest rib on their lower left abdomen. Participants were also instructed to place two sensors measuring GSR on the inside arch of their right foot. The GSR sensors were placed
on the participant’s feet instead of their fingers/palms to limit interference caused by finger movements during the computer tasks. Both computer-based tasks were performed on a laptop. Participants were instructed to use the provided mouse or the laptop’s track pad depending on their level of comfort with each. The primary task used Microsoft Word and the secondary tasks used Microsoft Excel.

**Stimuli**

Participants were required to speak for 60 seconds on a procedural discourse prompt, which included outlining the steps or process required to accomplish a specific task. An example of a procedural task would be “describe the steps of planning and preparing a birthday party for a 6-year-old.” A full list of procedural discourse prompts used in the study can be found in Appendix C.

The primary computer-based task involved making formatting changes to a typed paragraph in Microsoft Word software with two levels of difficulty, Level 1 being the easiest and Level 2 being the most challenging. Difficulty Level 1 required the participant to highlight each instance of the word “the” they came across while reading the passage during the 60-second time frame. Difficulty Level 2 included instructing the participant to highlight each “the” as well as underlining each time they saw the word “a” in the passage.

Additionally, the participants completed a data entry task which involved typing items from a written shopping list into the correct category in an Excel spreadsheet. The categories included produce, dairy, baking supplies, meats, and the freezer section. For both the primary and secondary computer tasks, participants were instructed that both speed and accuracy will be considered and were aware of the 60 second time constraint.
**Procedure**

Each participant engaged in a speech-only task, the primary and secondary computer-based tasks only, and a combined speech and computer-based tasks. The order of all tasks was randomized for each participant to avoid sequencing effects. For the speech task, the participants were provided a list of twenty-one procedural discourse prompts and were instructed to choose 5 prompts that they felt they could discuss for a minimum of one minute. For the dual task conditions, the participants were instructed to speak continuously for the entirety of the task. The experimenter encouraged the participant to keep speaking until at least 60 seconds had passed. Before completing each kind of task for the first time, both written and verbal instructions were given, and the participants were allowed a short period of time to get comfortable with the task using a practice task.

**Data Analysis**

Praat speech analysis software (Version 6.2.14; Boersma & Weenink, 2022). Was used to extract acoustic measures from the audio recordings. Because this was a spontaneous spoken language generation task, the measures chosen were more appropriate for interpreting paragraph level speech as opposed to segmental level acoustic metrics. The same speech measures were used in both the isolated speech task and the combined tasks to allow for comparison of participant performance between tasks. Before the recordings were analyzed, non-speech sounds such as coughing, experimenter speech, and pauses between tasks were deleted from the recordings. Once these items were removed, the first 60 seconds of each speech task were used in the analysis.

Acoustic speech measures included the mean and standard deviation of intensity and fundamental frequency as indices of prosody, speaking time ratio to reflect pausing, and speech
rate in words per minute. The softest speech sound in each recording were chosen as a dB floor to eliminate the influence of non-speech sounds or pauses on the intensity measures. The intensity record from Praat was exported as a comma separated values file (csv) which was analyzed with a custom Matlab application (Version 2021b; Mathworks, 2021). This application computed both mean and standard deviation of the intensity during each recording. Speaking time ratio, a measure of time speaking versus pausing was computed in a Matlab application and expressed as a proportion. 1.0 would indicate the sample included no pause time, with the participant speaking the whole time. Seventy-five percent speech and 25% pause would be indicated with a .75 and so on. Speech rate was measured in words per minute, which involved counting the number of words produced between 10 and 40 seconds in each 60 second speech sample and then multiplying it by two.

Performance on the primary computer-based tasks was quantified as the number of words correctly formatted. The participants were given a paragraph much longer than would be possible to format in a 60 second window of time. This enabled researchers to measure the overall number of correctly formatted words per 60 seconds. Other measures used to quantify performance on these tasks included reporting the number of correctly formatted words compared to the number of words that should have been formatted and were not (the number of highlights and/or underlines missed). For each task the participant was given scores that included the total number of correct highlights, the total number of correct underlines, the total number of highlights missed, and the total number of underlines missed. This provided scores that could be compared between tasks while accounting for both speed and accuracy. Similarly, scores on the secondary computer-based task were calculated by counting the total number of words correctly sorted and the number of words with spelling errors.
Physiologic measures were collected and recorded to the computer using the 60 second segments corresponding to each task completed. The interval between 10 and 50 seconds was used for analysis due to the software needing an adjustment period at the beginning and end of each recording. For both the primary and secondary computer-based tasks measures of HR, HRV and GSR were compared during single task measures (speech alone and computer tasks alone) and dual task measures (speech and computer tasks combined).

**Statistical Analysis**

A repeated measures analysis of variance (ANOVA) using SPSS 28 software tested changes in the dependent measures (acoustic and physiologic measures) in all dual-task and single-task conditions. Both within subject (single versus dual task) and between subject factors (gender) were considered. Isolated and concurrent task conditions were compared within subjects while gender factors were compared between subjects. Since gender effects and interactions were only found for speech acoustic measures, all other testing combined male and female data. Significant differences between the experimental conditions were examined using concurrent contrast analyses with the ANOVA. Significant results were determined at \( p < .05 \) in the results of the ANOVA testing. Effect sizes (ES) were reported as partial eta squared metrics. When the Mauchly’s test of sphericity was significant, non-integer Huynh-Feldt adjusted degrees of freedom were used. When interrater reliability was assessed, the average correlation between the original and remeasured data was .982.

**Results**

**Effects of Computer Task on Speech Measures**

Descriptive statistics for the speech measures are found in Table 1 and Figure 1. The ANOVA revealed a significant main effect of condition on words per minute \( F(2.812, 78.732) = \)
8.910, $p < .001$, $ES = .241$. Concurrent contrasts revealed that the discourse with data entry led to a significant decrease in words per minute compared to the discourse only condition $F(1, 28) = 31.293, p < .001$, $ES = .528$. Words per minute also decreased significantly in Level 1 formatting with discourse compared to the discourse only condition $F(1, 28) = 5.124, p = .032$, $ES = .155$.

A significant main effect of condition on speaking time ratio was revealed by the ANOVA $F(3, 84) = 11.751, p < .001$, $ES = .296$. The ANOVA also revealed a condition by gender interaction $F(3, 84) = 4.111, p = .009$, $ES = .128$. Concurrent contrasts revealed that the data entry with discourse $F(1, 28) = 29.057, p < .001$, $ES = .509$, Level 1 formatting $F(1, 28) = 4.944, p = .034$, $ES = .150$, and Level 2 formatting $F(1, 28) = 6.669, p = .015$, $ES = .192$ led to a significant decrease in speaking time compared to the discourse only condition. The contrasts also revealed a gender interaction during data entry $F(1, 28) = 5.352, p = .028$, $ES = .160$ and Level 2 formatting $F(1, 28) = 8.280, p = .008$, $ES = .228$ with women decreasing and men remaining the same compared to the discourse only condition.
Table 1

Descriptive Statistics for the Speech Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Discourse Only</th>
<th>Discourse DE</th>
<th>Discourse Lev 1</th>
<th>Discourse Lev 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Mean F0</td>
<td>Female</td>
<td>211.3</td>
<td>17.6</td>
<td>215.4</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>122.9</td>
<td>12.4</td>
<td>124.3</td>
</tr>
<tr>
<td>STSD</td>
<td>Female</td>
<td>2.6</td>
<td>0.7</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>2.4</td>
<td>0.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Mean dB</td>
<td>Female</td>
<td>67.2</td>
<td>3.1</td>
<td>67.7</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>68.0</td>
<td>5.5</td>
<td>67.2</td>
</tr>
<tr>
<td>SD dB</td>
<td>Female</td>
<td>4.4</td>
<td>1.1</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>4.7</td>
<td>1.1</td>
<td>4.4</td>
</tr>
<tr>
<td>WPM</td>
<td>Female</td>
<td>81.3</td>
<td>20.6</td>
<td>69.2</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>88.4</td>
<td>16.1</td>
<td>73.2</td>
</tr>
<tr>
<td>STR</td>
<td>Female</td>
<td>0.82</td>
<td>0.05</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>0.76</td>
<td>0.07</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Note. Discourse DE= discourse with data entry; Discourse Lev 1= discourse with Level 1 formatting; Discourse Lev 2= discourse with Level 2 formatting; Mean F0= mean fundamental frequency; STSD= semitone standard deviation; Mean dB= mean intensity (dB SLP at 50 cm); SD dB= standard deviation of intensity; WPM= words per minute; STR= speaking time ratio.
**Figure 1**

*Means and Standard Deviations of Speaking Time Ratio Across the Experimental Conditions*

![Bar chart showing means and standard deviations of speaking time ratio across experimental conditions.](chart.png)

*Note.* * Denotes a significant difference from the discourse only condition.

