DIVIDED ATTENTION, PERCEPTION AND AUDITORY RECALL

By

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This document is dedicated, with much love, to my husband, Keith; my older daughter and niece, Shauna; to my two younger daughters, Michaela and Rainey; to my extended family and friends; and to my God, all of whom make my life meaningful and worth living.

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DIVIDED ATTENTION, PERCEPTION AND AUDITORY RECALL

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The purpose of this research was to evaluate the effects of divided attention on speech perception and auditory recall. Participants included 16 military and 16 non-military adults, aged 18-50, with hearing thresholds no worse than those categorized as the U.S. Army's Hearing 1 profile, and with forward and reverse digit spans of at least four. Participants studied selected words and sentences prior to testing to accomplish implicit and explicit priming. Speech perception was assessed using Hearing-In-Noise (HINT) sentences presented with and without uncorrelated combat noise in the sound field at 65 dB SPL at 0º azimuth. The combat noise was presented at 5 dB less than the sentences. Participants were required to repeat 30 HINT sentences in each of four conditions: 1) in quiet, 2) in combat noise, 3) in quiet with an additional task, and 4) in combat noise with an additional task. Following each condition, participants were asked to answer questions to assess recall of the HINT sentence material.

There were no group differences in HINT item identification in the four conditions. Significant differences were found in HINT item identification scores between the quiet

and noise conditions, and among priming conditions. Auditory recall performance was significantly altered by noise, task and priming conditions, with significant interactions noted between each pairing of conditions.

The mean reaction times for the military group were generally longer than the non-military group. Demographic comparisons showed considerable disparity between the groups, in particular with regard to gender and age. Because of the mean age differences between the groups, a comparison between age and reaction times was made for the divided attention task conditions, which did not reveal any significant effect. Although age and gender differences were significant, they did not appear to affect the outcome of the results when comparing the groups. No statistical differences were noted when comparing reaction times to video game frequency or self-rated skill, thus indicating that the amount of time a person plays video games, or his/her self-rated skill, has little impact on reaction times.

CHAPTER 1
INTRODUCTION

Divided attention, or an intentional effort to be aware of two or more items simultaneously, has been studied fairly extensively in its relation to perceptual performance. Two other terms relating to this construct appear in the body of literature on divided attention: multi-tasking (i.e.,, doing two or more things at once), and dual-tasking (i.e.,, when an individual does two task simultaneously). Human listeners must frequently dual-task or multi-task while attempting to comprehend speech, often in the presence of noise. These situations require complex and adaptive attentional control to produce successful speech perception.

Attention has many facets: selective attention, divided attention, sustained attention, switching attention, etc., each of which is fascinating in its own right when it comes to the role it plays in speech perception. According to Hartley (1992), James in 1890 defines attention as “the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others.” (pg. 3) Hartley also claims James emphasized attention as a filtering aspect. By selecting certain information for priority processing, people can attend to and manage different input at the same time. Generally, the nature of the information managed, and how the information is managed, is often debated. Agreement exists when tasks are performed simultaneously. A person needs to manage simultaneous tasks differently than when the tasks are performed alone.

Because of this, Hartley (1992) redefines attention as being responsible for selectively preparing, maintaining preparation, and processing certain aspects of experience. When coordinating multiple tasks, attention is a key factor. Another construct, working memory, is difficult to separate from attention because it could be considered a broader attention task. Gottwald, Mihajlovic, Wilde, and Mehdorn (2003) essentially describe working memory as the ability to re-organize and coordinate new information by perceiving and processing it.

Some of the types of attention mentioned above may play a role in how speech is perceived when a person is required to divide his/her attention between two tasks. For instance, selective attention, or "the ability to attend selectively," is very important because if an individual can not attend to relevant information while ignoring irrelevant information, then that individual may not be able to effectively complete a task requirement. Sustained attention, or vigilance, is also deemed important because it describes a person's ability to "maintain concentration or focus over time," which of course is important in divided attention tasks. Vigilance and attention are closely associated. According to Keith (1994), vigilance integrates three dimensions of attention that are distinct: alertness, selection and effort. And when switching attention between tasks, researchers have found there may be a cost to performance by the individual (i.e., slower performance or less efficient performance), if the task requires the individual alternate between tasks (McDowd and Shaw, 2000; Rubenstein and Meyer and Meyer, 2001; Shellenbargar, 2003; Multitasking, 2005). How does all of this relate to speech perception? According to McDowd and Shaw (2000), people typically comprehend language when multiple sources are competing for attention, by focusing on relevant information and disregarding other irrelevant information.

How attention affects one's memory and ability to encode or retrieve words has been fairly extensively studied. People have more difficulty with recall and recognition if their attention is divided (i.e., performing another task, etc) during encoding than if divided during retrieval (Craik, Naveh-Benjamin, Ishaik, and Anderson, 2000; Fernandes and Moscovitch, 2003; Mulligan, 1998; Naveh-Benjamin, Craik, Perretta, and Toney, 2000; and Naveh-Benjamin, Craik, Guez, Kreuger, 2005; Wallace et al., 2001). Other research comparing the divided attention tasks of older and younger adults has shown that divided attention tasks are more difficult for older individuals than for younger individuals (Castel and Craik, 1999; Fernandes and Moscovitch, 2003; Hartley, 1992; McDowd and Shaw, 2000). This may be due to many factors, possibly including a reduction in attentional resources or a reduction in the ability to control the allotting of attention with aging. Generally, older adults may have more difficulty than younger adults when forming new associations, binding features together and combining items (Castel and Craik, 1999). Memory itself is not a simple construct. Two apparent factors are implicit and explicit memory. Implicit memory is knowledge that can be retrieved without conscious recollection, while explicit memory is knowledge that can be retrieved only through conscious recollection and usually involves a particular event (Anderson, 1995; Schacter, 1996).

The purpose of the proposed research is to assess to what extent divided attention affects a person's speech understanding ability, or causes a breakdown in auditory input, memory encoding and retrieval, and performance. Specifically, this project will evaluate recognition of sentences in combat noise and in divided attention conditions, as well as auditory recall in implicit and explicit memory paradigms in listeners with and without military training.

CHAPTER 2
REVIEW OF THE LITERATURE

Divided attention is the intentional effort to be aware of two or more things simultaneously. More importantly, sustained attention (or vigilance) is a person's ability to continue to focus or concentrate on something over time, as mentioned previously. Sustained attention is required for information processing (DeGangi and Porges, 1990). According to DeGangi and Porges (1990), sustained attention is "the ability to direct and focus cognitive activity on specific stimuli," and includes three stages: attention getting, attention holding, and attention releasing. The authors describe attention as alerting a person to the stimulus, and requiring "complex active thought processing." Attention is important to learning and requires a stimulus that is qualitative in nature. Attention holding is essentially described as the maintaining of the stimulus, which must be "intricate or novel" in order for a person to continue to attend to the stimulus and "encourage information processing." It relies on how complex the stimulus is and the energy needed to attend to a stimulus. It also requires a person to remain motivated to the stimulus. If a person has an attention problem, low motivation, processing problems, a cognitive impairment, or learning problems, the motivation to hold their attention to a stimulus will be low. The final stage of sustained attention is attention releasing. This is defined as "the releasing or turning off of attention from a stimulus." It can occur because a person has lost interest in the stimulus, is fatigued, or the stimulus is no longer present. Releasing of attention from the stimulus permits closure from a task and allows a person to “switch attention to something else.” Attention releasing is also an important factor in learning (DeGangi and Porges, 1990).

Speech Perception, Dichotic Digits, Auditory Encoding and Retrieval

Speech Perception

The perception of speech is multifaceted. Speech perception is basically defined as decoding a message from varying sounds delivered from a speaker. Speech is unique in that it contains individual sounds, syllables, words, sentences, phonemes, allophones, etc., and generally has different prosodic features, as well as differential features that may affect how it’s perceived (Borden and Harris, 1984; Pickett, 1986). There are many theories of speech perception. How speech is perceived is not the focus of this research. Instead, the focus will be on the use of speech perception tests in divided attention research to assess a person’s ability to recognize words or speech in a variety of situations (in quiet and in noise) while performing a secondary task (i.e., dividing their attention).

Encoding and Retrieval

Encoding is, in effect, the process of putting data (something we see, hear, think or feel) into our memory. The term “storage” is used to describe where we put the data. Retrieval is how the data is accessed, by using associated clues (Anderson, 1995; Schacter, 1996). Dividing attention during encoding generally impairs recognition and recall when a secondary task is performed. Some studies have shown that for some memory tests, dividing attention during the encoding process caused little to no decrease in performance. (Mulligan, 1998; Naveh-Benjamin et al., 2005; Wallace, Shaffer, Amberg, and Silvers, 2001) Memory essentially has three parts: encoding, storage, and retrieval (recall). For implicit memory tests without a strong conceptual component, dividing attention at encoding does not appear to impair them. Research showed that for the consciously controlled factors in memory, attention is relevant. Attention has little relevance for memory that occurs automatically (Wallace, 2001). Craik et al. (2000) also reported that dividing attention during encoding reduces subsequent memory performance when doing a memory task. According to Craik et al., researchers found when dividing attention at encoding, a larger decline in subsequent memory performance occurred than when dividing attention at retrieval (2000). Priming effects may actually improve recall performance on dual-task conditions. Priming effects are basically items we see or hear that may influence subsequent judgments or behaviors. Reported studies done by Murdock et al. in 1965, and confirmed by Baddeley et al. in 1969, indicated that free-recall performance improved under dual-task conditions when performance of the memory task was emphasized at study as opposed to performance of the secondary task (Craik et al., 2000). Craik et al. (2000) also reported that only minimal effects occurred when attention was divided during the retrieval phase and retrieval of memories actually “consumed more attentional capacity than encoding” (pg. 1744). Craik also reported that reaction time on the divided attention task during retrieval in the “free recall paradigm” was slower than reaction time on the divided attention task during encoding. The researchers noted that recent neuroimaging studies also suggested that prefrontal activation showed different patterns during episodic encoding and retrieval (2000).

Noise and Sound Effects

Noise, in effect, is any unwanted sound. The Miriam Webster online dictionary (2005) defines noise as: “a: sound, especially: one that lacks agreeable musical quality or is noticeably unpleasant; b: any sound that is undesired or interferes with one’s hearing of something; c: an unwanted signal or a disturbance (as static or a variation of voltage) in an electronic device or instrument (as radio or television); broadly: a disturbance interfering with the operation of a usually mechanical device or system." Noise effects on a participant's ability to understand speech has been studied with a multitude of various stimuli, including words and sentences. Studies have reported that perhaps background noise may cause direct effects (sensory input degradation) and indirect effects (requirement of additional effort to process the speech signal), which may increase cognitive load, thus impairing the elderly adults (Tun, 1998). Tun (1998) compared the ability to understand sentences in the presence of background babble in elderly participants and younger participants, finding that age did affect a person's ability to understand speech in the presence of background noise. Older listeners were less able to repeat the last word in the sentences in noise than younger listeners, and particularly so when speech was presented at faster rates. Younger adults were not exempt from the effects of background noise on speech understanding. Pichora-Fuller, Schneider, Daneman (1995) demonstrated similar differences between older and younger listeners in the identification of speech in background noise. This mainly affected concurrent memory load for both younger and older adults. Pichora-Fuller et al. (1995) also attributed age differences in performance primarily to perceptual processing rather than cognitive processing, and noted that elderly listeners expended more attentional resources in order to more effectively deal with the combined effects of the background noise and perceptual processing deficits.

In looking at yet another aspect of divided attention, a study done by Shinn-Cunningham and Ihlefeld (2004) explored the way sounds interact with each other (both acoustically and perceptually), and demonstrated that 1) overall performance was generally better in both selective and divided-attention tasks when "the sources are perceived at different locations than when they are perceived at the same location; and 2) if perceived sound locations are randomly changed between trials, performance is degraded compared to if source locations are fixed." These two effects were greater for selective attention tasks than for divided attention tasks. The authors' results suggest listeners tend to focus their attention toward the location where they expect the noise source will originate, and they do not expect that listeners "listen everywhere."

Multitalker babble, a source of noise commonly used as background noise for speech perception testing, is used because it is "the most common environmental noise encountered by listeners in everyday life and because babble is more unfavorable to speech perception than other types of competition (Wilson, Abrams, Pillion, 2003)." The Hearing in Noise Test (HINT) test is one test that can be used with multitalker babble or in quiet. The test measures speech intelligibility performance. Developed at the House Ear Institute in the early 1990s by Nilsson et al., the HINT consists of 25 word lists, each consisting of 10 short English sentences. It uses an adaptive threshold technique to estimate a 50% correct level for the patient responding to the sentences. If a patient responds correctly to the sentence, the level is decreased. An incorrect response causes the level to increase (Nilsson, Gelnett, Sullivan, Soli and Goldberg, 1992). The HINT test is valuable because using sentences helps to target a person's processing ability (i.e., auditory memory load, temporal processing), as well as providing more contextual information, rather than using single word response tests like the Northwestern University-6 (NU-6) test.

