THE EFFECTS OF SUB-TASK BOUNDARIES AND TIME ON TASK INTERLEAVING IN THE DRIVING ENVIRONMENT

by

David Grayson Kidd

A Dissertation
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Psychology

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Dedication

To my Mom, Kathleen, my sister, Anne, and my loving wife, Michelle.

Acknowledgments

First, I would like to thank my family. I am eternally grateful to my parents who gave me the opportunities to pursue and achieve my academic goals. I especially want to thank my mom, Kathleen, and sister, Anne, for their continual support throughout the entire dissertation process. The praise and support each of you provided me throughout my graduate career motivated me to continue the long march toward my Ph.D.

Endless gratitude goes to the love of my life Michelle. Michelle, you provided me with endless support and laughter when I needed it most. You never turned a mute ear to my complaining and were the voice of reason in the most difficult moments when the wheels seemed to be coming off of the track. I completed this dissertation for you as much as for myself, and I am ever grateful that I met such a wonderful and compassionate wife.

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Abstract

THE EFFECTS OF SUB-TASK BOUNDARIES AND TIME ON TASK INTERLEAVING IN THE DRIVING ENVIRONMENT

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George Mason University, 2011

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A wealth of research has identified how distractions impair driving performance and compromise safety. Research has shown that drivers can strategically adapt their interactions with distractions to mitigate decrements in driving performance, but the strategies that drivers use to achieve these outcomes are still unknown. When people engage in another visually demanding task while driving, they have to strategically alternate attention between driving and the distracting task to achieve performance objectives. This is known as task interleaving. Several studies have suggested that people switch between tasks at sub-task boundaries to minimize the cognitive cost associated with suspending and resuming a task. The driving environment, however, cannot be neglected for long without serious safety consequences and some sub-task boundaries may be unattainable. Uncertainty about the roadway environment increases when the driver is not attending to the roadway, and research has shown that growing uncertainty over time dictates how drivers look to and from the roadway.

Only two studies have examined task interleaving strategies in the driving environment, but the influence of sub-task boundaries and time on participants' task interleaving strategies in these studies was confounded. The current research expanded upon previous work

by systematically varying sub-task size and driving demand to tease apart the role that sub-task boundaries and elapsed time play in people's task interleaving strategies in the driving environment. Experiments 1 and 2 showed that drivers interleaved at sub-task boundaries less often when sub-tasks in a distractor task were larger. Additionally, Experiments 1 and 2 showed that the time people looked away from the roadway did not change significantly as sub-task size increased. Experiment 2 and 3 showed that task performance was more efficient when sub-tasks in the distractor task were chunked in memory. Experiment 3 showed that increasing lane width increased the time drivers were willing to neglect the driving task. While drivers still primarily switched between tasks as a function of time in Experiment 3, sub-task boundaries did influence task interleaving strategies when the sub-tasks of the distractor task were chunked in memory and participants had more time to look away from the roadway. Overall, task interleaving strategies were primarily influenced by time, but drivers seemed to be opportunistic and switched at sub-task boundaries when the time required to complete a sub-task aligned with the time constraints of the driving environment.

Chapter 1: Introduction

In an ideal world, driving would be free of distraction and drivers would always be focused on the roadway ahead. Unfortunately, in the real world this is not the case. Drivers often engage in non-driving activities while driving, such as eating, reaching for objects, sightseeing, and interacting with communication and entertainment devices (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Stutts et al., 2005). These non-driving activities interfere with other activities critical for safe driving (Regan, Lee, & Young, 2009). As a result, driver distraction can impair driving performance and compromise driver safety.

A large body of research has been dedicated to exploring driver distraction. Studies have repeatedly shown that distractions impair driving performance in a number of different ways. For example, distractions reduce drivers' abilities to maintain control of the vehicle. When distracted, drivers have more difficulty keeping their vehicle in the center of the lane (Bayly, Young, & Regan, 2009; Crisler et al., 2008; Horrey, Wickens, & Consalus, 2006) and they also have a more difficult time maintaining a constant distance to the vehicle ahead (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009; Strayer, Drews, & Johnston, 2003). Distractions also impair drivers' abilities to judge distances between objects on the roadway (Brown, Tickner, & Simmonds, 1969) and make appropriate gap judgment decisions (Cooper & Zheng, 2002). Lastly, distractions reduce drivers' abilities to detect hazards or objects in the roadway (Y. Lee, Lee, & Boyle, 2007) and increase response time to hazards (Chisholm, Caird, & Lockhart, 2008; J. D. Lee, Caven, Haake, & Brown, 2001; Levy, Pashler, & Boer, 2006).

Diminished performance associated with distractions can have disastrous outcomes. In 2008, driver distraction was implicated in 16 percent of all fatal crashes in the United States and 22 percent of all injury crashes (National Highway Traffic Safety Administration, 2009).

In two different studies, cell phone use alone has been associated with a fourfold increase in crash risk (see McCartt, Hellinga, & Bratiman, 2006, for a review). Text messaging has been shown to have far worse implications for driver safety. A study of commercial motor vehicle drivers found that drivers texting while driving were 23 times more likely to be involved in a safety critical event than when they were not distracted (Olson, Hanowski, Hickman, & Bocanegra, 2009). Cell phones are just one of a growing number of mobile entertainment and communication devices that are entering the driving environment. Surprisingly, however, the proliferation of mobile devices has not corresponded to a substantial increase in the overall number of crashes involving driver distraction (National Highway Traffic Safety Administration, 2009). This evidence suggests that drivers may be strategically adapting their behavior to cope with the performance decrements associated with distraction.

Research on multitasking performance suggests that drivers can strategically allocate resources to accommodate additional demand and maintain task performance (e.g., Navon & Gopher, 1979; Norman & Bobrow, 1975). One way that drivers adapt their behavior to compensate for distractions is by reducing driving demand. Evidence of this is that when distracted, drivers slow down (Ranney, Harbluk, & Noy, 2005), allow more distance between their vehicle and the vehicle ahead (Drews, Pasupathi, & Strayer, 2008; Strayer & Drews, 2004), and make fewer lane changes (Beede & Kass, 2006). Reducing the overall demand of the driving task allows more cognitive resources to be directed toward handling a distracting task.

Drivers can also strategically adapt their interactions with a distraction to compensate for decrements in performance during multitasking. Jamson, Westerman, Hockey, and Carsten (2004) found that when given the opportunity, drivers took longer to begin a secondary task compared to when task interactions were at a forced pace. This finding suggests that drivers may wait until periods of lower roadway demand before engaging in a distraction. However, other research suggests that drivers do not always respond in this fashion. For example, drivers were found to engage in distractions regardless of current roadway demand (Horrey & Lesch, 2009) or the demand imposed by the distracting task

(Hoffman, Lee, McGehee, Macias, & Gellatly, 2005). Furthermore, Lerner, Singer, and Huey (2009) found that drivers' willingness to engage in distracting tasks was only weakly related to roadway conditions. Thus, although it seems that drivers are capable of adapting their behavior, the extent to which they actually compensate for dual-task decrements in this manner is not clear.

The research discussed thus far provides evidence that drivers can strategically allocate resources between driving and a distracting task to achieve different performance objectives. It does not, however, provide any information about the strategies drivers use to achieve these outcomes. Driving is a visually demanding task that requires some degree of sustained visual attention. When people engage in another visually demanding task while driving, they have to decide when to direct their attention to the driving task (e.g., the road ahead) and when to direct their attention to the distracting task. The manner in which drivers alternate attention back and forth between driving and a distracting task constitutes a strategy of task interleaving. Task interleaving strategies are the mechanism through which drivers achieve performance objectives during distracted driving.

There are a number of different ways that drivers can interleave attention between driving and a distracting task. Imagine a driver who is dialing a cell phone number while driving. Drivers could minimize the amount of interleaving and dial the entire phone number before switching their attention back to the driving task (see Figure 1.1a). This strategy would allow drivers to enter the number quickly, but it would require them to glance away from the roadway for an extended period of time, sacrificing driving safety and increasing crash risk (e.g., Klauer et al., 2006). Another alternative would be to split the dialing task up into smaller pieces and switch more frequently between both tasks, perhaps after each digit in the number is entered (see Figure 1.1b). This strategy maximizes the amount of interleaving and allows the driver to monitor the driving environment more closely, but at the expense of dialing efficiency.

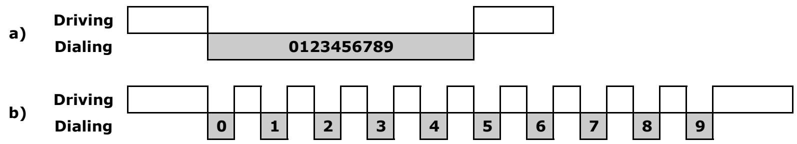


Figure 1.1: Driving and dialing a phone number (012-345-6789) using a) minimum and b) maximum task interleaving strategy.

The maximum and minimum task interleaving strategies represent endpoints on a continuum of task interleaving strategies that drivers may adopt. In general, people do not maximize or minimize task interleaving during multitasking but adopt a strategy between these two extremes (Payne, Duggan, & Neth, 2007). This is also the case in driving; drivers generally divide distracting tasks into smaller, more manageable chunks (Salvucci & Macuga, 2002). The question then, is what factors influence how drivers divide a distracting task into manageable chunks and where they decide to interleave a distracting task with driving.

One way that drivers can interleave a distracting task with driving is to switch to the driving task after completing sub-tasks in the distracting task (see Figure 1.2). For example, a United States (US) phone number consists of 10 digits (e.g., 012-345-6789) that can be broken down into 3 chunks (i.e., 012, 345, and 6789) that correspond to 3 different sub-tasks. A person dialing a phone number while driving could glance back to the roadway following the completion of each sub-task (i.e., after the third and sixth numbers). Studies have shown that people seem to prefer interleaving at sub-task boundaries. Salvucci and Bogunovich (2010) found that, when given the opportunity, people tended to defer an interrupting task until they had reached a sub-task boundary in the primary task. Similarly, Payne, Duggan, and Neth (2007) showed that when people generated as many words as possible from one of two sets of letters, they switched between sets of letters after a word had just been generated. Again, people chose to switch at sub-task boundaries. Finally, an observational study of information workers in the office environment showed that workers generally switched between tasks after reaching a point of closure where they completed their current action in a task or completed the task itself (Gonazalez & Mark, 2005).

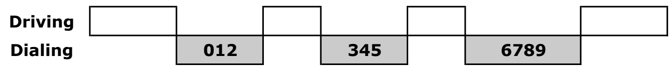


Figure 1.2: Interleaving dialing a phone number (012-345-6789) with driving at sub-task boundaries in the dialing task.

People may switch at sub-task boundaries because sub-task boundaries offer significant cognitive and performance benefits compared to switching at other points in a task. During task interleaving, performance on each task is repeatedly suspended and resumed. After a task is suspended, people have to remember what they were doing along with the information needed to accomplish what they were doing when they resume. The task-related information that people use to resume and execute a suspended task is known as the "problem state" (Salvucci & Taatgen, 2010). When people interleave in the middle of a sub-task, they have to maintain the problem state of the suspended sub-task and retrieve it from memory when they resume the task later on. Retrieving the problem state from memory takes time and effort, especially if the task has been suspended for a long period of time (Altmann & Trafton, 2002; Monk, Trafton, & Boehm-Davis, 2008). When people interleave at sub-task boundaries, however, the sub-task has been completed and the problem state of the sub-task does not need to be maintained. As a result, the cognitive resources that were used to maintain the problem state are released and cognitive workload decreases (Salvucci & Bogunovich, 2010).

Research on interrupted task performance demonstrates the cognitive benefits of suspending and resuming tasks at sub-task boundaries. For instance, Bailey and Iqbal (2008) found that interruptions at sub-task boundaries resulted in lower cognitive workload compared to interruptions at other points in the task. Monk, Boehm-Davis, and Trafton (2004) found that when participants were interrupted in the middle of a sub-task, it took them significantly longer to resume a VCR programming task than when they were interrupted at a sub-task boundary. Thus, drivers may switch at sub-task boundaries because additional cognitive resources are available to reduce the cost of switching between tasks.

Another factor that can influence when people switch between tasks in the driving environment is elapsed time. Vision is the primary resource that people use to gather information in the driving environment. When drivers look away from the roadway, they are unable to process visual information from the roadway and become uncertain about the state of the driving environment. Uncertainty about the driving environment continues to increase as long as visual attention is away from the roadway. According to Senders, Kristofferson, Levison, Dietrich, and Ward (1967), drivers will return their visual attention to the roadway when uncertainty about the driving environment exceeds some threshold. Thus, drivers may switch between tasks as a function of time to keep their uncertainty about the roadway environment at an acceptable level (see Figure 1.3 for an example of the uncertainty model applied to the dialing while driving example).

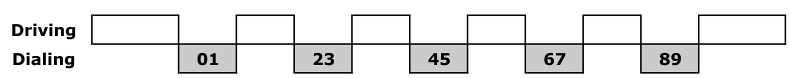


Figure 1.3: Interleaving dialing a phone number (012-345-6789) with driving at regular intervals following some constant period of time.

Studies investigating visual glance behavior suggest that visual attention does not have to be away from the roadway for too long before uncertainty about the driving environment reaches unacceptable levels. Wierwille (1993) found that most of drivers' glances away from the roadway were less than 1.6 seconds on average. Hoffman, Lee, and McGehee (2005) found that drivers looked away from the roadway between .76 and 1.14 seconds on average when reading in-vehicle text messages. Furthermore, Victor, Harbluk, and Engstrom (2005) found that glance durations frequently did not exceed 2 seconds when drivers were distracted by auditory and visual tasks. Gellatly and Kleiss (2000) found that when drivers were performing tasks on an in-vehicle information system they switched visual attention back and forth from the roadway and the in-vehicle information system about every one second. Uncertainty increases even faster when the driving environment becomes more demanding. Several studies have shown that drivers look away from the roadway less often and for shorter periods of time when the driving environment is more demanding and generates more uncertainty (Senders et al., 1967; Tsimhoni & Green, 2001; Tsimhoni, Smith, & Green, 2004). Together, these findings indicate that drivers become uncertain about the driving environment relatively quickly and do not divert their visual attention away from the roadway for long periods of time.

Only a couple of studies explicitly examined when people decide to switch between tasks in the driving environment. Brumby, Salvucci, and Howes (2009) conducted a study where drivers dialed a 10-digit US phone number while keeping their simulated vehicle in the center of a lane. Drivers were instructed to either prioritize dialing task performance or prioritize lane-keeping performance. Brumby et al. measured the time between key presses in the dialing task and found that, when lane-keeping performance was prioritized, the time between key presses was greatest at sub-task boundaries. This finding suggests that drivers switch between tasks at sub-task boundaries when they multitask in the driving environment.

One potential limitation with Brumby, Salvucci, and Howes' (2009) study is that the sub-tasks in the dialing task were relatively short. As mentioned previously, a US phone number consists of 3 small sub-tasks, 3 digits, 3 digits, and then 4 digits. Participants did not have to look away from the lane-keeping task for long before reaching a sub-task boundary in the dialing task. Based on these results, it is not clear if drivers were choosing to switch at sub-task boundaries or if sub-task boundaries occurred within the amount of time they were willing to look away from the roadway. Thus, the role that sub-task boundaries played in influencing participants' decisions to switch between tasks was confounded with the time it took participants to complete sub-tasks in this study.

Janssen and Brumby (2009) conducted a study that challenges Brumby et al.'s (2009) conclusions. In this study, people dialed a United Kingdom (UK) phone number while performing a lane-keeping task. The sub-tasks in a UK phone number were larger than those in a US phone number, consisting of dialing 5 digits and then 6 digits. Janssen and Brumby found that drivers did not exclusively switch from the dialing task to the driving task at sub-task boundaries. Instead, drivers seemed to switch after dialing 2 or 3 digits and were willing to switch at points other than sub-task boundaries. This finding suggests that time and not sub-task boundaries influenced decisions to switch in the driving environment. However, Janssen and Brumby did not directly manipulate the time required to complete the sub-tasks in the dialing task, so their findings cannot confirm that decisions to switch in the driving environment were more influenced by time than sub-task boundaries.

1.1 Current study

Drivers strategically allocate their resources when they are distracted to mitigate decrements in driving performance, but the specific strategies that they use are not clear. A number of studies have provided evidence that people switch at sub-task boundaries during multitasking, but there is conflicting evidence as to whether decisions to switch between tasks in the driving environment are likely to occur at sub-task boundaries or are influenced by time. The current research expands upon previous work by systematically varying sub-task size and driving demand to tease apart the role that sub-task boundaries and elapsed time play in people's decisions to switch between tasks in the driving environment.

Three experiments were conducted. In the first experiment, drivers entered in strings of numbers, such as phone numbers, zip codes, and number strings, that varied in sub-task size while keeping their vehicle in the center of a lane in a simulated driving task. The second experiment extended the first experiment by examining how prior knowledge of the distractor task influenced participants' decisions to switch. In this study, drivers entered strings of text that contained words or scrambled nonwords of various sizes while keeping their vehicle in the center of the lane. In the final experiment, roadway demand and uncertainty in the driving environment were manipulated by varying lane width to directly examine how time influenced decisions to switch between tasks in the driving environment.

Chapter 2: Experiment 1

The goal of this experiment was to systematically vary the size of sub-tasks in a distracting number-entry task that participants completed while driving to determine whether participants decided to switch between tasks at sub-task boundaries or as a function of time. All of the stimuli in the number entry task were 10 digits long, but were composed of different sized sub-tasks. If participants interleaved the number entry task at sub-task boundaries, then the following outcomes were expected. First, the latency between button presses (inter-button interval) at digit positions representing a sub-task boundary in a number stimulus should be significantly longer compared to the same digit position that is not a sub-task boundary in the other number stimuli (see Table 2.1 for predictions). Second, participants should switch from the number entry task to the lane-keeping task significantly more often at sub-task boundaries for each type of number entry stimulus regardless of sub-task size. Lastly, participants should look away from the roadway longer as sub-tasks become larger. If these expectations are not met, it would suggest that sub-task boundaries are not the primary factor that influences participants' task interleaving strategies.

Table 2.1: Predicted outcomes for the comparison of average inter-button interval at each sub-task boundary between each type of number stimulus. The phone number stimulus had sub-task boundaries at digit positions 4 and 7. The zip code stimulus had a sub-task boundary at digit position 6.

Comparison	Digit Position		
	4	6	7
Phone vs. Zip Code	P > Z	P < Z	P > Z
Phone vs. String	P > S	=	P > S
Zip Code vs. String	=	Z > S	=

2.1 Method

2.1.1 Participants

Forty-eight (16 men, 32 women) George Mason University undergraduate students were recruited to participate in this study. Participants ranged in age from 18 to 40 years and were 21 years old (SD = 4.8) on average. All participants had at least 2 years of driving experience and were fully licensed drivers. On average, participants had 52 months (SD = 48) of driving experience. All participants reported owning a cellular phone. Eighty-eight percent of participants reported using their cellular phone while driving and 67% of participants reported that they had sent or receive text messages while driving. All participants received course credit for participating in this study.

2.1.2 Apparatus

This study was conducted using a desktop driving simulator by Realtime Technologies, Inc. (RTI) (see Figure 2.1). The simulator was controlled using a Logitech force feedback racing wheel and pedals. The steering wheel was equipped with two response paddles that were used in the secondary task. RTI's SimVista (Version 2.24) authoring tool was used to create the simulated driving scenario and experimental tasks. The simulated environment was run using RTI's SimCreator (Version 2.28). All visuals were presented on a 20-inch LCD monitor at 60 frames per second. Behavioral performance data were collected at 100 Hz.

Figure 2.1: The desktop driving simulator. The numeric keypad was mounted to the right of the steering wheel.

Participants completed a number entry task using a numeric keypad mounted to the right of the steering wheel. The keys were remapped to match the layout of a cellular phone (see Figure 2.2).

Figure 2.2: Numeric keypad used in the number entry task.

2.1.3 Tasks

Participants completed two different tasks, a lane-keeping task and a number entry task. In the lane-keeping task, drivers navigated their vehicle down a straight, four-lane roadway while traveling at a fixed speed. Participants were instructed to use the steering wheel to keep their vehicle as close to the center of the right lane as possible. The right lane boundaries were indicated by lane markings and construction pylons. Construction pylons clearly identified the lane boundaries and encouraged participants not to deviate from the lane. If the simulated vehicle struck a construction pylon, then feedback was provided by a noticeable vibration in the roadway view and force feedback in the steering wheel. Participants' speed was held constant at 40 miles per hour (mph) to keep participants from reducing their speed to compensate for additional workload imposed by the number entry task.

Figure 2.3: An example of a number entry task stimulus at the top of the driving environment

A number entry task was used as a distractor task. In the number entry task, participants entered a string of numbers using the numeric keypad. Participants entered one of three types of number entry task stimuli: a United States (US) phone number (XXX-XXX-XXXX), a modified zip code (XXXXX-XXXXX), or a number string (XXXXXXXXXX). All of the task stimuli had the same number of digits (10), but differed in sub-task size. Sub-tasks in the US phone number were small (3-4 numbers) and there were 2 sub-task boundaries. The modified zip code stimuli were similar in format to US zip codes, but were 1 digit longer to match the length of the phone number and string stimuli. The zip code stimuli had medium sized sub-tasks (5 numbers) and there was 1 sub-task boundary. Lastly, the number string was one large "sub-task" with 10 numbers and no sub-task boundaries. All number entry task stimuli were randomly generated with the following constraints: no two consecutive digits were identical, randomly generated zip codes did not contain postal codes that were currently in use by the US Postal Service, and phone numbers did not contain an area code that was currently in use by the US telephone network. Number entry task stimuli were displayed at the top center of the LCD monitor and each digit in the string was 75 pixels tall (see Figure 2.3).

2.1.4 Interleaved Task Paradigm

In the dual-task condition, drivers responded to the number entry task stimuli while performing the lane-keeping task. The two tasks were completed in an interleaved task paradigm based on the occlusion paradigm. The occlusion paradigm is used to assess the visual demand of an in-vehicle device to determine if it is compatible with the driving task (Lansdown, Burns, & Parkes, 2004; Senders et al., 1967; Baumann, Keinath, Krems, & Bengler, 2004). In the occlusion paradigm, peoples' vision is intermittently obscured, or occluded, for a fixed period of time while they complete a task using an in-vehicle device. These occlusion periods simulate glances to the roadway. Visual demand is assessed by computing a ratio of the total time that the in-vehicle device or interface is visible during task performance including the occlusion periods, to the total time it takes to complete the same task without occlusion periods.

In the current experiment, the occlusion paradigm was modified and participants were given control of viewing and occlusion periods. In this manner, participants could interleave the number entry task with the lane-keeping task at their own pace. In the current paradigm, participants occluded the driving scene by pulling on one of two response paddles mounted behind the steering wheel. During the occlusion period, a black screen covered the roadway scene and participants could engage in the number entry task (see Figure 2.4). The vehicle continued to move along the roadway during the occlusion period even though the participants could not see the roadway. The number entry task stimuli were still available during the occlusion period in order to reduce any working memory demand associated with remembering the task stimuli.

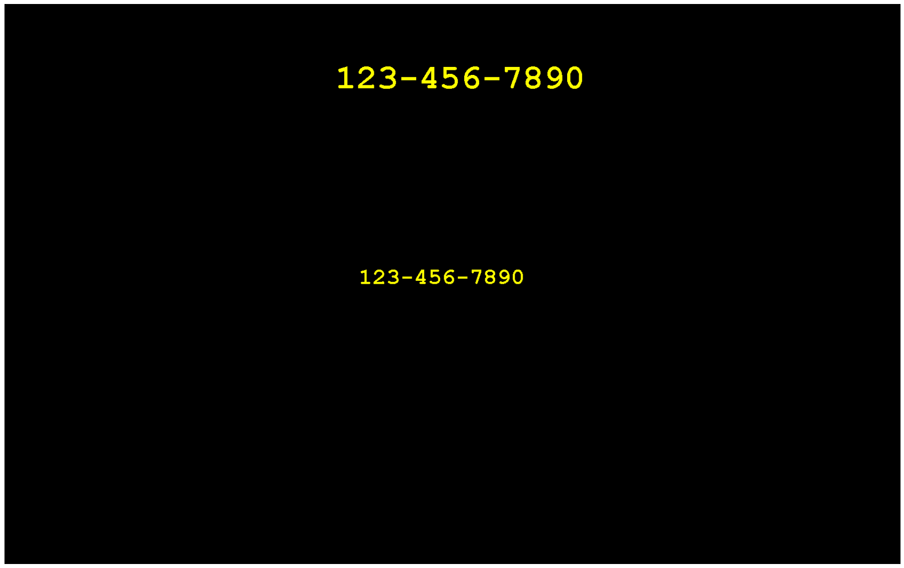


Figure 2.4: Driving environment is occluded by a black screen. The number entry stimuli was still available at the top of the screen and participants' responses appeared in the center of the screen.

When the roadway was occluded, participants entered the number stimulus using the numeric keypad. Hyphens in the phone number and zip code stimuli appeared automatically so participants only had to enter the ten digits in each number stimulus. Participants' responses appeared in the middle of the black screen occluding the roadway. The response text was 60 pixels tall. Participants could only enter digits when the response paddle was pulled and the roadway was occluded. Participants had full control over the duration and onset of the occlusion periods. After participants replicated the number entry task stimulus, they pressed the "Send" button to submit their response. At this point, the number entry task stimulus and response were removed from the visual scene. Participants were not given any feedback regarding the accuracy of their responses.

2.1.5 Design

This study employed a mixed design. The between-subjects factor was stimulus type (phone number, modified zip code, and number string), and the within-subjects factor was single- or dual-task performance. Sixteen participants were randomly assigned to each of the three stimulus type conditions. All participants completed the lane-keeping task and number entry task independent of one another (single-task condition) and concurrently (dual-task condition).

2.1.6 Procedure

At the beginning of the study, participants completed a demographic survey that collected information about age, driving experience, driving history, and experience with mobile communication and entertainment devices (see Appendix A). Following the demographic survey, participants completed a five minute practice scenario to become familiarized with the desktop driving simulator. Afterwards, participants were introduced to the number entry task and were given practice by entering six number entry stimuli that were not used in the experiment.

Participants completed five driving scenarios - two single-task scenarios and three dual-task scenarios. The two single-task scenarios were completed first and the order was counterbalanced across participants. In one single-task scenario, participants only performed the lane-keeping task. This scenario lasted five minutes. In the other single-task scenario, drivers only performed the number entry task. In this scenario, the simulated vehicle remained in park and participants entered 12 number entry task stimuli.