**Effects of Speaking on Computer Task Performance**

Descriptive statistics for the data entry task measures are found in Table 2 and Figure 2. The ANOVA revealed a significant decrease in the number of words correctly sorted in the data entry with discourse task compared to the data entry only task $F(1, 29) = 91.115, p < .001, ES = .759$. There was also a significant decrease in the number of words with spelling errors in the data entry with discourse task compared to the data entry only task $F(1, 29) = 4.677, p = .039, ES = .139$.

Descriptive statistics for the formatting task measures are found in Table 3 and Figure 3. ANOVA revealed a significant decrease in the number of correct highlights in both the Level 1 formatting with discourse task compared to the Level 1 formatting only task $F(1, 29) = 17.978, p < .001, ES = .383$ and the Level 2 formatting with discourse task compared to the Level 2 formatting only task $F(1, 29) = 8.855, p = .006, ES = .234$. A significant decrease of correct
underlines was also revealed when comparing Level 2 formatting with discourse to Level 2 formatting only $F(1, 29) = 13.470, p < .001, ES = .317$.

**Table 2**

*Descriptive Statistics for the Data Entry Computer Tasks With and Without Discourse*

<table>
<thead>
<tr>
<th>Variable</th>
<th>DE Only</th>
<th>DE with Discourse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Words Correctly Sorted</td>
<td>13.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Words with Spelling Errors</td>
<td>0.63</td>
<td>0.96</td>
</tr>
</tbody>
</table>

*Note.* DE Only = data entry only; DE with Discourse = data entry with discourse

**Figure 2**

*Means and Standard Deviations of Number of Words Correctly Sorted in Data Entry Only Compared to Data Entry With Discourse*
Table 3

Descriptive Statistics for the Level 1 and Level 2 Formatting Computer Tasks

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lev 1 Only</th>
<th>Lev 1 Dis</th>
<th>Lev 2 Only</th>
<th>Lev 2 Dis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Correct HL</td>
<td>8.4</td>
<td>2.6</td>
<td>6.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Correct UL</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note. Lev 1 Only= Level 1 formatting only; Lev 1 Dis= Level 1 formatting with discourse; Lev 2 Only= Level 2 formatting only; Lev 2 Dis= Level 2 with discourse; HL= highlighting; UL= underlining.

Figure 3

Means and Standard Deviations of Number of Correct Highlights With and Without Discourse

Note. * Denotes a significant difference from the formatting only condition.

Effects of Concurrent Speech and Computer Tasks on Physiologic Variables

Descriptive statistics for the physiologic measures are found in Table 4. To test for the effects of concurrently speaking while completing a computer task, separate ANOVAs were run.
for each computer task (data entry, Level 1 formatting, Level 2 formatting). In each instance, the ANOVA main effect reflected differences in the physiologic measures across the task only, speech only, and task while speaking conditions. Subsequent contrast analyses compared the physiologic measures for the computer task alone or the speaking task alone against the combined task and speaking condition.

The ANOVA for the physiologic measures during data entry revealed a significant main effect of condition on heart rate mean, heart rate max, heart rate variability LF, heart rate variability HF, heart rate variability low high ratio, and SDNN (see Table 5 for Data Entry Physiologic Variables ANOVA details). There were no significant changes in GSR.
### Table 4

**Descriptive Statistics of Physiologic Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dis Only</th>
<th>DE Only</th>
<th>DE Dis</th>
<th>Lev 1 Only</th>
<th>Lev 1 Dis</th>
<th>Lev 2 Only</th>
<th>Lev 2 Dis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>GSR</td>
<td>11.3</td>
<td>3.9</td>
<td>10.6</td>
<td>4.5</td>
<td>10.4</td>
<td>4.0</td>
<td>10.4</td>
</tr>
<tr>
<td>HR Mean</td>
<td>86.5</td>
<td>11.1</td>
<td>79.4</td>
<td>9.6</td>
<td>84.3</td>
<td>9.9</td>
<td>74.9</td>
</tr>
<tr>
<td>HR Min</td>
<td>71.1</td>
<td>10.1</td>
<td>68.9</td>
<td>10.1</td>
<td>71.2</td>
<td>10.6</td>
<td>65.0</td>
</tr>
<tr>
<td>HR Max</td>
<td>104.3</td>
<td>19.2</td>
<td>91.7</td>
<td>17.4</td>
<td>101.9</td>
<td>18.8</td>
<td>87.7</td>
</tr>
<tr>
<td>HRV LF</td>
<td>76.6</td>
<td>6.5</td>
<td>63.4</td>
<td>10.3</td>
<td>76.3</td>
<td>6.8</td>
<td>61.8</td>
</tr>
<tr>
<td>HRV HF</td>
<td>22.7</td>
<td>7.2</td>
<td>28.1</td>
<td>7.4</td>
<td>24.2</td>
<td>8.0</td>
<td>31.4</td>
</tr>
<tr>
<td>HRV L/H</td>
<td>4.6</td>
<td>1.9</td>
<td>3.3</td>
<td>2.0</td>
<td>4.7</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>RMSSD</td>
<td>43.5</td>
<td>32.4</td>
<td>47.8</td>
<td>45.8</td>
<td>39.6</td>
<td>24.5</td>
<td>47.1</td>
</tr>
<tr>
<td>SDNN</td>
<td>68.4</td>
<td>36.4</td>
<td>52.0</td>
<td>39.7</td>
<td>61.1</td>
<td>31.4</td>
<td>51.7</td>
</tr>
</tbody>
</table>

*Note.* M= mean; SD= standard deviation; Dis Only= discourse only; DE Only= data entry only; DE Dis= data entry with discourse; Lev 1 Only= Level 1 formatting only; Lev 1 Dis= Level 1 formatting with discourse; Lev 2 Only= Level 2 formatting only; Lev 2 Dis= Level 2 formatting with discourse; GSR= galvanic skin response; HR Mean= heart rate mean; HR Min= heart rate minimum; HR Max= heart rate maximum; HRV LF= heart rate variability in the low frequency range; HRV HF= heart rate variability in the high frequency range; HRV L/H= heart rate variability low/ high ratio; RMSSD= root mean square of the successive differences in heart beat intervals; SDNN= standard deviation of heart beat intervals.
### Table 5

**Significant ANOVA Main Effects of Speech and Data Entry on the Physiologic Measures**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\text{df}$</th>
<th>$\text{df error}$</th>
<th>$F$</th>
<th>$p$</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR Mean</td>
<td>2</td>
<td>58</td>
<td>10.332</td>
<td>&lt; .001</td>
<td>.263</td>
</tr>
<tr>
<td>HR Min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR Max</td>
<td>2</td>
<td>58</td>
<td>5.205</td>
<td>.008</td>
<td>.152</td>
</tr>
<tr>
<td>HRV LF</td>
<td>1.578</td>
<td>45.754</td>
<td>26.561</td>
<td>&lt; .001</td>
<td>.478</td>
</tr>
<tr>
<td>HRV HF</td>
<td>2</td>
<td>58</td>
<td>5.059</td>
<td>.009</td>
<td>.149</td>
</tr>
<tr>
<td>HRV L/H</td>
<td>2</td>
<td>58</td>
<td>3.988</td>
<td>.024</td>
<td>.121</td>
</tr>
<tr>
<td>RMSSD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDNN</td>
<td>2</td>
<td>58</td>
<td>3.322</td>
<td>.043</td>
<td>.103</td>
</tr>
</tbody>
</table>

*Note.* ES= effect size; GSR= galvanic skin response; HR Mean= heart rate mean; HR Min= heart rate minimum; HR Max= heart rate maximum; HRV LF= heart rate variability in the low frequency range; HRV HF= heart rate variability in the high frequency range; HRV L/H= heart rate variability low/ high ratio; RMSSD= root mean square of the successive differences in heart beat intervals; SDNN= standard deviation of heart beat intervals. Only significant results are reported in this table.