Memory

Memory and Divided Attention

Memory is the retention of information over time. There are several types of memory: long-term memory, short-term memory, working memory, implicit memory, explicit memory, etc. Long-term memory is the retention of memories thought to be stored for over 30 seconds (and retention may exceed decades). Short-term memory is the temporary retention of memory thought to be stored under 30 seconds. No research has been able to definitely isolate these suggested times (Anderson, 1995; Schacter, 1996). Short-term memory is integral to the allocation of cognitive resources to perform various mental tasks. Digit span is commonly used to measure short-term memory, and involves the number of digits recalled by an individual in correct serial order after either seeing or hearing them. For young children, the correct number the participant is expected to repeat corresponds to the participant's age; for example, a two-year-old should be able to repeat two numbers, a three-year-old three numbers, and so on up to age 7. From age 7 through adulthood the average digit span numbers repeated remains at seven. "Two processes are involved in digit span: the identification of the items, and the retention of order information. Individuals who are slow in identification have a shorter memory span" (Groth-Marnat, 2003). Digit span can be assessed in either a forward or backward test. Digit forward primarily involves sequential processing. Digit backward seems to engage both planning ability and sequential processing and requires much attention and concentration. "The ability to repeat digits backward is not only dependent on attention and concentration, general cognitive, and short-term memory functioning, but also requires verbal and visual (nonverbal visualization) mediation (pgs. 1209-18) ."

Working memory refers to the processes involved when a person tries to remember something, such as a string of numbers without writing it down (Anderson, 1995; Schacter, 1996). This research will highlight how implicit and explicit memory relates to divided attention tasks. As stated previously, implicit memory is basically knowledge retrieved without conscious recollection; while explicit memory is basically knowledge retrieved only with conscious recollection (Anderson, 1995; Schacter, 1996). Research has shown that if attention is divided during encoding, explicit test performance can be diminished although repetition priming may be unaffected (Mulligan, 1998; Shanks, 2004). Implicit and explicit memory will be discussed more fully later in this document.

Researchers have determined that dividing attention during encoding appears to produce little decrement in performance on the divided attention task for implicit memory tests. For explicit memory tests, dividing attention impairs performance (Wallace et al., 2001). A study by Mulligan (1998) focusing on five experiments where participants read study words under conditions of divided or full attention showed that dividing attention reduced conceptual priming on the word-association task, the matched explicit test, and associate-cue recall, as well as showing a reduced performance on the general knowledge test. Mulligan’s overall conclusion is perceptual implicit tests rely only minimally on attention-demanding encoding processes relative to other types of memory tests (1998). Craik and his colleagues (2000) concluded that when attention is divided during retrieval, it has little affect on recalling episodic memories; while dividing attention during encoding may have a negative impact on recall. The researchers proposed this might be due to the fact that the experimenter controls stimulus presentation and the operation and response is controlled by the participant. They tested the proposal by presenting word lists for learning and recall with paired-associative words (Craik, et al..2000). These words were either controlled by the participant or presented at a fixed rate. Their results point to more recall at retrieval for divided attention than at encoding, which was able to be "held" under the varying combinations of both experimenter and participant control. Craik et al. (2000) continued by reporting their results are compatible with the views of Fernandes and Moscovitch (2000) who conclude that tasks utilizing attentional resources will reduce simultaneous memory performance when they are performed at the time of memory encoding.

Implicit and Explicit Memory

Implicit memory is basically "knowledge that can be retrieved without conscious recollection (Yeates and Enrile, 2005)." Implicit memory is best revealed when performance on a task is improved. We demonstrate implicit memory when performing certain tasks, by activating sensory and motor systems. Implicit memory types include repetition priming and skill learning. We can use repetition priming when processing a stimulus because we've had previous experience with the stimulus. An example of implicit memory is when a participant is permitted to study a list of words included in a test, prior to testing. The premise is that participants will have the ability to match words or complete words seen before. Rajaram et al. (2001) reports implicit memory can be indirectly measured. This is done by using tests in which a person studies degraded or incomplete words and then assessing the advantage of studying the words. Skill learning requires automatic skills or movements that are learned. A person can only access these memories by executing or using them, and requires associating a certain stimuli with a response. Tests of implicit memory that do not have a "strong conceptual component" are typically not impaired at encoding when dividing attention (Wallace et al., 2001).

Implicit memory is a data driven phenomenon because physical features of the stimulus are required to process it. Once again, an example of implicit memory is when a person sees a particular word (i.e., CABIN) during the study period, and then recalls that same word during the testing period. It is essentially perceptual identification. Some tasks, known collectively as repetition priming tasks and are commonly used to elicit implicit memory are: tachistoscopic identification (the ability to identify and reproduce briefly presented visual stimuli, usually with durations less than 1/25 of a second, perceptual clarification, word fragments, and anagrams (Baddeley, 1997; Blaxton, 1989). Research on memory has shown that presenting words to be studied prior to testing will enhance performance on the test. This is considered a priming effect. Priming effects are said to arise in the perceptual representation systems (PRS) that permit us to translate sensory inputs into perceptions of objects, faces, or words (Mulligan, 2001; Rajaram et al., 2001, Shulman, 1997).

Explicit memory is "knowledge that can be retrieved only with conscious recollection" and usually involves a particular event Explicit memory is conceptually driven and involves recognition. It relies on the stimulus being conceptually processed (Kim et al., 2005; Willingham and Preuss, 1995; Yeates and Enrile, 2005). The temporal lobe is responsible for explicit memories. An example of explicit memory would be when a person sees the sentence; "the log ______ is in the woods" during the study period, and then sees the word "CABIN" during the test. Explicit memories are memories a person has of events that happen in the world around them, at a specific time and place. According to Rajaram et al (2001), "Explicit memory is measured directly by tests that assess the participant's ability to recollect studied words on tests of recall or recognition. (pg. 920) When a person stores explicit memories, the memories are stored with related experiences, and can be recalled or remembered. Explicit memories rely on previous knowledge and experiences.

A theory of implicit and explicit memory was initially developed to explain the finding that some memory functions in amnesia patients are spared, while others are impaired. (Graf and Masson, 1993) Graf and Masson (1993) reported amnesic patients would have a normal performance on memory tests entailing recall, although they were severely impaired on explicit memory tests. The researchers also reported that performance on implicit memory tests remained invariant across the lifespan, while test performance on explicit memory tests improves through early childhood and later declines in late adulthood.

Previously acquired information can enhance performance on an implicit memory task, although the person may not be consciously aware of previously acquiring the information. Willingham (1995) uses Graf and Schacter's 1985 definition to explain that implicit memory refers to a set of memory tasks and does not refer to episodes of initial encoding. People are not necessarily aware of engaging in recall. Implicit memories consist of memories that are needed to perform a task or produce a response, but cannot be remembered to use for actions and reasoning.

Divided attention does, in fact, appear to degrade performance on explicit memory tests. In essence, attention is needed for "consciously-controlled factors" when dealing with memory (Wallace et al., 2001).

Older vs. Younger Adults and Divided Attention

Hartley (1992) concluded age-related differences in attentional functioning may be explained by a reduction in the energy fueling cognitive processing. Regarding how adults comprehend text in the presence of irrelevant information, McDowd and Shaw (2000) state older adults have difficulty when trying to ignore any distracters that are embedded into the text. Distracters that are semantically related negatively affect adults. These authors continue by saying that attention is very relevant to how well a person comprehends speech. For speech to be perceived, the listener must extensively use their “working memory resources,” and auditory processes, which decline with aging (2000). McDowd and Shaw also reports studies have shown that aging adults do well in speech comprehension, even though their component processes or “skill domains” may have deteriorated. Because older adults have language skills that have become more “automatic and encapsulated” and a lifetime of experience from which to draw their linguistic knowledge, they may be able to compensate for deficits in lower-level cognitive skills. Other researchers have questioned whether aging adults maintain their language processing abilities in conditions of increased processing load (McDowd and Shaw, 2000). The researchers report some studies show aging adults seem to perform more poorly on secondary tasks when attention is divided, and seem to have more memory deficits in studies using text with lesser degrees of redundancy or predictability. The authors conclude that speech comprehension is sensitive to aging (2000). A study by Kemper, et al. (2003) revealed, older adults had speech that was less complex and fluent than their younger counterparts, and that younger and older adults adopted different strategies to dual-task demands. The dual tasks consisted of the older and younger adults being required to respond to questions while walking, finger-tapping, and ignoring speech in noise.

McDowd and Shaw (2000) also discuss the role of the executive process in the control of attention. They describe the executive process as “a superordinate, executive mechanism that controls the changing allocation of attention in complex tasks, such as dividing attention between two inputs, or dynamically switching between two tasks.” (pg. 275) Baddeley, in 1993, concluded that the essence of executive control is the ability to control action and integrate information (McDowd and Shaw, 2000). Executive control relates to divided attention in the fact that researchers commonly use divided attention and task switching to study executive control. A processing executive controls divided attention performance by allocating attention between tasks and by managing the flow of input and output from the two tasks. Because of this, older adults typically perform poorer under dual-task conditions than younger adults (McDowd and Shaw, 2000).

Naveh-Benjamin et al. (2005) cited many studies that conclude recall in older adults demands greater attentional resources and that secondary task costs are higher in older adults both during encoding and retrieval than for younger adults. Older adults also had more difficulty with cued-recall than younger participants. I would suspect that the proposed research would support the findings that older subjects have more difficulty with recall than younger subjects.

Anatomy

Many studies have been performed to try to determine what areas in the brain are responsible for attention using functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) imaging protocols. The prefrontal cortex (bilateral), temporal area, and parietal cortex, as well as the cerebellum have been implicated in attention-related tasks (Barrett, Large, Smith, Karayanidis, Michie, Kavanagh, Fawdry, Henderson, O'Sullivan, 2003; Behrmann, Beng, and Shomstein, 2004; Dannhauser, Walker, Stevens, Lee, Seal, and Shergill, 2005; Gottwald et al., 2003; Hugdahl, Thomsen, Erlsand, Rimol, and Niemi, 2003; Loose, Kaufmann, Auer, Lange, 2003). Prince, Daselaar, and Cabeza (2005) reported that association-related memory, or relational memory, is linked to the medial temporal lobes and the pre-frontal cortex. Specifically for encoding and retrieval, Prince et al. (2005) report that several regions of the brain that were activated during encoding were re-activated during retrieval, more so in a manner which was content-specific manner. The left hippocampus was the only region of the brain associated with relational memory and content.

For speech perception, few studies have been performed; therefore, researchers know little about "neuronal substrates" related to focused attention in speech perception (Hugdahl et al., 2003). In a passive listening condition, Hugdahl et al. (2003), determined "bilateral activation in the inferior section of the superior temporal gyrus" was noted, and participants attending to vowel sounds showed an increase in activation within the superior/medial temporal lobe, with leftward asymmetry." When participants focused on pseudo-and word-stimuli, there was more activity noted in the middle temporal lobe areas, extending more anterior when compared with passive listening conditions. Barrett et al. (2003) sought to determine what regions of the brain were responsible specifically for dividing and switching of attention between two features of a single object. They revealed activation in the prefrontal and temporal cortices of the brain as well as the cerebellum.

Reaction Time

One way in which the allocation of attentional resources can be quantified is by measuring reaction time. When a secondary task requires greater attention, reaction times in a primary task may be lengthened. Reaction time is an vital concept in performance during divided attention because dividing attention during tasks typically increases the time it takes for a person to complete a task (Craik et al., 2000; Fernandes and Moscovitch, 2002 and 2003; Naveh-Benjamin et al., 2000; Rajaram, 2001). Craik et al. (2000) measured reaction times for correct responses in their study regarding encoding and retrieval and found substantially longer reaction times in all divided attention conditions, suggesting that considerable attentional resources were required for both encoding and retrieval. Again, it is interesting to note that the reaction times were longer when the reaction time task was performed at retrieval rather than at encoding, suggesting that retrieval is more demanding than encoding when it comes to reaction times.

Multi-Attribute Task Battery (MATB)

The Multi-Attribute Task Battery (MATB) for Human Operator Workload and Strategic Behavior Research, developed by Comstock and Arnegard (1992), is a DOS-based computer test battery that has been used in many laboratory studies by researchers wishing to evaluate operator performance and workload. The task battery, initially developed for research conducted at the National Aeronautics and Space Administration (NASA), revolves around the simulation of tasks performed in aircraft or flight simulation; however, the task battery is adaptable for non-flight participants as well. The MATB primarily consists of four task areas: 1) a systems monitoring task, 2) a tracking task, 3) a communications task, and 4) a resource management task (i.e., fuel adjustment). The researcher can manipulate the parameters of the tasks in the setup program via a script file. Some or all of the tasks can be used. If the researcher runs the entire task battery, five data files will be created. Separate data files do exist for each of the four task conditions mentioned above, with an additional file for responses to the NASA Task Load Index Rating Scales. This allows the subtasks to be used in research, without having to use the full task battery.

Socialization and Divided Attention

Kosson and Newman (1989) conducted studies on divided attention and the effects of socialization on it. The research described two studies conducted to show how socialization affects one's ability to pay attention and focus during divided attention conditions. The studies involved comparisons between undersocialized and high-socialized college students who were given "information-processing tasks, a visual search, and a 'go-no go' auditory probe reaction time task." Undersocialized people, defined as those who tend to behave without considering social norms as measured by the Socialization scale developed by Gough in 1960, generally have difficulty considering others' perspectives when evaluating or perceiving their own behavior. The tasks used involved incentives and were administered by both male and female experimenters. The results of the study showed evidence that undersocialized participants were more sensitive when dealing with attentional allocations requiring dual task-situations and at least one manipulation where focus is required. Both studies demonstrated that individuals who scored low on the Socialization scale "performed relatively poorly on the auditory task under focusing conditions but displayed no primary task advantage and no significant performance deficits under divided attention conditions." Overall, the authors conclude, "undersocialized individuals focus on events of immediate significance and have less residual attention to process other events than more socialized individuals.