After the two single-task scenarios, participants completed three dual-task scenarios where they performed the number entry task and lane-keeping task concurrently. The first number entry task stimulus appeared 15 seconds after the start of each dual-task scenario to give participants time to stabilize their lane position. Participants entered 12 number entry task stimuli during each dual-task scenario. The 12 number entry task stimuli in each scenario were randomly selected without replacement from a library of over 70 possible stimuli for each stimulus type. All of the number stimuli that were used in this study can be viewed in Appendix B, C, and D. Participants had 15 seconds between the completion of a number entry task trial and the ensuing number entry task stimulus to re-stabilize their lane position. Participants were told that they could use any type of task interleaving strategy they wished to complete the number entry task while performing the lane-keeping task. Additionally, they were instructed to prioritize driving safety and lane-keeping task performance in each dual-task scenario.

At the end of the experiment, participants completed an implicit memory test to confirm that participants did not have prior knowledge of any of the number stimuli. Participants were asked to list as many of the number entry task stimuli presented during the experiment as they could. After the implicit memory test, participants were debriefed about the purpose of the study and dismissed.

2.1.7 Measures

Lane-keeping performance was measured using lateral deviation from the center of the lane, standard deviation of lane position, and lateral velocity. Deviation from lane center was the absolute value of the distance between the center of the subject vehicle and the lane center in meters. Deviation from lane center was recorded at each digit entry in dual-task scenarios and also averaged across single- and dual-task scenarios. The standard deviation of lane position (SDLP) was calculated in both single- and dual-task scenarios. In single-task scenarios, SDLP was calculated over the entire five minute duration of the scenario. In dual-task scenarios, SDLP was only calculated when participants were completing a number entry task trial. Lateral velocity indicated the stability of the subject vehicle in the lane. It was calculated by taking the lateral distance the subject vehicle traveled between two consecutive digit entries in the number-entry task and dividing this distance by the total time between the digit entries. The absolute value of this quotient indicated the lateral velocity observed between the two digit entries.

Number entry task performance was measured using inter-button interval (IBI), accuracy, and switch location. IBI was the latency between two consecutive button presses. Accuracy was calculated as the percent of correct responses during a scenario. Switch location was recorded at the digit position that followed a switch from the number entry task to the lane-keeping task. The average duration that participants viewed the roadway (viewing period) and occluded the roadway to perform the number entry task (occlusion period) was recorded during each trial. The average duration of occlusion and viewing periods were used to assess participants visual sampling strategies. Lastly, the average number of digits entered during each occlusion period in each trial was also recorded.

2.2 Results

All dependent measures in the number entry and lane-keeping task were aggregated across trials for each participant. Data from the first dual-task scenario were not included in any of the analyses because this was participants' first exposure to dual-task performance and it was likely heavily influenced by learning effects. Inaccurate trials were removed from the data set. An inaccurate trial was defined as a trial where the number entered by the participant was incorrect or where a mistake occurred during entry that was corrected. Ten percent of all trials were inaccurate and removed. A one-way analysis of variance (ANOVA) was performed on the percentage of trials removed to see if the amount of data removed varied as a function of the type of number stimulus. The percentage of trials removed did not vary reliably as a function of the type of number stimulus, $F(2,\ 45) = 2.3$, $p = .11$. This finding suggests that the type of number stimulus did not influence the exclusion of trials from the data set.

2.2.1 Dual-task performance costs

Before exploring task interleaving strategies, it was important to establish the existence of dual-task costs in task performance. A series of 3 Number Stimulus (Phone, Modified zip code, String) x 2 Task Condition (Single, Dual) mixed factorial ANOVAs were conducted on accuracy, IBI, average deviation from lane center, and standard deviation of lane position (SDLP). Note, accuracy in the number entry task during single- and dual-task scenarios was evaluated using the full data set including inaccurate trial data. The analyses provided evidence that participants performed significantly worse on both the number entry task and lane-keeping task during dual-task performance compared to single-task performance (see

Table 2.2). Accuracy was significantly lower in the dual-task scenarios compared to the single-task scenarios, $F(1, 45) = 9.7$, $p < .001$. Average inter-button interval (IBI) was also significantly slower in dual-task scenarios than in single-task scenarios, $F(1, 45) = 33.7$, $p < .001$. The average latency between button presses was 1.57 seconds slower in dual-task scenarios compared to single-task trials. Accuracy and average IBI did not vary reliably as a function of type of number stimulus (Fs < 1) or the interaction between task condition and type of number stimulus (Fs < 1.2).

Table 2.2: Single- and dual-task performance in the number entry and lane-keeping tasks. Mean values are displayed with SD in parentheses.

Scenario	Number Entry Task		Lane-Keeping Task	
	Accuracy (%)	IBI (Sec)	SDLP	Deviation from lane center (M)
Single-task	100 (0)	2.29 (0.5)	0.24 (0.21)	0.29 (0.11)
Dual-task	96.8 (7)	3.86 (2)	0.43 (0.30)	0.33 (0.12)

Despite instructions to focus on lane-keeping, lane-keeping task performance suffered during dual-task performance. Standard deviation of lane position was significantly greater in dual-task scenarios than in single-task scenarios, $F(1, 45) = 13.1$, $p < .001$. This finding indicates that participants were less able to maintain a steady lane position when they were distracted by the number entry task compared to when they were only performing the lane-keeping task. Average deviation from lane center was also significantly higher in dual-task scenarios compared to single-task scenarios, $F(1, 45) = 13.1$, $p < .05$. On average, participants strayed 0.04 meters farther away from lane center during dual-task performance compared to single-task performance. Both measures of lane-keeping task performance did not reliably differ by type of number stimulus (Fs < 1.7) or the interaction between task condition and type of number stimulus (Fs < 1.5).

2.2.2 Task performance at sub-task boundaries

Sub-task boundaries were located at different digit positions for each type of number stimulus in the number entry task. Two sub-task boundaries existed in the phone number stimulus and were before the fourth digit and seventh digit. The modified zip code had one sub-task boundary that occurred before the sixth digit. The number string did not have a sub-task boundary. The following analyses focused on differences in number entry task and lane-keeping task performance at the digit positions following each sub-task boundary across the different types of number stimuli. Data were analyzed using a series of 3 Digit Position (4, 6, 7) x 3 Number Stimulus (Phone, Modified zip code, String) mixed factorial ANOVAs with particular focus on the interaction between the two factors. Post-hoc tests were conducted using paired-samples and independent samples t-tests with Bonferroni corrections.

Difference scores between single- and dual-task performance were calculated for inter-button interval (IBI) and average deviation from lane center to account for differences in the average latency of button presses and average distance from the lane center between individuals. In the discussion to follow, IBI and deviation from lane center reflect the average dual-task cost, or difference between single- and dual-task performance, aggregated across participants. At some digit positions, dual-task cost was negative, that is, dual-task performance was better than single-task performance on average at that digit position.

Number entry task performance

The average dual-task cost in IBI at each digit position for each type of number stimulus is displayed in Figure 2.5. A mixed factorial ANOVA revealed a significant interaction between digit position and number stimulus, $F(4, 90) = 24.4$, $p < .001$. Digit position 4 followed a sub-task boundary in the phone number stimulus. Average IBI in the phone number stimulus at digit position 4 was expected to be significantly greater than average IBI in both the zip code and string stimulus conditions. Post-hoc tests confirmed that the average IBI in the phone number stimulus was significantly greater than average IBI in the string stimulus at digit position 4, $p < .01$. However, average IBI in the phone number condition was not significantly different from average IBI in the zip code stimulus as expected. These findings suggested that participants in the phone number condition were switching between tasks more often than participants in the string stimulus condition at digit position 4, but not more often than participants in the zip code condition. No difference was expected to occur between the string stimulus and zip code stimulus at digit position 4 since this was not a sub-task boundary for either stimulus. As expected, post-hoc tests revealed no significant difference in IBI between the zip code stimulus and the string stimulus at digit position 4.

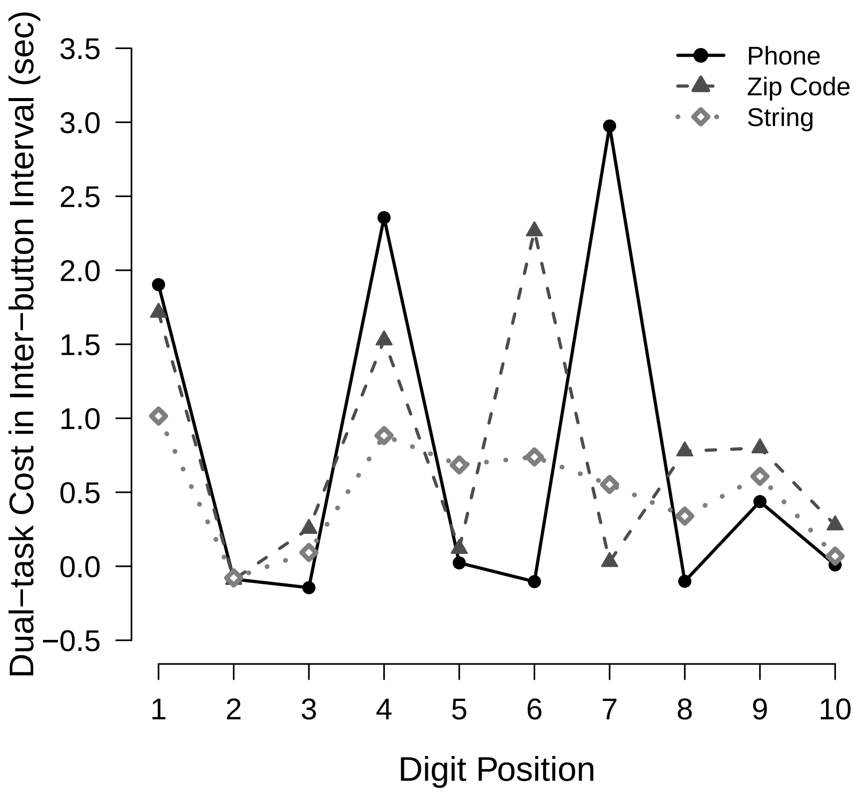


Figure 2.5: Average dual-task cost in inter-button interval at all 10 digit positions as a function of type of number stimulus. The sub-task boundaries for the phone number stimulus were at digit positions 4 and 7. The sub-task boundary for the zip code stimulus was at digit position 6.

Digit position 6 followed a sub-task boundary in the zip code stimulus condition. Average IBI for the zip code stimulus was expected to be significantly greater than average IBI in the phone number stimulus and string stimulus at digit position 6. As expected, IBI in the zip code stimulus was significantly greater than both the phone number ($p <$

.001) and string stimuli ($p < .01$). These findings suggested that participants were switching between tasks at the sub-task boundary in the zip code stimulus more often than the phone number and string conditions at digit position 6. Average IBI in the phone number stimulus condition was not expected to be different from average IBI in the string stimulus condition at digit position 6. The post-hoc test did not confirm this prediction. IBI in the string stimulus was significantly greater than the phone number stimulus at this sub-task boundary, $p < .01$.

The second sub-task boundary in the phone number stimulus was located at digit position 7. Average IBI in the phone number stimulus at this digit position was expected to be greater than both the zip code stimulus and string stimulus conditions. Post-hoc tests confirmed that average IBI in the phone number stimulus condition was significantly longer than both the zip code stimulus ($p < .001$) and string stimulus ($p < .001$) conditions. These findings suggested that participants in the phone number stimulus condition were switching between tasks at this digit position more often than participants in the zip code and string stimulus conditions. Average IBI in the zip code stimulus and string stimulus was not expected to be different, however, the post-hoc test approached significance, $p = .06$. IBI in the string stimulus condition was 0.52 seconds greater on average than in the zip code stimulus. This suggests that more participants were switching between tasks in the string stimulus condition than in the zip code stimulus condition at digit position 7.

Table 2.3 summarizes the statistical outcomes for the post-hoc comparisons of dual-task cost in IBI for each type of number stimulus at digit positions 4, 6, and 7. Most of the predicted outcomes were confirmed. At each digit position, average IBI was generally greater in the number stimulus condition with a sub-task boundary compared to the number stimulus conditions without a sub-task boundary.

Table 2.3: Statistical outcomes for the comparison of average inter-button interval at each sub-task boundary between each type of number stimulus. Cells shaded in gray indicate comparisons where the outcome did not match the prediction.

Comparison	Digit Position		
	4	6	7
Phone vs. Zip Code	=	P < Z	P > Z
Phone vs. String	P > S	P < S	P > S
Zip Code vs. String	=	Z > S	=

Lane-keeping task performance

The IBI data suggested that, for the most part, participants switched between tasks at sub-task boundaries. If participants were indeed switching back to the lane-keeping task at sub-task boundaries, then lane-keeping task performance should be better at digit positions that followed a sub-task boundary in a number stimulus compared to the same digit position that did not follow a sub-task boundary in the other number stimulus conditions. The difference in average deviation from lane center between single- and dual-task lane-keeping performance was analyzed using a mixed factorial ANOVA. Contrary to expectations, there was no significant interaction between sub-task boundary location and number stimulus, $F(4, 90) = 0.4$, $p = .84$. This finding suggests that participants did not change their vehicle position relative to the center of the lane any differently at the sub-task boundaries as a function of type of number stimulus

Average lateral velocity at each sub-task boundary location across the different number stimuli was also examined as an additional measure of lane-keeping performance. There was a significant interaction between digit position and number stimulus, $F(4, 90) = 27.3$, $p < .001$. Post-hoc tests were conducted at digit positions 4, 6, and 7 to compare lateral velocity between each type of number stimulus (see Figure 2.6 for lateral velocity at all digit positions for each type of number stimulus). Digit position 4 followed a sub-task boundary in the phone number stimulus; however, there were no significant differences in lateral velocity between any of the number stimulus conditions at this digit position. At digit position 6, however, lateral velocity in the zip code stimulus condition was significantly less than both the phone number stimulus ($p < .01$) and string stimulus ($p < .05$). This finding suggests that participants stabilized the lateral movement of their vehicle at the sub-task boundary in the zip code. There was no significant difference in lateral velocity between the phone number stimulus and string stimulus at digit position 6.

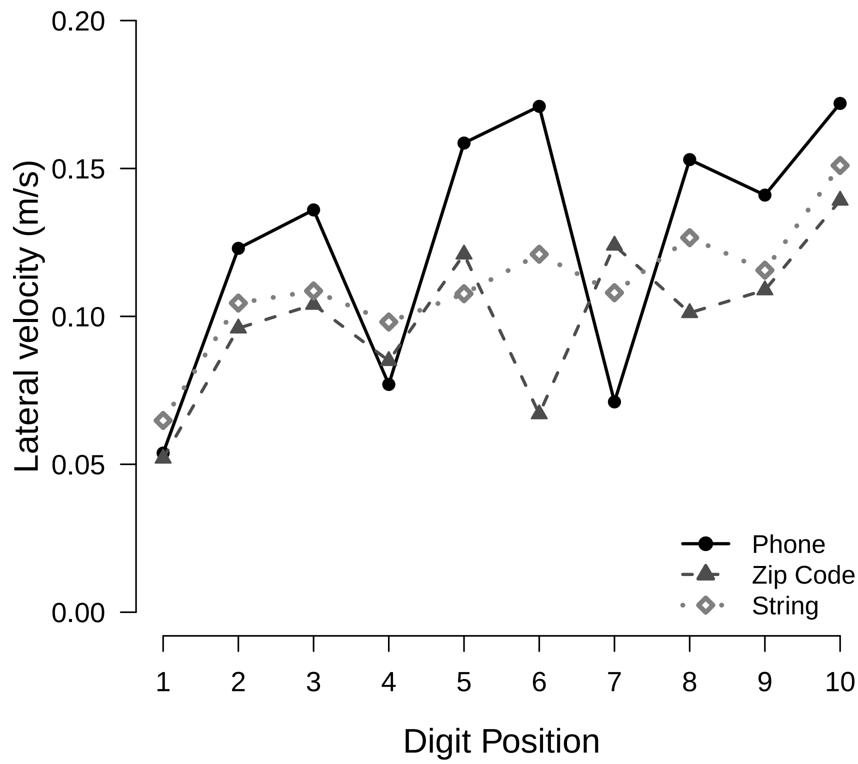


Figure 2.6: Average lateral velocity at all 10 digit positions as a function of type of number stimulus. The sub-task boundaries for the phone number stimulus were at digit positions 4 and 7. The sub-task boundary for the zip code stimulus was at digit position 6.

Lastly, post-hoc tests at digit position 7 showed that lateral velocity in the phone number stimulus condition was significantly less than lateral velocity in the zip code stimulus condition ($p < .01$). The difference between the phone number and string stimulus conditions at digit position 7 approached significance ($p = .08$). Lateral velocity in the phone number stimulus condition was less than lateral velocity in the string stimulus condition at digit position 7. There was no significant difference in lateral velocity between the zip code stimulus and string stimulus conditions at digit position 7. These findings suggested that participants stabilized their lateral velocity at the second sub-task boundary in the phone number stimulus.

Together, these findings provide evidence that, although participants did not move their vehicle significantly closer to the center of the lane at sub-task boundaries, they did, for the most part, reduce the lateral velocity of their vehicle at sub-task boundaries in the number entry stimuli.

2.2.3 Switch frequencies

If participants switched between tasks at sub-task boundaries, more switches would be expected to occur between sub-tasks than within sub-tasks for *all* types of number stimuli. The percentage of switches from the number entry task to the lane-keeping task between and within sub-tasks was calculated across all trials for each participant. The percent of total switches between and within sub-tasks was compared using a mixed factorial ANOVA. The string stimulus was not included in this analysis because it did not have any sub-task boundaries. A 2 Number Entry Stimulus (Phone, Zip Code) x 2 Switch Location (Between sub-task, Within sub-task) mixed factorial ANOVA revealed a significant interaction between switch location and number entry stimulus, $F(1, 30) = 60.9$, $p < .001$. The percentage of switches between sub-tasks compared to the percentage of switches within sub-tasks varied significantly as a function of type of number stimulus (see Table 2.4). In the phone number condition, participants switched at the sub-task boundaries over 80% of the time. In the zip code condition, however, participants only switched within sub-task boundaries two thirds of the time. This finding provides evidence that people switched at sub-task boundaries less often when the sub-tasks in the number entry task were larger.

Table 2.4: Average percent of total switches that occurred between and within sub-tasks. Mean values are displayed with SD in parentheses.

Number Stimulus	Switch Location	
	Between	Within
Phone	81.5 (19.6)	18.5 (20)
Zip Code	33.4 (14.9)	66.6 (14.9)

2.2.4 Viewing and occlusion periods

If participants interleaved at sub-task boundaries, then their visual sampling strategies should vary by number stimulus condition. Participants' visual sampling strategies were examined by looking at the average time they viewed the roadway (viewing period) and the average time they viewed the number entry task (occlusion period). The average duration of occlusion and viewing periods was calculated for each trial and then aggregated across all accurate trials for each participant. Viewing periods ranged between 1.17 seconds to 5.36 seconds and were 1.71 seconds long (SD = 1.63) on average. Occlusion periods were 0.74 seconds long (SD = 0.45) on average and ranged from 0.35 seconds to 2.02 seconds. One-way ANOVAs were conducted to see if there were any reliable differences in viewing and occlusion period duration as a function of type of number stimulus. The duration of occlusion and viewing periods did not reliably vary as a function of type of number stimulus (Fs < 1). Thus, participants' visual sampling strategies did not vary as a function of sub-task size.

2.2.5 Digit entry during occlusions

The pattern of digit entry during occlusion periods in the number entry task was examined to gain more insight into the task interleaving strategies participants used to complete the number entry task. The average number of digits entered during occlusion periods in each trial was calculated and then aggregated for each participant. If participants interleaved at sub-task boundaries, then the average number of digits entered during an occlusion period should increase as sub-tasks become larger. A one-way ANOVA revealed no significant effects of type of number stimulus on the average number of digits entered during an occlusion period. On average, participants in the phone number condition entered 2.9 digits ($SD =$ 0.82), participants in the zip code condition entered 2.5 digits ($SD = 0.90$), and participants in the string condition entered 2.7 digits ($SD = 0.82$) during each occlusion period. Thus, even though the number stimuli had sub-tasks of different sizes, there was no significant difference in the average number of digits participants entered during an occlusion period as a function of the type of number stimulus.

Lastly, the patterns that participants used to enter digits were classified and examined. Digit entry patterns were calculated by totaling the number of digits entered during each occlusion period when participants entered a number stimulus. For example, consider the number entry stimulus 123-456-7890. If a participant entered 123 during the first occlusion period, 456 during the second occlusion period, and 7890 during the fourth occlusion period, then his or her digit entry pattern would be classified as 3-3-4. Note that switches in this entry pattern only occur at sub-task boundaries and matches the representational structure of the phone number stimulus. The entry patterns used in all accurate number entry trials in the second and third dual-task scenarios were classified and the frequency of each pattern was tabulated for all three types of number stimuli.

The percentage of all digit entry patterns that matched the representational structure of each number stimulus is shown in Table 2.5. If participants interleaved at sub-task boundaries, the frequency of digit entry patterns that matched the representational structure of the number stimuli should not differ as a function of type of number stimulus. A Chi-square test revealed that the percentage of digit entry patterns that matched the representational structure of the number stimuli was reliably different across the type of number stimulus, $\chi^2(2) = 257.9$, $p < .001$. As sub-task size increased, participants' entry patterns resembled the representational structure of the number stimuli less often. Thus, participants did not strictly follow a sub-task boundary strategy and frequently interleaved the number entry task at points other than sub-task boundaries as sub-tasks increased in size.

Table 2.5: Percent of text entry patterns where switches only occurred at sub-task boundaries as a function number stimulus.

Number stimulus	Percent
Phone	56.3
Zip Code	12.0
String	0.3

2.2.6 Implicit memory test

After the experiment, participants were asked to recall as many of the number stimuli entered in the dual-task scenarios as possible. Participants had to recall the number stimulus in its entirety in order for it to be accepted as a correct response. None of the participants correctly recalled any of the number entry task stimuli after the experiment. This finding confirms that participants were not familiar with the number stimuli.

2.3 Discussion

The goal of Experiment 1 was to determine whether drivers decided to switch from a number entry task to driving at sub-task boundaries or if they decided to switch as a function of time. If participants interleaved at sub-task boundaries, then inter-button interval (IBI) should have been significantly greater at sub-task boundaries. As expected, IBI was significantly greater at digit positions that followed a sub-task boundary in a number stimulus compared to the same digit position that did not follow a sub-task boundary in the other number entry stimuli. In addition to increased IBI, average lateral velocity was smaller at digit positions that followed a sub-task boundary compared to the same digit position that did not follow a sub-task boundary in other number stimuli. This provided evidence that participants switched at sub-task boundaries to stabilize their lane position. Together, these findings replicate previous research (Brumby, Salvucci, & Howes, 2009), and, on the surface, suggest that participants were interleaving the number entry task with the lane-keeping task at sub-task boundaries.

However, participants frequently switched at points other than sub-task boundaries, particularly when entering larger sub-tasks. Sub-tasks in the phone number stimulus were relatively small. Eighty percent of all switches in the phone number condition occurred at sub-task boundaries and the majority of digit entry patterns matched the structure of the US phone number. In contrast, when completing larger sub-tasks in the zip code condition, only one-third of all switches were at sub-task boundaries and participants' digit entry patterns frequently did not match the representational structure of the zip code stimulus. These findings provide evidence that participants were not interleaving at sub-task boundaries as suggested in previous research (Brumby et al., 2009), and were using other types of strategies such as elapsed time to interleave the two tasks.

Further evidence comes from the fact that participants did not look away from the roadway any longer when completing number stimuli with larger sub-tasks compared to number stimuli with smaller sub-tasks. This suggests that participants were focused on maintaining an acceptable level of uncertainty about the roadway environment more than they focused on reaching sub-task boundaries. A possible alternative explanation is that participants increased the rate of digit entry to accommodate larger sub-tasks in the same amount of time. However, the number of digits entered during an average occlusion period did not vary as a function of sub-task size. Based on the findings, it seems that participants decided to switch between tasks based upon time. These findings are consistent with previous research that has found that drivers only look away from the roadway for a limited period of time, and if they are unable to complete a task in this short period of time, then they will interrupt task performance to return visual attention to the road (Gellatly & Kleiss, 2000; Wierwille, 1993).

If most of the evidence suggested that participants did not interleave at sub-task boundaries, then why were there significant changes in IBI and lateral velocity at sub-task boundaries even with larger sub-tasks (i.e., zip code)? Smaller sub-tasks "fit" better into the visual demands of the driving environment. Small sub-tasks, such as those in a US phone number, do not take a large amount of time to complete and can be completed without neglecting the driving task for an unacceptably long period of time (Chiang, Brooks, & Weir, 2004; Tsimhoni & Green, 2001). Larger sub-tasks, such as those in the zip code stimulus and number string stimulus, took a longer amount of time to complete and it was clear that drivers did not look away from the roadway long enough to complete these tasks in a single occlusion period. The significant differences in IBI and lateral velocity observed at sub-task boundaries in the zip code stimulus may have reflected a common switch location that was shared by a variety of task interleaving strategies. Though participants could not complete larger sub-tasks during a single occlusion period, they may have switched at sub-task boundaries when given the opportunity during subsequent occlusion periods. Thus, the significant increases in IBI and decreases in lateral velocity observed at sub-task boundaries may be an artifact associated with smaller sub-tasks and a shared switch point among a variety of task interleaving strategies where switches were not exclusively constrained to sub-task boundaries.

In summary, Experiment 1 addressed confounds in previous research and teased apart the influence of sub-task boundaries and elapsed time on task interleaving strategies. The findings from Experiment 1 suggested that sub-task boundaries were not the primary factor underlying decisions to switch between tasks in the driving environment. Participants did not look away from the roadway long enough to accommodate larger sub-tasks. As a result, they switched at locations other than sub-task boundaries more frequently when completing larger sub-tasks. Time seemed to play a more influential role in decisions to switch between two interleaved tasks in the driving environment than sub-task boundaries.

Chapter 3: Experiment 2

The findings from Experiment 1 provided evidence that people do not exclusively switch between two interleaved tasks at sub-task boundaries and elapsed time may play a greater role in influencing task interleaving strategies in the driving environment. Participants in Experiment 1, however, had no prior experience with the number entry task stimuli. For example, participants may have recognized that the phone number stimuli in Experiment 1 looked like US phone numbers, but they would have never dialed any of the phone numbers used in Experiment 1 before because the phone numbers did not exist. Participants had extensive experience with the distractor task stimuli in previous research on task interleaving in the driving environment (Brumby et al., 2009; Janssen & Brumby, 2009). According to Salvucci and Taatgen's (2008) theory of threaded cognition, individual steps within a task become more connected with experience. With enough experience, the individual steps in a task are consolidated into chunks or sub-tasks in declarative memory. Chunking may facilitate task interleaving at sub-task boundaries since the entire sub-task is retrieved as a single unit and not individual task steps. Participants in Experiment 1 lacked the experience required for chunking the sub-tasks in the phone number and modified zip code and this may have discouraged them from interleaving at sub-task boundaries.