Concurrent contrasts compared data entry alone to data entry with discourse. This revealed that the mean heart rate, heart rate max, heart rate variability LF, and heart rate variability low high ratio significantly increased when completing the data entry task with discourse as compared to data entry alone (see Table 6 for contrast analysis results of the physiologic variables for all three computer tasks alone compared to the respective task while speaking condition).
Table 6

Significant Contrast Analyses of the Physiologic Variables for Each Computer Task Alone Compared to the Computer Task While Speaking Condition

<table>
<thead>
<tr>
<th>Variable</th>
<th>DE Only</th>
<th></th>
<th>Lev 1 Only</th>
<th></th>
<th>Lev 2 Only</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>ES</td>
<td>F</td>
<td>p</td>
<td>ES</td>
</tr>
<tr>
<td>GSR</td>
<td>11.534</td>
<td>.002</td>
<td>.285</td>
<td>54.170</td>
<td>&lt;.001</td>
<td>.651</td>
</tr>
<tr>
<td>HR Mean</td>
<td>5.684</td>
<td>.024</td>
<td>.164</td>
<td>7.286</td>
<td>.011</td>
<td>.201</td>
</tr>
<tr>
<td>HR Max</td>
<td>6.960</td>
<td>.013</td>
<td>.194</td>
<td>49.415</td>
<td>&lt;.001</td>
<td>.630</td>
</tr>
<tr>
<td>HRV LF</td>
<td>31.200</td>
<td>&lt;.001</td>
<td>.518</td>
<td>40.024</td>
<td>&lt;.001</td>
<td>.580</td>
</tr>
<tr>
<td>HRV HF</td>
<td>10.968</td>
<td>.002</td>
<td>.274</td>
<td>22.622</td>
<td>&lt;.001</td>
<td>.438</td>
</tr>
<tr>
<td>HRV L/H</td>
<td>4.625</td>
<td>.040</td>
<td>.138</td>
<td>5.454</td>
<td>.027</td>
<td>.158</td>
</tr>
<tr>
<td>RMSSD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDNN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. DE Only = data entry only; Lev 1 Only = Level 1 formatting only; Lev 2 Only = Level 2 formatting only; ES = effect size; GSR = galvanic skin response; HR Mean = heart rate mean; HR Min = heart rate minimum; HR Max = heart rate maximum; HRV LF = heart rate variability in the low frequency range; HRV HF = heart rate variability in the high frequency range; HRV L/H = heart rate variability low/high ratio; RMSSD = root mean square of the successive differences in heart beat intervals; SDNN = standard deviation of heart beat intervals. Only significant results are reported in this table.
The ANOVA tests for the physiologic measures during Level 1 formatting revealed a significant main effect of condition on mean heart rate, minimum heart rate, maximum heart rate, heart rate variability LF, heart rate variability HF, and heart rate variability low high ratio (see Table 7 for Level 1 physiologic variables main ANOVA details). Concurrent contrasts revealed that combining discourse and Level 1 formatting led to a significant decrease in mean heart rate $F(1, 29) = 11.733, p = .002, ES = .288$ and a significant increase heart rate variability HF $F(1, 29) = 4.659, p = .039, ES = .138$ when compared to discourse only. Concurrent contrasts also revealed that combining Level 1 formatting with discourse led to a significant increase in mean heart rate, minimum heart rate, maximum heart rate, heart rate variability LF, and heart rate variability low high ratio when compared to Level 1 formatting only. Concurrent contrasts also revealed that combining Level 1 formatting with discourse led to a significant decrease in heart rate variability HF when compared to Level 1 formatting only (see Table 6 for contrast analysis results for the physiologic variables for computer tasks only compared to the combined computer task and speaking conditions).
Table 7

*Significant ANOVA Main Effects of Speech and Level 1 Formatting on the Physiologic Measures*

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>df error</th>
<th>F</th>
<th>p</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSR</td>
<td>1.407</td>
<td>40.807</td>
<td>33.75</td>
<td>&lt; .001</td>
<td>.538</td>
</tr>
<tr>
<td>HR Mean</td>
<td>2</td>
<td>58</td>
<td>7.645</td>
<td>.001</td>
<td>.209</td>
</tr>
<tr>
<td>HR Min</td>
<td>1.118</td>
<td>32.423</td>
<td>10.164</td>
<td>.002</td>
<td>.260</td>
</tr>
<tr>
<td>HR Max</td>
<td>1.118</td>
<td>32.423</td>
<td>10.164</td>
<td>.002</td>
<td>.260</td>
</tr>
<tr>
<td>HRV LF</td>
<td>2</td>
<td>58</td>
<td>30.761</td>
<td>&lt; .001</td>
<td>.515</td>
</tr>
<tr>
<td>HRV HF</td>
<td>2</td>
<td>58</td>
<td>15.998</td>
<td>&lt; .001</td>
<td>.356</td>
</tr>
<tr>
<td>HRV L/H</td>
<td>1.361</td>
<td>39.47</td>
<td>8.231</td>
<td>.003</td>
<td>.221</td>
</tr>
<tr>
<td>RMSSD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDNN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. ES = effect size; GSR= galvanic skin response; HR Mean= heart rate mean; HR Min= heart rate minimum; HR Min= heart rate maximum; HRV LF= heart rate variability in the low frequency range; HRV HF= heart rate variability in the high frequency range; HRV L/H= heart rate variability low/ high ratio; RMSSD= root mean square of the successive differences in heart beat intervals; SDNN= standard deviation of heart beat intervals. Only significant results are reported in this table.

The ANOVA tests for the physiologic measures during Level 2 formatting revealed a significant main effect of condition on mean heart rate, minimum heart rate, maximin heart rate, heart rate variability LF, heart rate variability HF, heart rate variability low high ratio, and SDNN (see Table 8 for Level 2 physiologic variables ANOVA main effect details). Concurrent contrasts revealed a significant decrease in mean heart rate between discourse only and formatting Level 2 with discourse $F(1, 29) = 11.491, p = .002, ES = .284$. Concurrent contrasts revealed a significant increase in minimum heart rate, maximum heart rate, heart rate variability LF, and heart rate variability low high ratio between Level 2 formatting only and Level 2 formatting with discourse. Concurrent contrasts revealed a significant decrease in heart rate
variability HF between Level 2 formatting only and Level 2 formatting with discourse (see Table 6 for contrast statistics of physiologic variables of computer tasks only compared to the combined computer task and speaking conditions).

**Table 8**

*Significant ANOVA Main Effects of Speech and Level 2 Formatting on the Physiologic Measures*

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>df error</th>
<th>F</th>
<th>p</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR Mean</td>
<td>1.244</td>
<td>36.064</td>
<td>4.098</td>
<td>.042</td>
<td>.124</td>
</tr>
<tr>
<td>HR Min</td>
<td>1.621</td>
<td>47.023</td>
<td>9.740</td>
<td>.001</td>
<td>.251</td>
</tr>
<tr>
<td>HR Max</td>
<td>1.653</td>
<td>47.926</td>
<td>4.043</td>
<td>.031</td>
<td>.122</td>
</tr>
<tr>
<td>HRV LF</td>
<td>1.643</td>
<td>47.647</td>
<td>44.469</td>
<td>&lt; .001</td>
<td>.605</td>
</tr>
<tr>
<td>HRV HF</td>
<td>2</td>
<td>58</td>
<td>19.834</td>
<td>&lt; .001</td>
<td>.406</td>
</tr>
<tr>
<td>HRV L/H</td>
<td>1.732</td>
<td>50.227</td>
<td>17.326</td>
<td>&lt; .001</td>
<td>.374</td>
</tr>
<tr>
<td>RMSSD</td>
<td>1.745</td>
<td>50.605</td>
<td>3.769</td>
<td>.035</td>
<td>.115</td>
</tr>
<tr>
<td>SDNN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* ES = effect size; GSR = galvanic skin response; HR Mean = heart rate mean; HR Min = heart rate minimum; HR Max = heart rate maximum; HRV LF = heart rate variability in the low frequency range; HRV HF = heart rate variability in the high frequency range; HRV L/H = heart rate variability low/ high ratio; RMSSD = root mean square of the successive differences in heart beat intervals; SDNN = standard deviation of heart beat intervals. Only significant results are reported in this table.

**Discussion**

The purpose of this study was to examine the effects of concurrent speech and computer tasks on each other. It also examined the effects of speech and computer tasks on physiologic variables (as a reflection of stress). Statistical analysis revealed several significant effects on speech measures, computer task performance, and on the physiologic variables.
Effects of Computer Tasks on Speech Measures

The results of this study showed that performing computer tasks while speaking can negatively impact speech. Words per minute decreased in both the data entry and Level 1 formatting tasks and speaking time decreased during all three concurrent computer tasks. These findings are consistent with previous research indicating that overall speech performance is impacted by multitasking, particularly visuomotor tasks, language tasks, and cognitive tasks (Bailey & Dromey, 2015; Dromey & Bates, 2005). One conflicting result compared to previous studies included the increase in speaking speed observed in young adults while performing visuomotor tasks at the same time (Dromey & Bates, 2005). The current study revealed a decrease in speed as the number of words per minute significantly decreased during the dual tasks. Dromey and Bates suggested that the increase in speaking rate found in their study could have occurred because their visuomotor tasks may not have been difficult enough to impact speech rate (Dromey & Bates, 2005). The finding of decreased speaking rate in the current study is consistent with the findings from Kemper et al. (2005), that paragraph level changes (decline in utterance length, grammatical complexity, and information content) occurred in young adults’ speech while performing motor tasks and speaking. Another study (Dromey & Simmons, 2019) examined an everyday task (speaking while driving) and found a bidirectional impact between speaking and driving. Dromey and Simmons (2019) used similar speech measures to the current study because both experiments included naturalistic speech tasks (a monologue in Dromey and Simmons and a procedural discourse in the current study). Both studies showed a decrease in overall speaking time during the dual tasks. The results of the current study also align with literature reporting that motor tracking computer-based tasks can lead to more pause time in speech (Kemper et al., 2011).
One possible explanation for the decrease in words per minute and speaking time is that the participants required more time to process and form their speech while performing the computer tasks. It is possible that it took more cognitive effort to plan and produce the procedural discourse tasks as well as the computer tasks (which both required enough focus to either highlight a specific word from a paragraph or sort a list of words into categories). Both the speaking tasks and the computer task required attention, causing interference. It is also possible that there was a change in respiratory rate as a natural response to a stressful situation. Kurnianwan et al. (2013), explained that this natural change in respiratory rate can cause shorter sentences, decreasing the articulation rate.