There was no association between undersocialization and the inability to perform under dual-task or focused conditions. The main effects for incentives and concurrent load concluded that when the individuals allocated their additional processing resources to one task, it interfered with the performance on the other. On the other hand, high-socialized participants had more difficulty on the dual-task situation once an incentive was introduced. The authors attribute this to the possibility that for many people, when dividing attention equally between two meaningful inputs, it may be easier to attend preferentially to one of them (Kosson and Newman, 1989).

CHAPTER 3
MATERIALS AND METHODS

Materials

Participants

Thirty-two participants were recruited for this study, sixteen military soldiers and sixteen adults without military experience. A questionnaire was given to the participants prior to testing to obtain most of the demographic data (See Appendix A).

All participants included in this study met the following criteria:

1. Participants were between 18 and 50 years of age

2. Participants all held at least a high-school diploma

3. Hearing threshold levels equal to or better than that categorized as H-1 profile, or Hearing 1 profile, thresholds defined as follows: Average hearing thresholds, bilaterally, can not exceed 25 dB HL at 500, 1000, and 2000 Hz, with no individual threshold greater than 30 dB. Four thousand Hz cannot exceed 45 dB HL, bilaterally (Army Regulation 40-501, 2004). The H-1 profile criteria are being used because they pose no restriction on an Army soldier's assignment and therefore reflect the population of soldiers needing to recall speech information delivered in a combat noise environment.

4. Participants were in generally good health, with no handicapping condition that would prevent them from completing the desired tasks. Handicapping conditions excluding participants were vision problems prohibiting easy use of a computer; hand, arm, or shoulder problems that would prohibit easy operation of a joystick; or speech problems that would obviate clear repetition of experimental stimuli.

5. Participants were all fluent in English.

6. Prior to participating in the study, each participant was required to sign an Informed Consent Form approved by the University of Florida Institutional Review Board (IRB) and must indicate a willingness to participate in the study. A copy of the Informed Consent Form may be found in Appendix B.

This research study evaluated the participant's ability to recognize sentences in combat noise and in divided attention conditions, as well as assessing auditory recall in implicit and explicit memory paradigms. Each participant completed four stages of the study in sequence: 1) digit span testing to assess short-term auditory memory status, 2) priming for implicit and explicit memory, 3) auditory sentence identification, and 4) recall testing.

Experimental Conditions

Overview

Prior to participation in the experiment, each subject was asked to fill out an informed consent (IRB) form (see appendix B) and given a questionnaire to complete. The questionnaire asked for the following information: visual deficits, demographic information, and video game experience (see appendix A). After completion of the questionnaire, the examiner asked the participant to repeat a series of digits, both forward and backward, to test short-term memory (see digit span testing below). Following the digit span test, the participant was seated in the sound booth and given an audiometric evaluation (air conduction thresholds only, 0.25 to 6 kHz) to ensure hearing threshold levels were within the Army's H-1 hearing standards. Following the hearing evaluation, the participants were given an implicit/explicit priming study sheet (see Priming below) and were asked to study it for 3 minutes. After the participant studied the list, s/he was given an instruction sheet to read (see appendix C) explaining requirements for the computer divided attention task. The examiner then repeated the instructions verbally with the participant again to ensure the participant understood the task requirements. The participant was also reminded they were to repeat the HINT sentences after each sentence was heard, exactly as they heard it. Guessing was allowed and encouraged. For the divided attention condition, the participant was asked to repeat the HINT sentences while doing the computer-based MATB systems monitoring task. The computer was placed on the participant's lap for the quiet + task and the noise + task conditions. Following each of the four test conditions, the participant was given a sheet with 30 questions to answer. The participants were asked to answer the questions to the best of his/her ability. Again, guessing was encouraged (see Implicit/Explicit Recall section below). Reaction times for the MATB divided attention task were recorded in the computer database and printed later for statistical comparison.

Digit Span Testing. A forward and reverse digit span test was administered to each participant prior to testing to assess short-term memory. The forward digit span test was presented in a monotone voice by the examiner. The participant was asked first to repeat the numbers as heard in the forward sequence, beginning with four numbers (e.g., if the examiner says "1, 4, 3, 2," the participant would repeat back "1, 4, 3, 2"). If the participant repeated the numbers correctly, the examiner presented a series of five numbers, then six numbers, etc.... until the person was unable to correctly repeat back all the numbers. If the participant missed one or more numbers in a series, another series of numbers of the same length was presented. If the participant repeated those numbers correctly, the examiner then increased the series of numbers by one. This test continued until the participant missed two series of numbers in a row, or until the participant repeated a series of nine numbers in a row correctly. The participant's digit span score was then recorded as the total numbers correctly repeated prior to missing the two series of numbers in a row.

The reverse or backward digit span test was presented in a similar manner to the forward test except that the examiner presented the series of numbers forward (e.g., 1, 2, 3, 4) and the participant was required to repeat the numbers back in the reverse order (e.g., 4, 3, 2, 1). The examiner continued increasing the series of numbers presented until the participant missed two series in a row, or until the participant reached a series of nine numbers in a row. Each participant was required to accurately repeat back at least 5 digits in the forward recall condition and 4 digits in the reverse recall condition. (See Appendix D).

Priming. For memory priming, each participant was provided a list of 30 words (for implicit priming) combined with a list of 30 conceptually similar sentences (for explicit priming). The list of words was extracted from those contained within the Hearing-in-Noise Test (HINT; to be discussed in the next section). The participant was asked to study the list of words and sentences for 3 minutes prior to the auditory sentence identification testing. The explicit priming sentences, while conceptually similar, did not contain the words used in the HINT sentences. (see appendix E).

Auditory Sentence Recognition. An adapted version of the Hearing in Noise Test (HINT), developed by the House Institute in Los Angeles, California was used as an assessment tool for this research. As stated previously, the HINT is "a test that measures speech intelligibility using both ears (binaural directional hearing) and plays a critical roll in assessing one's ability to communicate with speech in noisy settings." The test consists of 25 phonemically-balanced lists of 10 short sentences, and requires the participant to recognize and repeat short sentences under both noisy and quiet conditions. Sentences included in the HINT test are spoken by a male voice, are of approximate equal difficulty (1^{st} grade level), and contain approximately equal number of syllables (6 to 8). (Hearing in Noise Test, 2005; Nilsson et al., 1994; Soli and Nilsson, 1994). This research used the first 12 HINT sentence lists, each containing 10 sentences (120 sentences total). Appendix F contains the 12 HINT sentence lists used in this research. The individual lists of HINT sentences were randomized and presented under four varying conditions (30 sentences in each condition). The order of the conditions was also randomized among the participants. The four conditions were as follows:

A. in a quiet sound field environment with 1 speaker at 0º azimuth (directly in front of the participant).

B. with combat noise at a +5 signal-to-noise ratio (SNR) with the sentences delivered at 0º azimuth and the noise delivered over 4 speakers at 45º, 135º, 225º and 315º (See Figure 3-1).

C. in the quiet sound field environment (as described in A.) with a distracter task (MATB).

D. with the combat noise (as described in B.) and a distracter task (MATB).

Sentences and Noise. Compact disc (CD) recordings of the HINT sentences and combat noise were made using Adobe Audition 1.0 software. Track one of the CD consisted of a

1 kHz frequency-modulated (FM) calibration tone equal to the RMS of the HINT sentences. Groups of thirty HINT sentences were recorded on the subsequent 4 tracks of the CD (e.g., track two contained HINT lists 1 through 3, track three contained HINT lists 4 through 6, track four contained HINT lists 7 through 9, and track five contained HINT lists 10 through 12). The combat noise, recorded on separate CDs, was attenuated 30 dB (using Adobe Audition 1.0) between each of the sentences to allow a quiet period for the participant to repeat the sentence. The combat noise was recorded to begin at full volume .4 sec before the HINT sentence began and attenuated at .4 sec after the HINT sentence ended. To achieve uncorrelated noise in the sound field condition, three of the combat noise sources were delayed (by 1.0, 2.0 and 3.0 ms using Adobe Audition 1.0). The four uncorrelated noise sources were recorded on two separate CDs (two on the two

channels of one CD, and two on the two channels of a second CD). Each combat noise CD also contained a 1 kHz frequency modulated calibration tone equal to the RMS level of the noise.

All four noise speakers were located 36 inches away from the participant at the angles listed above and were 37 inches above the floor of the booth. The HINT sentences were presented to the participant through a single speaker (Tannoy system 600) placed 40-inches in front of the participant. The sentences were presented at 64.4 dB SPL using a Sony 5 CD Change Disc Exchange System (Model No. CDP-CD 375), routed through a Grason Stadler 61 Audiometer (model no. 1761). The uncorrelated combat noise used was simulated battlefield noise containing continuous (aircraft and vehicular) and impulse (weapons discharge and explosives) sounds. These recordings were obtained as .wav files from LTC Lorraine Babeu at the Army Research Lab in Aberdeen Proving Ground, Maryland. The noise was presented utilizing two separate Sony 5 CD Changer Disc Exchange Systems (Model No. CDP-CE 375), routed through two Crown D75A amplifiers, with two channels each, to four Definitive Technology speakers (Model BP-2X). A brief sample of the combat noise waveform is included in Figure 3-2. The overall SPL output at the position of the participants for the 4 noise speakers, measured within the sound booth using a Quest Technologies, Type 2, sound level meter (serial no. HUA040046), A-rating scale was 59.8 dB. The effective signal-to-noise ratio (SNR) was therefore +4.6 dB. All CD players were started and stopped simultaneously with a single remote control device.

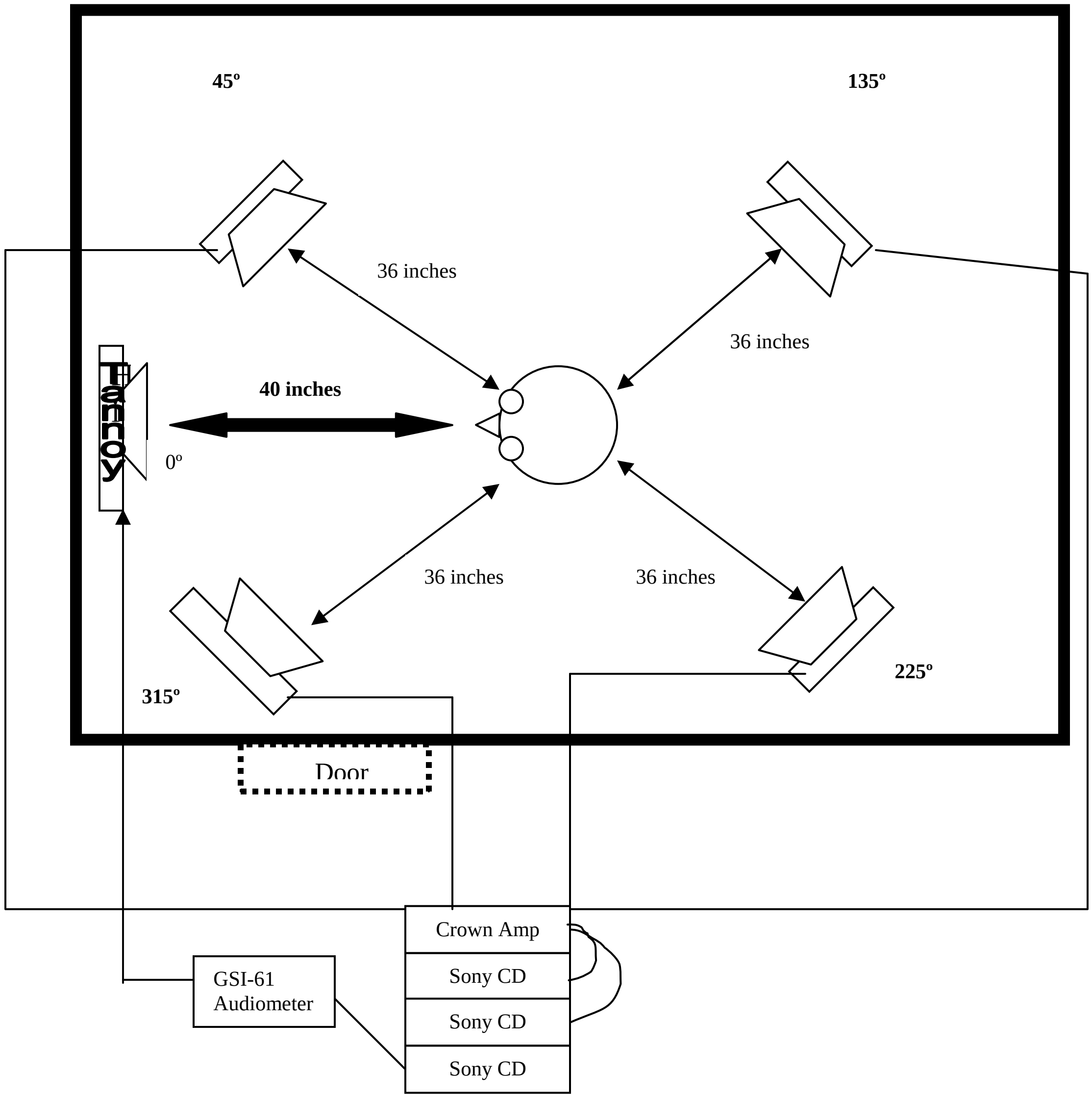


Figure 3-1. Layout of speakers and participant within audiometric soundbooth. HINT sentences were played through Sony CD player and delivered through the Tannoy speaker located at 0º azimuth, 40 inches in front of the participant; and the combat noise was played using two Sony CD players and delivered through four Definitive Technology speakers each 36 inches from the participant at the following angles: 45º, 135º, 225º and 315º.