Experiment 2 examined how chunking of sub-tasks influences task interleaving strategies during distracted driving. In this study, participants entered text messages while driving. The meaningfulness of the content in the text messages was manipulated. Prior research has shown that meaningfulness facilitates chunking of information into sub-tasks (Ellis, Parente, & Shumate, 1974; Ellis & Shumate, 1973). The text messages all contained the same number of characters but included words of different lengths similar to Experiment 1. The meaningfulness of the text message content was manipulated by having participants enter words or scrambled versions of the words (nonwords). Sub-task size was also manipulated by varying the size of the words contained in the text messages. Messages contained three 3-letter words, two 5-letter words, or one 11-letter word. If chunking facilitated interleaving at sub-task boundaries, then the following outcomes were expected. First, when text messages contained words, the latency between button presses was expected to be significantly longer at character positions following a sub-task boundary compared to text stimuli without a sub-task boundary at the same character positions (see Table 3.1 for predictions). Second, when text messages contained words, more switches were expected to occur at sub-task boundaries than other points in the task regardless of sub-task size. Third, when entering text messages with words, people were expected to look away from the roadway for longer periods of time to accommodate larger sub-tasks. Lastly, lane-keeping performance should improve at sub-task boundaries when participants typed words. That is, lateral velocity and average deviation from lane center should be significantly lower at sub-task boundaries compared to other points in the task.

Table 3.1: Predicted outcomes for the comparison of average inter-button interval at each sub-task boundary between each type of text entry stimulus in the meaningful word condition. The 3 word condition had sub-task boundaries at character positions 4, 5, 8, and 9. The 2 word condition had a sub-task boundary at character positions 6 and 7.

Comparison	Character Position					
	4	5	6	7	8	9
3 words vs. 2 words	$3 > 2$	$3 > 2$	$3 < 2$	$3 < 2$	$3 > 2$	$3 > 2$
3 words vs. 1 word	$3 > 1$	$3 > 1$	=	=	$3 > 1$	$3 > 1$
2 words vs. 1 word	=	=	$2 > 1$	$2 > 1$	=	=

Text messages containing nonwords were not expected to facilitate task interleaving at sub-task boundaries. This condition is a replication of Experiment 1 with a different type of task. As such, the findings from Experiment 1 were expected to be replicated when participants entered text messages containing nonwords. Specifically, the latency between buttons presses was expected to be significantly higher at sub-task boundaries. However, as sub-tasks became larger, participants were expected to switch at sub-task boundaries less frequently compared to other locations in the sub-tasks. Additionally, visual sampling strategies were not expected to vary as a function of sub-task size. Lastly, lane-keeping performance was not expected to improve significantly at sub-task boundaries when participants typed text messages containing nonwords.

3.1 Method

3.1.1 Participants

Ninety-six (31 men, 65 women) George Mason University undergraduate students were recruited to participate in this study. Participants ranged in age from 18 to 35 years and were 21 years old (SD = 3.1) on average. All participants had at least 2 years of driving experience and were fully licensed drivers. On average, participants had 45.5 months (SD = 31.3) of driving experience. All participants reported owning a cell phone and 96% of these participants reported using their cellular phone while driving. Eighty-seven percent of participants reported that they send or receive text messages while driving. Participants received course credit for participating in this study.

3.1.2 Apparatus

This study was conducted using the same desktop driving simulator from Experiment 1. Participants completed a text entry task using a mini QWERTY keyboard that was mounted to the right of the steering wheel (see Figure 3.1).

Figure 3.1: Mini QWERTY keyboard.

3.1.3 Tasks

Participants completed the same lane-keeping task from Experiment 1. Participants were distracted by a text entry task in which they entered a string of characters using the mini QWERTY keyboard. The text messages were all 11 characters long including spaces. The sub-task size in each of the text message conditions was manipulated similar to the manipulation of number stimuli in Experiment 1. Text messages consisted of three 3-letter words (e.g., LAG PEG LOP), two 5-letter words (e.g., NYLON TITAN), or a single 11-letter word (e.g., ALGEBRAISTS). Text stimuli were displayed in the same location as in Experiment 1 and were also 75 pixels tall. All text stimuli were created by selecting words at random from a bank of common 3-letter, 5-letter, and 11-letter words. Words in each text stimulus were screened to ensure that no two consecutive letters within a word were the same character.

Meaningfulness was manipulated by varying the content of the text messages. The messages either contained English words that did not form a grammatically correct sentence or nonwords which were scrambled versions of the English words. Nonword versions of each text stimulus were created by reordering the characters in each word in the text stimuli until no two consecutive characters in the word were the same. Text messages were reordered at the word level to ensure that each word in a meaningful text stimulus required a similar amount of physical movement during entry as the same nonword in the corresponding text message with nonwords.

3.1.4 Design

This study employed a mixed design. There were two between-subjects factors, number of words (1, 2, 3) and meaningfulness (word, nonword). There was one within-subjects factor, which was single- or dual-task performance. Sixteen participants were randomly assigned to each of the possible 6 combinations of the two between-subject factors. All participants completed the lane-keeping task and text entry task independent of one another (single-task condition) as well as concurrently (dual-task condition).

3.1.5 Procedure

The procedure in Experiment 2 was identical to the procedure in Experiment 1 except that participants completed the text entry task instead of the number entry task. Text entry task stimuli were randomly selected from a library of over 400 possible stimuli for each experimental condition. All of the possible text stimuli used in each word condition can be seen in Appendices E, F, and G. As in Experiment 1, participants were instructed that they could use any type of task interleaving strategy that they wished when performing the text entry task while driving. They were also instructed to prioritize lane-keeping task performance.

3.1.6 Measures

The same dependent measures used in Experiment 1 were also used in Experiment 2. Lane-keeping performance was measured using lateral deviation from center line, standard deviation of lane position, and lateral velocity. Text entry task performance was measured using inter-button interval and accuracy. The location in the text entry task where participants switched from the text entry task to the lane-keeping task was recorded. Lastly, the average duration that participants viewed the text entry task (occlusion period) and viewed the roadway (viewing period) when entering a text stimulus was recorded.

3.2 Results

All dependent measures were aggregated across single-task scenarios and across the second and third dual-task scenarios for each participant. The first dual-task scenario was not included in the analysis since it was the participants' first exposure to dual-task performance. Inaccurate trials were removed from the data set before aggregating. Twenty-one percent of all trials in Experiment 2 were removed, more than twice the number removed in Experiment 1. The greater number of inaccurate trials observed in Experiment 2 suggests that the text entry task was more difficult than the number entry task in Experiment 1. A 2 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) analysis of variance (ANOVA) was performed on the percentage of trials removed. The percentage of trials removed did not vary reliably as a function of either of these factors or their interaction, $F(2, 90) = 0.6$, $p = 0.6$.

3.2.1 Dual-task performance

A series of 2 task condition (single, dual) x 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) mixed factorial ANOVAs were conducted to determine if there were dual-task costs in text entry task and lane-keeping task performance. Note, accuracy in the text entry task during single- and dual-task scenarios was evaluated using the full data set that included inaccurate trial data. The ANOVAs confirmed that performance in the text entry task and lane-keeping task was significantly worse in dual-task scenarios than in single-task scenarios (see Table 3.2). Participants were significantly less accurate when entering text messages in dual-task scenarios compared to single-task scenarios, $F(1, 90) = 43.7$, $p < .001$. Text entry task accuracy did not vary significantly as a function of word condition, meaningfulness, or the interaction between these factors (Fs < 1.5).

Table 3.2: Single- and dual-task performance in the text entry and lane-keeping tasks. Mean values are displayed with SD in parentheses.

Scenario	Text Entry Task		Lane-Keeping Task	
	Accuracy (%)	IBI (Sec)	SDLP	Deviation from lane center (M)
Single-task	100 (0)	2.73 (0.65)	0.28 (0.28)	0.31 (0.13)
Dual-task	87.8 (18)	4.35 (1.53)	0.77 (0.56)	0.47 (0.25)

Not only were participants less accurate in dual-task scenarios compared to single-task scenarios, but they also entered characters in the text message at a significantly slower rate, $F(1, 94) = 136.0$, $p < .001$. The inter-button interval (IBI) in dual-task scenarios was 1.62 seconds slower on average than in single-task scenarios. Dual-task costs in IBI also varied significantly as a function of word condition, $F(2, 92) = 7.4$, $p < .01$. The dual-task costs were greater in text messages with larger sub-tasks compared to smaller sub-tasks. IBI in dual-task scenarios was 2.15 seconds slower compared to single-task scenarios in the 1 word condition, 1.6 seconds slower in the 2 words condition, and 1 second slower in the 3 words condition. Dual-task costs in IBI were also significantly greater for text messages with nonwords compared to text messages with words, $F(1, 93) = 5.1$, $p < .05$. Average IBI was 1.9 seconds slower in dual-task scenarios compared to single-task scenarios in the nonword condition, whereas average IBI was only 1.3 seconds slower in the word condition. Lastly, the interaction between word condition and meaningfulness was marginally significant, $F(2, 93) = 3.0$, $p = .05$. Average IBI across single- and dual-task scenarios was similar in each word condition when the text message contained nonwords, but when the text message contained words average IBI decreased as word size decreased (see Table 3.3).

Table 3.3: Average inter-button interval as a function of word condition and meaningfulness. Mean values are displayed with SD in parentheses.

Word Condition	Words	Nonwords
1 Word	4.10 (1.35)	3.89 (1.83)
2 Words	3.40 (1.24)	3.51 (1.50)
3 Words	2.76 (0.84)	3.59 (1.37)

Text entry while driving significantly impaired lane-keeping performance even though participants were instructed to prioritize the lane-keeping task. A 2 task condition (single, dual) x 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) mixed factorial ANOVA revealed a significant main effect of task condition for standard deviation of lane position (SDLP), $F(1, 94) = 72.6$, $p < .001$. Participants' lane position was 2 times more variable in dual-task scenarios than in single-task scenarios (see Table 3.2). Participants also deviated significantly more from the center of the lane during dual-task scenarios compared to single-task scenarios, $F(1, 94) = 40.8$, $p < .001$. Average deviation from lane center and SDLP did not vary reliably as a function any of the other factors or their interactions (Fs < 1.1).

3.2.2 Task performance at sub-task boundaries

As in Experiment 1, sub-task boundaries preceded different character positions in each word condition. The 1 word condition did not have any sub-task boundaries. The 2 words condition had 1 sub-task boundary, and the 3 words condition had 2 sub-task boundaries. What was unique about the text messages used in this experiment compared to the number entry stimuli in Experiment 1 was that participants had to enter an additional character (i.e., a space) between sub-tasks. As a result, there were 2 character positions at each sub-task boundary – one character position that followed the last character in a word and a second character position that followed the space between words. In the 2 words condition, character positions 6 and 7 followed the sub-task boundary. In the 3 words condition character positions 4 and 5 followed the first sub-task boundary and character positions 8 and 9 followed the second sub-task boundary. The following analyses focused on differences in text entry task and lane-keeping task performance at these character positions.

Data were analyzed using a series of 6 character position (4, 5, 6, 7, 8, 9) x 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) mixed factorial ANOVAs. The results focus on the interactions between these factors. Post-hoc tests were conducted using paired samples and independent samples t-tests. A Bonferroni correction was used for all post-hoc tests to adjust for alpha inflation.

As in Experiment 1, the difference between single- and dual-task performance was calculated for IBI and average deviation from lane center to account for differences in the average latency of button presses and average distance from the lane center between individual participants. IBI and average deviation from lane center are discussed in terms of dual-task cost.

Text entry task performance

Meaningfulness was expected to facilitate task interleaving at sub-task boundaries. Average dual-task cost in IBI was expected to be greater at character positions that followed sub-task boundaries in text messages with words than in text messages with nonwords. Additionally, this difference should be observed across all word conditions. A 6 character position x 3 word condition x 2 meaningfulness mixed factorial ANOVA was performed on the average dual-task cost in IBI. There was no significant 2-way interaction between character position and meaningfulness, $F(5,\ 450) = 1.4$, $p = 0.2$, or 3-way interaction between character position, word condition, and meaningfulness,$F(10,\ 450) = 0.9$, $p = 0.5$. Thus, the meaningfulness of the content in the text messages did seem to seem to influence task interleaving strategies.

Average dual-task cost in IBI was expected to be greater at character positions that followed a sub-task boundary than at character positions that did not represent a sub-task boundary. There was a significant interaction between character position and word condition in average dual-task cost in IBI, $F(10,\ 450) = 6.9$, $p < .001$. Average dual-task cost in IBI at each character position is shown in Figure 3.2 for all 3 word conditions.

Character positions 4 and 5 followed the first sub-task boundary in the 3 words condition, so IBI was expected to be greater in the 3 words condition than the 1 word and 2 words condition at these character positions. Unexpectedly, there were no significant differences in IBI between any of the word conditions at character position 4. At character position 5, IBI in the 3 words condition was significantly greater than the 2 words condition as predicted, $p < .001$. IBI in the 3 words condition was not significantly greater than the 1 word condition, however, at character position 5. Lastly, there was no significant difference in IBI between the 2 words and 1 word condition at character position 5.

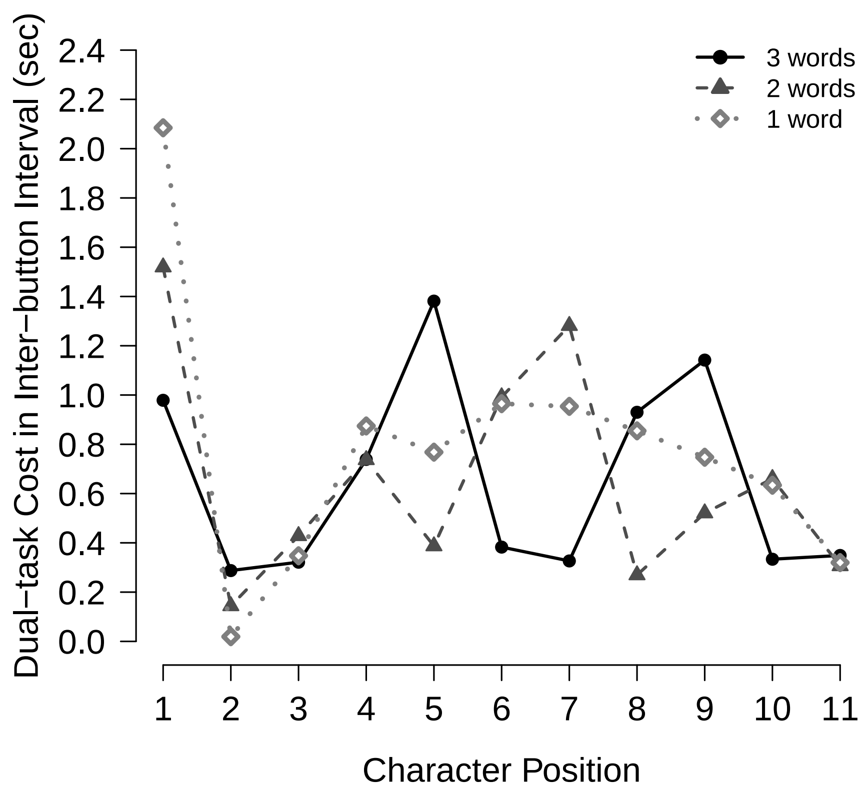


Figure 3.2: Average dual-task cost in inter-button interval at all 11 character position as a function of word condition. The sub-task boundaries for the 3 words condition were at character positions 4, 5, 8, and 9. The sub-task boundary for the 2 words condition was at character positions 6 and 7.

Character positions 6 and 7 followed the sub-task boundary in the 2 words condition. IBI at character positions 6 and 7 was expected to be significantly greater in the 2 words condition than in the 1 word and 3 words conditions. At character position 6, the difference between average IBI in the 2 words and the 3 words condition approached significance, $p = .05$. Average IBI in the 2 words condition was greater than average IBI in the 3 words condition. Unexpectedly, there was no significant difference between the 2 words and 1 word conditions at character position 6. Additionally, average IBI in the 1 word condition was not significantly different from average IBI in the 3 words condition. At character position 7, average IBI in the 2 words condition was significantly greater than the 3 words condition as predicted, $p < .001$. Contrary to expectations, there was no significant difference in average IBI between the 2 words and 1 word conditions at character position 7. Additionally, average IBI in the 1 word condition was significantly greater than average IBI in the 3 words condition at character position 7, $p < .001$, even though they were not expected to be different.

Character positions 8 and 9 followed the second sub-task boundary in the 3 words condition. Average IBI was expected to be significantly greater in the 3 words condition than the 2 words and 1 word conditions at these character positions. As expected, average IBI in the 3 words conditions was significantly greater from average IBI in the 2 words condition at character position 8, $p < .001$. There was no significant difference in average IBI, however, between the 3 words and 1 word conditions at character position 8. Unexpectedly, average IBI in the 1 word condition was significantly greater than average IBI in the 2 words condition, $p < .05$. At character position 9, there were no significant differences in average IBI between the 3 words condition and the 1 word and 2 words conditions. Lastly, average IBI was not significantly different between the 1 word and 2 words conditions at character position 9. These two conditions were not expected to be different at character position 9.

The statistical outcomes of the post-hoc comparisons between each of the word conditions at character positions 4 through 9 are summarized in Table 3.4. A number of the statistical outcomes did not match the outcomes that would be expected if participants interleaved at sub-task boundaries (indicated by cells shaded in gray). Average dual-task cost in IBI was not always greater at character positions that followed a sub-task boundary than at character positions that did not represent a sub-task boundary. This evidence suggests that task interleaving did not explicitly occur at sub-task boundaries.

Table 3.4: Statistical outcomes for the comparison of average dual-task cost in inter-button interval at each sub-task boundary between each type of text entry stimulus. Cells shaded in gray indicate comparisons where the outcome did not match predictions.

Comparison	Character Position					
	4	5	6	7	8	9
3 words vs. 2 words	=	3 > 2	=	3 < 2	3 > 2	=
3 words vs. 1 word	=	=	=	3 < 1	=	=
2 words vs. 1 word	=	=	=	=	2 < 1	=

Lane-keeping task performance

Lane-keeping performance was measured using the dual-task cost in average deviation from lane center and average lateral velocity at character positions that followed sub-task boundaries. A 6 character position x 3 word condition x 2 meaningfulness mixed factorial ANOVA was performed on dual-task cost in average deviation from lane center. A significant interaction between meaningfulness and character position was found, $F(5, 450) = 3.5$, $p < .01$. Overall, average deviation from lane center increased in the nonword condition from character positions 4 to 9 while it remained steady in the word condition from character positions 4 to 9 (see Figure 3.3). Post-hoc tests were performed on the simple effects at each character position. The difference in average deviation from lane center between the nonword condition and the word condition approached significance at character positions 8 and 9, $p = .05$ and $p = .06$ respectively. This suggests that participants had a more difficult time keeping their vehicle in the center of the lane during text entry when they were typing in text messages with nonwords compared to when they were typing in text messages with words.

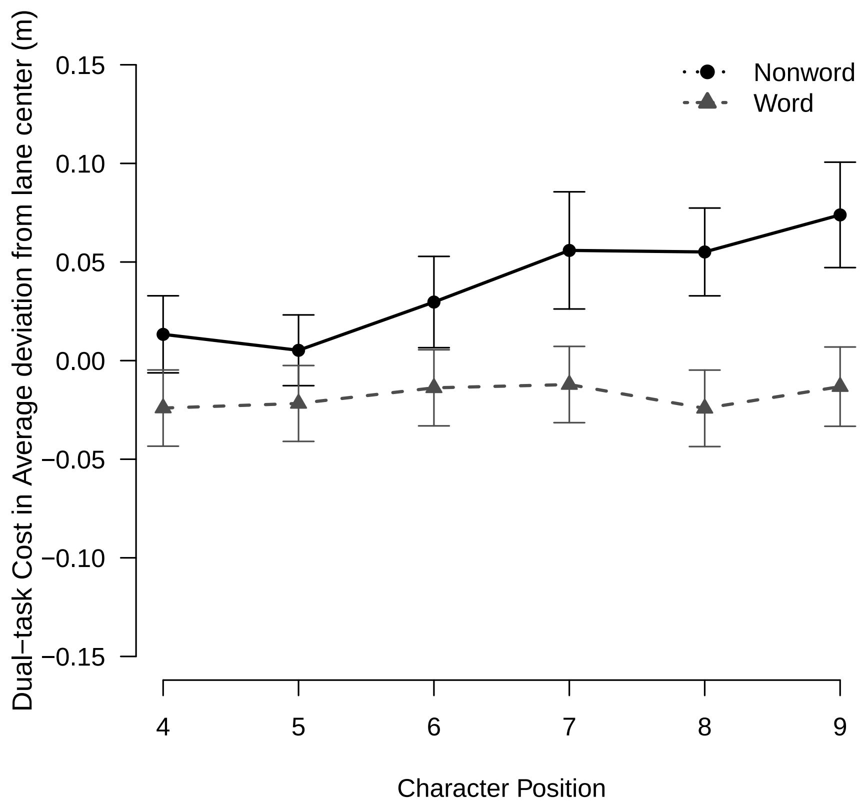


Figure 3.3: Average dual-task cost in deviation from lane center as a function of meaningfulness at character positions 4 through 9. Error bars represent ±1 standard error.

Average deviation from lane center also varied as a function of word condition. The interaction between word condition and character position approached significance, $F(10, 450) = 1.7$, $p = .09$. Dual-task cost in deviation from lane center in the 2 words and 1 word conditions increased on average across character positions 4 through 9 (see Figure 3.4). However, in the 3 words condition dual-task cost in average deviation from lane center appeared to decrease from character positions 4 to 5 and 7 to 8. These character positions followed sub-task boundaries in the 3 words condition. Post-hoc tests were performed to compare average deviation from lane center between each word condition at each of the character positions. The post-hoc tests did not reveal any significant differences in average deviation from lane center between the different word conditions at character positions 4 through 9. However, the general pattern observed in the 3 words condition provides some evidence that participants' lane-keeping performance improved at sub-task boundaries in this condition. The 3-way interaction between character position, word condition, and meaningfulness failed to reach significance, ($F < 1$).

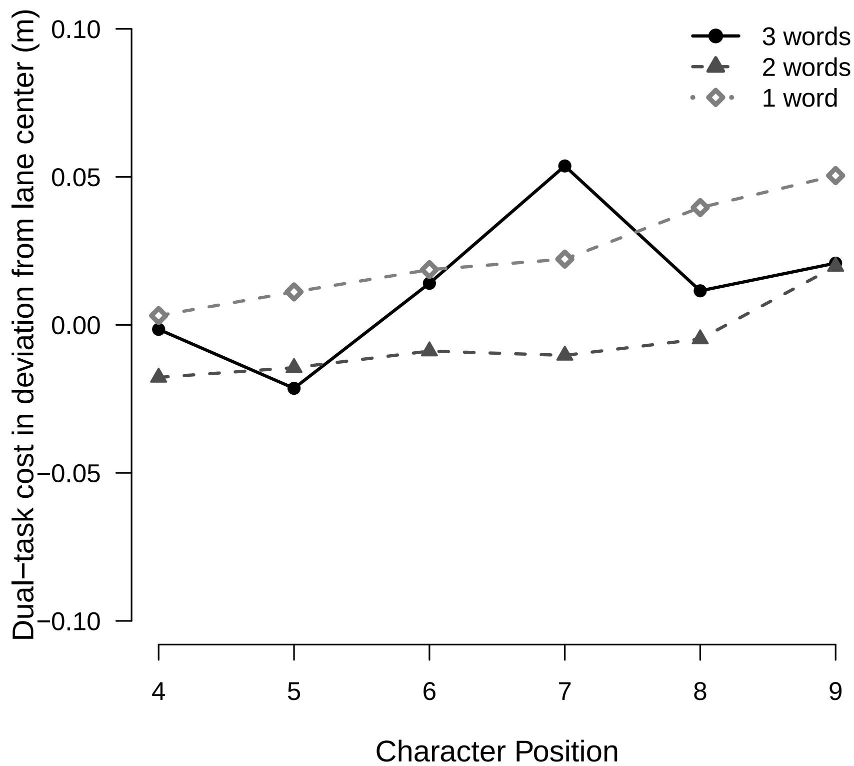


Figure 3.4: Average dual-task cost in deviation from lane center as a function of word condition at character positions 4 through 9.

The patterns of lateral velocity at character positions 4 through 9 appeared to be different across word conditions (see Figure 3.5). A 6 character position x 3 word condition x 2 meaningfulness mixed factorial ANOVA was performed on lateral velocity. The ANOVA revealed a significant interaction between character position and word condition, $F(10, 450) = 4.4$, $p < .001$. Lateral velocity tended to decrease at the two sub-task boundaries in the 3 words condition (character positions 4, 5, 8, and 9) and the single sub-task boundary in the 2 words condition (character positions 6 and 7). Post-hoc tests were performed to determine if lateral velocity was significantly different between the three word conditions at each character position. None of the post-hoc tests were significant. Though none of the post-hoc tests were significant, it is important to note that the general pattern observed in lateral velocity suggested that participants reduced the lateral movement of their vehicle at sub-task boundaries in the 3 words and 2 words conditions. All other interactions in the mixed factorial ANOVA failed to reach significance (Fs < 1).

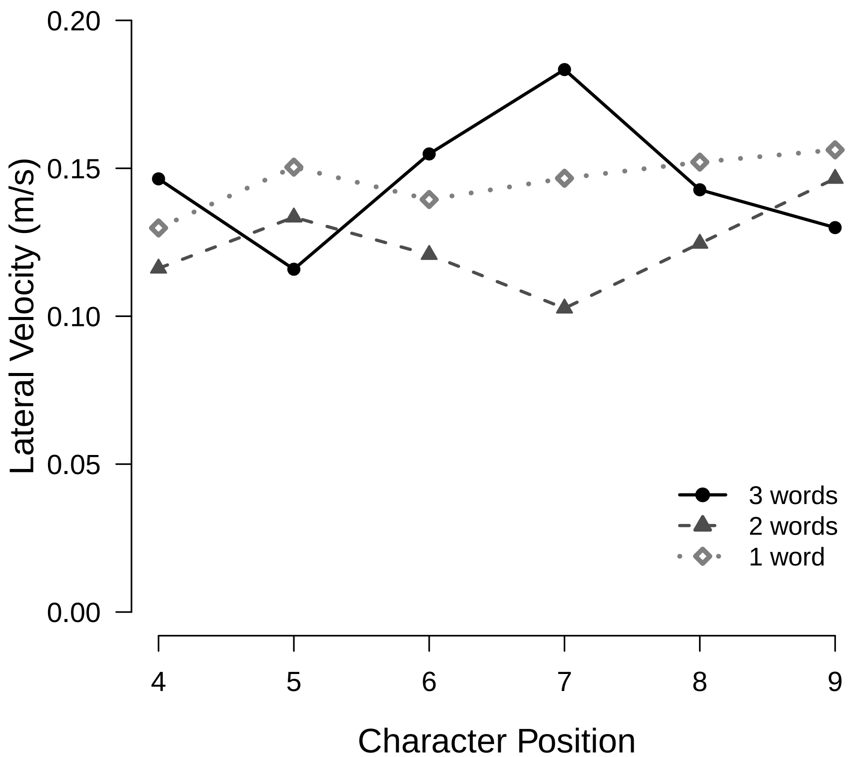


Figure 3.5: Average lateral velocity as a function of word condition at character positions 4 through 9.