The only gender effects found were in the speech variables. One expected group difference was found in fundamental frequency. This was expected due to known frequency differences in male and female speech. The contrasts also revealed a gender interaction of speaking time during data entry and Level 2 formatting with women decreasing and men remaining the same compared to the discourse only condition. This interaction was small and was not observed in any other conditions. Therefore, it may not be possible to generalize the implications of this effect to a broader context.

**Effects of Speaking on Computer Task Performance**

Performance on all computer tasks was negatively impacted by speech multitasking. This impact was observed through a significant decrease in the number of words correctly sorted in the data entry task and the number of correct highlights and underlines in the formatting tasks. This indicates a decrease in the speed with which the computer task can be performed while speaking. While many current studies involving multitasking on computers do not directly assess speech multitasking while performing computer tasks, these results align with evidence from the
current literature stating that in general, dividing attention while media multitasking causes interference in the media-based task (Bowman et al., 2010; Deng, 2020; Glenn, 2017; Ophir et al., 2009; Steinborn & Huestegge, 2017; Wiradhany et al., 2019; Yeykelis et al., 2014). The results are also consistent with the literature reporting that speech multitasking negatively impacted motor tracking computer-based tasks (Kemper et al., 2011). The computer-based tasks in this study were created to allow measurable performance on tasks that people may perform on their computers in everyday life. Because of this it can be inferred that speaking while performing tasks on the computer can have a negative impact on the speed with which the work can be done.

One unexpected observation was the significant decrease in the number of words with spelling errors in the data entry with discourse task compared to the data entry only task (a measure taken to assess accuracy of performance on the computer-based tasks). One would expect to see an increase in errors/decrease in accuracy as the additional work (the speech task) is added; however, this was not the case. This could be due to there being fewer opportunities to mis-key words as the total number of words participants correctly sorted significantly decreased when speaking was added to the computer tasks.

**Effects of Concurrent Speech and Computer Tasks on Physiologic Variables**

There were no significant findings in GSR measures during this study. This could in part be due to measuring GSR through the feet, a less sensitive measure, instead of the hand to prevent artifacts from hand movements during typing.

On the other hand, mean heart rate increased significantly in the data entry with discourse task and the Level 1 formatting with discourse tasks as compared to the computer tasks alone. This could be attributed to the increase in stress during multitasking, or it could be attributed to
the natural increase in heart rate that occurs during speech due to changes in respiration (Freed et al., 1989). Similarly, heart rate max increased in the data entry dual task; heart rate min and max increased in the Level 1 formatting dual task; and minimum and maximum heart rate increased in the Level 2 formatting dual task. It remains unclear whether the heart rate increases during these combined computer task and speaking conditions resulted from the addition of cognitive load or the respiratory changes inherent in speaking compared to silent task performance.

When comparing the computer tasks alone to the computer tasks with discourse, HRV LF and HRV low high ratio both increased in all three dual task conditions. An increase in variability in these measures is usually a positive indicator of long-term health and a healthier response to stress (Steffen et al., 2017). These findings were corroborated by a significant decrease in HRV HF during the Level 1 formatting dual task, another positive indicator of long-term health (Steffen et al., 2017).

When comparing discourse alone to computer tasks with discourse, only one significant physiologic change between tasks was revealed. In the Level 2 formatting task, a significant decrease in mean heart rate was observed in the dual task as compared to speaking alone. This could have occurred due to the participants’ decreased focus on speech during the dual task. This could mean less respiratory effort was required, leading to a decrease in mean heart rate (Steffen et al., 2017).

Abur et al. (2017) found that in a less naturalistic task (reading shorter sentences out loud), speaking with increased cognitive load caused increased autonomic arousal in the short term. While this is what we hypothesized would happen during the more naturalistic tasks of the current study, this is not what was observed statistically. This may be linked to the measure of GSR from the finger instead of the feet during the Abur et al. study. It could also be due to
participants in Abur et al. (2017), using shorter sentences rather than attempting to provide a minute long discourse while physiologic response was being measured. It is possible that this difference in speech tasks impacted respiratory rate enough to impact the physiologic findings in the current study (Kurniawan et al., 2013).

It is important to note anecdotally that during the recordings, participants appeared more stressed during dual tasks than in the computer or discourse alone tasks. They often appeared flustered and reluctant to start the dual tasks. Upon finishing the experiment, the participants almost always reported feeling overwhelmed by completing the computer tasks and speaking tasks simultaneously. While informal observations appear to indicate an increase in stress, the physiologic measures did not reflect this. It is possible that the measures used were not sensitive enough to short term changes in stress during speech tasks. Therefore, they may not have been the appropriate measures to determine if an increase in stress occurred while performing the dual task conditions. Sources used to determine the validity of using HR, HRV, and GSR as measures of short-term stress indicated that these are each appropriate measures of short-term physiologic response. This is only the case; however, if they are used in conjunction with other measures. For example, GSR would not be appropriate to indicate short term stress on its own but when combined with HR and HRV it would be appropriate (Kim et al., 2018; Sharma et al., 2016).

**Limitations of the Present Study and Directions for Future Research**

One possible limitation of the current study involved how GSR was measured. GSR is most often measured with electrodes attached to a participant’s fingers; however, in this study it was necessary to attach the GSR probes to the participant’s foot to prevent artifacts from hand movements while typing. While using the foot to measure GSR is a viable option, using the
participants feet instead of their fingers could have impacted the sensitivity of the GSR measurements, thus limiting the detection of potentially significant findings.

While analyzing data, another possible limitation of these physiologic measures was highlighted. In planning the study, heart rate was chosen as an indirect measure of short-term stress based on the understanding that heart rate, heart rate variability, and galvanic skin response can be appropriate indicators of this kind of stress. While this is true, they are better suited to measuring long term stress (Steffen et al., 2017); thus, they are difficult to interpret when measured during speech. Because of this, these measures must be interpreted with caution. Another possible limitation to note is that heart rate and heart rate variability results were likely impacted by speaking tasks, making it difficult to differentiate between changes occurring because of stress and changes occurring because of the speaking task itself, especially speech breathing patterns (Steffen et al., 2017). Future research could include a non-speaking baseline of physiologic data for each participant to help clarify these findings. It could also be beneficial to include a resting period between tasks to prevent carry over of physiological responses. Other further research on this topic could examine physiologic arousal under a variety of task conditions with or without speech.

The speech measures in the current study were primarily measures of prosody due to the naturalistic speech tasks the participants were asked to perform. This included mean and standard deviation of fundamental frequency and intensity, speaking time compared to pausing time, and words per minute (speech rate). These measures may not have been sensitive to small changes in speech due to the measures being over multiple sentences rather than smaller, targeted segments of speech. There could have been more significant findings when using more detailed, sensitive
measures of changes in speech such as articulatory acoustic metrics. This may have impacted the number of significant findings revealed in the speech measures.

Because of time constraints related to participant recruitment, the current study focuses on divided attention during dual speech and computer tasks in young adults with typical speech and language; however, it is possible that these findings would differ for older adults and or people with speech or language disorders. Future research could examine whether older adults or individuals with speech-language disorders might perform differently on speech, computer, and physiologic measures during multitasking.

Conclusions

The present study has revealed that there is bidirectional interference between both tasks when performing a procedural discourse and computer task as compared to the discourse task or computer tasks alone. The physiologic measures used in the present study did not appear to reveal an increase in short term stress, possibly due to the use of measures that were not sensitive to stress that would be discovered in the short duration of this study.