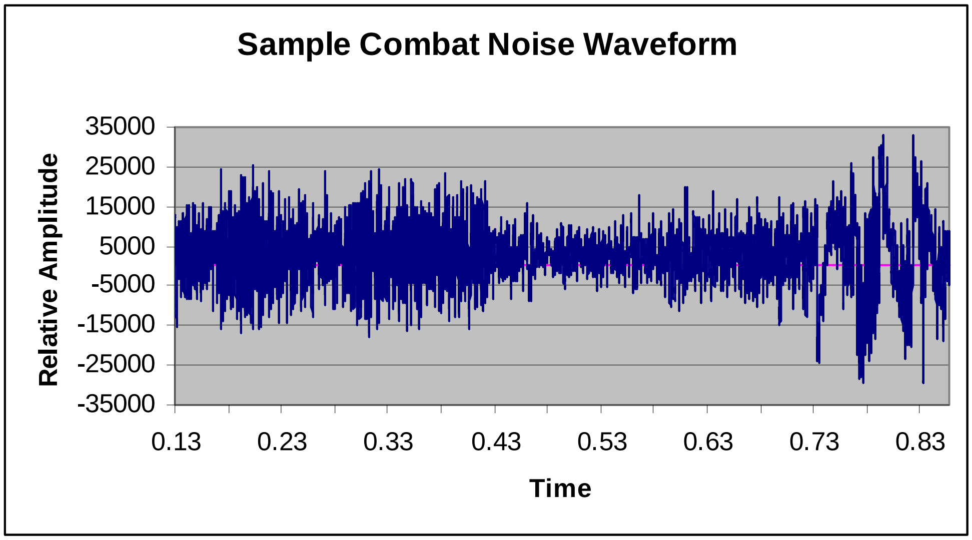


Figure 3-2. Sample combat noise waveform.

Each participant listened to the HINT sentences and noise in an IAC, double-walled sound booth (resealed/calibrated 2005). The participant was asked to repeat each sentence after it was heard. The examiner marked wrong any key words repeated incorrectly, or not repeated at all, by the participant. The total number of key words per 30-sentence groups used in each test condition ranged from 156 to 162 (each 10-sentence list ranged from 51 to 57 key words). An audiotape recording was made of the testing sessions for 4 of the participants at random for scoring by a rater blinded to the subject's group and task condition. The comparison of HINT key word scores between raters provided an assessment of scoring reliability.

Implicit/Explicit Recall. Following the presentation of the sentences in each condition, thirty questions were given to the participant to test his/her recall: ten questions designed to elicit implicit memory, ten designed to elicit explicit memory, and ten designed to elicit unprimed recall. Two separate versions of the questions, matched to the same study sheet version given to the participant to study earlier, were used. Half of the participants were given list one, and the other half of the participants were given list two, in randomized fashion. An example of a question that may stimulate explicit memory for the sentence, “A boy fell from the window” would be, “Who fell from the window?” The participant’s response should then be, “a boy.” An example of an implicit item is when the participant reads a question, “What did the ball break,” and then sees the broken word in the answer column, “w _ _ d _ w.” The person would then need to write the word, “window” in order for the answer to be counted as correct. Since this example has an implicitly-based answer, the participant would only have to recall part of the word by filling in the blank letters. For explicitly-based questions and unprimed questions, the participant would have to recall the correct answer to the questions with no assistance. The implicit and explicit questions were randomized per set of 10 sentences per participant (See appendix G). When referencing appendix G, be reminded that the participant was only given the implicit, explicit, or unprimed questions, along with the implicit helper answer (columns 1 and 2), and not the correct response and paradigm which are also listed in appendix G in columns 3 and 4.

Visual-Motor Task

The visual-motor test used as the distracter task in this research was the systems monitoring portion of the Multi-Attribute Task Battery (MATB). As stated previously, this task battery has been used in many laboratory studies involving operator performance and workload. The task battery originally revolved around aircraft or flight simulation, but is adaptable for non-flight participants as well. The MATB computer task was presented using a Gateway 450 Notebook computer placed on the participant’s lap. The monitoring portion of the task battery involved several components. One component consisted of monitoring gauges and warning lights. During this portion of the test, the participant was asked to respond to the warning light by pressing the corresponding function key if he/she saw the green light go OFF (F5) or if the red light went ON (F6). Another part of the systems monitoring task required the participant to monitor four separate arrows contained within rectangular boxes. The participant was asked to press the corresponding function key (F1 through F4) if the arrows, which were moving throughout the duration of the test, moved more than one deviation above or below the midpoint line at any time during the test (see instructions Appendix C). When the participant pressed the corresponding function key, a yellow line at the bottom of the space where the arrow was moving would appear. Once the corresponding function was pressed, the arrow would then move quickly back to the midpoint and stop moving for a brief time before it began moving up and down again.

Test performance was reported in terms of response time (in seconds) to events occurring at eight preset times (57.01, 63.05, 81.01, 102.05, 152.03, 163.01, 178.01, and 204.04). Each participant's response times were recorded in both the quiet + task and noise + task conditions. (See appendix H for an example of response time printout). Participants who did not respond to the event within 20 seconds were assigned a reaction time of 20.01 seconds.

Hypotheses

The hypotheses for this research included, but were not limited to, the following:

Regarding HINT identification performance:

1. All participants' mean performance will be better on single tasks than on the divided attention tasks.

2. Both military and non-military participants will have a similar mean performance on the HINT sentences alone.

3. Military participants will have better mean performances on the HINT sentences using the combat background noise than non-military adults.

Regarding Recall performance:

1. Non-military participants will have higher mean implicit and explicit recall performance than military participants.

2. Mean recall performance will be poorer with the addition of the background noise among the groups.

3. Mean performances on recall tasks for older participants, age 40-50, will be slightly worse than participants younger than age 40.

Regarding Reaction Time measures:

1. Mean reaction time on the MATB divided attention tasks will increase with the addition of the combat noise.

2. Mean reaction time for military participants on the MATB divided attention tasks will be better than non-military adults.

3. Participants with prior video game experience will have better reaction times on MATB divided attention task than those without prior video game experience.

Statistical Analysis

The data were analyzed using independent t-tests for between-groups comparisons and repeated measures ANOVA with post hoc t-testing to evaluate significant main effects for within subject comparisons. Non-parametric analyses (Kruskal Wallis, Mann Whitney and Friedman's tests) were undertaken to verify parametric results. All statistical analyses were tested at alpha = .05, to determine the significance of the results.

CHAPTER 4
RESULTS

This research study measured the effects of noise and divided attention on auditory perception and memory recall. The data obtained included descriptive results from a questionnaire to obtain demographic information, a forward and reverse digit span test to assess short-term memory, and an audiometric screening to assess hearing sensitivity. Experimental data regarding sound field speech identification performance was obtained in four test conditions: 1) in quiet, 2) in noise, 3) in quiet with an additional task (quiet + task), and 4) in noise with an additional task (noise + task). The Multi-Attribute Task Battery (MATB), a computer-based task requiring the participant to respond to specific onscreen events by pressing the corresponding function key served as the additional task.

Demographic Profile

Table 4.1 contains a summary of the data obtained from the questionnaire given to the two groups (military and non-military) of participants. As shown, there are several differences between the groups. Specifically, the military group, averaging 37.4 years of age (SD =6.7), was 15.6 years older than the non-military group, which averaged 21.8 years of age (SD=2.6). McDowd and Shaw (2000) demonstrated that age can impact how well a person comprehends speech and attends to various divided attention tasks, but that this effect is most pronounced in older individuals (usually 60+ years). Because the mean age for the older group in this study was only 37.4, age is not expected to significantly affect identification and recall scores. These results will be discussed in the HINT identification and Recall sections.

Table 4-1: Summary of Demographic Data for Military Group and Non-Military Groups

Variable	Group: Military (N=16)	Group: Non-Military (N=16)
Age (years)		
Mean	37.4	21.8
SD	6.7	2.6
Gender (N)		
Male	14	1
Female	2	15
Education Level (N)		
High School	3	1
Current College Student	5	14
College Graduate	8	1
Degree (N)		
None	8	15
Bachelors Degree	7	1
Masters Degree	1	0
Handidness (N)		
Right	15	14
Left	1	2

(SD = Standard Deviation)

Education level for both groups varied, with the military group having 3 high school graduates, 5 currently enrolled college students and 8 college graduates; non-military had 14 currently enrolled college students and 1 each in the high school graduate and college graduate categories. Degrees obtained varied between the groups, with the military group having 8 participants with no college degree, 7 with a Bachelors degree, and 1 with a Masters degree. The non-military group had 15 participants with no degree, and one with a Bachelors degree.

The military group had 14 males and 2 females, while the non-military group had 15 females and 1 male. A Fisher's exact test was used to analyze the distribution of gender between the groups and indicated gender was significantly related to group membership ($p < .000$).

HINT Identification Performance

Between Groups

Both the military and the non-military group appeared to perform equally well in terms of HINT key-item identification. Independent t-tests were used to compare the scores between the groups with no significant differences being observed ($p > .05$). The mean identification scores for each group in each of the four test conditions are displayed in table 4-2. Non-parametric analyses (Kruskal-Wallis) showed no significant differences in the test conditions between the groups, as well. A scatter plot of the HINT key item identification scores is presented in Figure 4-1. Noteworthy in this figure are the extremely high levels of performance in quiet without and with the additional task, and the greater spread of identification scores in the presence of the combat noise for both the military and non-military groups. Because of the age disparity

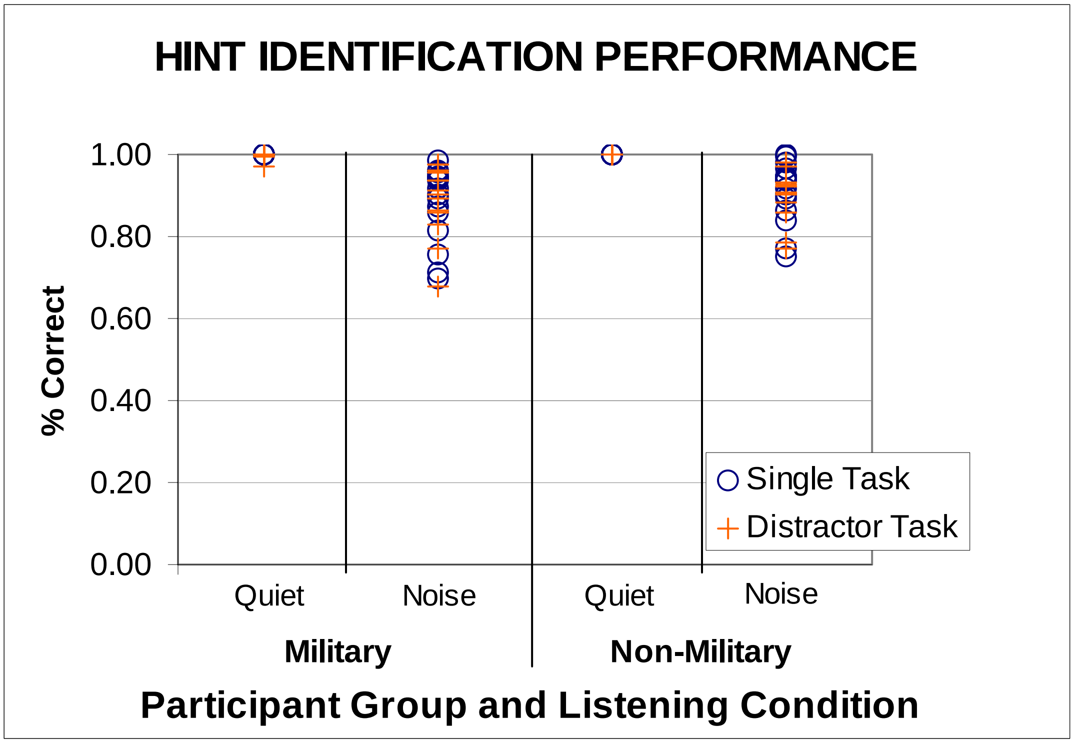


Figure 4-1: HINT identification performance among the participants (military vs. non-military)

between the groups, an analysis of covariance (ANCOVA) was conducted adjusting for age in each condition. This analysis yielded no significant differences between the military and non-military groups.

HINT Reliability

An individual blinded to test conditions (other than the noise condition) scored 10% of the participants' HINT results via audio tape recordings to assess reliability. The inter-rater scoring agreement of 99.7%, overall (100% for items in quiet, and 98.7% for items in noise), suggested good reliability in scoring of the HINT sentences. A Chi-square test of association revealed a strong association ($p<.0001$) between the raters' scoring.

Task Effects

Comparisons between HINT key-item identification scores in the single and dual-task conditions for each group (military and non-military, separately) were conducted using paired t-tests. There were scores no significant differences in either the military or non-military groups ($p>.05$). The non-parametric analyses (Friedman's test) also showed no significant difference for task condition.

Within Groups--Combined

Because no significant differences were observed between groups, participant groups were combined and a repeated measure ANOVA used to analyze the scores in the four test conditions. HINT key-item performance was found to be significantly impacted by noise condition, but not by task condition. Specifically, the noise condition (quiet vs. noise) produced differences in HINT item identification scores ($F=91.655$, $p < .000$). Participants repeated fewer key items correctly in noise than in quiet.