In summary, meaningfulness of the text stimuli influenced overall lane-keeping performance, but not as a function of word condition. This provides additional evidence that meaningfulness did not influence task interleaving strategies across distractor tasks that varied in sub-task size. Participants seemed to improve lane-keeping performance at sub-task boundaries, especially in the 3 words condition. However, average deviation from lane center and lateral velocity were not statistically different between each word condition at character positions 4 through 9.

3.2.3 Switch frequencies

If participants switched between tasks at sub-task boundaries, then significantly more switches should have occurred at sub-task boundaries compared to other points in the text entry task in *all* three word conditions. The percentage of switches from the text entry task to the lane-keeping task between versus within sub-tasks was calculated across all trials for each participant. The 1 word condition was not included in the analysis because it did not contain any sub-task boundaries. A 2 word condition (2 words, 3 words) x 2 meaningfulness (word, nonword) x 2 switch location (between sub-task, within sub-task) mixed factorial ANOVA revealed a significant interaction between switch location and word condition, $F(1, 60) = 23.3$, $p < .001$. Contrary to expectations, the percentage of switches observed between sub-tasks was not greater than the percentage of switches observed within sub-tasks for all word conditions. Although 70% percent ($SD = 24$) of all switches in the 3 words condition occurred at sub-task boundaries, only 43% of all switches ($SD = 23$) were between sub-tasks for the 2 words condition. As found in Experiment 1, participants switched at sub-task boundaries less often when sub-tasks became larger.

If chunking of the sub-tasks facilitated interleaving at sub-task boundaries, then more switches should occur between sub-tasks for text messages with words. Furthermore, the percentage of switches between sub-tasks should not be affected by sub-task size when text messages contained words. A significant interaction between switch location and meaningfulness was found, $F(1, 60) = 6.4$, $p < .05$. Overall, more switches occurred between sub-tasks when participants entered words compared to nonwords (see Table 3.5). The interaction between switch location, word condition, and meaningfulness, however, was not significant, $F(1, 60) = 0$, $p = .98$. Participants switched at sub-task boundaries less frequently as sub-tasks increased in size even when they typed meaningful text messages.

Table 3.5: Average percent of total switches that occurred between and within sub-tasks as a function of meaningfulness for the 3 words condition, 2 words condition, and overall. Mean values are displayed with SD in parentheses.

Word Condition	Between sub-tasks		Within sub-tasks	
	Word	Nonword	Word	Nonword
3 words	77.5 (22.0)	63.1 (24.3)	22.5 (22.0)	36.9 (24.3)
2 words	50.0 (28.1)	35.8 (14.0)	50.0 (28.1)	64.2 (14.0)
Overall	42.5 (38.2)	33.0 (30.6)	57.5 (38.2)	67.0 (30.6)

3.2.4 Viewing and occlusion periods

Visual sampling strategies were expected to vary as a function of word condition since the sub-tasks in each word condition varied in size. Average duration of occlusion and viewing periods was calculated for each trial and then aggregated across all accurate trials for each participant. On average, occlusion periods were 1.68 seconds (SD = 1.32) in duration and ranged from 0.24 seconds to 8.95 seconds. A 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) between-subjects ANOVA was performed on occlusion period duration. The ANOVA revealed no significant differences in occlusion period duration by word condition, meaningfulness, or the interaction between word condition and meaningfulness (Fs < 1.9). As in Experiment 1, participants did not adjust the period of time they looked away from the roadway as a function of sub-task size.

Average viewing period duration ranged from 0.95 seconds to 4.81 seconds with a mean duration of 2.16 seconds (SD = 0.81). A 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) between-subjects ANOVA was performed on viewing period duration. The ANOVA revealed a main effect of word condition on viewing period duration, $F(2, 90) = 8.3$, $p < .001$. Viewing periods in the 1 word condition (M = 2.59 sec, SD = 0.88) were significantly longer than the 2 words condition (M = 1.99, SD = 0.76) and the 3 words condition (M = 1.91, SD = 0.58), $p < .01$ and $p < .001$ respectively. Viewing period durations were also reliably different between words and nonwords, $F(1, 90) = 6.7$, $p < .05$. Average viewing period durations were longer in the nonword condition (M = 2.36 sec, SD = 0.88) compared to the word condition (M = 1.97 sec, SD = 0.68).

Thus, participants did not alter the time they occluded the roadway as a function of word condition or meaningfulness, but they did alter how long they viewed the roadway as a function of these factors. Participants viewed the roadway for longer periods of time when entering in larger words and when entering in text messages consisting of nonwords.

3.2.5 Text entry during occlusions

Participants' text entry patterns were examined to identify the strategies they used to interleave the text entry task with the lane-keeping task. First, the average number of characters entered during occlusion periods in each trial was calculated and aggregated across participants. A 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) ANOVA was performed on the average number of characters entered during an occlusion period. The main effect of meaningfulness approached significance, $F(2, 90) = 3.1$, $p = .08$. Participants entered more characters, on average, during an occlusion period when they typed words ($M = 3.01$, $SD = 1.81$) compared to when they typed nonwords ($M = 2.39$, $SD = 1.59$). There was no significant main effect of word condition or interaction between word condition and meaningfulness ($F\text{s} < 1$). These findings provide some evidence that text entry was faster when the content of the text message was meaningful to participants.

Next, text entry patterns were examined. Text entry patterns were calculated and classified in the same manner as the number entry patterns in Experiment 1. Since the sub-task boundaries in the text messages included 2 different character positions, multiple text entry patterns matched the representation structure of the 3 words and 2 words conditions. In the 3 words condition, task interleaving with entry patterns of 4-4-3, 4-3-4, and 3-4-4 indicated switches occurring only at sub-task boundaries. In the 2 words condition, both a 6-5 and 5-6 text entry pattern indicated switches occurring only at sub-task boundaries. The percentage of trials where participants entered the entire text entry stimulus in the 1 word condition was also calculated and included in the analyses.

A Chi-square test was conducted to determine if text entry patterns that matched the representational structure of the text stimuli varied as a function of sub-task size. This analysis revealed that the percentage of text entry patterns that matched the representational structure of the text stimuli varied significantly across word conditions, $\chi^2(2) = 188.6$, $p < .001$. As found in Experiment 1, participants' entry patterns matched the representational structure of the stimuli less frequently as sub-tasks became larger. In the 3 words condition, interleaving only occurred at sub-task boundaries in 39% of the entry patterns. In the 2 words and 1 word conditions, however, interleaving only occurred at sub-task boundaries in 13% and 5% of the entry patterns respectively.

If meaningfulness facilitated task interleaving at sub-task boundaries, then the percentage of text entry patterns that matched the representational structure of the different word conditions was expected to be greater for text messages with words than text messages with nonwords. The percentage of entry patterns where switches only occurred at sub-task boundaries are shown in Table 3.6 as a function of word condition and meaningfulness. On the whole, more text entry patterns matched the representational structure of the text stimuli when the text messages contained words compared to nonwords, $\chi^2(1) = 30.8$, $p < .001$; however, this percentage still decreased as sub-tasks increased in size for text messages with words and nonwords. A Chi-square test of independence confirmed that the pattern of percentages observed across the three word conditions did not vary as a function of meaningfulness, $\chi^2(2) = 2.0$, $p = 0.4$. This finding suggests that the percentage of trials where participants only switched at sub-task boundaries did not differ between as a function of meaningfulness as sub-tasks in the text messages became larger.

Table 3.6: Percent of text entry patterns where switches only occurred at sub-task boundaries as a function of word condition and meaningfulness.

Word Condition	Meaningfulness	
	Word	Nonword
3 words	51	27
2 words	15	11
1 word	8	3

3.2.6 Implicit memory test

After the experiment, participants were asked to recall as many of the words entered in the dual-task scenarios as possible. Unlike Experiment 1, participants did not have to recall the entire text message. Participants had to recall each of the word(s) or nonword(s) in their entirety to be considered as a correct response. The total number of words or nonwords that were correctly recalled were tallied for each participant. Next, the proportion of the total number of words participants recalled to the total number of words presented was calculated to account for differences in the total number of words presented in each word condition - 108 total words in the 3 words condition, 72 total words in the 2 words condition, and 36 total words in the 1 word condition. A 3 word condition (1 word, 2 words, 3 words) x 2 meaningfulness (word, nonword) ANOVA was performed on the percentage of words recalled. The ANOVA revealed a significant main effect of meaningfulness on the percentage of words recalled, $F(1, 90) = 29.7$, $p < .001$. On average, participants recalled more than three times as many words ($M = 4.1\%$, $SD = 3.3$) than nonwords ($M = 1.3\%$, $SD = 2$). There was also a main effect of word condition, $F(2, 90) = 7.8$, $p < .001$. Participants recalled 4% ($SD = 3$) of the words in the 3 words condition, 2.6% ($SD = 3.2$) of the words in the 2 words condition, and only 1.5% of the words in the 1 word condition ($SD = 2.5$). The interaction between word condition and meaningfulness failed to reach significance ($F < 1$). These findings provided evidence that participants were better able to remember words than nonwords and were also more familiar with shorter words compared to longer words.

3.3 Discussion

The goal of Experiment 2 was to determine if chunking of sub-tasks in declarative memory facilitated task interleaving at sub-task boundaries. Data from Experiment 2 confirmed that text messages containing words were encoded better than text messages with nonwords. More participants successfully recalled words than nonwords suggesting that words were more likely to be represented as single chunks of information in declarative memory than nonwords (Ellis et al., 1974; Ellis & Shumate, 1973).

Chunking of sub-tasks in memory led to more efficient task performance. Average dual-task cost in IBI was 46% less when participants entered words than when they entered nonwords. Additionally, participants entered more characters on average during an occlusion period when the text message contained words than when it contained nonwords. As a result, participants could complete more of a sub-task in a given period of time when they typed in words. Greater overall text entry efficiency might explain why participants switched at sub-task boundaries 15% more often when they typed words compared to nonwords.

Although words were more likely to be represented as sub-tasks in memory, the findings from Experiment 2 suggested that meaningfulness did not influence participants' task interleaving strategies. Average IBI at character positions that followed sub-task boundaries did not vary as a function of meaningfulness in any of the word conditions. Additionally, although the percentage of switches that occurred at sub-task boundaries was greater in the word condition than nonword condition, people still switched at sub-task boundaries less often as sub-tasks became larger even when the text messages were meaningful. Lastly, participants did not look away from the roadway longer to accommodate larger sub-tasks when they entered in words. Thus, there was no evidence that sub-task boundaries influenced task interleaving strategies as sub-tasks became larger even when sub-tasks were chunked in memory.

As found in Experiment 1, people frequently switched between the text entry task and lane-keeping task at points other than sub-task boundaries. The percentage of switches that occurred at sub-task boundaries in Experiment 2 decreased as sub-tasks increased in size, participants' text entry patterns frequently did not match the representational structure of the text stimuli especially as sub-tasks increased in size, and the period of time that participants occluded the roadway did not vary as a function of sub-task size. Additionally, a number of the outcomes in dual-task cost in IBI that were expected if participants switched at sub-task boundaries were not confirmed. For the most part, the latencies between button presses were not significantly longer at character positions that followed a sub-task boundary compared to text stimuli without a sub-task boundary at the same character positions.

Interestingly, lane-keeping performance improved at sub-task boundaries, especially when the text message contained small sub-tasks. This finding is surprising considering that participants frequently switched at places other than sub-task boundaries. One possible explanation is that sub-task boundaries provided participants with a better opportunity to improve lane-keeping performance than when they switched at other points in the task. At sub-task boundaries, participants would not have to maintain the problem state from the text entry task in memory while focusing on the lane-keeping task. As a result, they would have more cognitive resources to devote to the lane-keeping task when they switched at sub-task boundaries compared to other points in the task.

The text entry task used in Experiment 2 seemed to be more demanding than the number entry task used in Experiment 1. Fewer switches occurred at sub-task boundaries in all conditions as a whole in Experiment 2 compared to Experiment 1. Average IBI in dual-task scenarios was 13% greater in the text entry task than in the number entry task. Also, participants' accuracy in the text entry task was 9% lower in dual-task scenarios than in the number entry task. The text entry task may have been more difficult than the number entry task because the QWERTY keyboard had 2.5 times as many buttons as the numeric keypad used in Experiment 1. The larger button set on the QWERTY keyboard would have increased the amount of time participants needed to locate the correct button and the probability of pressing an incorrect button. Participants looked away from the roadway more than twice as long on average in Experiment 2 compared to Experiment 1, which suggests the text entry task was more visually demanding than the number entry task (e.g., Chisholm et al., 2008; Hoffman et al., 2005; Horrey et al., 2006). Even though participants looked away from the roadway longer in Experiment 2, they were still unable to reach sub-task boundaries in larger sub-tasks before switching tasks.

Sub-task size and meaningfulness did not influence the amount of time participants looked away from the roadway, but these factors did influence how long participants looked at the roadway during task interleaving. Participants viewed the roadway significantly longer on average in the 1 word condition compared to the 3 words and 2 words conditions. Glances to the roadway were also longer when participants entered text messages with nonwords compared to text messages with words. Participants may have looked at the roadway longer to accommodate increased task demand in the 1 word condition and the meaningless nonword condition. Average dual-task cost in IBI was greater in the 1 word condition compared to the 2 words and 3 words conditions and greater in the nonword condition compared to the word condition. By devoting more time to the lane-keeping task, participants could ensure that their lane position was stable before engaging in more difficult text entry conditions. Indeed, there was some evidence that lane-keeping performance did vary as a function of word condition or meaningfulness, so participants may have accommodated greater demands in the text entry task by viewing the roadway for longer viewing periods of time.

In summary, the findings from Experiment 2 provided additional evidence that subtask boundaries were not the primary factor underlying decisions to switch between tasks even when sub-tasks were chunked in declarative memory. As sub-tasks became larger, participants switched at sub-task boundaries less often regardless of the meaningfulness of the stimuli. Furthermore, participants did not adjust the period of time they looked away from the roadway to accommodate larger sub-tasks or the more demanding text message stimuli with nonwords. Task performance was more efficient when stimuli were meaningful and allowed people to complete more of a sub-task in the period of time that they looked away from the roadway. Thus, as found in Experiment 1, participants' decisions to switch between tasks were not primarily influenced by the location of sub-task boundaries in the distractor task. Again, time seemed to play a more influential role in when people switched between two interleaved tasks in the driving environment.

Chapter 4: Experiment 3

Experiments 1 and 2 did not provide any evidence that sub-task boundaries were the primary factor that influenced when people decided to switch between two interleaved tasks in the driving environment. In both of these experiments, the driving task was particularly demanding and drivers were not able to look away from the roadway for long without risking substantial decrements in lane-keeping performance. Decreasing the demand of the lane-keeping task should reduce the rate that uncertainty about the roadway increases during glances away from the roadway (e.g., Horrey et al., 2006; Tsimhoni et al., 2004; Senders et al., 1967). As a result, drivers should have more time to look away from the roadway when the lane-keeping task is less demanding

The purpose of Experiment 3 was to determine if people switch at sub-task boundaries when they have more than enough time to complete a sub-task during a single glance away from the roadway. In Experiment 3, drivers typed in text messages while performing the lane-keeping task. The demand of the lane-keeping task was manipulated by varying lane width. Wider lanes were expected to decrease the difficulty of the lane-keeping task. As a result, the duration of time that participants occluded the roadway was expected to be greater when lanes were wide compared to when lanes were narrow. Additionally, a greater percentage of switches from the text entry task to the lane-keeping task were expected to occur at sub-task boundaries when participants were driving in wide lanes compared to when they were driving in narrow lanes.

The meaningfulness of the text messages was manipulated again in Experiment 3. Meaningful stimuli were expected to be represented as sub-tasks in memory. As a result, participants were expected to switch at sub-task boundaries more often when typing words than when typing nonwords. Additionally, participants should have more time to look away from the roadway on wide roadways. The extra time afforded by wide roadways was expected to allow participants typing nonwords to switch at sub-task boundaries as often as or even more often than participants typing text messages on narrow roadways regardless of meaningfulness. Additionally, chunking of sub-tasks in memory may only facilitate task interleaving at sub-task boundaries in the absence of time pressure. If this was the case, then participants should switch at sub-task boundaries more often when they typed words while driving on wide roadways than when they typed nonwords on wide roadways.

4.1 Method

4.1.1 Participants

Fifty-six (18 men, 38 women) George Mason University undergraduate students were recruited to participate in this study. Participants ranged in age from 17 to 39 years and were 20 years old (SD = 3.6) on average. All participants had at least 2 years of driving experience and held a valid license. On average, participants had 44.7 months (SD = 44.7) of driving experience. All participants reported owning a cell phone and 94% of these participants reported using their cellular phone while driving. Eighty-two percent of participants reported that they send or receive text messages while driving. Participants received course credit for participating in this study.

4.1.2 Apparatus

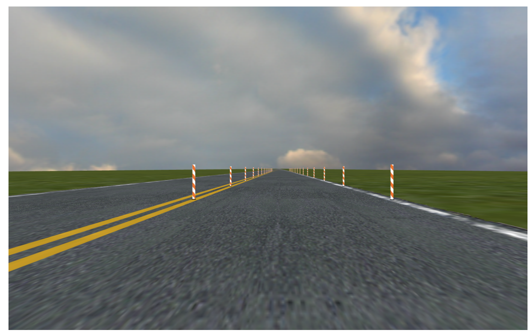
The driving simulator and text entry device used in Experiment 2 were also used in Experiment 3.

4.1.3 Tasks

Participants performed the lane-keeping task while completing the text entry task as in Experiment 2. In this study, however, participants either drove in a narrow lane or in a wide lane (see Figure 4.1). The narrow lane was the same one used in Experiments 1 and

2 and was 3.4 meters (11.2 feet) wide. The narrow lane width was slightly narrower than the standard 12-foot wide lane width on the US Interstate Highway System. The wide lane was 6.7 meters wide (22 feet), just about twice the width of the narrow lane. The lane boundaries of both the narrow and wide lanes were marked with standard lane markings and construction pylons as in the previous two experiments. Participants' vehicle speed was fixed at 40 mph.

(a) Narrow lane



(b) Wide lane

Figure 4.1: Different lane widths in the lane-keeping task.

The text entry task in this study was the same as in Experiment 2 except only the 2 words condition was used. Only the 2 words stimulus was used because the size of sub-tasks fit the aims of this experiment well. Based on data from Experiments 1 and 2, the amount of time required to enter 5 digits or characters often exceeded the amount of time that participants were willing to occlude the driving environment on narrow roadways. However, given that a fair amount of switches still occurred at sub-task boundaries in the modified zip code condition in Experiment 1 (33%) and the 2 words condition in Experiment 2 (43%), sub-tasks with 5 digits or characters were not excessively long to preclude participants from completing these sub-tasks. Thus, in less demanding roadway conditions, participants should have been able to look away from the roadway long enough to complete sub-tasks in the 2 words condition.

The meaningfulness of the text messages was also manipulated. Text messages consisted of either words or nonwords. The text messages were randomly selected from the same library of stimuli used in Experiment 2 (see Appendix F).

4.1.4 Design

This study used a mixed design. There were two between-subjects factors, lane width (narrow, wide) and meaningfulness (word, nonword). The within-subjects factor was task condition, single- or dual-task performance. Fourteen participants were randomly assigned to each combination of the lane width and meaningfulness factors. Each participant completed the lane-keeping and text entry tasks independent of one another (single-task condition) as well as concurrently (dual-task condition).

4.1.5 Procedure

The procedure for Experiment 3 was identical to Experiment 2.

4.1.6 Measures

Experiment 3 used the same measures of text entry task and lane-keeping task performance as Experiment 2.

4.2 Results

Each dependent measure was aggregated across single-task scenarios and across the second and third dual-task scenarios for each participant. The first dual-task trial was not included in the data analysis. Inaccurate trials were removed before aggregating the data. Inaccurate trials comprised 23.5% of all trial data which was consistent with the inaccuracy rate observed in Experiment 2. A 2 lane width (narrow, wide) x 2 meaningfulness (word, nonword) analysis of variance (ANOVA) was performed on the percentage of trials removed. The percentage of trials removed did not vary reliably as a function of either of these factors or their interaction (Fs < 2.6).

4.2.1 Dual-task performance

Task performance in dual-task scenarios was worse than task performance in single-task scenarios (see Table 4.1). A 2 task condition (single-task, dual-task) x 2 lane width (narrow, wide) x 2 meaningfulness (word, nonword) mixed factorial ANOVA was performed on the full data set to examine text entry accuracy. Accuracy in the text entry task was significantly worse in dual-task scenarios compared to single-task scenarios, $F(1, 52) = 38.3$, $p < .001$. No other significant effects were found on text entry accuracy (Fs < 1).

Table 4.1: Single- and dual-task performance in the text entry and lane-keeping tasks. Mean values are displayed with SD in parentheses.

Scenario	Text Entry Task		Lane-Keeping Task	
	Accuracy (%)	IBI (Sec)	SDLP	Deviation from lane center (M)
Single-task	100 (0)	2.73 (1.18)	0.33 (0.20)	0.36 (0.17)
Dual-task	86.3 (16.24)	4.07 (1.30)	0.69 (0.38)	0.50 (0.23)

The average inter-button interval (IBI) in accurate trials was examined using a 2 task condition x 2 lane width x 2 meaningfulness mixed factorial ANOVA. A significant main effect of task condition on IBI was found, $F(1, 52) = 51.8$, $p < .001$. IBI in dual-task scenarios was 1.34 seconds slower than in single-task scenarios. The interaction between task condition and lane width on dual-task cost in IBI approached significance, $F(1, 52) = 3.6$, $p = .06$. Dual-task cost in IBI tended to be larger when drivers were driving on narrow roadways (1.69 sec) compared to when they drove on wider roadways (0.98 sec).

In addition to text entry task performance, dual-task costs were also found in the lane-keeping task. Standard deviation of lane position (SDLP) was significantly greater in dual-task scenarios than in single-task scenarios, $F(1, 52) = 55.8$, $p < .001$. Average SDLP was more than twice as large in dual-task scenarios compared to single-task scenarios (see Table 4.1). Additionally, participants deviated farther from the lane center on average in dual-task scenarios than in single-task scenarios, $F(1, 52) = 11.5$, $p < .01$. A significant main effect of lane width on average deviation from lane center was also found, $F(1, 52) =$

14.1, $p < .001$. On average, participants were 64% farther away from the lane center when driving on narrow roadways (M = 0.34 m, SD = 0.17) compared to wide roadways (M = 0.52 m, SD = 0.22). This finding suggests that the lane-keeping task was less demanding on wide roadways compared to narrow roadways, because participants could afford to let their vehicle drift farther away from the lane center without compromising driving safety.

4.2.2 Switch frequencies

In Experiment 3, the text stimuli contained only a single sub-task boundary that occurred between the two 5-letter words. Two character positions were located at the sub-task boundary for this text stimulus, character positions 6 and 7. Switches from the text entry task to the lane-keeping task could either occur between sub-tasks (i.e., at character position 6 or 7) or within sub-tasks. More switches were expected to occur at sub-task boundaries on wide roadways compared to narrow roadways. Additionally, this effect was expected to be more pronounced when participants entered text messages with words compared to when they entered text messages with nonwords. A 2 switch location x 2 lane width x 2 meaningfulness mixed factorial ANOVA revealed that the interaction between switch location and lane width approached significance, $F(1, 52) = 3.2$, $p = .08$. Additionally, there was significant 3-way interaction between switch location, lane width, and meaningfulness, $F(1, 52) = 4.9$, $p < .05$. Overall, more switches occurred at sub-task boundaries when participants were driving on wide roadways (M = 44.5%, SD = 18.1) compared to narrow roadways (M = 36.9%, SD = 15.4). However, as seen in Figure 4.2, the increase in switches at sub-task boundaries on wide roadways only occurred when participants entered text messages with words. When participants entered text messages with nonwords on wide roadways, they did not switch at sub-task boundaries any more frequently than participants that entered text messages with words or nonwords on narrow roadways. Thus, people switched at sub-task boundaries more often on wider roadways, but only when they entered in text messages with words.

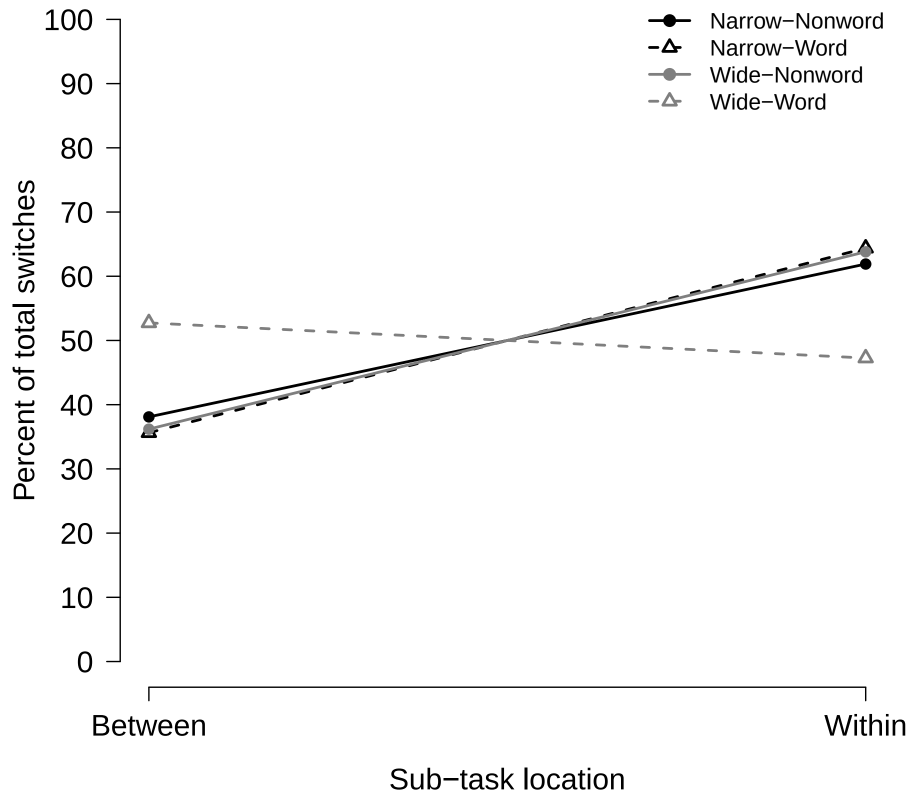


Figure 4.2: Percent of total switches between- and within-sub-tasks as a function of lane width and meaningfulness.