With both the computer tasks and the speech tasks showing interference, it is likely that most young adults would experience a decrease in performance during everyday multitasking. Many people with both typical and disordered speech converse while using computers daily at work, school, or even while creating a grocery list at home. A better understanding of the interference that occurs in both speaking and computer use will help inform therapy with individuals with communication disorders. This may allow speech-language pathologists to create therapy activities that are more like what patients will be experiencing in their everyday lives.
References


https://doi.org/10.1044/1092-4388(2005/020)

https://doi.org/10.1044/2018_JSLHR-S-MSC18-18-0146

http://doi.org/10.1109/CNT.2014.7062747


https://scholarsarchive.byu.edu/etd/6294/


https://doi.org/10.1080/138255890968466


Appendix A

Annotated Bibliography


Objective: The purpose of this study was to determine the relationship in healthy adults between cognitive load, autonomic arousal, and voice production. Participants: The study included 16 total participants including eight males and eight females. Method: Each participant performed two cognitive tasks. In both they were asked to say a sentence using a Stroop task (they were presented with a word for color). In the first task, the congruent task, the participants were asked to say the font color, which was the same as the printed color. In the second task, the non-congruent task, the participants were asked to say font color which was different than the printed color, increasing the cognitive load. During these tasks, autonomic arousal measures were conducted including pulse volume amplitude, pulse period, and skin conductance response amplitude. Acoustic measures were analyzed in eight sentences for each cognitive load condition per participant. These included sound pressure level, fundamental frequency, cepstral peak prominence, and low-to-high spectral energy ratio. Results: The skin conductance response amplitudes showed significantly greater response when the participants were performing the non-congruent cognitive task (increased cognitive load). The other two autonomic measures also increased with cognitive load, but these results were not statistically significant. Changes to cepstral peak prominence and low-to-high spectral energy ratio were also associated with increase in cognitive load. Authors’ Conclusion: The findings showed
that as cognitive load increased, autonomic arousal and voice production changed. The author’s concluded that changes in these measures are physiologic and acoustic markers of an increasing cognitive load, although sound pressure level and fundamental frequency are less impacted than voice quality. **Relevance to Current Study:** This study measures physiological and voice production response to an increasing cognitive load and will provide ideas for how the current study will measure physiological response and speech changes during different levels of multitasking.


**Objective:** The purpose of this study was to determine if speech performed with concurrent nonspeech tasks would cause interference, or a decline in performance, in younger, middle-aged, and older adults. **Participants:** This study included 30 males and 30 females with no history of speech or language disorders. One participant was the exception as they had typical articulation errors that had been treated during childhood. There were 10 males and 10 females from each age group including younger adults (20-30 years), middle-aged adults (40-50 years), and older adults (58-70 years). English was the native language for all participants. **Method:** The participants were each seated in a sound booth with a lightweight head-mounted strain gauge system that measured vertical movements of the participants’ lips. There were four tasks that each participant completed including a speech task, a linguistic task, a cognitive task, and a manual labor task. Each task was completed in isolation, then each non speech task was completed simultaneously with a speech task. The speech samples were analyzed for Utterance
duration (ms) to represent speaking rate, STI to measure the variability of speech movements across repetitions, and vocal intensity. \textit{Results:} The study showed age effects during the speech task in mean utterance duration as it increased for the older adults. It also showed that performance on non-speech tasks decreased as participant age increased. The linguistic and cognitive tasks done concurrently with the speech task both showed an increase in negative UL-LL correlation and LL STI from the speech task alone. \textit{Authors’ Conclusion:} Multitasking may negatively impact older adults more than younger adults when performing cognitive tasks. They also concluded that the type of task done while speaking impacts the stability of speech movement patterning differently. The author’s also infer that participating in speech tasks while attention is undivided (in a quiet therapy room) may not be applicable to the level of difficulty that everyday multitasking during speech provides. \textit{Relevance to Current Study:} This study helps provide an idea of the effects of different task types on speech when attention is divided; however, the speech tasks were not representative of everyday speech. The current study can build on this foundation and by discovering how divided attention affects more ecologically valid speech tasks.


\textit{Objective:} The purpose of this study was to determine the impact of daily stressors on fluency in adults with fluency disorders. \textit{Participants:} This study included twenty-four university students including 20 males and 4 females with their onset of stuttering beginning before age 5. \textit{Method:} Daily stressors were measures using The Daily Stress
Inventory, which provided an inventory of stress levels over 24 hours. Fluency was measured using the Perception of Fluency Form. Both inventories were taken daily over a 22 day period. Results: A greater number of disfluencies were recorded on high stress days as compared to low stress days. Authors’ Conclusion: Daily stressors can increase the number of stuttering events a person experiences. These could potentially be reduced through therapy that helps manage these daily stressors. Relevance to Current Study: This study provided background on stress exacerbating communication disorders and will provide background for the current study.


Objective: The purpose of this study was to learn the effects of media multitasking (instant messaging) on academic reading. Participants: The participants included 46 college age males and 43 college age females with a mean age of 20.17. Method: A computer program simulated reading while receiving instant messages. There were three groups that participants were randomly assigned to. These included receiving and responding to instant messages before reading the passage, receiving and responding to instant messages while reading the passage, and receiving no instant messages while reading. After completing the reading and messages, students participated in a 25-question multiple choice test. Results: Receiving and responding to messages while reading significantly increased the time it took to read the passage (22-59% longer) when compared to receiving and responding to messages before reading or not messaging at all. Comprehension was not impacted by messaging during or before as compared to not at
Authors’ Conclusion: While reading speed is negatively impacted by messaging simultaneously, overall comprehension of the reading is not. Because of this, students may need more time to complete academic tasks when they choose to multitask.

Relevance to Current Study: The current study focuses on media multitasking during a task that requires cognitive effort. The current study can build on this knowledge as it explores media multitasking and speech.


Objective: The purpose of this paper is to review the literature about discourse treatment for those with word retrieval deficits from aphasia to better understand what should be considered in aphasia treatment and research. Method: Seven research studies involving discourse treatment were reviewed. Results: All studies reviewed showed improved word retrieval abilities after therapy involving discourse such as structured narratives or structured conversation. Authors’ Conclusion: Using discourse in therapy is a promising method of treatment of word retrieval in people with aphasia. Relevance to Current Study: This review provides a clear description of multiple kinds of discourse. This is beneficial in deciding the type of discourse the current study used when collecting a speech sample.


Objective: The purpose of this study was to determine how university students multitask using laptops and cellphones while studying, how interruptions cause task switching
during study time, and what are student responses when interrupted externally.

*Participants:* The participants included 16 students (10 females and 6 males) from a medium-sized university in Hong Kong with varying years in school, majors, and engagement with digital technology. *Method:* The students participated in an interview to report information such as study habits, computer and cellphone usage, multitasking habits while studying, and how they use technology for learning. In addition to the interview, the students used self-reporting and video-stimulated recall to report multitasking behaviors. Students were recorded studying in the lab for 1-hour increments. The cameras recorded both the students and the screens on their devices. The students watched the video and were interviewed again to learn triggers for task switches, decision making process surrounding task switching, etc. *Results:* Observation data showed that completing subtasks was a large reason for task switching decisions coming from within the participant. Students also switched tasks when they felt stuck on a task (the task seemed too difficult). Easy tasks often triggered an attempt at multitasking. Task motivation was also a big factor in task switching (urgency, perceived importance, interest). Instant messages on cell phones were found to be the highest outside distractor that triggered task switching. *Authors’ Conclusion:* Internal forces determine how a person reacts to interruption while studying. Interruption from external sources such as notifications leads to internal decision making. Students should be taught optimal timing for task switching and should be familiar with the interaction between internal and external distractions. *Relevance to Current Study:* The current study will focus on media use and speech multitasking. This article explains the complexity of media multitasking and can provide information when planning media tasks in the current study.

https://doi.org/10.5772/intechopen.69894

*Objective:* The purpose of this paper is to review the literature on how discourse is used in everyday life and combine the current research on discourse treatment for both children and adults. *Method:* The author reviewed the current literature on discourse treatment and assessment. *Results:* Discourse types are likely to impact how a speaker performs. Multilevel discourse therapies are being created in the field of speech-language pathology. These appear to be the best approach in discourse therapy. *Authors’ Conclusion:* Discourse therapy is beneficial because it represents everyday language use. Multilevel discourse treatment and assessment should be considered using clinical judgement. *Relevance to Current Study:* This review provides a clear description of what discourse is and how it applies to daily life. This is beneficial in supporting the current study’s use of discourse as a more ecologically valid method of collecting a speech sample.


https://doi.org/10.1044/1092-4388(2005/020)

*Objective:* The purpose of this study was to determine if speaking while performing motor tasks, cognitive tasks, or linguistic tasks would lead to a decline in performance compared to either speaking or the other task alone. *Participants:* Ten college age males and 10 college age females with no history of speech, language, or hearing disorders participated in the experiment. *Method:* Participants’ lip and jaw movements were
measured using a strain gauge system with a microphone attached. This was mounted to the participants’ heads. A sound level meter was also used, placed 100 cm from each participant’s mouth. Seven tasks were performed in the 35-40 minute session by each participant, including four isolated performance tasks (a speech-only task, a linguistic-only task, a cognitive-only task, and a visuomotor only task). The three non-speech tasks were immediately followed by performing each task along with a concurrent speech task. These were analyzed for utterance duration, displacement, velocity, correlation, spatiotemporal index (STI) for the lower lip-plus-jaw, and task scores and latencies.