HINT Key-Item Priming

Priming effects were also noted for HINT key items. Specifically, a repeated measures ANOVA was used to make between participant comparisons in the noise and noise + task conditions. These analyses revealed priming did appear to improve primed-item scores

($p < .013$). Also, an interaction between priming and task was noted ($p <.008$). This interaction reflected the resistance of implicitly and explicitly primed scores to the interference from the additional task, while unprimed scores dropped significantly ($p = 0.03$). Figure 4-2 shows mean HINT primed key-item identification performance for the each of the groups in the noise and noise + task conditions. Both military and non-military participants appeared to do better on implicitly and explicitly primed key-items with the additional task in noise, overall. However, without an additional task in noise, explicitly primed items produced similar scores to the unprimed items for both the military and non-military participants.

Table 4-2. Mean HINT Key-Item Performance scores

	Military	Non-military
Quiet	1.00	1.00
Noise	.881	.912
Quiet + Task	.997	1.00
Noise + Task	.894	.905

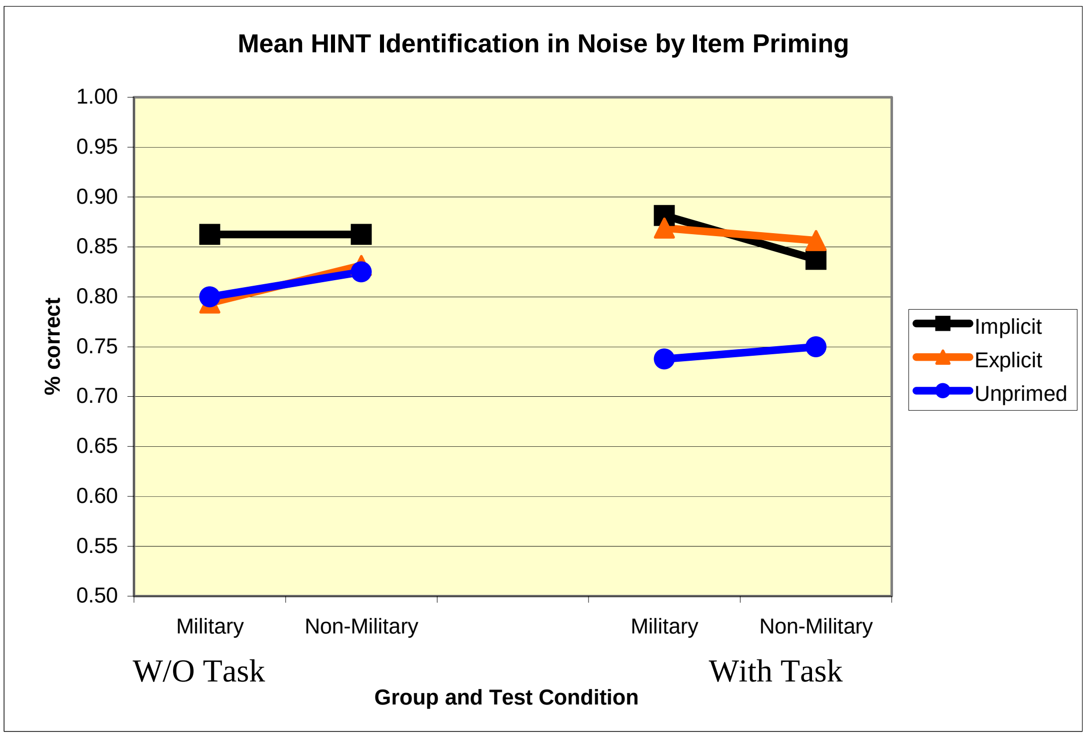


Figure 4-2: HINT primed key-item identification performance for the noise and noise+task conditions by groups.

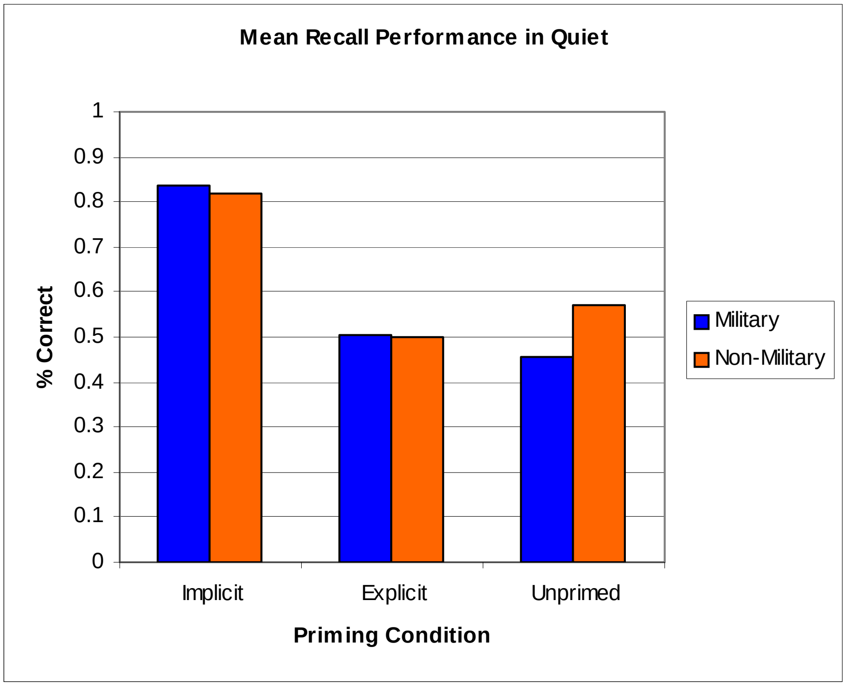
Auditory Recall and Priming

Between Group Comparisons

Both the military and the non-military groups showed no differences in their ability to recall primed items in any of the four test conditions ($p > .05$). Comparisons between the groups (military vs. non-military) were made using independent t-tests and repeated measures ANOVA to evaluate the performance on auditory recall and recall priming effects. Again, because of the age disparity between the groups, an analysis of covariance (ANCOVA) was conducted adjusting for age in each condition. This analysis yielded no significant differences between the military and non-military groups.

Within Group Comparisons

A repeated measures ANOVA was undertaken with the participants from both groups combined to assess the effects of priming, task condition, and noise condition on auditory recall. This analysis revealed priming, task and noise significantly affect auditory recall. In particular, recall performance was higher in the noise than in the quiet condition ($F=8.368$, $p=.007$), in the single task than in the dual-task condition ($F=54.063$, $p<.000$), and in the implicit priming condition than in the explicit or unprimed conditions ($F=328.267$, $p<.000$). Interactions were also noted in the quiet vs. noise and priming ($F=15.056$, $p<.000$), and between the single vs. dual-task and priming ($F=4.857$, $p=.011$). See figure 4-3 for mean recall performance for each group in each condition. This is consistent with studies reported by Craik (2000) that priming may actually improve recall performance on dual-task conditions, as well as with the studies reported by Milligan (1998), Shanks (2004) and Wallace (2001) that dividing attention during encoding can affect explicit recall. Auditory recall was also compared between male and female participants using an independent t-test, which revealed no differences in recall performance between genders.



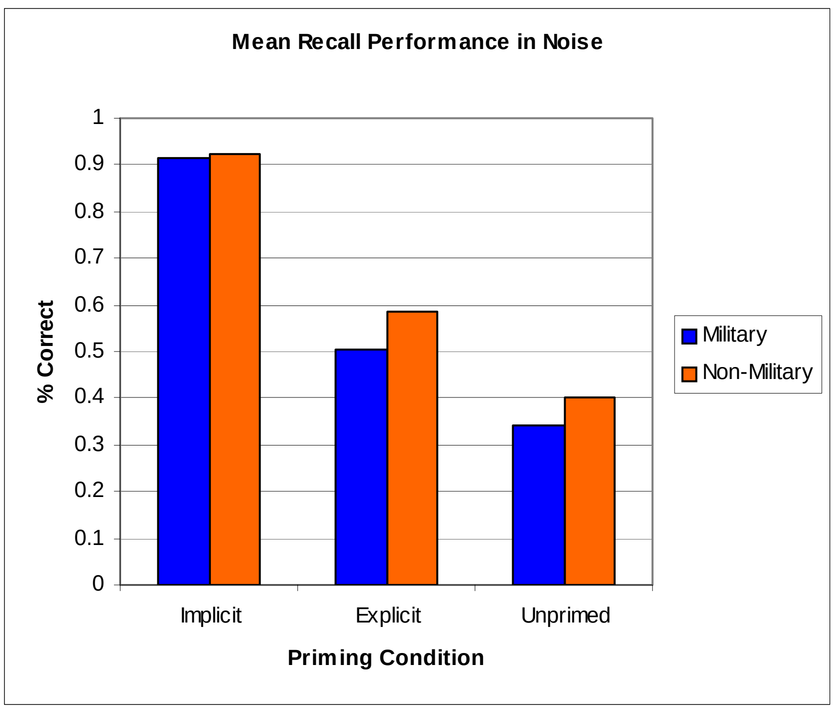
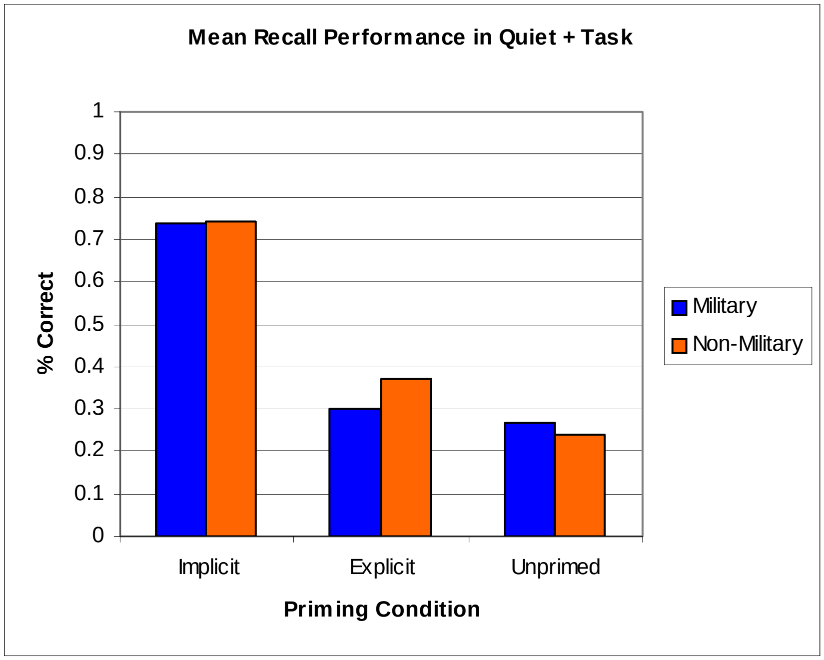


Figure 4-3: Mean recall performance for implicit, explicit, and unprimed items per group and condition



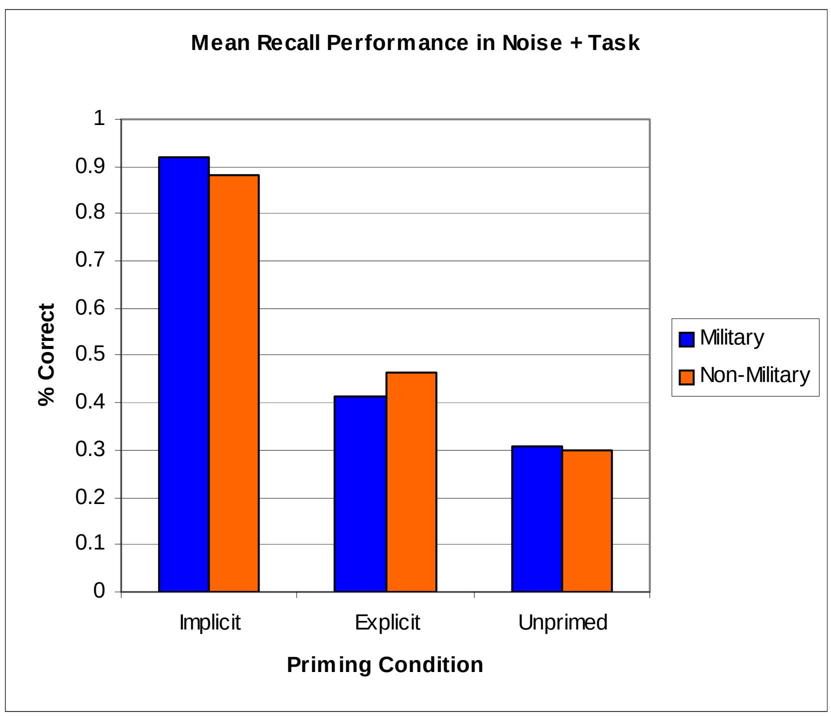


Figure 4-3. Continued

Reaction Times

Between Groups

Reaction times, in general, did not differ between the groups for the noise + task condition ($p = .230$). However, a difference in reaction times between the groups on the MATB task was noted during the quiet + task condition ($p = .033$). The average reaction times for the military group were longer in this condition. Independent t-tests were utilized to make the statistical comparisons. Prior to the analyses being conducted, a log10 transformation was performed on the mean reaction times per participant (Salthouse and Hedden, 002). Figure 4-4 shows the mean reaction times for each group for the quiet + task and the noise + task conditions.