4.2.3 Viewing and occlusion periods

The average duration of occlusion and viewing periods in accurate trials were aggregated for each participant. Occlusion period duration ranged from 0.23 seconds to 5.87 seconds and was 1.61 seconds (SD = 1.19) on average. Participants were expected to occlude the roadway for longer periods of time when driving on wider roadways. A 2 lane width (narrow, wide) x 2 meaningfulness (word, nonword) mixed factorial ANOVA revealed a significant main effect of lane width on occlusion period duration, $F(1, 52) = 7.1$, $p < .05$. As expected, participants occluded the roadway for longer periods of time on average when driving on wider roadways ($M = 1.97$ sec, $SD = 1.43$) compared to narrow roadways ($M = 1.26$ sec, $SD = 0.76$). This suggested that wide roadways were less demanding than narrow roadways. No other main effects or interactions reached statistical significance (Fs < 1).

Next, the average amount of time participants viewed the roadway before switching back to the text entry task was examined. Overall, viewing period durations ranged from 0.63 seconds to 4.18 seconds and were 1.89 seconds (SD = 0.63) in duration on average. A 2 lane width x 2 meaningfulness mixed factorial ANOVA revealed a significant main effect of lane width on viewing period duration, $F(1, 52) = 5.4$, $p < .05$. Average viewing periods were 0.38 seconds longer on narrow roadways (M = 2.08 sec, SD = 0.62) than on wide roadways (M = 1.7 sec, SD = 0.58). This suggested that participants needed to view the roadway for a longer amount of time on narrow roadways to achieve an acceptable lane position compared to wide roadways. No other main effects of interactions reached statistical significance (Fs < 1).

4.2.4 Text entry during occlusions

The average number of characters entered during an occlusion period was calculated for each participant. More characters were expected to be entered on average when text messages contained words compared to when text messages contained nonwords. A 2 lane width (narrow, wide) x 2 meaningfulness (word, nonword) mixed factorial ANOVA was conducted on the average number of characters entered during an occlusion period. Unexpectedly, no significant main effect of meaningfulness was found ($F < 1$). The main effect of lane width, however, did approach significance, $F(1, 52) = 3.7$, $p = .06$. Participants driving on wide roadways entered more characters during each occlusion period (M = 2.93, SD = 1.66) compared to participants driving on narrow roadways (M = 2.22, SD = 1.06). This finding is not surprising, considering that participants occluded the roadway for longer periods of time on wide roadways compared to narrow roadways. The interaction between lane width and meaningfulness was not significant, $F(1, 52) = 2.3$, $p = .13$.

Text entry patterns were calculated in the same manner as in Experiment 2. Text entry patterns of 5-6 and 6-5 matched the representational structure of the text stimuli in this experiment. More entry patterns were expected to match the representational structure of the 2 words stimulus on wider roadways compared to narrow roadways. A Chi-square test confirmed that the frequency of text entry patterns that matched the representational structure varied as a function of lane width, $\chi^2(1) = 28.7$, $p < .001$. More text entry patterns matched the representational structure of the text stimulus on wide roadways (20%) than narrow roadways (8%).

Entry patterns were also expected to match the representational structure of the text message more often when participants typed in words. Meaningfulness significantly influenced the frequency that participants' entry patterns matched the representational structure of the text message stimulus, $\chi^2(1) = 44.2$, $p < .001$. Participants' entry patterns matched the representational structure of the text stimulus in 22% of all trials where they typed text messages with words. This amount was more than three times greater than when they entered typed text messages with nonwords (7%).

Interestingly, both of the main effects of lane width and meaningfulness were qualified by an interaction between these two factors. The percentage of all text entry patterns that matched the representational structure of the text stimulus is presented in Table 4.2 for all four conditions. A Chi-square test showed that there was a significant relationship between lane width and meaingfulness on the frequency of text entry patterns that matched the representational structure of the text stimulus, $\chi^2(1) = 5.7$, $p < .05$. On narrow roadways, meaningfulness did not influence the frequency that participants' entry patterns matched the representational structure of the text stimulus. On wide roadways, however, entry patterns matched the representational structure more often when participants typed text messages with words compared to when they typed text messages with nonwords. These findings provided evidence that people switched at sub-task boundaries more often when they had more time to look away from the roadway, but only when the sub-tasks were chunked in declarative memory.

Table 4.2: Percent of text entry patterns that matched the representational structure of the text stimulus as a function of meaningfulness and lane width.

Meaningfulness	Lane width	
	Narrow	Wide
Nonword	6.5	7.0
Word	10.2	32.8

4.2.5 Task performance at sub-task boundaries

Dual-task cost in IBI and average deviation from lane center was calculated in the same manner as Experiments 1 and 2. The 2 words text stimuli were used in all four conditions, so all four conditions shared the same sub-task boundary. In order to determine if participants switched at the sub-task boundary in each condition, dual-task cost in IBI, dual-task cost in average deviation from lane center, and lateral velocity were collapsed across character positions that were located within the two sub-tasks (character positions 1, 2, 3, 4, 5, 8, 9, 10, and 11) and between the two sub-tasks (character positions 6 and 7). Each dependent measure was then evaluated using a 2 switch location (between sub-task, within sub-task) x 2 lane width (narrow, wide) x 2 meaningfulness (word, nonword) mixed factorial ANOVA.

Text entry task performance

Dual-task cost in IBI was expected to be greater between sub-tasks than within sub-tasks if participants switched at the sub-task boundary in the text message. A 2 switch location x 2 lane width x 2 meaningfulness mixed factorial ANOVA was conducted on the dual-task cost in IBI. The ANOVA revealed a significant main effect of switch location, $F(1, 52) = 52.1$, $p < .001$. Average dual-task cost in IBI was significantly greater between sub-tasks ($M = 1.15$ sec, $SD = 1.02$) than within sub-tasks ($M = 0.49$ sec, $SD = 0.85$). This finding suggested that participants were switching at the sub-task boundary. The interaction between switch location and meaningfulness approached significance, $F(1, 52) = 3.3$, $p = .07$. Average dual-task cost in IBI was greater in the nonword condition compared to the word condition between sub-tasks but not within sub-tasks (see Figure 4.3). All other interactions failed to reach significance (Fs < 2.6).

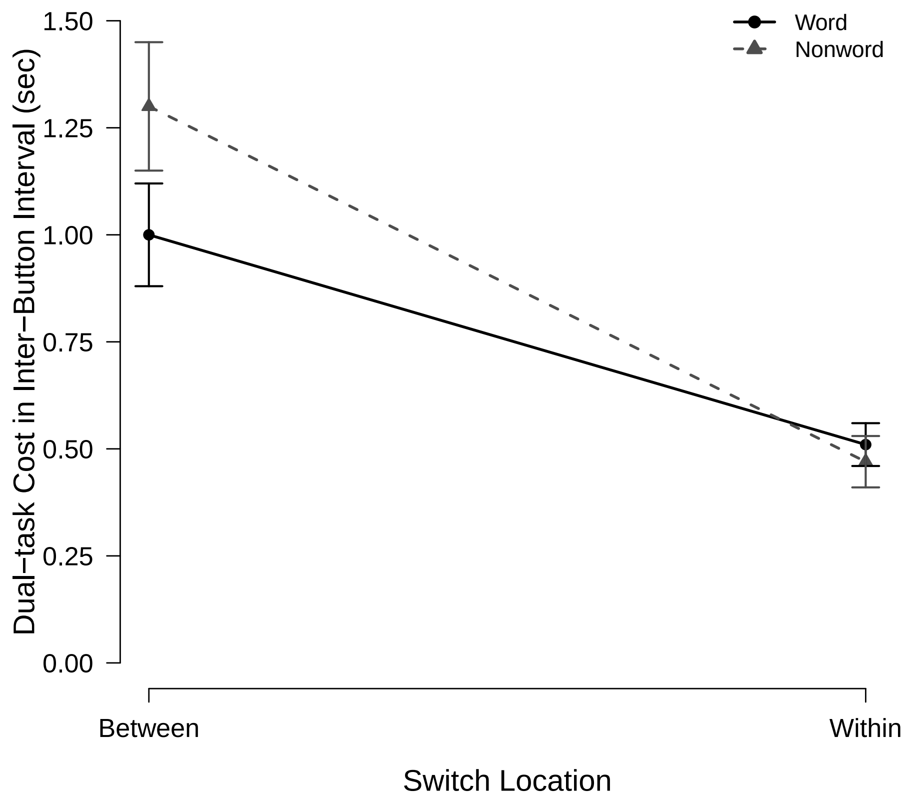


Figure 4.3: Average dual-task cost in inter-button interval between- and within- sub-tasks as a function of meaningfulness.

Lane-keeping task performance

Lane-keeping performance was expected to improve between sub-tasks if participants interleaved at sub-task boundaries. A 2 switch location x 2 lane width x 2 meaningfulness mixed factorial ANOVA was performed on average dual-task cost in deviation from lane center. No significant main effects or interactions were found (Fs < 1.5). A 2 switch location x 2 lane width x 2 meaningfulness mixed factorial ANOVA was also performed on average lateral velocity. A significant main effect of switch location on lateral velocity was found, $F(1,\ 52) = 10.9$, $p < .01$. As seen in Figure 4.4, lateral velocity was significantly lower between sub-tasks compared to within sub-tasks. This finding suggests that participants stabilized their lateral movement in the lane at the sub-task boundary more than at other locations in the text entry stimuli. All other interactions failed to reach significance (Fs < 1).

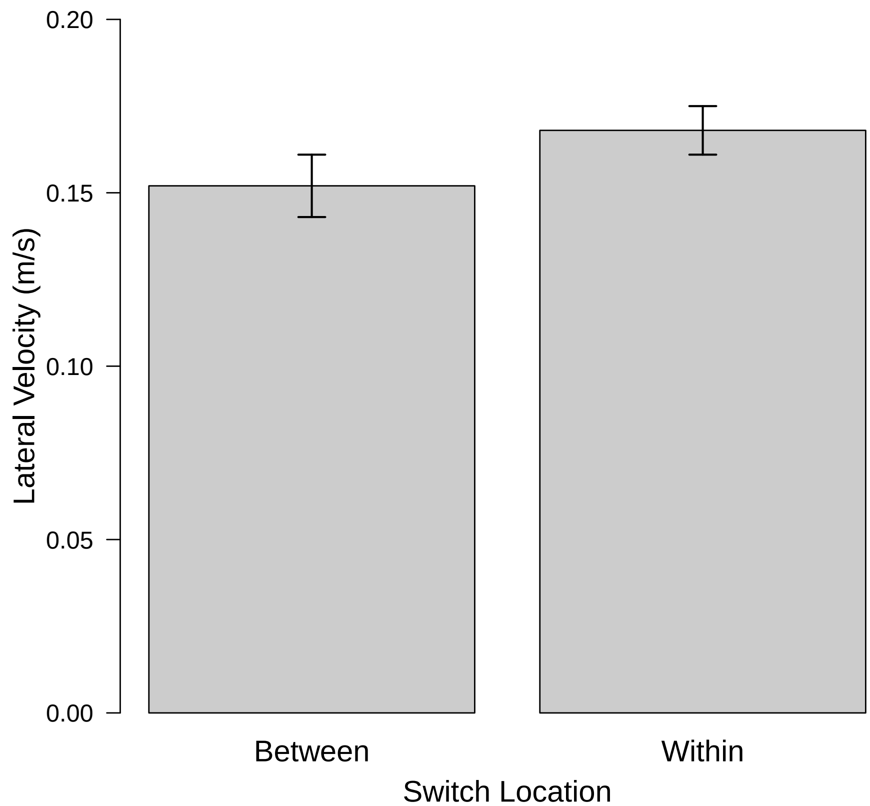


Figure 4.4: Average lateral velocity as a function of switch location.

4.2.6 Implicit memory test

At the end of Experiment 3, participants were asked to recall as many of the word(s) or nonword(s) they entered in the dual-task scenarios as possible. Words or nonwords had to be recalled in their entirety to be considered as a correct response. The total number of words or nonwords that were correctly recalled were tallied for each participant. Participants were expected to recall more words than nonwords. The total number of words and nonwords that were correctly recalled was analyzed using a 2 lane width (narrow, wide) x 2 meaningfulness (word, nonword) mixed factorial ANOVA. A significant main effect of meaningfulness was found, $F(1, 52) = 42.1$, $p < .001$. On average, more than three times as many words were recalled ($M = 3.9$, $SD = 1.8$) than nonwords ($M = 1.0$, $SD = 1.4$). No other significant effects were found, Fs < 1. This finding confirms that the meaningfulness manipulation was effective. Words were more likely to be recalled from memory than nonwords.

4.3 Discussion

The goal of Experiment 3 was to investigate if task interleaving strategies were influenced by sub-task boundaries when participants had more time to look away from the roadway. It was hypothesized that wider lanes in the lane-keeping task would be less demanding than narrow lanes and give participants more time to look away from the roadway. Increasing the width of the roadway reduced the demand of the lane-keeping task and allowed participants to devote more time to the text entry task. The average period of time that participants looked away from the roadway during a single occlusion period was 56% longer on wider roadways compared to narrow roadways. Additionally, participants looked at the roadway for shorter periods of time when driving on wider roadways compared to narrower roadways. Thus, increasing the width of the lane appeared to reduce the demand of the driving task and participants' uncertainty about the driving environment during glances away from the roadway (Senders et al., 1967; Tsimhoni & Green, 2001; Tsimhoni et al., 2004).

Participants also switched at sub-task boundaries nearly 8% more frequently when driving on wide roadways compared to narrow roadways. This effect, however, was really dependent on the meaningfulness of the text message. Over half of all the switches participants made when typing text messages with words on wide roadways were at sub-task boundaries. In the other three conditions this rate was less than 39%. Furthermore, participants only switched at the sub-task boundary in one-third of all trials that they completed when entering words on wide roadways; this was two to three times as many trials as observed in the other three conditions. Together, these findings provide evidence that task interleaving strategies were influenced by sub-task boundaries when participants' uncertainty about the driving environment was lower on wide roadways and when they were entering meaningful information that was chunked as sub-tasks in declarative memory.

Together, the findings from Experiments 2 and 3 provide additional evidence that meaningfulness can affect task interleaving strategies under certain conditions. Table 4.3 shows the average occlusion period duration, the total percent of switches at sub-task boundaries, and the total percent of entry patterns that matched the representational structure of the 2 words stimulus in Experiment 2 and all four conditions in Experiment 3. In Experiment 3, participants' entry patterns matched the representational structure of the stimulus in nearly one-third of all trials when they drove on wide roadways and typed words. This rate was drastically less (only 7%) when participants typed nonwords on wide roadways. When typing words on narrow roadways, participants tended to switch at sub-task boundaries more often (Experiment 2); however, their entry patterns did not match the representational structure of the 2 words stimulus any more often than when they typed nonwords on narrow roadways. Overall, meaningfulness only increased the rate that entry patterns matched the representational structure of the 2 words stimulus on wide roadways. The findings from Experiments 2 and 3 provided evidence that sub-task boundaries influenced task interleaving strategies when sub-tasks were chunked in memory, but only when participants had enough time to complete the sub-task in a single glance. When participants did not have enough time (e.g., when driving on more demanding, narrow roadways) they seemed to break the sub-task into smaller, more manageable chunks even if the sub-task was chunked in memory (i.e., meaningful stimuli in Experiment 2).

Table 4.3: Average duration of occlusion periods, average total percent of switches made at sub-task boundaries, and the total percent of entry patterns that matched the representational structure of the 2 words stimulus in Experiments 2 and 3.

Experiment and Condition	Occlusion period duration (sec)	Switches at sub-task boundaries (%)	Entry patterns (%)
Experiment 2: Nonword - Narrow Lane	1.30	35.8	11.1
Experiment 2: Word - Narrow Lane	2.04	50.0	14.6
Experiment 3: Nonword - Narrow Lane	1.39	38.1	6.5
Experiment 3: Word - Narrow Lane	1.12	35.6	10.2
Experiment 3: Nonword - Wide Lane	1.92	36.2	7.0
Experiment 3: Word - Wide Lane	2.02	52.7	32.8

Meaningfulness facilitated interleaving at sub-task boundaries on narrow roadways in Experiment 2, but not in Experiment 3. This finding may not have been replicated in Experiment 3 because the efficiency of text entry performance did not vary as a function of meaningfulness. Participants typed more characters during an average occlusion period when text messages contained words in Experiment 2, but this was not the case in Experiment 3. Average occlusion period duration did not vary as a function of meaningfulness, so on average participants typed the same number of characters during each occlusion period when typing words and nonwords on narrow roadways. Words were encoded in memory better than nonwords as evidenced by the implicit memory test findings. Yet, the more efficient cognitive processes in the word conditions did not lead to faster text entry performance in Experiment 3. Additional research is warranted to better understand this relationship.

In summary, the results from Experiment 3 further indicated that decisions to switch between two interleaved tasks in the driving environment were primarily influenced by the the time participants were willing to look away from the roadway. Increasing lane width decreased the demand of the lane-keeping task and increased the duration of time participants looked away from the roadway. When participants had more time, they switched at sub-task boundaries more often. Meaningfulness did not enhance text entry performance in Experiment 3 as it did in Experiment 2, but it influenced participants' task interleaving strategies. Task interleaving strategies were influenced by sub-task boundaries when participants had more time on wide roadways and were typing meaningful text messages. In conclusion, Experiment 3 provided explicit evidence that task interleaving strategies in the driving environment were more influenced by the time visual attention was away from the roadway than sub-task boundaries.

Chapter 5: General Discussion

The purpose of these studies was to investigate how sub-task boundaries and elapsed time influence task interleaving strategies in the driving environment. Experiment 1 extended upon previous task interleaving research (Brumby et al., 2009; Janssen & Brumby, 2009) and provided evidence that task interleaving strategies in the driving environment were influenced more by elapsed time than sub-task boundaries in a number entry task. Experiment 2 replicated the findings from Experiment 1 with a different distractor task and demonstrated that elapsed time still influenced task interleaving strategies more than sub-task boundaries even when sub-tasks were chunked in memory. Lastly, the demand of the driving environment was varied in Experiment 3 to manipulate participants' level of uncertainty about the driving environment during glances away from the roadway. Drivers looked away from the roadway longer when the driving environment was less demanding. Additionally, sub-task boundaries influenced task interleaving strategies when the sub-tasks in the distractor task were chunked in memory, but only when drivers had more time to look away from the roadway. Together, these studies provide strong evidence that elapsed time influences task interleaving strategies in the driving environment more than sub-task boundaries.

These studies also provide evidence that drivers are opportunistic when switching between tasks in the driving environment. Specifically, drivers seem to switch at sub-task boundaries when the sub-task "fits" well with the time constraints of the driving environment. For example, the smaller sub-tasks in Experiments 1 and 2 fit well with the time constraints imposed by lane-keeping on narrow roadways. Participants frequently switched at sub-task boundaries when completing small sub-tasks on narrow roadways. Sub-task boundaries did not influence task interleaving strategies when participants typed the larger sub-tasks in the zip code and 2 words conditions on narrow roadways, but influenced task interleaving strategies when participants had enough time to complete the larger sub-tasks in the 2 words condition on wider roadways (note, this was only the case when the sub-task was chunked in memory). This hypothesis would explain why sub-task boundaries influenced task interleaving strategies in Brumby, Salvucci, and Howes' (2009) study but not in Janssen and Brumby's (2009) study. The smaller sub-tasks in the US phone number fit into the time constraints of the driving environment better than the larger sub-tasks in the UK phone number. Future research should continue to explore how sub-task boundaries and the temporal characteristics of the driving environment interact to influence task interleaving strategies.

To date, most interruptions research has provided evidence that people decide to switch at sub-task boundaries to reduce cognitive costs and workload. Interruptions research has mostly explored switch decisions using task environments without significant time pressure. The findings from the current study showed that the temporal characteristics of a task environment influence decisions to switch. In continuously changing environments such as driving, the time away from the changing task environment plays a larger role in decisions to switch than reducing the cognitive costs associated with switching between tasks. People may only be willing to keep their attention away from a changing task environment as long as their uncertainty about the environment is at an acceptable level (e.g., Senders et al., 1967). The extent to which sub-task boundaries and time contribute independently to people's decisions to switch may vary as a function of the temporal characteristics of the task environment and how each of these factors contributes to task performance.

The task interleaving strategies observed in this study present a unique challenge to theories of multitasking behavior. Specifically, when uncertainty about the driving environment reached an unacceptable level, drivers interrupted their performance on the distractor task to return visual attention to the roadway. This behavior suggests that task interleaving strategies during multitasking can be modulated in a top-down manner. Current theoretical accounts of multitasking have some difficulty explaining this type of behavior. For example, multiple resource theory is a popular theory of multitasking that posits that dual-task interference results from multiple demands being placed on similar resources (Wickens, 2002, 2008). Multiple resource theory, however, does not make any predictions about the sequence of task processes or how competing processes interact over time. Meyer and Kieras's (1997a, 1997b) EPIC architecture incorporates a general executive mechanism that can schedule the execution of behaviors according to task priority; however, the EPIC architecture seems better suited for simpler multitasking phenomena. Numerous production rules would be required to model behavior in more complex environments, so EPIC may not provide the most parsimonious account of multitasking behavior in complex environments.

Threaded cognition (Salvucci & Taatgen, 2008) is a more recent theory of multitasking behavior that provides a more parsimonious and eloquent account of these findings than other theories of multitasking. As discussed earlier, in threaded cognition different series of task goals are represented as threads. Threads use resources (e.g., visual attention) in a greedy but polite manner where threads immediately acquire a resource when it is available, but release it as soon as the thread has been processed. This means that there is no executive controller that schedules the processing of threads. Threads are also able to modulate their own use of resources based upon task-specific knowledge. One example of task-specific knowledge is task priority. Low priority task threads will relinquish a resource if it is needed by a higher priority task thread. The results from this study provide evidence that time is another piece of task-specific knowledge that can influence the order that threads are processed during multitasking (e.g., Salvucci, Taatgen, & Kushleyeva, 2006).

The current study's findings also highlight a methodological limitation in prior research. Brumby, Salvucci, and Howes's (2009) and Janssen and Brumby's (2009) studies both used latencies between key presses to infer participants' task interleaving strategies. This study used a similar measure, inter-button interval (IBI), and also found that IBI increased at sub-task boundaries. Based upon other indicators of task interleaving strategies, however, it was clear that using the pattern of latencies between key presses as a sole indicator of task interleaving strategies can lead to incorrect inferences. IBI is sensitive to the frequency of switches made at a specific location in a task, but does not indicate how long attention was directed to the task before the switch occurred. Only when examining glance duration and entry patterns in each trial did it become clear that participants were primarily interleaving as a function of time. IBI was greater at sub-task boundaries because it was a common point to interleave among a number of different task interleaving strategies, not because it was the only place participants were interleaving.

5.1 Limitations

In the current research, lane-keeping task performance was prioritized over the distractor task. Task priority has been shown to influence multitasking performance (Navon & Gopher, 1979; Norman & Bobrow, 1975), allocation of visual resources between concurrent tasks (Horrey et al., 2006), and when people switch between tasks (Brumby et al., 2009). Switch decisions may have been heavily influenced by time in the driving environment because performance in the prioritized lane-keeping task was dependent upon the frequency of corrective steering movements over time. Drivers could only make accurate adjustments to lane position when they were looking at the roadway. If lane-keeping task performance was less important than distractor task performance, then drivers may have looked away from the roadway longer and switched at sub-task boundaries more often. Further research is needed to understand how task priority interacts with the temporal demands of the driving environment to influence decisions to switch between tasks that vary in sub-task size.

It is important to note that the location of the entry device required participants to look away from the computer screen to locate numbers or characters. Measures of visual sampling strategies in this study were not based on where participants were actually looking, but based on the time that the lane-keeping task (viewing periods) or distractor task (occlusion periods) was active during the driving simulation. Participants' visual attention could have been directed toward the entry device even when the lane-keeping task was the current active task. Thus, even though the interleaved task paradigm afforded the precise measurement of switches between tasks in the driving environment, it only approximated how visual attention shifted between both tasks.

Another limitation of the task paradigm used in this study is that it assumes focal vision is necessary to complete both tasks. Although most tasks do require focal vision, there is evidence that lane-keeping is supported by ambient vision and can be performed satisfactorily in the absence of focal vision (Horrey et al., 2006). Depriving participants of ambient vision in the lane-keeping task may have placed a ceiling on the duration of time participants glanced away from the roadway. Task interleaving strategies and decisions to switch may have been different if ambient vision was allowed. Focal vision, however, is the primary means that people gather information in the driving environment. Additionally, it plays a greater role in visual sampling strategies in the driving environment than ambient vision. Thus, though depriving participants of ambient vision in the current study may have impacted lane-keeping task performance, it likely had a minimal impact on the way they distributed visual attention between the driving environment and distractor tasks. Future research should use eye-tracking to validate and extend these findings.

5.2 Practical applications

The findings from these studies can be used to improve the design of in-vehicle devices and other mobile devices that may be deployed in the driving environment. As found in previous research (Horrey et al., 2006; Victor et al., 2005; Wierwille, 1993), time was the most influential factor in determining when drivers switched between tasks in the driving environment. Unlike previous studies, however, this study explicitly showed that drivers are more concerned with the amount of time they engage in a distracting task and neglect the driving environment than where they stop when performing the distracting task. Visually demanding in-vehicle devices should support short bursts of visual interaction from the driver and be able to be broken into smaller, manageable components. Ideally, in-vehicle tasks would be composed of small sub-tasks that not only fit the temporal demands of the driving environment, but give drivers the opportunity to interleave at sub-task boundaries and minimize cognitive costs when switching between tasks.