**Results:** For the linguistic and speech combined task, it was found that the speakers were less consistent in their labial movements and had an increased speech intensity when combining the speech and linguistic task than they did when performing the speech task alone. **Authors’ Conclusion:** Typically speaking adults have a different level of performance when participating in multiple activities at the same time. The authors inferred that if adults with typical speech and language perform differently when multitasking, then adults and children with impaired speech and language will experience difficulty with speech and multitasking as well. **Relevance to Current Study:** This study shows that there are changes to participants’ speech when performing complex language tasks, cognitive tasks, and visuomotor tasks at the same time. This gives a knowledge base that multitasking impacts speech and will provide a foundation when determining how different levels of multitasking may impact speech in the current study.


https://doi.org/10.1044/2018_JSLHR-S-MSC18-18-0146
Objective: To determine the interference between speaking and driving tasks that are performed concurrently. Participants: The participants included 30 males and 30 females with no history of communication disorders divided into 3 age groups. Method: After performing some practice tasks, each participant completed a monologue speech tasks, a driving task, and a concurrent driving and speech task. Results: There was significant interference in speaking time ratio, intensity, speed, and steering wheel control. Authors’ Conclusion: Both speech and driving performance are impacted by multitasking. Relevance to Current Study: The current study also focuses on divided attention during speech. Similar measures are used to analyze a discourse sample.


Objective: The purpose of this study was to determine the relationship between galvanic skin response (GSR) and physical stress. Participants: This study included 17 male participants and 8 female participants between the age of 18 and 25. Method: A baseline blood pressure and galvanic skin response were taken for each participant under calm conditions. Galvanic skin response was measured at three levels (low stressed, medium stressed, or highly stressed). Blood pressure was measured using a BP cuff. BP and GSR were measured again after participants ran flights of stairs, which were compared to determine changes in stress levels. Results: Participants whose GSR was high prior to running were considered mentally stressed. Those who began with low BP and GSR but ended with high were considered physically stressed due to the task. Those whose BP and
GSR remained the same were considered the “normal condition.” 80% of participants became physically stressed because of the task. The remaining participants were considered mentally stressed. Authors’ Conclusion: Exercise results in higher GSR, or physical stress; however, physical stress is not related to emotional stress. Relevance to Current Study: The literature review in this study provides important information about the relationship between GSR and stress. This supports the use of GSR as a measure of stress in the current study.


Relevance to Current Study: This chapter provided background knowledge on the different kinds of attention. This will allow for better understanding of divided attention, assisting in the planning of appropriate divided attention tasks for the current study.


Objective: The purpose of this study was to determine if heart rate and blood pressure increase while speaking. Participants: The participants included 37 people with cardiac disease. Method: Blood pressure and heart rate were recorded while participants were sitting at rest quietly and while talking. Results: Speaking significantly increased Heart rate, systolic blood pressure, and diastolic blood pressure. Authors’ Conclusion: Verbal communications should be included in cardiac evaluation of patients with coronary heart
disease. Relevance to Current Study: The current study uses heart rate as a measure of stress during speech tasks.


Objective: The purpose of this study was to determine the effects of simulated driving on different conversation speaking modalities. Participants: The study included 60 participants, 30 females and 30 males, with no history of speech, language, or hearing disorders, divided into three groups (age: 20’s, 40’s and 60’s). Method: Each participant did two driving simulation tasks. One in isolation and one while having a conversation with a passenger in the car or speaking with someone over a cell phone (hand-held or hands-free). Speech measures and driving measures were observed such as speaking time ratio, mean, and standard deviation of intensity, as well as mean, standard deviation of fundamental frequency in semitones, 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. Results: The participants’ intensity increased when driving and speaking on the hand-held-phone compared to the speaking only condition. The participants had more pauses in their speech when performing the hands-free and passenger divided attention conditions than when compared to speaking alone activities (the exception being the 60-year old male group). Authors’ Conclusion: The findings showed that speech and non-speech tasks impact each other negatively when performed at the same time. The authors also inferred that intensity increased when holding the phone because of the additional motor task that holding the phone required.
Attentional demands while driving created more need for pauses to allow for time to form conversational responses. *Relevance to Current Study:* This study addresses divided attention during driving and speaking tasks. This gives a knowledge base that multitasking impacts speech and will provide a foundation when determining how different levels of multitasking may impact speech in the current study.


*Relevance to Current Study:* This provides a background on some early theories of divided attention, contributing to the rationale for the current study.


*Objective:* The purpose of this study was to determine how walking while talking impacts the speech of adults (both older and young). *Participants:* The participants included 24 healthy young adults (age 18-28) and 24 healthy older adults (age 70-80). All participants had typical hearing. *Method:* All participants performed cognitive tests focusing on processing speed, working memory, verbal ability, and inhibition to determine differences (both between age groups and individually). There were five tasks that the participants completed, including an isolated walking task; an isolated talking task; a combined walking and talking task; a combined walking, talking, and carrying a grocery bag (10 lbs.) task, and a combined walking, talking, and climbing steps task. All tests and tasks were completed in a random order. Questions were asked of participants to elicit a language sample, including describing vacations, describing influences in their lives (events or people), etc. *Results:* The young adults' speech while walking and while
walking with groceries resulted in a decline in utterance length, grammatical complexity, and information content. The older adults had a restricted speech register when compared to younger adults so instead of restricting their speech grammatically, they adopted a slower speech and walking rate. As the demands of multitasking became greater, they slowed their rate more, decreased the length of utterances and added more fillers. Their grammatical complexity did not change. 

Authors’ Conclusion: The strategies young and older adults use when multitasking during speech are different from each other.

Relevance to Current Study: The current study will focus on multitasking during speech in typical adults. This study provides a knowledge foundation about the effects of multitasking on some aspects of speech.


https://doi.org/10.1080/13825585.2010.527317

Objective: The purpose of this study was to analyze the cost of speech production in young and older adults through three questions: Does tracking performance decline during the pauses before difficult utterances? Does tracking performance decline during difficult utterances? And does tracking performance decline during pauses after difficult utterances? Participants: The participants included 40 young adults (between the ages 18 and 34) and 40 older adults (between the ages 65 and 85). The participants were tested to determine differences in verbal ability, working memory, inhibition, and processing speed. Method: Further speech analysis was performed on the speech samples taken under dual task conditions in the study “The Effects of Dual Task Demands on Young
and Older Adults Speech (Kemper et al., 2008). Coders tagged onset and offset of each utterance. The ROSS program was used to automatically determine the pauses between utterances. They also analyzed the original tracking sample for tracking error and time on target. 

**Results:** Tracking error increased and time on target decreased when the next utterance was propositionally dense or if the next utterance contained many words. Time on target declined during sentences that had increased propositional density and/or grammatical complexity. **Authors’ Conclusion:** Speakers who are planning utterances that contain a lot of information have more difficulty with pursuit motor tracking as a dual task. Speech tracking is more difficult during the pauses after utterances with many propositions or words, longer utterances, or utterances spoken more quickly. This shows that adults need time recovering after a difficult utterance. There are consequences in both speech and other tasks when trying to perform both tasks at once. **Relevance to Current Study:** This study provides a foundation of knowledge about how multitasking impacts speech tasks and will provide foundational knowledge for the current study.


**Objective:** The purpose of this study was to determine the impact that dual tasks have on young and older adult’s language. **Participants:** The participants included 40 young adults (between the ages 18 and 34) and 40 older adults (between the ages 65 and 85). The participants were tested to determine differences in verbal ability, working memory, inhibition, and processing speed. **Method:** A digital pursuit rotor tracker was used as a motor task instead of walking or other gross motor tasks to eliminate the impact it may
have on speech or respiration, which could possibly skew the results of the language analysis. Using the digital pursuit tracker, the client would attempt to keep the crosshairs of the mouse over the moving target. For the dual task condition participants used the tracker while reading and responding to a language prompt. A baseline language sample was collected for each participant. The two prompts used included “where were you and what were you doing on 9/11?” and “describe someone you admire and why you admire them.” Each sample was analyzed for the fluency, grammatical complexity, and content.

Results: Young adults showed a decline in propositional content, grammatical complexity, and sentence length when performing dual tasks. Older adults on the other hand, decreased their speaking rate during dual tasks when compared to their single task baseline. While they spoke more slowly, their language did not suffer disruptions like that of the young adults. As far as motor costs, both young and older adults experienced a similar decline in time on target. Authors’ Conclusion: Language production is negatively impacted by dual task demands, specifically pursuit rotor tracking. Young adults have faster, more complex speech than older adults; however, it is more vulnerable to dual task demands. Relevance to Current Study: While this study focused more on how dual tasks impact language, it will be beneficial when determining types of dual tasks used in the current study. They also had to account for changes in speech while performing the dual tasks, which will be the focus of the current study.