The number of instances of response times marked as 20.01 seconds (“timed-out” which may have included instances of no response or uncorrected erroneous response) were compared between the groups for both the quiet + task and the noise + task conditions. This comparison revealed that the military group had more “timed out” responses than the non-military group in the quiet + task condition (Chi-Square = 4.73, df =1). It is interesting to note that this corresponds with the significant difference in mean reaction time reported above. However, an additional comparison of mean reaction times when the “timed out” responses were excluded revealed no significant differences between groups for the quiet + task or the noise + task conditions. Because the MATB program only reported reaction time in terms of the elapsed time between an event requiring a response and the occurrence of the correct response, it is not known whether some longer reaction times were obtained through participants pressing the incorrect function key.

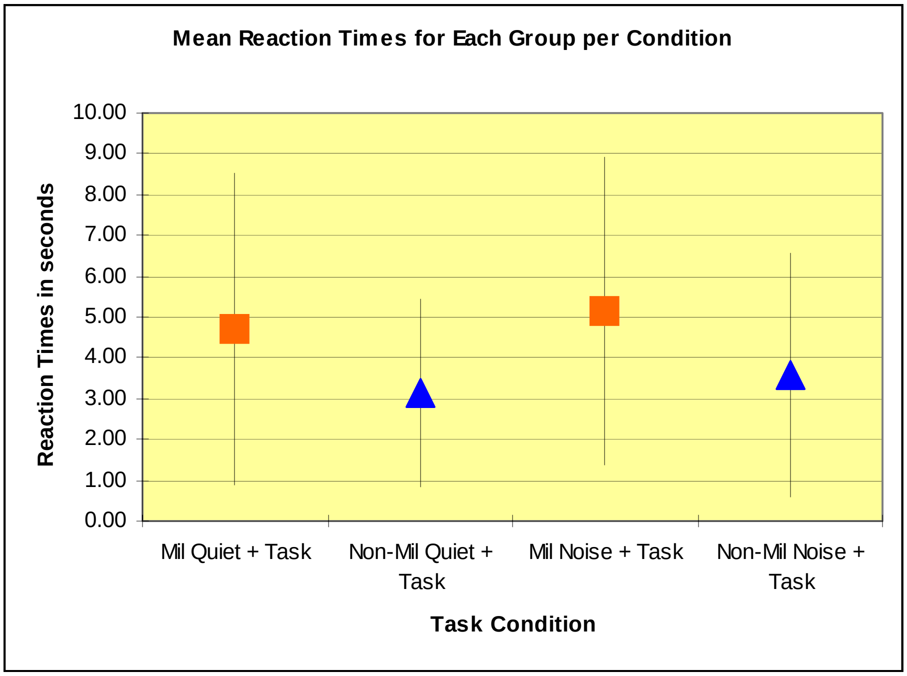


Figure 4-4: Mean reaction times by group

Within Groups

Reaction times for the divided attention tasks were also assessed using a paired t-test collapsed across the participant groups, and yielded no significant differences among the participants within the groups. In addition, an analysis to evaluate age effects on reaction times in both the quiet + task and noise + task conditions was performed, including all participants. A linear regression model was used to make these comparisons and showed no significant differences (F=2.087, p=.142) among the participants for age vs. reaction time.

Video Games

The amount of time a participant played a video game, and their self-assessment of video game skill were compared to the reaction times obtained from the MATB task in both the quiet + task or noise + task conditions. The Mann-Whitney non-parametric statistical test was used to compare video game frequency to reaction times in both the quiet + task and the noise + task conditions and revealed no significant differences ($p=.796$ and $p=.921$, respectively). Likewise, no significant differences were noted using the Kruskal-Wallis non-parametric test to compare self-rated video game skill to reaction times in the quiet + task and the noise + task conditions ($p=.710$ and $p=.767$, respectively). Figure 4-5 displays the participants' reported video game frequency and skill ratings.

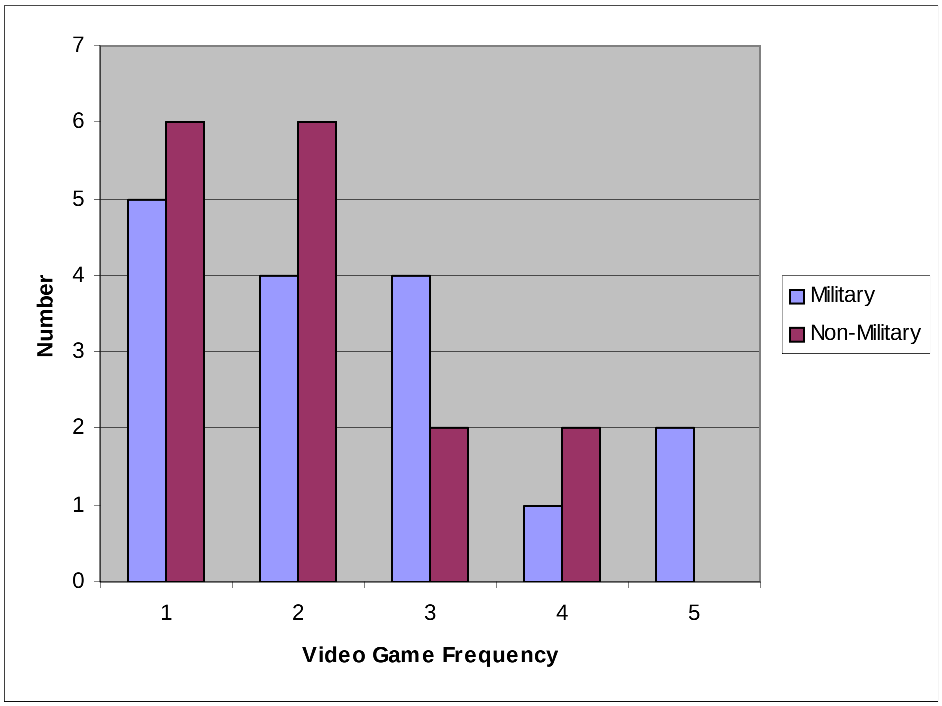


Figure 4-5: Reported video game frequency and skill ratings among the participants

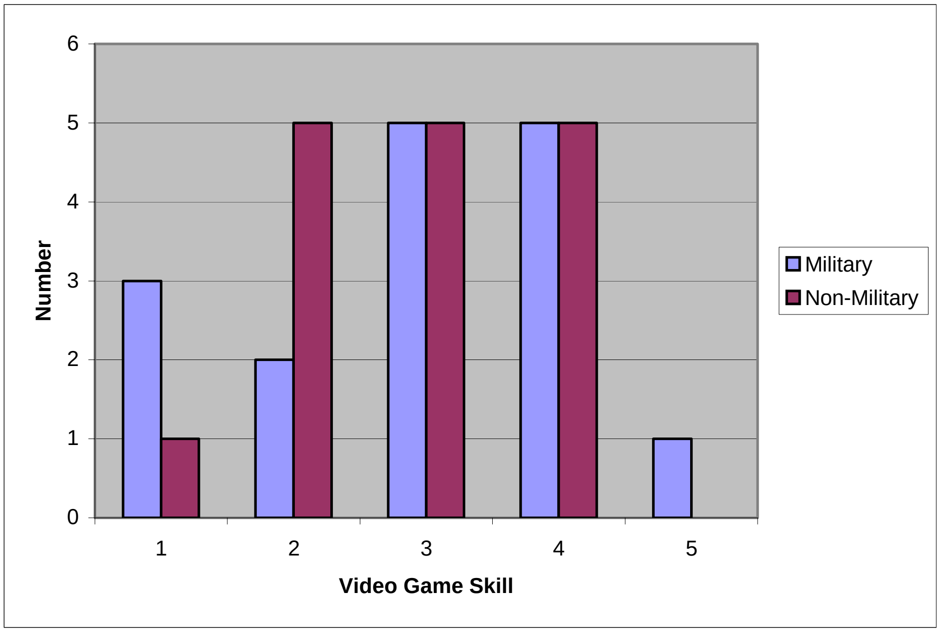


Figure 4-5. Continued

CHAPTER 5
DISCUSSION

The purpose of this research was to determine if divided attention affects speech perception and auditory recall in listeners with and without military training. Recall that the HINT test was used as a tool to measure speech perception in a sound field environment under four conditions: 1) in quiet, 2) in noise, 3) in quiet with a divided attention task, and 4) in noise with a divided attention task. HINT sentences were delivered at 0º azimuth at 64.4 dB SPL. For the noise conditions, the noise was delivered through four speakers located at the following azimuths: 45º, 135º, 225º and 315º. The signal to noise ratio for the HINT sentences to noise was +5 dB. Independent t-tests were generally used to make between group statistical comparisons of the data, while repeated measures ANOVA and paired t-tests were used to make total participant and within group statistical comparisons. An ANCOVA was also conducted for HINT scores and auditory recall scores to adjust for age disparities between the groups.

No significant between group differences were observed with the exception of longer reaction times for the participants with military training in the quiet + task condition. These results revealed that military soldiers did not have an advantage over non-soldiers when it came to understanding speech-in-noise or when performing an additional task. These results beg the following questions: 1) did these particular military soldiers have enough experience or training working in noise, to have performed better than the non-soldiers; 2) does the type of job experience or training actually matter;

and 3) was the signal-to-noise ratio enough to produce sufficient difficulty for understanding speech-in-noise?

It may be that the recorded combat noise used in this study did not sufficiently recreate the sensation of combat which would prove more distracting for those without military training, or that the participants without military training have had more extensive experience with combat noise similar to that used in this study through entertainment media. It may be that any effect military training may have had was obscured by the age and gender differences between the groups. At present there are insufficient data to draw conclusions regarding which, if any, of these possible explanations is valid.

Significant differences were observed for several of the within group and total participant statistical comparisons for HINT key item identification by condition, HINT key item priming effects, auditory recall by condition, and auditory recall priming effects. These will be considered here.

Quiet vs. Noise Conditions

As reported by Crandell and Smaldino (2002), background noise can affect how speech is perceived due to masking of both the linguistic and acoustic cues of the message. However, speech perception for normal hearing adults typically won't be significantly affected until signal-to-ratios reach 0. Miller and Nicely in 1955 reported that wide-band noise affected speech intelligibility, causing confusions among consonants in a similar manner as low-pass filtering and in particular altering the identification of place of articulation (Gelfand, 1998). The vast majority of the participants in this study performed better in the quiet than the noise conditions, resulting in a statistically significant difference between these conditions. Previous studies have documented that older adult listeners (Pichora-Fuller et al., 1995; Tun, 1998) as well as children (Stansfield et al. 2005) had more difficulty understanding speech in noise, however, no current literature exists demonstrating the specific effects of noise on understanding speech in noise for younger and middle-aged adults (18-50). A regression analysis comparing age to HINT noise scores did not reveal a significant relation between these variables in our sample.

Single vs. Divided Attention Conditions

The current research revealed participants did not show any significant differences in HINT key item sentence identification between the single and dual task conditions. However, HINT performance for the quiet vs. noise and for priming recall was degraded. According to McDowd and Shaw (2000), Rubenstein and Meyer (2001), and Shellenbarger (2003), switching attention between tasks should produce a cost to performance; however, when people typically comprehend language during a competing source scenario, they are generally able to focus on relevant information and disregard other information, which could have been what was occurring in this research for HINT identification. A question remains, however, whether or not the divided attention condition used in this research was difficult enough to produce a cost to performance. Dividing attention did produce degraded recall performance in the quiet and noise conditions. This result is supported by previous literature (Craik et al., 2000; Fernandes and Moscovitch, 2003; Mulligan, 1998; Naveh-Benjamin et al., 2000 and 2005; Wallace et al., 2001) showing that people do have more difficulty with recall and recognition if their attention is divided during encoding.

Priming By Item and in Auditory Recall

Statistically significant priming effects were observed in identification and recall performance, indicating that item identification and recall can be enhanced when priming, particularly implicit priming is used. These results are consistent with previous research reported by Mulligan (2001), Rajaram et al (2001), Shulman (1997) and Wallace et al (2001) citing implicit memory is typically not affected when attention is divided at encoding, and implicit priming effects do aid us in retrieving words, as well as with memory. However, previous research done by Craik et al. (2000) and Mulligan (1998) reported dividing attention could negatively affect conceptual (or explicit) priming and recall. Wallace et al. (2001) also reported explicit memory and explicit test performance could be diminished if attention is divided at encoding. Our results were consistent with this body of literature, as our research study revealed that participants had lower explicit scores in noise and in divided attention scenarios, while maintaining scores in the implicit condition.

Significant differences in auditory recall performance were noted between the quiet and noise conditions, the single and dual-task conditions, and among the priming conditions. In addition, significant interactions were found between each pairing of the quiet vs. noise, single vs. dual task, and priming effects on recall performance. Again, these significant results and interactions reveal that auditory recall is affected by noise and divided attention. Pichora-Fuller and her colleagues (1995) reported effects of concurrent memory load produced decrements in speech understanding in noise for both younger and older adults. The interaction between noise and task condition may reflect the additional effort required for processing the speech signal in noise (indirect component) as reported by Tun (1998). The interaction between task condition and priming condition is consistent with the previous literature stated above (Craik et al., 2000 and Mulligan, 1998) reporting dividing attention at encoding can affect both conceptual priming and recall, specifically explicit priming more so than implicit.

Reaction Times vs. Divided Attention and Age

Reaction time comparisons made between the groups revealed a significant difference between the groups in the quiet + task condition only; however, no significant findings were statistically observed between the groups for the noise + task condition, or within the groups for age or video game frequency or self-rating. Additional analyses of reaction time data excluding instances of reaction times marked as 20.01 seconds revealed no significant differences between the groups for the task conditions. In addition, while significant differences were noted between the groups for age and gender, these differences did not appear to be related to HINT identification or recall.