The findings also suggested that task efficiency is a major component of proper in-vehicle device design. Participants were faster and more efficient when they entered information that was chunked in memory. As a result, participants were able to complete more of the task within the period of time they were looking away from the roadway. Designers can use drivers' prior experience and knowledge when developing devices for the vehicle to minimize the amount of learning that must take place to consolidate the task steps into sub-tasks in declarative memory. More efficient task performance will also reduce the overall time that drivers are distracted and minimize the chance that they will miss safety critical information in the roadway environment.

5.3 Conclusion

In conclusion, task interleaving strategies in the driving environment were predominantly influenced by the amount of time that drivers were willing to divert visual attention away from the roadway. The effect of sub-task boundaries on switching behavior was shown to be an artifact of small sub-tasks that "fit" within the durations that drivers were willing to look away from the roadway. When sub-task became larger, participants switched at sub-task boundaries less frequently. In addition, participants looked away from the roadway longer when the lane-keeping task was less demanding on wider roadways. Sub- task boundaries only influenced task interleaving strategies when the lane-keeping task was less demanding and participants had more time. Overall, task interleaving strategies were primarily influenced by time, but drivers seemed to be opportunistic and switched at sub-task boundaries when the time required to complete a sub-task aligned with the time constraints of the driving environment.

Appendix A: Demographics survey

Date: ____________   Participant ID: ____________

Please fill-in the following information, and return the sheet to the researcher when you are finished.

1. Age: ______ years

2. Home town (City, State): ____

3. Class standing: ❑ Freshman ❑ Sophomore ❑ Junior ❑ Senior ❑ Other

4. Gender: ❑ Female ❑ Male

5. Native language: ❑ English ❑ Other (please specify) ________________________

6. How many months have you been a licensed driver? _________ months

7. What type of cellular phone best describes the phone you currently own?

   ❑ Conventional phone
   ❑ Conventional phone with QWERTY keyboard
   ❑ Smart phone or personal digital assistant (PDA) with <u>keyboard</u>
   ❑ Smart phone or personal digital assistant (PDA) with <u>touch screen</u>
   ❑ I do not own a cellular phone

8. How frequently do you use a cell phone <u>while driving</u>?

   ❑ Daily
   ❑ Few times per week
   ❑ Few times per month
   ❑ Less than once a month
   ❑ Never
   ❑ I do not own a cellular phone

9. How often do you use a hands-free device when using a cell phone while driving?

   ❑ Always hands-free
   ❑ Hands-free more than 75 percent of the time but not always
   ❑ Hands-free more than half of the time but less than 75 percent of the time
   ❑ Hands-free about half of the time
   ❑ Hands-free less than half of the time, but more than 25 percent of the time
   ❑ Always hand-held
   ❑ Not applicable, I do not use a cell phone while driving

10. What best describes the text entry method of your current cellular phone?

   ❑ Multi-tap method (pressing a single button several times to type a letter using a 12-key keypad)
   ❑ T9 predictive entry with a 12-key keypad
   ❑ QWERTY Keyboard or a variant – non-predictive entry
   ❑ QWERTY Keyboard or a variant – predictive entry
   ❑ I do not own a cellular phone or my phone does not do text entry

Date: ____________ Participant ID: ____________

11. How frequently do you text message when driving?

- ❑ Daily
- ❑ Few times per week
- ❑ Few times per month
- ❑ Less than once a month
- ❑ Never
- ❑ I do not own a cellular phone

12. If you text message while driving, please describe the primary method you use to enter text while driving (for example, holding the steering wheel with one hand while the other hand is used to enter the text message):

Appendix B: Phone number stimuli

642-721-0140
272-940-9684
436-263-1282
958-215-0781
761-795-0341
358-943-4021
359-473-7268
436-731-6471
645-706-2054
329-694-0619
842-827-9843
263-018-5647
279-562-3502
739-101-9815
827-165-1395
654-529-1614
738-095-0985
368-097-0608
542-025-3297
656-587-3851
728-684-9240
459-046-7693
751-468-5462
549-676-5348
560-364-0352
483-293-8052
923-619-3787
483-631-6508
546-849-5495
687-052-7831
746-542-5982
457-464-6182
746-843-0648
930-923-2545
529-140-1987
789-617-3814
328-080-1326
725-430-7457
746-350-9426
537-952-8650
753-241-2841
840-759-1275
625-942-0201
489-807-6816
826-972-1860
384-870-2616
421-031-8738
529-863-5394
353-281-8575
367-596-1231
569-243-6962
543-981-3236
981-750-3857
461-309-5386
243-538-1626
560-462-9704
348-165-9578
642-914-0106
329-182-9525
528-352-8073
363-217-5254
746-405-0176
837-176-9479
827-681-2912
521-543-5450
584-085-6258
465-013-2304
943-986-0829
981-382-4393
427-169-6393
645-816-0758
461-637-8907
426-737-4910
729-105-3216
648-253-4808
723-203-0405
635-124-6104
683-251-2028
930-540-6309
257-646-1646
526-405-3138
483-493-2143
854-878-5349
658-752-7819
439-570-9328
461-349-0704
474-761-4942
683-967-5204
837-202-6781
834-151-8393
827-830-4287
524-835-3109
324-687-3463
468-476-2619
741-274-6575
838-781-6410
263-797-4245
362-809-0548
578-532-3965
629-291-9646
481-652-6271
482-091-2931
451-507-2924
280-489-4252
427-486-5428
820-260-1943
485-960-7353
728-321-8913
642-152-7283
680-382-8671
589-384-8401
359-204-6014
535-732-4735
428-095-3784
685-272-0360
460-215-9697
987-283-4349
578-051-5794
461-032-7826
350-396-4381
746-103-0383
576-396-9046
943-750-9438
525-640-9232
527-386-1617
529-404-7285
383-954-6028
729-804-5685
258-198-5832
457-093-4939
948-329-3419
525-437-2521
680-352-3568
354-863-7927
536-408-9324
474-575-1608
782-397-8908
643-928-4565
645-239-2046
328-981-7301
854-204-6129
237-309-6946
389-075-8671
934-604-8960
634-028-3759
326-370-2747
275-843-7921
358-583-5274
652-927-9895
583-595-8404
782-052-7090
275-617-0132
983-738-4819
324-380-2634

Appendix C: Modified zip code stimuli

91264-53528
25706-04698
85635-81850
76082-73575
48270-17314
15759-70618
08752-94615
42629-13514
43842-02760
71328-02528
71401-70823
85806-38946
15970-58216
57878-93079
54697-93251
39750-23016
58978-75464
67140-45396
19591-26840
92956-50936
06740-68531
24943-60596
42743-05047
29742-40821
32584-70893
45635-35203
12564-56102
15790-98645
21613-73806
34767-10754
49127-85409
18343-80627
78151-24824
36821-26357
47972-17202
72678-01924
70931-35212
56516-96218
31073-03531
64621-97305
78416-98173
01594-81793
07054-30654
81021-35860
34168-02953
39236-80205
29503-07187
23805-87212
89459-58295
16350-63575
98068-37821
87343-16582
49708-90409
84159-14323
76835-15686
50573-59238
96836-96091
73473-08418
61586-51319
35202-64748
49890-67361
71326-93965
08325-14087
92418-90874
06805-46739
15027-40191
76791-21351
72036-59430
89160-20571
18584-50729
02489-81950
86967-46062
70670-32747
70201-01210
23495-45451
49094-70764
78709-01420
76571-43631
97017-82497
25813-91830
84157-03565
70343-28264
39127-94628
91745-25380
38073-74265
83412-94593
79701-90153
98584-27683
34239-35691
90164-19105
29135-84940
76909-85275
46979-51739
18580-75269
30715-89315
60635-15742
32341-40184
04130-54389
96203-02783
73460-53047
69073-04627
85627-96429
75320-45252
14250-72174
30378-63403
35297-18491
29324-70919
80426-51680
85486-29832
63420-51348
21279-12935
30106-06187
46045-65324
32968-69018
07409-85278
52489-73791
95409-09721
68591-50650
45804-02469
40602-56592
82173-98273
76076-07454
75419-69702
61657-62520
87267-53521

Appendix D: Number string stimuli

8270650629	7340716471	7082939042	6549546015
6328250659	2343954690	9580790732	5182132961
1216060752	3749491638	7102731370	5987174904
3765974635	9026823589	7906561319	8129413617
2327598467	5627830494	8023952648	1618571045
6708507942	9150546760	9469267258	3696250683
6142792537	6765604879	8763836015	5175614217
1576120394	1747954686	7545906293	2847928381
5916587382	6705759010	4758765928	6203014852
8506852160	4374525782	1509281341	7652837919
3561213572	7083851354	8732432635	7346036091
8716943435	1736306986	5416106832	1561579653
2428492941	1731982060	3264532645	9370148673
1823731924	4525935121	5416104269	3525101785
4936029489	3018648351	9013959271	2568768086
5679504951	9546130708	1741791346	5376360310
6834706486	4973751818	5403436578	4987593819
6168568483	983674352	3543409598	8523289731
6323743164	8616897869	4648694728	6915253952
7396450931	3524278410	3152562645	1954806958
3459795803	4736985463	3712902169	9215831904
9807243987	4825094934	1035101459	8173212541
1841879232	9567392383	1239149049	7605295862
8713932095	8303063616	9847201453	2157523479
1407151039	6253798015	2591016493	7679645634
5841824272	8241857592	9083785036	5414923414
4790730567	6963494950	2695324081	3752067540
3759898981	6414106167	7307897641	2867647598
6927602191	2456392450	7409391989	8945390253
9853537216	9284606843	6968769057	3834271095
5185343572	7121321594	5478416383	1654512972
2507506575	2673641562	5701873453	4248579153
8521785716	3547975170	6391514795	3752323134
7575060153	1259530869	3676260921	5639645462
2478345469	5870486491	3284316184	1283152582
9304851709	9613478716	7271803020	6497973495
7206035973	1310549589	1437834046	1879630929
9517807169	7238094914	7253762836	1327269186
9691735398	2352654852	9016805690	7204542463
9581323135	5612187230	4703617064	9282631935
2472867543	7878696839	5801450265	4158562754
9378682181	9480897531	4657907829	
9103274716	6265854681	4140756831	
2468702817	3857658491	4652807076	
8578713403	6039816329	3848092089	
8910562375	6271606383	5613721567	
2071024167	1230676581	1316541659	
4027576067	5096426268	8493593405	
1243796530	3156587930	3434263862	

Appendix E: Three words text stimuli

Word	Nonword	Word	Nonword
HEW ROM LEZ	EHW MOR ZLE	ALP POM HEX	LAP OPM EXH
MAR BEN JAW	AMR EBN AJW	GEM HUP BOT	MGE UHP TOB
TOE AUK ZIT	OTE AKU ITZ	BIS ENG MAT	ISB NGE TMA
BRA WIT ANY	RAB WTI NYA	WOG SAW LEX	GWO AWS ELX
MUG OHM GUY	UMG HOM YUG	NOW KAT JOT	WNO KTA OJT
LAM GIN SOU	ALM GNI USO	LIN LES RAW	ILN SEL AWR
ION ABS GAP	ONI BAS APG	BAS HOE ASH	BSA EHO SHA
OMS MUT RAY	SMO UTM YRA	MAW TEN SEL	AMW NET ELS
TIE UTE TRY	TEI UET RTY	JAW HOP JEU	AJW OHP UJE
ARS TEG SEX	SRA GET ESX	BIG ASK ARB	IBG SAK RBA
MOG ASK MOS	GOM SAK SOM	WIS PYA MOB	SWI APY MBO
SHY PER ASK	HSY REP SAK	RAP BIT RAP	PRA TIB PRA
NEG WAX AIN	EGN AXW NAI	AGE TEN WOK	GAE NET OKW
RYA POT PAN	RAY TPO NPA	LEY SOP TAJ	LYE OPS AJT
KAS UTE GAB	KSA UET ABG	YOB KIP OHS	OBY IPK HOS
LAP POW HER	PAL OWP HRE	ENS WIN JAR	NSE INW JRA
ORB WYE ELS	BRO YEW ESL	BOW APE RAP	OWB PAE PRA
TYE RAN MOP	ETY RNA MPO	SOY PHT BIO	YSO THP BOI
POI PAS WHA	OPI APS AWH	NAP RUN MAY	PNA NUR AYM
LES SAX ISM	SEL XSA MIS	NAE PAM SUK	NEA AMP UKS
PEH TOR LAS	HEP TRO LSA	BYE LES NAH	YEB SEL AHN
UGH EGO LEY	GUH GOE LYE	TIP AWL SKY	PIT WLA SYK
GIB HIP BAG	IBG IPH AGB	OPE LAT TOM	PEO TAL MOT
GOT TOW SUB	OTG WTO SBU	SUP BAH RAM	USP BHA RMA
GAM GUM OHM	AMG MGU HOM	HIM WOE PEW	IHM EOW WEP
RUT AIT POI	RTU TAI OPI	ASK ELK ELK	SAK EKL EKL
WYN YOB SEN	YNW OBY ESN	ILK BAT SYN	LKI BTA SNY
HEP WHY HEM	PEH YHW MHE	NOS UGH BOY	ONS GUH BYO
GEY LAS LEU	EGY LSA EUL	POX ANY NIM	OPX NYA MNI
WIG RIM YOK	IWG RMI KYO	BUN MIL GIN	UNB LMI GNI
BEY AIL POW	BYE IAL OWP	OBE ARB KIS	EOB RBA KSI
TRY ZAX SOT	RTY AZX TSO	AXE MET HEY	XEA TEM YEH
SOU HAW ERS	USO AWH SRE	ONE WAW NAY	ENO AWW NYA
BUS OUT SUM	BSU UOT SMU	BUN WET BOP	UNB EWT PBO
TUN ARS AGO	UNT SRA AOG	OHS SKY SOM	HOS SYK OMS
ALT RAX SAU	TAL XAR SUA	KIT AIL AIL	ITK IAL IAL
MAE ZIP LAR	AEM IZP LRA	MOA GIN LEA	OAM GNI EAL
SET LIP GIB	EST LPI IBG	APT GOS OXY	TPA SOG XOY
NOG UNS URN	ONG SNU NUR	NEG ASK HOG	EGN SAK OGH
TIN TOY LEK	TNI YOT KLE	ENS MOW HUM	NSE OMW UMH
TIP ZAS NET	PIT AZS TEN	KAY GAG MOG	YAK AGG GOM
GOT RIN SON	OTG NRI SNO	PEW NOH LUG	WEP ONH UGL
TAE SEA LEU	ATE ESA EUL	PUN SAU MON	PNU SUA ONM
ZIT OHM SPY	ITZ HOM PYS	SEW OKE JUG	WSE OEK JGU
SOB SAT REI	OBS TSA ERI	LIN TEW HEW	ILN WET EHW
BES NIM WAR	BSE MNI WRA	SEA RUN SIP	ESA NUR ISP
GOB ELK JOW	OBG EKL WJO	MIR BRO KOR	RMI ROB ROK
RAN MIX TEN	RNA XMI NET	YAP WEN LEK	PAY WNE KLE

Word	Nonword	Word	Nonword
JET NEG OUR	TJE EGN ROU	PIN AMP TUX	NIP PMA XTU
YIP NOH PUB	IPY ONH UPB	RUE YUP GHI	REU PYU IGH
PIA SET HOY	AIP EST YHO	LEI OAT OHS	ELI ATO HOS
IMP LIT UTS	MPI TLI SUT	PYX BOX HAG	YXP BXO GHA
HET PUN PER	TEH PNU REP	NOM LEA POT	MNO EAL TPO
TEG MUS ALP	GET MSU LAP	INK ISM YEH	NIK MIS EHY
EAT BUG RAH	TEA UGB HRA	PHI RUG OMS	PIH URG SMO
ROT WOK UGH	RTO OKW GUH	JOE TUB HET	EJO BTU TEH
LAS MET SOU	LSA TEM USO	ONS KEG OBE	NOS KGE EOB
OPT TOP ZAP	TPO POT AZP	BOT NIT USE	TOB TNI EUS
PIU HIT SUE	IUP HTI ESU	OAR HOS LAW	RAO SOH AWL
HEX GUT ARM	EXH TGU MAR	BOA HIS BIZ	BAO SHI IBZ
JAG REG NAG	AGJ RGE GAN	TAB TOM WAW	ABT MOT AWW
WOE EGO BAY	EOW GOE YAB	HIT WOE SEW	HTI EOW WSE
TAE HAG KAE	ATE GHA AKE	TAP RIA KOB	PTA ARI OBK
NOR TSK GIN	NRO TKS GNI	HIE JEU OUT	EHI UJE UOT
SUB NEB GOA	SBU EBN GAO	TOP KOR KEX	POT ROK KXE
YEW URP HAE	EWY PRU AEH	GAP LEI HEY	APG ELI YEH
SKI WET JUN	SIK EWT UJN	SIB BEN HET	SBI EBN TEH
LIN ENG WHA	ILN NGE AWH	JEW ABS NOW	JWE BAS WNO
AMU ROM BOP	AUM MOR PBO	BIG ARB SOX	IBG RBA OXS
PUG BUG TOG	GUP UGB GOT	OPS RAW HAG	PSO AWR GHA
TAJ PES WAY	AJT EPS AWY	NOR ERS ALB	NRO SRE LAB
MEN SET OHS	ENM EST HOS	URN ASP PAM	NUR APS AMP
UTE ORB KOA	UET BRO OKA	AWN ELM WAY	NAW LME AWY
KHI PRY MUS	HKI RPY MSU	ROT SKY TIL	RTO SYK TLI
ANY GIB HEX	NYA IBG EXH	GOT PAX HEP	OTG AXP PEH
POM BOT POI	OPM TOB OPI	ISM SAL BUS	MIS LAS BSU
JUN KYE OPE	UJN KEY PEO	ION TAO OBE	ONI ATO EOB
AWL PIE SUM	WLA IPE SMU	BAS GHI BAG	BSA IGH AGB
TOP NET APT	POT TEN TPA	HAG MAX KIR	GHA XAM KRI
WAT BUR HEW	TWA URB EHW	XIS SUN GYP	SIX UNS GPY
WYN ERS OAR	YNW SRE RAO	JIN RAY WYN	NJI YRA YNW
HAM PES WET	MAH EPS EWT	PAH GAG BIO	HPA AGG BOI
SIT GIP WHY	TIS IGP YHW	NUS LAT WOP	SUN TAL POW
TAB KEG GEL	ABT KGE GLE	PYX IRE RAG	YXP EIR ARG
NOS SEW MAX	ONS WSE XAM	SEW TIE WAS	WSE TEI AWS
MUN JIG JAG	NUM GIJ AGJ	SAT NEB OHS	TSA EBN HOS
ORE GAP JOG	REO APG OJG	NET TOR RAY	TEN TRO YRA
AHI BEG TIN	HAI BGE TNI	BAM ABA GIB	AMB BAA IBG
RAI URN REX	IAR NUR RXE	GOB SOW POM	OBG WSO OPM
LAT RYE RUE	TAL EYR REU	JUG JIG BAN	JGU GIJ BNA
ALB KOI BUS	LAB IKO BSU	EON YAP BAR	ENO PAY ARB
TAG KAY ERA	TGA YAK RAE	MIB WAY GUN	MBI AWY UNG
ETA ASK WRY	TAE SAK YRW	JAY LEU GOY	AJY EUL GYO
NEG BUN KOB	EGN UNB OBK	GOT BOW WOK	OTG OWB OKW
BEG TWO ELS	BGE WOT ESL	AYE BUN LOG	EYA UNB OLG
JUT GYM SAG	JTU MYG GSA	ENS JEW HAT	NSE JWE ATH

Word	Nonword	Word	Nonword
SON SEA ION	SNO ESA ONI	AMP YET YUM	PMA ETY UYM
OUR ZEP ILK	ROU EPZ LKI	BOP UGH SEN	PBO GUH ESN
GUM SIP EMU	MGU ISP UEM	PAP PUB PAS	APP UPB APS
POL LUX PUG	PLO UXL GUP	ROM GAB LOT	MOR ABG OLT
KAT SEI BOY	KTA IES BYO	GUL AYE ASK	GLU EYA SAK
NOB AHS MHO	ONB HAS HOM	THY BUY STY	YTH BYU YST
HEM LOT SUN	MHE OLT UNS	YOK WOT HOS	KYO TWO SOH
OBE RAG ARS	EOB ARG SRA	GUM YAG URN	MGU GAY NUR
AIS YEW MUN	SIA EWY NUM	TRY KAS MOL	RTY KSA MLO
MOS SLY YUP	SOM YLS PYU	GHI ZEP SUK	IGH EPZ UKS
WHA MUG OKA	AWH UMG AKO	ZEK ASK MET	ZKE SAK TEM
THO RUB GAM	HOT BUR AMG	GAS NIT TIS	SGA TNI STI
HUB MEL LIE	UBH ELM EIL	ELS EAR TYE	ESL ERA ETY
GET TAJ ZAS	GTE AJT AZS	ALS GAB KOA	LAS ABG OKA
ETA TAS RUB	TAE SAT BUR	LET JEU RIA	LTE UJE ARI
WHA ARM UPS	AWH MAR SUP	NAW PIA POM	NWA AIP OPM
NUS LUM ORT	SUN LMU RTO	ELK BAH MET	EKL BHA TEM
PUG HEN PAH	GUP EHN HPA	TAJ UNS REM	AJT SNU EMR
NOR BAY TAP	NRO YAB PTA	KOB GOS TAO	OBK SOG ATO
LAW GUT ZEP	AWL TGU EPZ	ZIT POI NEG	ITZ OPI EGN
GET MAW MOR	GTE AMW OMR	HOT MOG NAM	HTO GOM NMA
GUM KAE SAL	MGU AKE LAS	BUT URB WIS	UTB RUB SWI
KOI KUE ROW	IKO KEU WOR	LAM ALT SAE	ALM TAL EAS
SEW YEP NAH	WSE PYE AHN	OAT GIP PEA	ATO IGP EAP
NTH MUN JOW	TNH NUM WJO	BES MIR YUM	BSE RMI UYM
KOB OBA PAX	OBK ABO AXP	SEW NOS PAL	WSE ONS APL
OBI XIS HIM	IOB SIX IHM	RAM RAJ KOP	RMA AJR OPK
POT PLY LEX	TPO PYL ELX	YAR PES ZIT	AYR EPS ITZ
PUN WHY MAY	PNU YHW AYM	TOE POL JOW	OTE PLO WJO
NIM GNU GOT	MNI GUN OTG	ELK ELK SOB	EKL EKL OBS
JAM PIA WHA	MAJ AIP AWH	BAG GAP MAY	AGB APG AYM
HAO ROW GYM	OHA WOR MYG	YAK AHI NIT	YKA HAI TNI
UGH GNU OBE	GUH GUN EOB	ARB URB MAG	RBA RUB MGA
NOW NEB OBA	WNO EBN ABO	PAS HOE RIB	APS EHO BIR
TUP AIS HET	PUT SIA TEH	UPS SOL TEN	SUP LOS NET
HAM SAY HIE	MAH AYS EHI	SKY GEN BAN	SYK ENG BNA
LAY TAB WIG	YAL ABT IWG	UGH OBA GOX	GUH ABO OGX
MIG TIE YON	GIM TEI OYN	AWN WEN BEG	NAW WNE BGE
URN ROB LIE	NUR BRO EIL	WEB MAT MEL	BWE TMA ELM
POM TYE HUG	OPM ETY UGH	BEL LOP HIS	LBE OLP SHI
RYE JEU HIE	EYR UJE EHI	ASK MIX GOB	SAK XMI OBG
LAX HUG LEI	XAL UGH ELI	THE YEP IRK	HTE PYE RKI
ENS MOR OAT	NSE OMR ATO	SOU LAM TAG	USO ALM TGA
WAY TAB GET	AWY ABT GTE	WET HAP OAR	EWT PAH RAO
MUT MON OAT	UTM ONM ATO	LEU AIN YAP	EUL NAI PAY
MOT PAY KIT	OTM AYP ITK	EGO STY YEN	GOE YST EYN
PEG USE SAB	GEP EUS BAS	YEW GOA HAJ	EWY GAO AJH
PAN LIT ARB	NPA TLI RBA	YEW SAP HIM	EWY SPA IHM

Word	Nonword	Word	Nonword
SET WAS GIP	EST AWS IGP	PUT ARB KAB	TUP RBA ABK
NOB LIB YET	ONB ILB ETY	OBI ABA WAG	IOB BAA AGW
AMP HET JIG	PMA TEH GIJ	BUT SHE LEU	UTB ESH EUL
ASP KAS TIP	APS KSA PIT	ZOA GUT ZAX	ZAO TGU AZX
APT JAY SUE	TPA AJY ESU	PEH SIN WAP	HEP ISN PAW
ELK NAE SRI	EKL NEA RSI	PRY PUS MAS	RPY SPU AMS
SAL OWN SEG	LAS NOW SGE	HUB ROE YUK	UBH ERO KUY
ORT TAX RIG	RTO XTA GIR	KEG LAY TOY	KGE YAL YOT
SKA AWL ELS	AKS WLA ESL	REX BAP NOW	RXE PAB WNO
KUE PEG RIM	KEU GEP RMI	HAY RYA LAT	YAH RAY TAL
JEU BIN GOY	UJE NBI GYO	HET KEY LEZ	TEH EYK ZLE
WIZ SER PET	WZI RES ETP	GAB NOR YAG	ABG NRO GAY
NTH GAM SKI	TNH AMG SIK	GAG HAO MOR	AGG OHA OMR
AUK WOG SEI	AKU GWO IES	MEN NTH AIS	ENM TNH SIA
SIB HUN KEX	SBI NHU KXE	UGH SOY NUB	GUH YSO NBU
YAR AWN PUT	AYR NAW TUP	ZAG WEN SOB	AGZ WNE OBS
SOW YEP YAM	WSO PYE AMY	SPY NUB YUP	PYS NBU PYU
AYE AIN WAR	EYA NAI WRA	AGE NAE RIN	GAE NEA NRI
JOT HUG SUM	OJT UGH SMU	SPY SET ARK	PYS EST KRA
MOB ZAP UTA	MBO AZP AUT	ORS NIB HUE	OSR BNI HEU
KAB AIT LOG	ABK TAI OLG	SAL PHI KOR	LAS PIH ROK
LEZ TEA OMS	ZLE AET SMO	WOK YOM BIT	OKW MYO TIB
URN KAB SEL	NUR ABK ELS	HUN MAR NOB	NHU AMR ONB
PIU HAM OKE	IUP MAH OEK	KIT URP HET	ITK PRU TEH
IRE RIN AGS	EIR NRI ASG	OKA ASK PAN	AKO SAK NPA
BAY ZAG AGS	YAB AGZ ASG	MIB KIN AHI	MBI INK HAI
BOA POM JIB	BAO OPM IBJ	MIS BAH RAN	MSI BHA RNA
RIM YEN PST	RMI EYN TSP	GOT RHO REI	OTG ORH ERI
WYE SKA EMS	YEW AKS ESM	MEN WOS ZAX	ENM SOW AZX
MAX NIB HEM	XAM BNI MHE	THO SIM BOS	HOT SMI SOB
ABY KEG ZEP	BAY KGE EPZ	TIE TOW NOS	TEI WTO ONS
KAY HOY SOB	YAK YHO OBS	PAL TOW SET	APL WTO EST
YOW NOG YIN	WOY ONG IYN	RUE SEL WEN	REU ELS WNE
PAT AHS LOX	TAP HAS LXO	PUT RAG WAE	TUP ARG WEA
PHI REB LOP	PIH RBE OLP	KIS TUG YEA	KSI UGT EAY
TUN MUG MAY	UNT UMG AYM	NIB AHS NEB	BNI HAS EBN
WIG YAG TUB	IWG GAY BTU	GYM TRY BRO	MYG RTY ROB
BOP POM IRE	PBO OPM EIR	GUT SEL AMU	TGU ELS AUM
REM ZEK NAE	EMR ZKE NEA	TUG PEN RET	UGT EPN ETR
BIZ BIN WAX	IBZ NBI AXW	MAG GUM SOB	MGA MGU OBS
SIX POH KYE	ISX OPH KEY	TAS EAR BOT	SAT ERA TOB
GIT LAS AHS	IGT LSA HAS	LEZ HIE LIE	ZLE EHI EIL
OAR ABS MIG	RAO BAS GIM	ELS TAN YON	ESL NAT OYN
BRA HIT SAX	RAB HTI XSA	SAX NAW BIO	XSA NWA BOI
JUN LAW YOU	UJN AWL YUO	HOS HUT NUB	SOH UTH NBU
SLY HUN IMP	YLS NHU MPI	EMU RIM LEZ	UEM RMI ZLE
LEX AWL ZAS	ELX WLA AZS	OHS WAN BAL	HOS NAW BLA
UNS HAE BOT	SNU AEH TOB	ALB HAY ALP	LAB YAH LAP