**Objective:** This review of the literature was done to determine the efficacy of choosing heart rate variability as a measure of physiological stress. **Method:** 37 publications were reviewed for the rationale of using heart rate variability as an indicator of stress. **Results:** Stress induced by multiple different methods caused changes in heart rate variability. **Authors’ Conclusion:** Heart rate variability can be used as an objective measure of physiological stress. **Relevance to Current Study:** This supports the use of heart rate variability as a measure of stress in the current study.


**Relevance to Current Study:** This chapter provides background knowledge on the functional space model of attention.


https://doi.org/10.1109/CBMS.2013.6627790

**Objective:** The purpose of this study was to better understand how to classify stress using galvanic skin response and speech. **Participants:** 10 volunteers participated in the study (age and gender were not reported). **Method:** Facial expressions, speech, and skin conductance were recorded while participants performed low stress-inducing tasks (easy math calculations) and high stress-inducing tasks (difficult math calculations). **Results:** Changes in speech are a good indicator of stress; however, it is most accurate when comparing a person’s speech to their own baseline. GSR is a good measure for stress.
when combined with other stress measures. Authors’ Conclusion: Galvanic skin response and speech can be measured as an indicator of stress; however, researchers must be careful how they use these measures to ensure accuracy. Relevance to Current Study: The current study will use GSR as a measure of stress. This paper examines galvanic skin response and speech as a measure of stress.


Objective: The purpose of this study was to describe a theory of divided attention and interference. Authors’ Conclusion: The authors explain that according to this theory there are multiple kinds of attention that can be used, causing more interference in tasks that use similar kinds of attention. Relevance to Current Study: This study provides a description of Navon and Gopher’s theory of attention, which will assist in explaining theories of divided attention in the current study.


Objective: The purpose of this analysis was to determine if the literature supports the single-bottleneck model of attention. Method: The current literature surrounding the bottleneck model was reviewed and compared. Results: The bottleneck model helps explain the interference observed in simple dual tasks; however, it does not explain every complexity of dual task interference. Authors’ Conclusion: The bottleneck theory is limited in its ability to explain why interference occurs in complicated divided attention tasks. Relevance to Current Study: This study provides a description of the bottleneck
theory of attention, which will assist in explaining theories of divided attention in the current study.


**Objective:** The purpose of this analysis was to better understand what happens when tasks are competing for single attentional resources. **Method:** Five studies on perception and attention were analyzed for allocation of attentional resources during tasks. **Results:** Dual tasks that showed interference with each other appeared to share a common processing resource. **Authors’ Conclusion:** There is a pool of attentional resources that can be used to perform tasks. The amount available for each task is determined by the allocation of processing resources. Interference can occur in one or both tasks when available resources are not great enough for both tasks. **Relevance to Current Study:** This will help provide background on theories regarding attention.


**Objective:** The purpose of this study is to determine if chronic media multitasking impacts cognitive control abilities and vice versa. **Participants:** 262 college students participated in the initial questionnaire. Students below one standard deviation under the mean and students above one standard deviation above the mean participated in the rest of the study. **Method:** There were five parts to the study: the media questionnaire, cognitive experiments (filtering/response inhibition, two and three-back tasks, task switching and the AX-CPT letter task), and another questionnaire set. A questionnaire
was used to identify heavy media multitaskers (HMMs) and light media multitaskers (LMMs). In the first cognitive task, participants were tested on their ability to filter out distractions in the environment by determining if a rectangle in a group of rectangles had rotated at all between the first image and the second while ignoring the other rectangles and their movements. In the AX-CPT task they were presented pairs of letters and asked to click “yes” if the pair “AX” appeared on the screen and “no” if any other combination of letters were displayed. Students were also asked to sort words into two categories while withholding a response if they hear a tone/stop-signal. In part two of the cognitive tasks, participants were presented with single letters on the screen followed by pauses. They were then presented with one of the letters again and were asked to report if it was the second or third letter presented. In part three of the cognitive tasks, the cost of task switching was measured by switching between classifying letters and numbers. Results: HMMs had a more difficult time ignoring environmental stimuli that were irrelevant than LMMs. LMMs had less difficulty ignoring stimuli in their memory that were irrelevant and are more effective in ignoring irrelevant task sets while task switching. Authors’ Conclusion: College students who do not frequently multitask using media are better at focusing their attention on the task at hand when there are environmental distractions than heavy media multitaskers. Another possibility is that those who multitask with media often are being distracted by the extra media they are consuming while multitasking, Relevance to Current Study: The current study focuses on media multitasking. This study will support the current study as it explains the impact media multitasking can have on cognitive tasks.

**Objective:** This paper included a series of four studies that seek to determine the relationship between media multitasking and sustained attention ability on a general level. Study 1 aimed to determine the relationship between performance on a Metronome Response Task and multitasking using media (self-reported). Study 2 sought to determine if the relationships found in study 1 would generalize to a different measure of sustained attention. Study 3 aimed to replicate studies 1 and 2 to determine if the results were the same. Study 4 aimed to determine if a behavioral test of sustained attention, a vigilance task, was impacted by media multitasking. **Participants:** Study 1: 34 female and 43 undergraduate university students. Study 2: 63 female and 20 male undergraduate university students. Study 3a: 94 females and 80 males participated through Amazon Mechanical Turk online. Study 3b: 77 females and 75 males participated through Amazon Mechanical Turk online. Study 4: 49 females and 81 males participated through Amazon Mechanical Turk online. **Method:** Study 1: Sustained attention was measured by requiring participants to push a button at the same time as an audio tone was presented. Rhythmic Response Times were measured and calculated. Media multitasking was measured using a self-reported Media Multitasking Index (MMI) questionnaire. Mind wandering was self-reported. Study 2: Measured sustained attention using the Sustained Attention to Response Task (SART), which involved viewing a series of numbers in different font sizes and pressing the spacebar when the number presented was not a 3. Study 3: The same tasks from studies 1 and 2 were administered in smaller numbers.
followed by an added questionnaire about “in-the-moment” media multitasking. The new questionnaire determined if the participants were using any form of media while participating in the study. Study 4: Participants performed a similar task to studies 2 and 3b, although the target digits were presented less often. They also participated in the in-the-moment media multitasking questionnaire. Results: Study 1: Participants with higher levels of media multitasking had more varied responses to the MRT and media multitasking was not found to be related to mind wandering as measured in this study. Study 2: No association between sustained attention and media multitasking was observed. Study 3a: Participants with higher levels of media multitasking had more varied responses to the MRT. Study 3b: No association between sustained attention and media multitasking was observed. Study 4: There was no association between media multitasking and vigilance over time. Authors’ Conclusion: Frequent media multitasking does not decrease sustained attention on a general level. Relevance to Current Study: This study focuses on media multitasking and its impact on sustained attention. While the current study does not focus on sustained attention per se, the information provided will help inform the media multitasking portion.


*Objective:* The purpose of this review was to introduce galvanic skin response and its relation to physiological response caused by the sympathetic nervous system. *Method:* Current literature was reviewed and compiled to provide an introduction to galvanic skin response. *Authors’ Conclusion:* Galvanic skin response is an accurate measure of sympathetic nervous system response. It can also be used as a measure of stress due to
the sympathetic nervous systems stress response. **Relevance to Current Study:** The current study will use galvanic skin response as a measure of stress. This provides background and supports the appropriate use of galvanic skin response as a measure of stress.


**Objective:** The purpose of this study was to examine whether breathing at resonance frequency would improve heart rate variability, blood pressure, and mood compared to breathing one breath per minute above resonance frequency and resting quietly.

**Participants:** This study included 95 young adult participants (60% of which were female.) **Method:** Participants were divided into three groups including resonance frequency breathing, breathing at 1 breath/min above established resonance frequency, and a control group measuring sitting at rest. Heart rate variability, blood pressure, and mood/anxious arousal were measured. **Results:** A healthier physiologic response and better mood were observed in the resonance frequency breathing. **Authors’ Conclusion:**

The use of resonance breathing in stress reduction is supported by the results of this study. **Relevance to Current Study:** This study uses physiologic measures very similar to those used in the current study. Because of this the current study can provide insight on how to best interpret these measures.

Objective: The purpose of this study was to determine phone usage impact on information processing including both controlled and automatic components.