No significant differences were noted when comparing reaction times between the groups in the noise + task condition, and within each group (military vs. non-military) for the quiet + task and noise + task condition. A significant difference was noted between the groups, however, for reaction times in the quiet + task condition. Since reaction times were not assessed for the MATB test alone, it is difficult to quantify these results as being consistent with previous research (Craik et al., 2000; Fernandes and Moscovitch, 2002 and 2003; Naveh-Benjamin et al., 2000; Rajaram, 2001) stating reaction times are typically lengthened in divided attention scenarios.

It is important to note that, according to Craik et al. (2000), reaction times appear to be much longer when attention is divided at retrieval than at encoding, suggesting more demands are placed on personal resources when dividing attention at retrieval. These results beg the questions: 1) was the divided attention task used in this research difficult enough to significantly delay reaction times, 2) were the participants concentrating more on the computer-based divided attention task than to the auditory task, and 3) should the divided attention task have been presented during retrieval of the sentences, rather than during encoding of the sentences?

Of notable mention is the fact that the military group had slightly longer reaction times in the divided attention tasks than the non-military group. Since the military group had a greater mean age compared with the non-military group (37.4 years to 21.8 years), a statistical comparison was made to assess whether or not age played any roll in the causing longer reaction times for the military group. This comparison yielded no significant differences for age, for the military vs. non-military participants. Little research has been done to evaluate reaction times for adults aged 30-60. Most research for divided attention has focused on comparisons of older adults (aged 60 and older) compared with younger adults (aged 18 to 30). However, in a recent research study by Williams et al. (2005), inconsistency in reaction times across the lifespan was evaluated revealing that across age, inconsistency in reaction times varied. These results are consistent with individual differences in “moment-to-moment change.” A U-shaped curve described the relationship between age and inconsistency in reaction times. Williams et al. (2005) reported that as age increased among the participants in childhood, lower levels of inconsistency were noted; however, as age increased among the adult participants, higher levels of inconsistency in reaction times were observed. Beginning between the ages of 30 and 40, Williams’ participants demonstrated a larger spread of scores. This could describe what occurred in the current research study regarding the observed longer reaction times of the military group compared with the non-military group: that reaction times may become more inconsistent among the older participants. One might also predict that inconsistency would show up if the current research protocol were to be undertaken with younger children as well.

Limitations of the Research

As with any research, potential limitations are possible. This research study is no different. The age and gender differences between the groups represent sampling artifacts that mitigate some potential conclusions from the obtained data. Although some of the data obtained in this research are consistent with previous published research, the data can only be generalized for, younger to middle-aged healthy adults with essentially normal hearing. The data obtained may not be applied to older, hearing impaired, or unhealthy adults.

Another notable limitation regarding this research is that the sentences were presented in a sound field condition in front of the participant, at a 0° azimuth, while uncorrelated combat noise was presented at the same time in the sound field condition at 45°, 135°, 225° and 315°.   While consistent with other research, this speaker-listener orientation may not be applicable to other listening conditions. Also, the listener was not afforded the opportunity to gain additional information through visual cues of speech, which may have helped overall performance for HINT key item sentence identification. However, it should be noted that many military soldiers are not always afforded the opportunity to obtain visual speech cues when listening and trying to understand speech in noisy combat conditions.

Future Directions

As with any research, the current research poses ideas for future research. First, it would be interesting to tailor future research to specifically obtain data on the effects of divided attention and personal resource depletion in middle-aged adults. Since little research has been done in this area, it would be interesting to determine at what age, if any, a significant decrease in performance is observed for aging adults.

Second, it would be interesting to delve more into researching what effects dividing attention during retrieval of information has on military soldiers.

Third, an additional area interest for research would be to assess how well military soldiers understand specific job-related phrases or sentences in the presence of combat noise, and while doing more job-related tasks as the divided attention component. This research could possibly compare military soldiers within military occupational specialties (MOSs) to see if differences exist regarding speech understanding and performance relating to their specific jobs within and between MOSs.

Fourth, future research using divided attention and speech understanding comparing participants who have been diagnosed with auditory processing disorder or attention deficit disorder, compared with those who do not have those disorders, would also be of interest.

APPENDIX A
QUESTIONNAIRE FOR PARTICIPANTS

Divided Attention, Perception and Auditory Recall Research Questionnaire

Participant # _______________

Thank you for you time and for participating in this research. Please answer the following questions completely and to the best of your ability. Your identity will be kept confidential and the researchers will only know you as a participant number. If you have any questions regarding this questionnaire, please ask the examiner to assist you. Your participation in this research is completely voluntary and greatly appreciated.

Please CIRCLE the yes/no answers, put an X in front of, or fill in the blanks as indicated for the following questions:

1. Do you have any visual color deficiencies (i.e., red/green color blind)? Yes No **If yes, please tell the examiner before completing the rest of this questionnaire.**

2. Do you have vision problems prohibiting you to clearly see a computer screen? Yes No **If yes, please tell the examiner before completing the rest of this questionnaire.**

3. Are you a member of the U.S. military? Yes No If yes, what is your current rank _______: and how many **total** years of service do you have? _______

4. What is your current age? _____ years

5. What is your gender? male female

6. What level of education have you obtained thus far?

____high school graduate only
____current college student
____college graduate

7. If you are a college graduate, what level of degree have you obtained thus far?

____Bachelors Degree
____Masters Degree
____Doctoral Degree

8. Are you (please circle one): a) right handed b) left handed?

9. In the past **5 years**, how often have you played video games? Please circle one of the following:

a) Very frequently b) Frequently c) Occasionally d) Rarely e) Never

10. How would you rate your video game skills?
a) Very Good b) Good c) Fair d) Poor e) No skill

APPENDIX B
INFORMED CONSENT FORM

UNIVERSITY OF FLORIDA

Department of Communication Sciences & Disorders

336 Dauer Hall
P.O. Box 117420
Gainesville, Florida 32611-7420
(352) 392-2113
Fax (352) 846-0243

Informed Consent

Protocol Title: Divided Attention, Perception, and Auditory Recall

Please read this consent document carefully before you decide to participate in this study.

Purpose of the research study: To obtain information on listening and memory in people with and without military training.

What you will be asked to do in the study: In this study you will be asked to complete several tasks: 1) to repeat back a series of numbers in both forward and backward order, 2) to study a list of words and sentences for 5 minutes, 3) to perform a video game task and repeat back sentences both in quiet and in the presence of battlefield-type background noise presented via speakers, and 4) to respond to questions regarding sentences heard in step 3.

Time required: The approximate time required for this study is a total of 1.5 hours.

Risks and Benefits: The rating procedures used in this study has no potential risks or benefits.

Compensation: You will be paid $10 per hour for your time, with a cap of $20.

Confidentiality: Your identity will be kept confidential to the extent provided by law. Your name will not be used in any recording or reporting.

Voluntary participation: Your participation in this study is completely voluntary. There is no penalty for not participating.

Right to withdraw from the study: You have the right to withdraw from the study at anytime without consequence.

Whom to contact if you have questions about the study: Lynnette Bardolf, Ph.D. candidate, Communication Sciences and Disorders, (352) 283-1633, 356 Dauer Hall, P.O. Box 117420 Gainesville, FL 32611-7420, lbardolf@ufl.edu; or you may contact Dr. Scott Griffiths, Communication Sciences and Disorders, (352) 392-2113, x248, 356 Dauer Hall, P.O. Box 117420, Gainesville, FL 32611-7420, sgriff@csd.ufl.edu

Whom to contact about your rights as a research participant in the study: UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; ph 392-0433.

Agreement:

I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant: ____ Date: _________________

Principal Investigator: ___________________________________ Date: _________________

APPENDIX C
INSTRUCTIONS FOR DIVIDED ATTENTION STUDY

Thank you for participating in this research study. Your time is greatly appreciated.

This study will require you to pay close attention to the tasks at hand. You will be listening to sentences in 4 separate conditions (120 sentences total). After you hear each sentence, please repeat it back. If noise is present along with the sentence, please repeat the sentence back **after** the noise has finished.

When we get to the computer-task portion of the study, it will require that you monitor the red and green lights, as well as monitoring some arrows, at the top left portion of the screen. When you see the green light go **OFF**, please push the F5 key as soon as possible. When you see the red light go **ON**, please press the F6 key as soon as possible. When you the arrows moving up and down, **press the corresponding labeled keys (F1, F2, F3, and F4)**. You will need to press the corresponding function keys as soon as possible once you see the arrows deviate **more than 1 line above or below the center mark**. If the computer screen stops as any time during the testing, please let the examiner know. The examiner will familiarize you with the computer before you begin the computer-task portion of the test.

Please continue to repeat back the sentences no matter what task you are doing (in addition to repeating the sentences), if a secondary task is required. If you need a break during the testing, please wait until after the test condition is finished. Each test condition takes approximately 3 minutes, 45 seconds. You will be given a sheet to fill out after each condition.

Do you have any questions at this time?

APPENDIX D
FORWARD AND REVERSE DIGIT SPAN TEST

Participant # _________

Forward Digit Span Test:

4 digits:

1st try: 5 9 7 1
2nd try: 4 8 2 3

5 digits:

1st try: 8 6 5 1 4
2nd try: 9 3 4 2 8

6 digits:

1st try: 5 9 6 1 3 2
2nd try: 4 8 9 7 6 3

7 digits:

1st try: 9 4 7 8 2 6 3
2nd try: 0 4 1 8 3 2 7

8 digits:

1st try: 4 8 6 3 5 9 0 2
2nd try: 9 4 0 3 1 8 2 7

9 digits:

1st try: 0 5 7 9 8 4 3 1 2
2nd try: 2 5 3 7 5 9 6 8 1

Forward Score: ___________

Reverse Digit Span Test:

4 digits:

1st try: 9 7 1 3
2nd try: 0 8 4 1

5 digits:

1st try: 6 8 9 0 4
2nd try: 9 5 8 6 1

6 digits:

1st try: 7 4 6 9 0 1
2nd try: 5 4 0 7 2 9

7 digits:

1st try: 0 8 4 3 1 9 0
2nd try: 5 3 1 9 6 7 2

8 digits:

1st try: 9 8 1 6 5 3 0 3
2nd try: 4 9 6 2 4 9 0 2

9 digits:

1st try: 3 6 7 8 9 2 1 5 0
2nd try: 7 9 5 4 2 8 6 1 3

Reverse Score: ___________

APPENDIX E
IMPLICIT AND EXPLICIT PRIMING STUDY LISTS BY VERSION

Divided Attention, Perception and Auditory Recall Research Study Sheet
(Version 1)

picture
An open flame is dangerous.
dirty
The robber took all their cash.
faucet
The plant blossomed in the soil.
sister
The store is not open during the noon eating hour.
funny noise
The pages reveal a tale.
mother
The small child ran away from his house.
saucer
The lady placed her items in her suitcase.
pitcher
Some people viewed the frightening film.
flowers
Some people brought their meal outdoors.
vacation
The infant cracked his sippy glass.
dishcloth
The baking appliance is ajar.
mother
The person is walking to the other side of the street.
children
Mom baked a goodie to celebrate the child's birth.
window
The clear crystals we eat taste honey-like.
firetruck
There was an atrocious locomotive collision.
police
The man misplaced his cap the other day.
truck
The hen produced some offspring shells

orange
Mom closed the glass panes.
sister
The young lady is merry.
lemon pie
The male child fell asleep before his bedtime.

drinking
The vehicle needs to slow down.
police
The competitor's cleat fell off his foot.
strawberry
The citrus arrived in a square container.
credit card
The dirt sweeper is at the edge of the room.
matches
The pasteurized cow's liquid is by the anterior entryway.
yellow
The woman relaxes in her seat.
vacation
The not-so-short guy fastened his sneakers.
closet
Some people sat for sixty minutes.
plates
The supermarket worker vends margarine.
mailman
The large branch toppled onto the roof.
chocolate
The woman dressed in a jacket.
football
The boy injured his lower appendage for the second time.
shopping
The toy sphere propelled into the air.
school
The infant wants his milk feeder.
mother
The little guy escaped from his learning environment.
dinner
The male child destroyed the pine gate.
nervous
The aquatic creature moved through the natural fresh-water holding area
bakery
The man took the canines for a stroll.
cold cuts
Frigid flakes of precipitation occur in the season after fall.
street
The kid tore apart the sack.

<u>Divided Attention, Perception and Auditory Recall Research Study Sheet (Version 2)</u>

husband
The child toppled through the glass pane.
bad dogs
The plant blossomed in the soil.
floor
The boy frightened his female sibling.
faucet
The pages reveal a tale.
brother
The feline sprung across the gate.
going out
The grown kitty sipped from the bowl.
vacation
The male child stood on his hands.
letter
The infant cracked his sippy glass.
outside
The kids rinsed the circular dishes.
vacation
Mom mixed her herbal liquid.
pasture
The glasses are on furniture used for eating.
football
The clear crystals we eat taste honey-like.
kitchen
Mom picked up the pot.
birthday
The hen produced some offspring shells.
yesterday
The amphibious creature moved through the fresh-water holding area
nervous
Mom closed the glass panes.
mother
The lady tidied her home
strawberries
The kid tore apart the sack.
friend
The group is good at competing.
train

The open flame was too warm.
drinking
The vehicle needs to slow down.
dirty
The cop assisted the person manning the vehicle.
mirror
The woman misplaced her piece of plastic capable of buying things.
strawberry
The fire starters are located on the ledge.
stick
Mom pulled out the sliding clothes hanger.
little boy
The woman is cleaning the outfit she just bought.
shoes
Some people sat for sixty minutes.
closet
The large branch toppled onto the roof.
butter
Some people ate cocoa flavored mousse.
string
The woman dressed in a jacket.
bread
The feline slept on the furniture used for sleeping.
spoon
The learning institution closed sooner than usual this day.
laughing
The irate gentleman bellowed.
bottle
The vehicle crept to the top of the peak.
Wooden fence

Drops of precipitation fell from the sky.
neighbor
The girl's female sibling remained for the noon eating hour.
winter
The male child proceeded to his sleeping area before his normal time.
cold cuts
The little ones assisted their professor.
lemon pie
Mom pulled out the sliding holder.