Word	Nonword	Word	Nonword
TAB MAR TAU	ABT AMR UTA	LAG PEG LOP	GLA GEP OLP
NOG WAP PET	ONG PAW ETP	HUG ORB SOX	UGH BRO OXS
WAY HAT OAT	AWY ATH ATO	KOS GAT YIN	OKS GTA IYN
YEP HON BIG	PYE ONH IBG	WHY RAH BUY	YHW HRA BYU
GOY ETA NOG	GYO TAE ONG	AGE ROM BUN	GAE MOR UNB
ION GOB PUG	ONI OBG GUP	LOP ERG SAE	OLP EGR EAS
ZOA ALE TEL	ZAO EAL ELT	ERS RUB TRY	SRE BUR RTY
SEG JAW GIB	SGE AJW IBG	WIG BES HEM	IWG BSE MHE
ROB ASP PAT	BRO APS TAP	RIP JAG SIR	IRP AGJ RSI
AHI LEI ELK	HAI ELI EKL	BET NAE YEW	TEB NEA EWY
YAK GEM GAR	YKA MGE RGA	KIP UTS UTA	IPK SUT AUT
KOP MOA NUT	OPK OAM TUN	GEL MOB SPY	GLE MBO PYS
HOE ANI TOR	EHO NAI TRO	AWN PEW NAM	NAW WEP NMA
RIP HAP AIL	IRP PAH IAL	SYN HIP PER	SNY IPH REP
GOB TOP ZEP	OBG POT EPZ	TEL RAJ BUT	ELT AJR UTB
NAW TUB NIP	NWA BTU NPI	PIU RUG NEG	IUP URG EGN
YOK SUK HAS	KYO UKS HSA	URN SUB PIU	NUR SBU IUP
ZIN GAT KOI	NIZ GTA IKO	NIT PES GHI	TNI EPS IGH
RIP IRE NAB	IRP EIR BNA	YEN KOR YUK	EYN ROK KUY
IMP NOR RET	MPI NRO ETR	TEW ENS RAJ	WET NSE AJR
JIG NIB POW	GIJ BNI OWP	HEY AGO BAL	YEH AOG BLA
WRY MIL KAB	YRW LMI ABK	HIS RUB KIP	SHI BUR IPK
SER AIL MEN	RES IAL ENM	GUY PAP BEG	YUG APP BGE
PRO KEP MIR	RPO PEK RMI	NIB AIM YUP	BNI IMA PYU
RAX RAI POM	XAR IAR OPM	TOY PAP HOB	YOT APP BOH
PAX HOE HUB	AXP EHO UBH	YES RES RAP	SEY SRE PRA
ARM HAM SIM	MAR MAH SMI	MHO SAY POT	HOM AYS TPO
TAW POT ETH	TWA TPO THE	RAI ION HUG	IAR ONI UGH
JAR PUS SIP	JRA SPU ISP	SOB BUT RES	OBS UTB SRE
JUS MIX PEW	JSU XMI WEP	MET AMI POL	TEM IMA PLO
SON PEG POW	SNO GEP OWP	NOR UGH OHM	NRO GUH HOM
MAS BEN NOS	AMS EBN ONS	ERN LAT PHT	ENR TAL THP
TWO JUT AIN	WOT JTU NAI	ROM PAS SAU	MOR APS SUA
AIT PIG SHE	TAI IPG ESH	POL KUE YAM	PLO KEU AMY
MAE RAS YAP	AEM ARS PAY	ABS ONE GOS	BAS ENO SOG
ONE PES LUG	ENO EPS UGL	KOB YAG WAB	OBK GAY BWA
OPS PAS BOX	PSO APS BXO	JOE RAH SUN	EJO HRA UNS
ZAP YOM OUR	AZP MYO ROU	SYN BAT UTS	SNY BTA SUT
YET ABS SIB	ETY BAS SBI	URB HIM WOS	RUB IHM SOW
MOP OBI NAM	MPO IOB NMA	KOP WAW MAW	OPK AWW AMW
KEN AIN NOB	NKE NAI ONB	EMS ZAP RUT	ESM AZP RTU
NAW AXE TAX	NWA XEA XTA	KOI YAR HUN	IKO AYR NHU
WAS ALP BOS	AWS LAP SOB	OBI TWA OBE	IOB AWT EOB
RIM GEY JUS	RMI EGY JSU	WEN SIN HIS	WNE ISN SHI
MOB RAT MOS	MBO RTA SOM	RUB YOU PUL	BUR YUO ULP
KIR GAL AZO	KRI GLA AOZ	PHI NUS ITS	PIH SUN TIS
GIE LOT EGO	GEI OLT GOE	AIT OBA SKY	TAI ABO SYK
REI USE ROB	ERI EUS BRO	NOR GYM WAR	NRO MYG WRA

Appendix F: Two words text stimuli

Word	Nonword	Word	Nonword
TABES EUROS	TBASE RSUEO	SHENT MOUSY	TNEHS UMOYS
MEALY HALMS	EMLYA MHLAS	BRUGH SAYER	UGRHB ESRYA
BLANK BIROS	KBALN OBSRI	GOBAN UMAMI	NBGAO UAIMM
UNHAT HYMNS	AUNHT NYMSH	BEANS MANGA	ENABS MGNAA
PROWL MERES	PRWOL RSEME	SWAGE EPHAS	WGEAS HPASE
RIMER BOGEY	REMRI EGBOY	TULES BURLS	TUELS LRUBS
HUMAN BLENT	HUAMN ELBNT	HOAGY HOWKS	OAHGY SOHWK
MILKS GAPES	IMSKL SEGAP	TALKS ANKUS	TSKLA NSUAK
PLATS MONOS	PLTAS ONSOM	MOANS LIMAS	AOMNS MASLI
HELOT HALOS	LTOHE AOLHS	ARAME BETEL	AMARE ELEBT
BROME INSET	RBOEM NTSIE	LENIS MUONS	NIESL SUONM
WAWLS BROWN	AWSWL OWBNR	PHONY KORAT	PYNOH AKRTO
UMIAK PLAGE	AMIUK PEAGL	ANISE STENT	NASEI TESTN
LYING RAPES	GLNIY RESPA	KNISH TALKS	HSKNI TSKLA
GAUGE BETEL	AEUGG ELEBT	AGERS MURKY	GSEAR RMKYU
WOMAN WOMBY	MOAWN OWBMY	RUSTS STASH	TRUSS ASTHS
MITES YELPS	ITESM ESLPY	SPURT PIETY	RUTPS TPEYI
LIMBS PHOTO	BLIMS HOPOT	MOTEY GRUMP	TEMOY URPMG
SKUAS TRASH	KSUSA SATHR	ROGUE ZOMBI	OUGRE OBMIZ
WORTH GLIAL	WRHOT LIALG	RESEW PROLE	WRESE PLEOR
EXITS PALEA	SEITX EAPAL	PLUSH GUANS	LSUHP SGAUN
SYKES BLAST	SEYKS BTLSA	METER SILTS	ETEMR TSLIS
HAOLE STAPH	LAEHO APTSH	WALER SEPIA	AEWLR SPIAE
LAYIN RESTS	INYLA RETSS	EARTH JISMS	HAETR MISJS
KERNS STEMS	ERSKN SMTSE	LIKES OUTER	SELKI UEORT
LIBER SASIN	LEBIR NISAS	STAGE BEGOT	TSEAG EGTOB
APTER SLIPS	EAPTR SLSPI	TURNS MINKE	TNSRU MIEKN
TOPOS ERUGO	TOPSO EUORG	HERMS BRUSK	HESRM KRUBS
BATON MURKY	TABNO RMKYU	GORSE PEKOE	REGSO OEPEK
SHUNS PLAYS	SHNSU PALSY	OBEYS EYRES	YEBSO SERYE
YOUNG AZINE	GYOUN NIZEA	GLOWS POBOY	GLWOS YBPOO
IMAGO PEAKS	IAOGM KAPSE	OUTBY SIGHT	OYTBU THISG
BRUGH HOPES	UGRHB SOPEH	SILEX MALTY	IEXLS LYTMA
THROE BOGEY	OETHR EGBOY	THEWY PLOTS	EHYTW LOSTP
ALONG SNORE	NOAGL ORESN	TELIA GLOBE	IEALT LBEOG
MOLAR AGLET	OLMAR ETALG	APRES HOLTS	ESRAP LTSHO
JUBES BEGUM	BEUJS GMEUB	GORGE LINOS	OGREG INLSO
THING SPRAT	NIGHT TRAPS	RAGIS TERGA	AGSIR ATGER
WIMPY RAKUS	WYMIP ARSUK	AXING TOWNS	IXGAN NWSTO
TOLAN MOTEL	NOLAT LEMTO	GRIPE MESNE	EIRPG ENSME
KNOSP PINON	OSNPK NPONI	SMARM HEIST	MSMRA HETSI
YERKS SLING	SREKY SGINL	MIREX NOISY	MRIXE ISNOY
PYINS ROUTS	ISYPN SUOTR	SWINK RAGIS	WKISN AGSIR
PROGS PREYS	PSGOR PEYRS	BUTEO STORM	TBUOE OTSMR
GYROS SNOTS	SGROY NSOTS	WASHY ISTLE	SWHYA SILET
SOLAN BITES	NSOAL SBITE	WAXEN SLEWS	NWAEX SWSLE
WEARY WHINS	YEAWR NWSIH	SLUNK SKEAN	SUNKL KSNEA
OASTS SEMEN	ASOTS EMSNE	STALE GROTS	SATEL SROGT

Word	Nonword	Word	Nonword
ALOHA SHILY	OLAHA HLSIY	BRATS HOSEN	ABTRS HNSEO
TATAR LURES	ARATT SRULE	POUTS MORPH	UTPOS POHMR
HOLMS RAMIE	HSOLM EMRIA	SERIN RAKUS	IRSNE ARSUK
REWIN TAWSE	WRNIE WSTAE	BRIMS BOXES	RBISM SEOXB
GRIME KEIRS	EMIRG ESKRI	SHOER PUPAE	ROSEH PUAEP
HOYAS POLES	OHAYS OSPLE	SHORE BOITE	OSHRE OEITB
OATER HALMS	TREOA MHLAS	SMARM WARTS	MSMRA WTASR
PORKS MANGY	ORSKP GMYAN	ELINT SATYR	TNLIE YATRS
GALAS BIALY	LSAGA BAIYL	HOMES PEONY	EMHSO YPNEO
JAPER LOBOS	PJREA SBOLO	TIRES ALANE	ESRTI LENAA
LARKS NITES	RSKLA IENST	MURAS GROUT	AUMRS ROUTG
YOKEL LAHAR	LOEYK HLRAA	PENGO PLYER	GPENO PELRY
BUNKO HOLMS	KOUNB HSOLM	TABUN AUNTS	BTUNA ANSUT
ONLAY MOLAL	ANLYO LOAML	BROIL TOPIS	IOBLR PSOTI
MESHY BANGS	MHEYS NSBAG	ZINGY KARST	IYZNG TRSAK
RAZOR GYRES	ROZRA SREYG	MORSE BRUGH	OSERM UGRHB
GHOST BUSTY	STOGH STBYU	SLURB PLEWS	RLUSB PLWES
SPINY NEUME	NYIPS EMENU	RAITA WITHY	IATAR YITHW
PAPAS HOSES	ASAPP HSEOS	GLUGS SKEIN	GLGSU NSIEK
TABER GUILT	BTREA UGITL	TILES AGAZE	LTSEI ZGEAA
PRIER HAYEY	ERPIR YAHYE	GOERS LYSIS	RESGO SYSIL
URIAL KORAS	LUIRA RSAKO	PEKOE TALAS	OEPEK SALTA
TANKA BASAL	KANAT ABLSA	AMENT PRIME	TMNEA PIMRE
BEAUT ASPER	ETBAU PARES	BRITH STOAE	RIHTB TASOE
HOMIE LITAS	IMHEO TLAIS	BITSY LEONE	BTSIY ONLEE
PLOTS AROMA	LOSTP AMAOR	TURBO BUMPS	RTOBU UBSPM
LAWNS BEMIX	LSAWN MBXIE	MINKE UNMET	MIEKN ETNMU
ALGAE ALGAE	AEGLA AEGLA	BURNT SKINT	RBTUN NTKSI
KITER LUMAS	EIRTK AMLUS	SHEAS TYPEY	EHASS YPEYT
LEARY GOWNS	RAYLE SNWOG	MONOS MOXAS	ONSOM OSXAM
GAWPS MOHEL	GWASP LEHMO	TALUK AUNTY	LTUAK NATYU
BOYLA RUBLE	ABYOL LUBRE	MARLY SURAL	YRLMA LRAUS
GESTS YENTE	SEGTS ETENY	UHLAN UMBOS	UALHN MSOBU
KILNS SHAKO	INSKL KOHSA	HYENA ARIAS	EAYHN SARAI
BIRLS KETOL	BILSR LKETO	UNWET SHULS	NUTEW USLHS
AWAIT LOUIS	AWTIA UISLO	GNARS MILPA	SNRAG MPILA
SINGS BANJO	SIGNS NBJOA	ETNAS BELGA	ASNTE LBAGE
TOGAS ENSKY	ATSGO NEYSK	WAGES MINIM	GESWA MNIMI
MIMES TEXAS	SMIME ETSAX	EYERS WHAMS	EYSER HSAWM
INPUT ROUTE	PUITN RTEOU	AURAE EARLY	AUREA AYERL
BAKER LIMNS	EABKR MISNL	SPEWS MASAS	PSWES SMSAA
MIXER EMBAY	XMIER YEAMB	SOKOL KORAS	KLOSO RSAKO
LIEUS TORES	SIEUL ERSTO	WITAN SLUGS	ATNWI GLSUS
MASER WHORT	REAMS RWHTO	JINGO YOUTH	GINOJ OTYUH
GUMBO AZANS	BUGOM ZANAS	PLUMB ARMER	LBPMU ARMRE
GERAH ANSAE	RGEAH AESAN	STOMP GLYPH	PMOTS YGLPH
NEWER MIRZA	NREWE AZMRI	PASHA ORBIT	SAPHA ORTBI
OLEUM TWINY	ULMOE WNITY	PERKS LUSTY	ESRPK STLYU

Word	Nonword	Word	Nonword
ROILS PHLOX	LOSRI PHXOL	WIMPS OMBRE	PISMW OMRBE
GONGS MONEY	GSNOG ONYEM	SEPTA STYES	ESAPT EYSST
HABUS MATZO	AUBSH TAOMZ	BHUTS MEOWS	SUHBT WSMOE
WONKY ALGAS	WKNYO AGLAS	PLASM MATZA	PLSAM AMTAZ
EXURB PIANS	XEBUR NISPA	KRUBI RENEW	BRKUI RWNEE
MOTEY GRAIL	TEMOY RAGIL	THAWS NUTSY	HSTAW TSUNY
WYLES LAMES	LWEYS MALES	ISBAS ATONE	ASIBS OATNE
TROMP AKENE	OMPTR ANKEE	LUMAS PALPS	AMLUS LPSPA
SNOBS GLEYS	OSBSN GYSLE	SHORN BIRSE	NROHS BRESI
GABLE NORTH	ALEGB NTHRO	SATEM TILES	TAMES LTSEI
TRUER OUPHS	ETRRU SOHPU	JULEP RESAT	PUEJL ASETR
SEPAL TUMOR	LAESP URTMO	ELANS JERKS	NALSE KERJS
EIKON PANES	NEKIO SAEPN	ZAIRE HOKUM	EZARI MHOUK
TIMER SERGE	REMTI SGREE	PUJAH LOSER	UPAHJ RSEOL
HUSKS EYERS	SKUHS EYSER	BIKIE LOSEL	EIKBI SOLEL
KLIKS SUETS	LKIKS EUTSS	BATIK HUNTS	BITKA TUHNS
TORTE SLOSH	ETORT LOSHS	THERM LEAPS	TMHER SLEPA
NOWAY ULNAR	WNYOA LARNU	SONLY SYREN	SLNOY RNYES
BOUSE SOILS	SBUEO OISLS	MITRE PAYOR	MERTI YARPO
GLIMS ARIEL	MIGSL IAREL	SANER BEGUM	ESRNA GMEUB
RHEME SENSE	HMREE NSESE	WHITE STYLE	HIWET YTELS
GENTS MEATS	SGENT EMATS	MILOS ALONE	OMLSI LEAON
BURNT LAMPS	RBTUN AMPSL	NIXES MISTY	XINSE TYSIM
HARTS ZIRAM	SHATR ZMRAI	MUNIS OUTBY	NSUMI OYTBU
NARIS BOSKY	SANIR YSBKO	SLOTH BRUME	TOLHS MREBU
SITAR INURN	IRTAS IRUNN	REWAX WHIPS	WARXE HWISP
TUYER ANTRE	TYUER ETRAN	KILTY PARIS	KLYTI ASRPI
PLANE SLOPE	ANEPL PELSO	PLEAS JUJUS	LPASE UJSUJ
LARGE SMOKY	LGARE MKYSO	WEANS EMBAY	EWASN YEAMB
WISES BONGO	SESWI GOBON	HORSY BIKIE	YRSOH EIKBI
TWIXT PARLE	WITXT ELAPR	THYMY SILOS	YHTYM SISOL
HELMS ISLET	LHSEM TSLEI	TRAIK SKUNK	ATRKI NSUKK
SISAL IXTLE	LSASI XLIET	ETUIS GUTSY	TIEUS USGYT
STETS MURKY	TSTES RMKYU	AMAIN NORTH	IAMAN NTHRO
MEATY POISE	AEMYT EOSPI	PRAMS HOSTA	SRPMA TSAOH
GLINT PEONY	INGTL YPNEO	AGHAS MASER	HAGAS REAMS
HALES JANES	EALSH JNEAS	BANTY JUKUS	BNAYT USUJK
HAJES TABLA	AHEJS BALTA	GUISE ZOMBI	UIGSE OBMIZ
SPLAT LABEL	LPSAT ABELL	TABER HAKES	BTREA SHEAK
LEBEN GAMBE	EBNEL BAGEM	LASES WARMS	ASELS SWRAM
WHERE UNBOX	REHWE UBONX	OUPHE LINGO	HOUEP GIONL
KUKRI UNAUS	KRKUI SAUNU	MBIRA PANSY	IBAMR ANYSP
LINES SWEPT	NIELS SPETW	AGENT MOLAR	NTGAE OLMAR
BAWLS OPALS	LABWS SLAOP	BANES SYLIS	EBNSA LSIYS
NEWSY SABER	ENYWS ABSER	NITER MATEY	TRNEI TEAMY
WEARS KOMBU	RWSEA KBOMU	PLANE HAKUS	ANEPL UKASH
STAMP KENOS	APMTS SNKEO	TAPER UMBER	PTRAE UERBM
WALTZ MINES	TWZAL EMINS	PRATS AZUKI	PRTAS AIKZU

Word	Nonword	Word	Nonword
GOTHS BOUSE	TSOHG SBUEO	BAWLS EMIRS	LABWS EMRSI
OURIE MIAOW	EIOUR WOIMA	LORAL ABOUT	OLRAL OBTUA
PURIS KNURL	UISPR NURLK	NAPAS ROSES	NAPSA SOESR
INEPT TAPES	EITPN PETAS	ZLOTE EBONS	LZETO SNOBE
SHUNT TESLA	USTHN AETSL	PARKS TOKEN	SRPAK KNEOT
LAYUP SYLIS	UAPYL LSIYS	EXULT REARS	ELXTU REASR
HIRES SLIER	RISEH IESRL	TEASE TYRES	EATSE YERTS
AXONE EPHOR	NAXEO EOHPR	WISHA BILKS	SAWHI BKSLI
YANGS SHOYU	SYGAN OYUHS	BOLUS GNARL	OLUSB RGLNA
HORNS BELGA	HOSNR LBAGE	PROEM ZESTS	OMPER TEZSS
RUBES BRUIT	BEURS ITRUB	TUXES BLAWS	ESUTX ABLWS
REWAX STEIN	WARXE NIEST	GIRTH NUTSY	IRHTG TSUNY
METAL TRUMP	AMETL UPTRM	BIGLY GLUME	GBILY MLGEU
PUSES PAPER	USEPS APERP	BREAK NITRO	ARBKE INTOR
KILOS KYLIX	ILSOK KYXLI	GAINS PORNO	GNASI OROPN
SENGI THUYA	IGESN UTAHY	POUTY BULGY	UTYPO UBYLG
NOMES SLIPS	NEOSM SLSPI	GLAZE HASPS	GZLEA SPSAH
RULER UNRIP	RERUL PRNIU	TUNES MOTEY	STENU TEMOY
ROTIS WOKEN	OSITR KNEOW	HALER PINTA	AEHLR TNPAI
GOATS KNITS	OATGS NTISK	GAZER KNOBS	AGEZR ONSBK
KERNS AREPA	ERSKN AREAP	STORE INEPT	OSTRE EITPN
SIALS SPUNK	LASIS PSUNK	ARTAL LUNES	RTLAA ELSNU
AMOLE GYBES	LMEAO EYSGB	INURE WOMEN	RNIEU NMWEO
MUSER RASER	SEURM ESARR	TAKEN RUGBY	ANTEK BYRGU
RUING SKELM	IGNUR ESLMK	BASER MEALY	SRABE EMLYA
BAITS HURST	SITAB UTSHR	ANKHS MUHLY	ANKSH MHYLU
OPERA PAIKS	PAORE SAPIK	PYXIS JUNTA	XYISP NTJUA
UNWIT YEAHS	TWNIU HYESA	HALON RUNGS	OAHLN GUSNR
SUPES BLIMY	PSUSE IMBYL	NYLON TITAN	YLNON IANTT
MESAS WEARY	SAMSE YEAWR	PARTY MUSTS	PRYTA STUMS
TERGA ABELE	ATGER LBAEE	GETUP SURAH	GEUTP RHASU
NEWSY KERNS	ENYWS ERSKN	LONER WASTE	ELRON STEWA
PINTS POPSY	PISNT YOSPP	KOLOS GUANS	OSKLO SGAUN
ANGST OUPHS	GSANT SOHPU	SPRAT UNAIS	TRAPS SUINA
TOKES RAWIN	KSEOT INWRA	GLIAS SLOSH	GILSA LOSHS
PASTS BUNYA	TSPSA BNYUA	SMITH TIERS	IMSHT ITRES
GIPSY ISLET	SPGIY TSLEI	THOLE GROWL	EHLOT WOLGR
SIKES LEGIT	IKSES EGILT	REPOS HANKS	RPOSE KNAHS
HEATS NIXES	ETSHA XINSE	TIROS GAULT	ORTIS GTULA
PRIOR RESAT	ROPIR ASETR	BOUSY WHALE	SYBUO EHWLA
TASTY KNAPS	TYSTA KNPSA	GRIST RAWLY	TRIGS WARLY
SOREL SAPOR	OLSRE RAPOS	TURNS ILEUS	TNSRU ELUSI
BHANG HAEMS	HGBNA MSHAE	RAXES PRINT	XSREA IRNPT
KORAS MUSER	RSAKO SEURM	GUEST ALIGN	SGUET NIALG
THROW SHAME	TORWH SMEHA	HALMS BINER	MHLAS RNEBI
NESTS POUTY	STNSE UTYPO	PISTE MULES	ISTEP MUELS
OXIME PANGS	EIOMX APSNG	MOILS RESOW	SLMIO EOWRS
TULIP ZAIRE	ITPUL EZARI	OXIMS BLAMS	MSXOI MASLB