Participants: The participants included 29 males and 10 females with an average age of 23.5 years. All participants were healthy and had typical or corrected vision. Method: The participants were seated in front of a screen. They were then asked to perform mental arithmetic to simulate features of information processing. This included problems that were both difficult and easy (24 of each randomly displayed). This allows for the participants to engage in obligatory encoding and obligatory retrieval. For the phone conditions, two experiments were done, one texting, and one talking. Mental arithmetic was performed alone as a single-task condition, as an expected load condition, interruptions from incoming texts and phone calls were anticipated, and mental arithmetic was performed in combination with actively talking on the phone or texting as a performed-load condition. Results: There was no negative impact on task performance when expecting a text, answering a question via text, or expecting a phone call. Talking on the phone in active conversation did negatively impact the primary task (although this was more pronounced with difficult problems). Authors’ Conclusion: While the text messages or expecting a call in the study did not impact the primary tasks, more difficult topics of conversation may still have a negative impact. Actively speaking on the phone can negatively impact cognitive tasks. Relevance to Current Study: This study shows that speaking over the phone negatively impacts a screen based cognitive task. This will provide information that will help in building the current study’s focus on screen-based multitasking and speech.
Objective: The purpose of this study was to determine the effects of background noise on five speech tasks with a range of automaticity in typical adults. Participants: Seven healthy females and 8 healthy males between the ages 21 and 53 participated. They did not smoke heavily, drink heavily, use recreational drugs, or have a history of neurological problems. Method: The speech tasks included having the participants produce a monologue on a topic of their choosing, reading the grandfather passage, counting one through 20, listing the days of the week, and producing an alternating motion rate task (AMR). Each participant produced all speech tasks twice, pausing for one minute between each task. After two hours all speech tasks were performed with background noise. Results: Less automatic tasks produced larger effect sizes than automatic tasks. Fundamental frequency and intensity increased in every task that included background noise. There was an increase in silence length and silence percentage in the reading task under background noise conditions. There was a decrease in total speech time when counting during background noise. There was no difference in noise vs no noise for AMRs. Authors’ Conclusion: Speech tasks that are not as automatic are more greatly affected by background noise than tasks that are more automatic. Relevance to Current Study: Producing speech in background noise provides some level of multitasking. In this study we learn that background noise can make speech production more labored during speech tasks that are not automatic. This study will provide ideas for possible speech tasks to be used in the current study.

*Relevance to Current Study:* This chapter provides background knowledge on the bottleneck theory and how it relates to attention.


*Objective:* The purpose of this study was to examine how internal and external distraction impact task performance of media users. *Participants:* 261 volunteers with a mean age of 25.31 participated in the study. This included 159 females and 102 males. *Method:* Each volunteer participated in a questionnaire that assessed media multitasking. This questionnaire creates a composite metric of media use and multitasking called the Media Multitasking Index (MMI). Data were collected in two formats. For 107 participants, data were collected in a lab on a computer that was shielded from the view of other participants. For 154 participants, second-year psychology students collected the data on their own laptops. Participants also performed a change-detection task where they were told to memorize two target objects while distractor objects came into view. They were then asked if the target objects changed position in a second display. A third measure determined mind-wandering during by asking the participants to rate how on task their mind was following change-detection tasks. *Results:* Performance on change-detection tasks declined as the number of distractors increased. Participants with a higher level of multitasking using media were not more strongly impacted by presence of distractors than participants who had lower levels. There was no connection discovered between
mind wandering and multitasking through media. Authors’ Conclusion: Media multitasking did not impact change detection task performance or mind-wandering. The authors concluded that this study provided evidence against the internal and external distraction hypothesis. Relevance to Current Study: The current study will involve media focused tasks to perform during speech. This study provides an understanding of current theories for media multitasking and will help inform the current study.


**Objective:** The purpose of this study was to determine how much task switching occurs during the participants’ computer use in a typical 10-hour day. They also wanted to determine how task switching relates to physiological response. **Participants:** Seven women and five men with an average age of 20.9 years participated in the study. Two of the participants majored in engineering and 10 of the participants majored in humanities and sciences. **Method:** Sympathetic arousal (skin conductance levels) were measured using a watch-like device worn on the wrist called an Affectiva Q-sensor. Movements were also recorded using an accelerometer in the same device. Tasks on the computer were recorded using a software that took screenshots 5 seconds apart. Different tasks included any application used on the computer both on the internet (Facebook, Netflix, email, etc.) and off the internet (Word, Excel, etc.). These were then divided into categories such as work and entertainment. Activity switching was measured. This was done during the students’ typical day on their personal laptops in their typical setting.
Each participant then took a survey to determine if their task switching choices were influenced by the knowledge that the software was running on the computer. \textit{Results:} The study showed that 75\% of tasks were viewed for less than a minute at a time. Overall, the participants’ arousal increased starting about 12 seconds before they switched tasks. This most often occurred when switching from work tasks to entertainment tasks. The two most commonly used activities on the computer were email and Facebook. \textit{Authors’ Conclusion:} The authors view multitasking as switching quickly between tasks. Arousal is increased in anticipation leading up to entertainment tasks. \textit{Relevance to Current Study:} This study measures physiological response while multitasking which will help inform the current study, which will measure physiological response while speaking and multitasking.
APPENDIX B

Consent/Institutional Review Board Approval Letter

Consent to be a Research Subject

Title of the Research Study: Effects of Concurrent Computer Use on Speech Acoustics and Physiologic Arousal
Principal Investigator: Christopher Dromey, PhD
IRB ID#: 

Introduction
This research study is being conducted by Professor Christopher Dromey, assisted by Tiana Bateman, Chanelle Thomas, and Paige Snow from the Department of Communication Disorders at Brigham Young University, to determine how speaking while completing another task can influence both the way a person speaks and how well they complete the other task. You were invited to participate because you are a native speaker of American English and have no history of speech, language, or hearing disorders.

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

- you will sit in a sound-treated booth in room 106 of the John Taylor Building for a recording session
- you will complete a brief hearing screening
- you will wear a headset microphone to record your speech
- you will have sensors attached to your foot to measure skin responses associated with stress
- you will be handed 3 small electrodes and asked to attach them to yourself near your collar bone and stomach
- you will read aloud sentences that will be presented on a computer screen in front of you
- you will be asked to describe how to complete a task, such as making a sandwich or carry on a conversation with the experimenter
- you will complete some computer-based tasks, such as formatting text, responding to yes/no questions about sentence accuracy or simple math problems
- sometimes you will be speaking while you do nothing else; sometimes you will be speaking at the same time you are working on a computer task
- total time commitment will be 60 minutes in one recording session
**Risks/Discomforts**
No risks are associated with the study beyond that experienced in everyday life. You might feel fatigued during the session, especially while multitasking.

You may take a break at any time during the study to rest. If the audio recordings were to be exposed to a breach of privacy, they will not have your name associated with them and will only involve everyday topics of conversation. See the Confidentiality section below.

**Benefits**
There will be no direct benefits to you as a participant. However, we anticipate that the findings from this study will benefit the field of speech pathology by helping us design better treatments for people with speech problems.

**Confidentiality**
The research data will be kept on password protected computer and only the researchers will have access to the data. Before we analyze the recordings, all identifying information will be removed so that your name will not be linked to the recordings. Only summary data from groups of participants will be reported in publications and presentations. After the study the de-identified data will be kept on a password-protected computer in the researcher’s office for possible future analysis with new techniques.

**Compensation**
You will receive $10 for your participation, whether you finish the recording or not; 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 without jeopardy to your class status, grade, or standing with the university.

**Questions about the Research**
If you have questions regarding this study, you may contact Christopher Dromey at 133 TLRB, 801-422-6461, dromey@byu.edu 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: _______
APPENDIX C

List of Possible Procedural Discourse Prompts

1. You are flying to another country. Explain the process required to board the plane, starting from the entrance to the airport.
2. You land in a large airport after a long flight and upon arrival at the baggage claim, your bag is not there. Explain the steps you would take to find your bag.
3. You get rear ended by another car at a traffic light. Explain what you would do and what you would need to do.
4. You finally get to take your dream vacation out of the country. Explain the necessary steps you would take to plan and prepare for this vacation.
5. Explain the steps necessary to plan a birthday party for a 6-year-old.
6. Explain the steps necessary to plan an elementary school field trip to the zoo.
7. Your car keeps overheating. Explain the steps you would take to get your car repaired.
8. You are interested in buying a house. Explain the steps you would need to take to make this happen.
9. You need a new job. Explain the steps you would take to find and acquire a new job.
10. You have decided to take your young nieces and nephews on a trip to an amusement park. Describe the steps you would need to take to plan and prepare for your trip.
11. Explain the steps involved in opening a new bank account, depositing money into the account, and withdrawing money from the account, as if I had never done it before.
12. Explain the process of finding and purchasing groceries at a grocery store.
13. Tell me the steps for writing and sending a thank you letter.
14. Explain what you would do if you discovered you had a flat tire while driving on the freeway.
15. You are asked to write a research essay on a topic that interests you. Explain the process required to write a good essay.
16. You decide to plant a garden. Explain the steps you would take to plan for and plant your garden.
17. You want to save money for a big purchase. Describe the steps you would take to create and maintain a budget.
18. Explain the steps you would need to take to start a new business.
19. Explain the process of making your favorite dessert or meal.
20. Explain how to play your favorite board or card game.
21. Explain how to play your favorite sport.