Word	Nonword	Word	Nonword
MULES STEWY	MUELS STWYE	BANGS BLUEY	NSBAG YLEBU
MATIN HOLMS	MTNAI HSOLM	MALMS MINKE	LMSMA MIEKN
ORATE RESAT	RETAO ASETR	SHUTS LIKEN	STHUS LNEIK
MOLAL TOGAS	LOAML ATSGO	LAIGH HERLS	HLAIG HLRSE
BAWTY THEGN	YABTW GHNET	MONIE ANKHS	OEMIN ANKSH
BEBOP MOKES	EBOPB EKSMO	ABASE WARES	EABAS EWRSA
SMELT REHAB	LEMST AEHRB	MARAS HUSKS	RAMSA SKUHS
HASTY HIJRA	AHTSY RHAIJ	STAIG PULIS	AGTIS SPILU
RUNTY ABELE	YRUTN LBAEE	LEARN LIGAN	RANLE NIGAL
GAGER METER	AGERG ETEMR	LUNAR MAIRS	ANRUL IAMRS
YORES AGLOW	YSEOR GAWLO	TABLA HUMOR	BALTA UMRHO
STOAI TWAES	ASTIO SWAET	MOLAL SYLIS	LOAML LSIYS
LAITH BUTEO	TILAH TBUOE	TRONE GLAZY	RONTE AGZYL
PAISA PLATS	SAPIA PLTAS	SAHIB REXES	AIBSH SEXER
OPENS KNOPS	ENSOP SOPKN	WHIPS LARKY	HWISP YARLK
SOTHS SHRIS	OSHST RSHIS	SPEIR SHEIK	PSEIR KIESH
WEIRS PYROS	ESWRI YOPRS	SLANK WHETS	NAKSL ESHTW
SLIMY AWARE	LIMYS ERAAW	BRUNT SHIRK	BUNRT HKRIS
GROAN IAMBS	GOANR SIBAM	SYKES BIALI	SEYKS AILIB
BLANK SOYUZ	KBALN YUSOZ	STILT ORANG	TILTS NAOGR
ABRIS SPIKE	RBISA SKPIE	LOUPS GALAX	SPLUO AXALG
PRIZE INTRO	IEPRZ ROINT	HYING SALPA	GNHIY APLSA
PAROL TAINS	OAPRL TNSIA	SOJAS KOALA	JSOAS ALAKO
BELGA TOLAS	LBAGE ASLTO	TRUTH BERKS	RTHUT KBESR
LATHS ASTER	TALHS ASRET	SORTA KANZU	OSTRA NKUAZ
SALON SOLUM	LNAOS LOUSM	TOUSE TRIES	ESOTU IESTR
LUNES GLUTS	ELSNU SLGUT	RESAT RUBEL	ASETR LBRUE
BEAUX KEMPS	AEBUX PMESK	KNAPS TRAMP	KNPSA MPART
STETS PULER	TSTES PELUR	MOTEL SATAY	LEMTO AYATS
YAMUN LABEL	AUYMN ABELL	MANLY SPARK	LMNYA SAKPR
TALAR STONY	TLRAA TYNSO	KIBES HAPLY	KSEBI PHYAL
PLINK BOARS	LNKIP SRBAO	MOIRE LEBEN	MORIE EBNEL
LEGAL SIZAR	GELAL ASZIR	HEIGH GRUEL	HEGHI GRULE
POETS SPITZ	SOPTE SZTPI	PAXES SKYEY	XESAP YKSEY
LOBES GEUMS	LEBSO SEGMU	ZERKS SPAES	SRZKE ASPES
GOBOS BLABS	SBOGO LBSBA	ETNAS BROMO	ASNTE ROBMO
WINKS REBUS	WKISN SUBRE	GRUME KALES	ERGUM ESAKL
OPERA BOWSE	PAORE BOSEW	SLURB GLANS	RLUSB GLSAN
TEMPT BELIE	TEPTM BIELE	WITHE TWINY	HWETI WNITY
TAPIS RAKUS	SAPTI ARSUK	WAXEN USHER	NWAEX RSEHU
JAMBE ROWEN	BMAJE NWEOR	SLUMP SWOBS	MSUPL BOWSS
KOANS SWATH	KSONA HTWAS	WAMES KOHLS	EMASW HSOKL
MOILS ONLAY	SLMIO ANLYO	LIARS TENIA	IRASL ANIET
ZETAS GEARS	TAZES ESRAG	MARKS AXIAL	RAMSK AILAX
TABES BARYE	TBASE BREAY	MIRKS SKELP	RIMKS KLSPE
PETAL THORO	AETPL OHORT	TORAH RELET	RHOTA ELTRE
SUBER HALES	BERSU EALSH	STORE STINT	OSTRE SITNT
MAGOT KITHS	OATMG TKIHS	SOJAS SAINT	JSOAS TASIN

Word	Nonword	Word	Nonword
ROWAN INKLE	AWORN KELNI	MATHS EATEN	HTSAM ENTAE
BEGUN ANLAS	EGBNU NALAS	UNLET YOKEL	ULNTE LOEYK
ATOMS WRATH	SMAOT HTWRA	WROTH BEIGY	RHTWO GEIYB
TRYMA AGING	MAYTR GAIGN	RELAY GAPES	AYREL SEGAP
BOHOS SPITS	OHOBS PSIST	SHEAR YOKES	SHERA OESKY
RETIA BROIL	ARITE IOBLR	WAGER STIRK	GARWE SRTKI
PISTE MASON	ISTEP OSNMA	HANKS BIONT	KNAHS INBTO
ENOLS THUYA	LNOES UTAHY	MARSH BLUER	SRHAM LBREU
SLIPS POTSY	SLSPI YTOPS		
MINKE KOINE	MIEKN ONEIK		

Appendix G: One word text stimuli

Word	Nonword	Word	Nonword
SPELUNKINGS	LKUINGSSNEP	UNSPIRITUAL	LPNUTSUIIAR
RIGHTEOUSLY	RGUTOYELSIH	APOSTOLATES	ASAOESTTOLP
TELEGRAPHER	RAGPHETEELR	HEMOPOIESES	OPEHSSOEMIE
ITINERATION	ITNATEIROIN	PEASANTRIES	ISAEASNERPT
EUHEMERISTS	HETSEMSEIUR	ENTHUSIASMS	HMTSAUISNSE
OXYGENATION	OIOGXEANTYN	PAWNBROKERS	RSPNOREAKBW
ELUTRIATORS	RLEORISTUTA	POLYESTROUS	TLUEYORSOPS
MARTENSITES	TMTRAENSIES	UPGATHERING	ETHRIGPNUAG
WHITEWASHES	HAWIESSHWET	SURPRINTING	RGTPRNUNSII
NONEARNINGS	SNANEINNORG	PERSONALITY	OESPRIANLYT
EMPLOYABLES	AMLBYPLOSEE	MULTIENZYME	MIZETMUYLEN
GENIALITIES	ENILTSIGAEI	REIMPORTING	PINERTMIROG
PRIESTLIEST	IESLSPITRTE	REREPEATING	REATNEEGPRI
PROSELYTIZE	EREPOTIZLSY	TASTEMAKERS	AETASKTESMR
REGATHERING	HINETRGEARG	PERIPHERIES	SEPRRIEPIHE
HOUSEPLANTS	EPNOSTLUHAS	GRUMBLINGLY	UNMRIGBYLGL
OBSTINATELY	LTENBSIOAYT	STIPULATION	TNASPLIOUTI
HEMERYTHRIN	INEHRYERMHT	STRANGERING	RGNRIGTSEAN
SIGNALMENTS	IGMSSNTELNA	MULTIPAROUS	RSPULITAMOU
PREPRINTING	PRPRGNITNEI	POLYTHEISMS	LPETHYSOISM
SYNTHESIZER	HETSNZIYRES	BREASTWORKS	RBTKAOERSSW
BOMBINATION	INBOTNOIABM	NONLUMINOUS	LMUNNOUISON
RINGMASTERS	EGISRNTARMS	TRISKELIONS	ERSTLIOIKSN
BOURGEONING	NOGREUGBONI	EXALTATIONS	INALTXESOAT
INSULATIONS	SIAOTSNLUIN	ALIENATIONS	ALNONAITSIE
SALINOMETER	SEINELARMTO	OPTOMETRIST	TPMRTEITSOO
MISTRUSTING	IMRITSNUGTS	INSURGENTLY	TLYSUIGRNEN
MONOTERPENE	NEMOEERNPTO	STRAIGHTEST	THETGSRTAIS
MIGRATIONAL	LMINAITAGRO	TEMPORIZERS	STIEEMORPZR
INTERNEURON	EUTNEIORRNN	MESOSPHERES	OSEPHERMSES
IMPALEMENTS	MAITSLNEMPE	REPLENISHER	ELHEPERNRSI
TRANSPLANTS	PRNLASSATTN	PROPRIETARY	IATRREPOPYR
PEROXISOMES	OESOEPIXMRS	AUTOLYSATES	TLASEYAUOTS
NEUTROPHILS	POLNESHUITR	PERSONALIZE	NSPELRIAOZE
THUMBPRINTS	TRSHTMUPINB	BARBAROUSLY	SRBYBORAULA
MYTHOGRAPHY	RPGYAMYHTHO	WINEMAKINGS	SWEMNAINIKG
PROTEINASES	SNATEEISPRO	NONPARTISAN	ONIPANNATRS
OUTPATIENTS	TAOENUITTSP	ALTERNATING	TNGEATIARLN
PARAMAGNETS	ASEARMTPGNA	LEGISLATING	TGSNLELAIGI
PROTONATION	ONARTPONIOT	REMIGRATION	NAGRIMEITRO
TAUTOLOGIES	GOTSULEOIAT	THAUMATURGY	RUYMAUTHATG
UNAMBITIOUS	IMUBTOAIUSN	HELIOGRAPHS	LOPGRHAHSIE
PHENOMENONS	ESHMNNNOEPO	ANTITUMORAL	OTMUNRLATIA
HAPTOGLOBIN	OPALNOIBTHG	ASTRINGENTS	GTNSTSNEAIR
STIMULATORY	YOTATMLRIUS	BREAKWATERS	TEKBRWARASE
EPITHELIUMS	UPMEITIHSLE	ABIOGENESES	AEGNSBEIOSE
PREMOISTENS	STERINPOMSE	ORIGINATION	ITOANGRIION
OBLITERATES	AERIEBTTOSL	ASPARAGINES	RSNEGAAASIP

Word	Nonword	Word	Nonword
SHANTYTOWNS	SHYSTNATWON	RESYNTHESES	YSTEHRSESNE
ORIENTALIZE	OAINERTIEZL	PROPHESIERS	RHPOSRIESEP
POSTERITIES	IPTOIRESEST	SPONSORSHIP	NOSRPPHSSIO
AMELIORATES	EMARSAIEOTL	ALKYLATIONS	YTSKNLIOLAA
UNLEARNABLE	ABELNNALERU	ANGIOMATOUS	MGOAITSOAUN
INTERPOSERS	PIRSEOETNRS	LIPOGENESES	ELEOGIPESNS
ENWREATHING	IARENGWTHEN	ISOBUTYLENE	NETSELUOIYB
SHOESTRINGS	SGEIHSONRST	SANITATIONS	NSATIOITANS
STRATHSPEYS	EPSRSSYHTAT	BIRTHRIGHTS	SRIGHHRTTIB
ANIMOSITIES	ASETIINOISM	PRELIMINARY	RAINPIMERYL
EMPOWERMENT	REMEPOMENTW	ABSTINENTLY	LASTNEIYNTB
MANORIALISM	AMIRLIASONM	MISANALYSES	LMAISEAYNSS
SUPERPOLITE	PTISLEOUEPR	PALMERWORMS	PRAMSMOLERW
SUBLUXATION	LXOINBSUUTA	TRAUMATISES	ATSIEUTSMAR
UNREPENTANT	APTNTUEERNN	THERMOPHILE	HIRETLHOMPE
KINESTHESES	KSESIEEHTNS	TROTHPLIGHT	PTGIROTLHHT
NEWSWRITING	NREIGNTWISW	SUBREPTIONS	RSUPOTBNSIE
STRONGBOXES	GBTOXEONRSS	SPONGEWARES	GEWSRAEPSNO
NEIGHBORING	RNGINHGOBEI	SEMINATURAL	URMIENSATAL
RAINBOWLIKE	KBROWNLIEAI	ANEMOGRAPHS	EGRNAAMSOPH
PRESENTABLY	YTEPLNBARSE	SKYWRITINGS	YGSWIRTKNIS
MARGUERITES	MSRITUAEGER	AMPHIBOLIES	ESALMOPBHII
RUMINATIONS	UASNIMNRIOT	AMELOBLASTS	TMLAAOLSBSE
SALUBRITIES	BLISERUSIAT	MULTIPHOTON	MHOIUPNTTLO
PERSUASIONS	SNRAIUPSSOE	INHALATIONS	HITIAONALSN
ANIMALITIES	AISEILTNIAM	HYALOPLASMS	OHLSLYAMPSA
ENMESHMENTS	THESMESNMNE	INTOLERABLY	EYNALOLBTIR
MAYORALTIES	SYIARLTMAEO	INTOLERABLE	LORETAEBLNI
METALWORKER	KAMRRLEOWTE	SENSITIZING	ZISNTEINSIG
WESTERNISES	SWSISEEENTR	WATERSPOUTS	PERSTSWAUOT
PHONOGRAPHY	RGOPHOYNAPH	EXUBERANTLY	YAEUTNBELRX
REGENERABLE	ERELNEGABRE	IONIZATIONS	ITSIONAOIZN
MIXOLOGISTS	OSGIXLMSTOI	REALPOLITIK	TKLIOPEALIR
MARATHONERS	EAOHARNRTSM	AGITATIONAL	GIOLAAATNTI
MANAGEMENTS	AESGTNMMNEA	ABJURATIONS	BAISTUARONJ
GENERALIZES	EAELRIZSENG	NYMPHOMANIA	YOHMPNAAIMN
GENERATIONS	ESGOIERTANN	JOURNALIZES	JOSIRELNZAU
STABILITIES	BISLIITSTEA	HAIRSTYLIST	YTRSTLHAISI
LIGHTSOMELY	LOYTELGSIMH	PASTORALISM	ATAIRPSSMOL
PUSTULATION	ASOLNUTIPTU	RESTRAINERS	NETISERSRRA
UNREASONING	NANOINERSGU	PALPITATION	POATATLIPNI
POSTPUBERTY	RTPSPYTUOBE	MORTALITIES	ISTIOMTALRE
WESTERNIZES	RSTZWNSEIEE	RESIGNATION	GRETISONANI
BRIGHTENERS	NGTRSBIRHEE	POSTORBITAL	OTPTBIRSOAL
TEMERARIOUS	SMUEORRTAIE	INTERNMENTS	RTMENIENNST
AUTONOMISTS	MANTISOUSOT	ABSOLUTIZES	LTOSUSAIZEB
MOUNTAINTOP	MUOAOTTINPN	NEPHELINITE	HEIEPLTNEIN
AUTOMATISMS	TOUSASAMIMT	PLANISPHERE	PERNHSLIAEP

Word	Nonword	Word	Nonword
SIMULATIONS	ILIUSSNOTMA	TAXONOMISTS	STOSNAIXMOT
SYBARITISMS	SIYTRAMBSIS	RITUALIZING	NGZIIRATULI
ALTERNATORS	ANTSELRTAOR	ENSHEATHING	NTHSAEEINGH
INSUPERABLY	LAIPERYUSBN	MISTHROWING	MNOSIWRITHG
LARGEMOUTHS	HRLOUSTAEMG	BATHYSPHERE	EYETSBAHRPH
RETAILORING	LRGNIIRAEOT	THERMALIZES	EIAZESHLTRM
TIEBREAKERS	TKREIEAESRB	EXHAUSTIBLE	TUALHBISEXE
STENOTHERMS	MSNTSEHTERO	TETRAMETERS	MTATRSETEER
INSTIGATING	ITNGIGTNIAS	SEISMOMETER	MROESESITME
PARAMETRIZE	AIMTAPEERZR	REPUGNANTLY	EPGNUTNYARL
ENTABLATURE	REUABELANTT	HYMNOLOGIES	EIGOOSNLHYM
NONROUTINES	TERINONSNUO	SANGUINARIA	UGIAINRANSA
PURITANISMS	RSINPSIMUAT	ANTIBARYONS	SNRIAAONTYB
EMPATHIZING	TPEIHNIMZAG	MOMENTARILY	AIRLTMMONEY
PEPSINOGENS	GNSNSPEEOPI	LAUREATIONS	RANTIUELASO
PRESTAMPING	PAPTIGRNSEM	TOLERATIONS	LTROSOIENTA
BOHEMIANISM	AIBSIOEMMHN	METHYLATION	TNTALMIOEYH
SULPHUREOUS	URHEOSPSLUU	BIBLIOLATER	BIELRLAOBIT
MONITORSHIP	RMNIOOSIHPT	EXPLORATORY	RYOPOARETLX
BRAINSTORMS	BOARRSTSMIN	UTOPIANISMS	MSASNUTIOIP
PLAGIARIZES	AIARSPEIGLZ	SEPARATISMS	TMAIRSPAESS
GROUPTHINKS	TGPHOUKSINR	OUTWRESTLES	TWEOESSRTLU
HYGROGRAPHS	HORPAHRGGYS	POLYPHONIES	HYOSPEPILNO
NOTIONALITY	AOINOITNLTY	STENOTYPING	YSGPNNETITO
INHIBITIONS	ISNIHINITOB	BEARABILITY	EIAYRILBTAB
AMALGAMATES	AMAMAGLTASE	TOTALIZATOR	OITAZOLTART
ANTIWRINKLE	AWKRIENNLIT	PREPARATORS	PSERARTOAPR
GYMNOSPERMY	RGOYSNEMPYM	BLAMEWORTHY	YOWLRMBAHET
REHUMANIZES	AUIESZENRMH	SUPERSTRIKE	USPETSKERIR
TRIPHTHONGS	GITHNPTORSH	EMPHASISING	EHGMSSPINAI
UNIGNORABLE	OUNRAGNLEBI	STRINGHALTS	NTSLIHTRGSA
PREMONITION	TOPNOIIREMN	EXTENUATION	ATUTNIENXEO
LARYNGOLOGY	AGRNLLGYOOY	REANALYZING	YGNZNEIAALR
NATURALISES	SNASULIAERT	ASTIGMATISM	MIGASIAMSTT
OUTWEIGHING	IOUGTEWNIGH	SUBMARINERS	INREMSBRUAS
REGENERATES	ENEERESTGAR	SUBJUGATORS	ABUSRTUJGOS
PRELITERARY	IRERAYLRPET	GEOBOTANIST	OGESTATINBO
HALOGENATES	LOSAENGAHTE	GRUBSTAKING	NGUKGSITRBA
REMONETIZES	MORIENTSEEZ	THERMOTAXES	TRSHMEEXAOT
PLAYWRIGHTS	WGALHPRTYSI	HEPTAMETERS	TESTPEAMERH
UREOTELISMS	SEUSIERTMOL	HYGROMETERS	SRETYMHRGEO
EXPURGATORS	OPGTRRSUEXA	REINSERTION	OINTINSRREE
SINOLOGISTS	LOGOITSISSN	MULTISYSTEM	MEYLTTSMSIU
KINESTHESIA	HINSEKTIESA	OUTPAINTING	IUANTITGOPN
MUSEOLOGIES	UEOSSMIOEGL	PROLOGUIZES	ZUIPLOOREGS
PROPOSITION	OPNOOSIPIRT	MONOLOGUIST	MLOSNOGTUIO
PROTOTROPHY	RPHOOPOTTRY	ALIGHTMENTS	IMSNEHLTTGA
BOILERPLATE	BRTOLAELEIP	MUTUALITIES	ULITUEMTSIA

Word	Nonword	Word	Nonword
GERMANIZING	NGRZIIMAGEN	TERMITARIUM	MITMIERTRUA
TRYPTOPHANS	RYTPTSNPOAH	TRINKETRIES	ETKNSERTRII
PREMATURELY	UERTEYPMLAR	ARTERIOGRAM	RGEOTRARIAM
SUBSTATIONS	BSTTSNSIUAO	ANTINEUTRON	TEUNNNIOTAR
ALGEBRAISTS	GARLITSSAEB	TELEPHONING	IHEPNEGLNOT
LYOPHILIZER	HILEYIPZROL	SUBLITERARY	LEUATBSRYIR
AMARANTHINE	NINRETMAHAA	MAGISTERIAL	RSALTIIAGEM
AMBLYGONITE	LGYOMABIETN	LOATHSOMELY	OSYLOATMHEL
MEGALOBLAST	AMEBALLGTOS	UNANIMITIES	ATNIISUMENI
MUTILATIONS	IUTLNSIATOM	ETHNOBOTANY	ANTHOYNOBET
INTERUNIONS	ENUNNSOIITR	PROPHYLAXIS	OPLYAPHIRSX
ALABASTRINE	IEABNASLRAT	TRYPTOPHANE	PHPEOYRATNT
ANTHOLOGIZE	HLOEZNTGOAI	NEUTRALIZES	SREATELIZNU
SOMERSAULTS	MSRTUSAOSLE	PLAGIARISMS	IARGALSMPSI
BURGOMASTER	RGBAMRSEUOT	TRANSPOSING	SONRATNPSGI
MYASTHENIAS	SYAIMHNEAST	TOXOPHILITE	EOITLHITXPO
OBTURATIONS	BORTNOSTAUI	REAUTHORIZE	EHARZIROUTE
WISENHEIMER	IEWMSEEHNIR	POSTMASTERS	STSMOERSPTA
MELIORATION	NRLIOETMAOI	INTENSIONAL	LNSIAOTENIN
PREPAYMENTS	ENSTAPYRMPE	INSTITUTION	UTITNIINTSO
TRANSIENTLY	EATNINYSLTR	HETEROTROPH	RTRHTOHOPEE
BARKENTINES	NSBIRNAKETE	TANTALIZERS	TLIAZARNSET
PROHIBITING	IGINOHBIPTR	IMPORTUNELY	MULEYITPNOR
MAGNETISING	TINIGASEGNM	MISANTHROPY	YAOMRPNHSTI
RESENTMENTS	EMNESTTNRSE	PORTERHOUSE	ERTESOHUORP
LAMPLIGHTER	ELTIAMHRLGP	UNANIMOUSLY	YIULUSMNNAO
SUBLIMITIES	UITBSESIMIL	AETIOLOGIES	SOAIELEGTIO
JOURNEYWORK	OJEKUNYOWRR	LITERALISTS	LTLRSIAESIT
BIMONTHLIES	MSIEBHNILTO	GEOMETRIZES	MZETSEEGIRO
PREREGISTER	REGRREPISTE	LETHALITIES	ILSALETTEHI
SEISMOMETRY	OTYMERISESM	PERITONITIS	IOTEPIRNIST
PROTOPLASTS	TRAOPSPLTSO	SPHINGOSINE	SONHGISEPNI
SNOWMOBILES	IBWNOOEMSLS	REPARTITION	NTOIRPEIATR
PLAISTERING	ANLSTGEIRIP	ORIENTATION	TIERTINAOON
EXTERIORIZE	EOXTREIEIRZ	RETRIBUTORY	OERIRBTUYTR
ANTIREALISM	LRIATEASNMI	PHOTOPHASES	OPOSTPSHEHA
TEMPERATELY	ELMATEYPETR	LIABILITIES	IBALESIILTI
BIBLIOLATRY	ILILBOYABRT	MARATHONING	NARMNHIGTAO
HOMOPHOBIAS	AIMPOOHOSHB	OUTSTUNTING	UNOSUGNTTTI
OBTAINMENTS	BNATNSOMETI	INSPIRATORS	PIROSIASRNT
KERATINIZES	NETSRKAZIEI	TROPOPAUSES	EUTAOPRPSSO
RELAXATIONS	LISAATORXEN	PAPERHANGER	AHEPRGEPRNA
MAGNETIZING	INENIZGGMAT	PHOTOSPHERE	TRSHPEHOEPO
MULTIPLEXOR	RXEIPULLMTO	OSTENTATION	ENOSINTTOAT
PHANTASMATA	TNPAAMASHAT	GLUTATHIONE	EUOHTGATLNI
INTERTWINES	TIRWEETSINN	PROGNATHISM	ASRMGHTOPIN
AGAMOSPERMY	MPSMEGYAROA	TRESTLEWORK	RERTWKSOTLE
HAPLOLOGIES	OLSHALGIOEP	APATOSAURUS	OPUASTARSAU

Word	Nonword
INTERIORIZE	OETIIERZRIN
MESOTHELIAL	LETAMLOIESH
HOSPITALISE	LSTPIESIAHO
LAMENTATION	NALATTNIMOE
NITROGENOUS	UOIOTNGNSRE
RESOLUTIONS	ULNOROSISET
UNRELIGIOUS	UGRNOULIIES
SUPRARENALS	USEANARSLRP
IGNIMBRITES	ENTSRIMIBIG
PLASMINOGEN	MANPINSOELG
LYOPHILISES	LSPIILHSEOY
SAUERBRATEN	ATUESRABREN
IMPREGNATES	EMAIPGRTESN
BUMPTIOUSLY	SBOUMYLUPTI
LANGOSTINOS	TGAONSNOSLI
INSINUATING	UINAGSNNITI
UNMEMORABLE	NBAEEMULOMR
STUMBLEBUMS	USMBTUELMSB
ARTHROPATHY	AOYPHRTTAHR
STARTLINGLY	YGALITSTRNL
SEIGNEURIAL	AIRGEUNSELI
WAITPERSONS	IERNOTSPASW
POLYMERASES	ELMOYRPESAS
ABLUTIONARY	TAILROYUBNA
LEUKOTRIENE	ELTRIEEOUKN
LITIGATIONS	IOITAGTLNSI
STRATEGIZES	REGTSISETAZ
TABULATIONS	OITLBNAASTU
EXEMPLARITY	PYTEEALMXIR
OPENABILITY	YTBENALPOII
EMPOISONING	NPMIINEOGOS
IMPOSTHUMES	TIUMPMEHSOS
INTRIGUANTS	INTITNGAURS
MEGAGAMETES	ATMGSAEMEEG
STRATEGISTS	TISETSSTRAG
LITHOPHYTES	TLOHHPESITY
SOLUBILIZES	ILBLSOIUZES
HYPERMNESIA	EMIRSPENHYA
RESPRINGING	RGPGSNEIIRN
LYOPHILIZES	HLOIZEPISYL
HORSESHOERS	EOHEOSRSSRH
PROTHROMBIN	PITBRMONRHO
REPROBATING	IRAEPONTBGR
ATOMIZATION	NTZOIMAIAOT
HYPSOMETERS	HYTPREEMSSO
LYSOGENISES	SYEONGISESL
SUBPOENAING	NEAPGUNISBO
MOTORMOUTHS	OTMOSHTMORU

Word	Nonword
PREMIERSHIP	PEPRIREHSMI
ERGOTAMINES	EGRSMITNOEA
USURPATIONS	PTRUOSUNASI
PYROLYZATES	ATOERLPSYYZ
ANEMOMETERS	NSEMOMAREET
NIGHTSHIRTS	RINGSSHTITH
MYXOMATOSIS	OTIYOMMSAXS
BARONETAGES	EONERABSAGT
ANESTHESIAS	NAETSESIHAS
OSTENSORIUM	SOEIMUROSNT
MILITARISES	TSIEAMLSIRI
PATRONIZING	IANNGTORPZI
HOMOGENATES	EOMGHAOTESN
ORTHONORMAL	TNOLOAHRROM
MISREMEMBER	EIRBMRSMMEE
ISOMERIZING	NEMZOIGIRSI
KARYOTYPING	PKGYNYTOAIR
MULTIPLIERS	SUPLRILIMTE
TELEOLOGIES	LETEEGIOOLS
REANOINTING	TNGINNEIRAO
MONOPOLISTS	INOSLOTSMOP

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Curriculum Vitae

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