APPENDIX F
HINT SENTENCES

Track 1

1. A boy fell from a window.
2. The wife helped her husband.
3. Big dogs can be dangerous.
4. Her shoes were very dirty.
5. The player lost a shoe.
6. Somebody stole that money.
7. The fire is very hot.
8. She's drinking from her own cup.
9. The picture came from a book.
10. The car is going too fast.

Track 2

1. A boy ran down the path.
2. Flowers grow in the garden.
3. Strawberry jam is sweet.
4. The shop closes for lunch.
5. The police helped the driver.
6. She looked in her mirror.
7. The match fell on the floor.
8. The fruit came in a box.
9. He really scared his sister.
10. The tub faucet is leaking.

Track 3

1. They heard a funny noise.
2. He found his brother hiding.
3. The dog played with a stick.
4. The book tells a story.
5. The matches are on the shelf.
6. The milk is by the front door.
7. The broom is in the corner.
8. The new road is on the map.
9. She lost her credit card.
10. The team is playing well.

Track 4

1. The little boy left home.
2. They're growing up too fast.
3. A cat jumped over the fence.
4. He wore his yellow shirt.
5. The lady sits in her chair.
6. He needs his vacation.
7. She's washing her new silk dress.
8. The cat drank from the saucer.
9. Mother opened the drawer.
10. The lady packed her bag.

Track 5

1. The boy did a handstand.
2. They took some food outside.
3. The young people are dancing.
4. They waited for an hour.
5. The shirt is in the closet.
6. They watched a scary movie.
7. The milk is in the pitcher.
8. The truck drove up the road.
9. The tall man tied his shoes.
10. A letter fell on the floor.

Track 6

1. The silly boy is hiding.
2. The dog growled at the neighbors.
3. A tree fell on the house.
4. Her husband brought some flowers.
5. The children washed the plates.
6. They went on vacation.
7. Mother tied the string too tight.
8. The mailman shut the gate.
9. A grocer sells butter.
10. The baby broke his cup.

Track 7

1. The cows are in the pasture.
2. The dishcloth is soaking wet.
3. They had some chocolate pudding.
4. She spoke to her eldest son.
5. The oven door is open.
6. She's paying for her bread.
7. My mother stirred her tea.
8. He broke his leg again.
9. The lady wore a coat.
10. The cups are on the table.

Track 8

1. The ball bounced very high.
2. Mother cooked a birthday cake.
3. The football game is over.
4. She stood near the window.
5. The kitchen clock was wrong.
6. The children helped their teacher.
7. They carried some shopping bags.
8. Someone is crossing the road.
9. She uses her spoon to eat.
10. The cat lay on the bed.

Track 9

1. School got out early today.
2. The football hit the goalpost.
3. The boy ran away from school.
4. Sugar is very sweet.
5. The two children are laughing.
6. A fire truck is coming.
7. Mother got a sauce pan.
8. The baby wants his bottle.
9. The ball broke the window.
10. There was a bad train wreck.

Track 10

1. The boy broke the wooden fence.
2. The angry man shouted.
3. Yesterday he lost his hat.
4. The nervous driver got lost.
5. The cook is baking a cake.
6. The chicken laid some eggs.
7. A fish swam in the pond.
8. They met some friends at dinner.
9. The man called the police.
10. The truck made it up the hill.

Track 11

1. The neighbor's boy has black hair.
2. The rain came pouring down.
3. The orange was very sweet.
4. He took the dogs for a walk.
5. Children like strawberries.
6. Her sister stayed for lunch.
7. The train was moving fast.
8. Mother shut the window.
9. The bakery is open.
10. Snow falls in the winter.

Track 12

1. The boy went to bed early.
2. The woman cleaned her house.
3. A sharp knife is dangerous.
4. The child ripped open the bag.
5. They had some cold cuts for lunch.
6. She's helping her friend move.
7. They ate the lemon pie.
8. They are crossing the street.
9. The sun melted the snow.
10. The little girl is happy.

APPENDIX G
HINT QUESTIONS BY VERSION

HINT Sentences (Version #1)

Subject # _____________

Condition #1		**Correct response**	**Paradigm**
Track 1			
1. Who did the wife help?		her husband	unprimed
2. What was very hot?		the fire	explicit
3. Where did the boy fall from?		the window	unprimed
4. What came from the book?	(p _ _ ct _ _ e)	picture	implicit
5. The car is going too what?		fast	explicit
6.. What is she doing from her cup?	(_r_ nk_ _ng)	drinking	implicit
7. What did somebody steal?		money	explicit
8. What is dangerous?		big dogs	unprimed
9. Her shoes where what?	(d _ r _ _)	dirty	implicit
10. What did the player loose?		a shoe	explicit
Track 2			
1. Where did the match fall?		on the floor	unprimed
2. What grows in the garden?		flowers	explicit
3. Who helped the driver	(p _ l _c _)	police	implicit
4. What did she look into?		a mirror	unprimed
5. The fruit came in what?		a box	explicit
6. What is leaking in the tub?	(f _ _ c _ t)	faucet	implicit
7. Where did the boy run?		down the path	unprimed
8. What kind of jam is sweet?	(_ tr _ w _ _ r r _)	strawberry	implicit
9. What closes for lunch?		the shop	explicit
10. Who did he scare?	(s _ st_ _)	sister	implicit
Track 3			
1. What is in the corner?		a broom	explicit
2. What did she loose?	(c _ _ d _ t c _ _ d)	credit card	implicit
3. Where did he find his brother?		hiding	unprimed
4. What did they hear?	(f _ _ ny n _ _ se)	funny noise	implicit
5. What did the dog play with?		a stick	unprimed
6. What tells a story?		a book	explicit
7. What is the team doing?		playing well	unprimed
8. Where is the new road?		on the map	unprimed
9. What is on the shelf?	(m _ _ ch _ _)	matches	implicit
10. What is by the front door?		milk	explicit

Condition #2		Correct response	Paradigm
Track 4			
1. What are they doing too fast?		growing up	unprimed
2. What did the cat jump over?		the fence	unprimed
3. Who left home?		the little boy	explicit
4. Who opened the drawer?	(_ oth_ _)	mother	implicit
5. What color shirt did he wear?	(_ el _ _ w)	yellow	implicit
6. Where did the lady sit?		in her chair	explicit
7. What did the cat drink from?	(s _ _ c _ r)	saucer	implicit
8. What did the lady pack?		her bag	explicit
9. What does he need?	(_ aca _ __n)	vacation	implicit
10. What was she washing?		her silk dress	unprimed
Track 5			
1. What are the young people doing?		dancing	unprimed
2. What did the tall man tie?		his shoes	explicit
3. Where is the milk?	(p _ _ ch _ r)	pitcher	implicit
4. Where did the letter fall?		on the floor	unprimed
5. What did they watch?		scary movie	explicit
6. Where is the shirt?	(cl _ _ e _)	closet	implicit
7. What type of acrobat did the boy do?		a handstand	unprimed
8. How long did they wait?		an hour	explicit
9. Where did the truck drive?		up the road	unprimed
10. Where did they take the food?		outside	explicit
Track 6			
1. What did the dog do to the neighbors?		growled at them	unprimed
2. What does the grocer sell?		butter	explicit
3. What did the baby break?		his cup	explicit
4. What did the husband bring her?	(f _ _ _ er _)	flowers	implicit
5. What fell on the house?		tree	explicit
6. What was the silly boy doing?		hiding	unprimed
7. What did the children wash?	(_ _ ate _)	plates	implicit
8. Where did they go?	(_ _ cat _ _ _)	vacation	implicit
9. Who shut the gate?	(m _ _ lm _ n)	mailman	implicit
10. What did the mother do with the string?		tied it too tight	unprimed

Condition #3		**Correct response**	**Paradigm**
Track 7			
1. What is soaking wet?	(di _ _ cl _ _ _)	dishcloth	implicit
2. Where were the cows?		in the pasture	unprimed
3. What flavor pudding did they have?	(_ _ oco _ _ te)	chocolate	implicit
4. Whom did she speak with in her family?		her eldest son	unprimed
5. What is open?		oven door	explicit
6. Who stirred her tea?	(m _ _ th _ _)	mother	implicit
7. What did the lady wear?		coat	explicit
8. What did he break again?		his leg	explicit
9. What was she paying for?		the bread	unprimed
10. Where were the cups?		on the table	unprimed
Track 8			
1. What type of game was over?	(f _ _ tb _ _)	football	implicit
2. Who helped their teacher?	(_ _ ild _ _ n)	children	implicit
3. What is someone crossing?		the road	explicit
4. Where did the cat lay?		on the bed	unprimed
5. What is she using to eat?		her spoon	unprimed
6. What type of bags did they carry?	(_ _ op _ _ ng)	shopping	implicit
7. What did she stand near?	(w _ _ d _ w)	window	implicit
8. The kitchen clock was what?		wrong	unprimed
9. What type of cake did mother cook?		birthday	explicit
10. What did the ball do?		bounced very high	explicit
Track 9			
1. What is very sweet?		sugar	explicit
2. What does the baby want?		bottle	explicit
3. What got out early today?	(sc _ _ _ l)	school	implicit
4. What hit the goalpost?		the football	unprimed
5. What is coming?	(fi _ _ tr _ _k)	firetruck	implicit
6. Who got a sauce pan?	(m _ th _ _)	mother	implicit
7. What are the two children doing?		laughing	unprimed
8. What did the ball break?		the window	unprimed
9. What type of wreck was there?		train	explicit
10. Who ran away from school?		boy	explicit

Condition #4		**Correct response**	**Paradigm**
Track 10			
1. What did the angry man do?		he shouted	unprimed
2. When did he loose his hat?		yesterday	explicit
3. What did the boy break?		wooden fence	explicit
4. What is she baking?		a cake	unprimed
5. What laid some eggs?		chicken	explicit
6. Who did the man call?	(_ ol _ _ e)	police	implicit
7. When did they meet some friends?	(d i _ _ _ r)	dinner	implicit
8. What made it up the hill?	(tr _ _ _)	truck	implicit
9. Where did the fish swim?		in the pond	explicit
10. What type of driver got lost?	(n _ _ v _ _ s)	nervous	implicit
Track 11			
1. What came pouring down?		rain	unprimed
2. What color was the neighbor boy's hair?		black	unprimed
3. What was very sweet?	(_ ran _ _)	orange	implicit
4. What did he take for a walk?		dog	explicit
5. Who shut the window?		mother	explicit
6. What is open?	(ba _ _ _ y)	bakery	implicit
7. When does snow fall?		winter	explicit
8. Who stayed for lunch?	(s _ st _ _)	sister	implicit
9. How was the train moving?		fast	unprimed
10. What kind of fruit did the children like?		strawberries	unprimed
Track 12			
1. What did the woman clean?		her house	unprimed
2. What was dangerous?		the sharp knife	unprimed
3. What did they have for lunch?	(c _ _ d c _ ts)	cold cuts	implicit
4. Who is she helping move?		her friend	unprimed
5. What did they eat?	(le _ _ n p _ e)	lemon pie	implicit
6. What are they crossing?	(_ tr _ _ t)	street	implicit
7. What did the sun melt?		the snow	unprimed
8. Who went to bed early?		boy	explicit
9. What did the child rip open?		bag	explicit
10. Who is happy?		little girl	explicit

Hint Sentences (Version #2)

Participant # ________

Condition #1		**Correct Response**	**Paradigm**
Track 1			
1. The wife helped whom?	(h_ _ b_ nd)	husband	implicit
2. What was very hot?		the fire	explicit
3. Who fell from the window?		the boy	explicit
4. Where did the picture come from?		a book	unprimed
5. The car is going too what?		fast	explicit
6.. What is she doing from her cup?	(_r_ nk_ _ng)	drinking	implicit
7. What was stolen?		money	unprimed
8. What can be dangerous?	(b _ g d _ _ s)	big dogs	implicit
9. Her shoes where what?	(d _ r _ _)	dirty	implicit
10. What did the player loose?		his shoe	unprimed
Track 2			
1. The match fell where?	(f_ _ _ r)	floor	implicit
2. What grows in the garden?		flowers	explicit
3. Who helped the driver?		police	explicit
4. What did she look into?	(m _ _ r _ r)	mirror	implicit
5. What came in a box?		fruit	unprimed
6. What is leaking in the tub?	(f _ _ c _ t)	faucet	implicit
7. What did the boy run down?		path	unprimed
8. What kind of jam is sweet?	(_ tr _ w _ _ r r _)	strawberry	implicit
9. What closed for lunch?		the shop	unprimed
10. Who did he scare?		sister	explicit
Track 3			
1. What was in the corner?		a broom	unprimed
2. What did she loose?		credit card	explicit
3. Who did he find hiding?	(br _ _h _ r)	brother	implicit
4. What did they hear?		a funny noise	unprimed
5. What did the dog play with?	(st _ _ k)	stick	implicit
6. What tells a story?		a book	explicit
7. What is the team doing well?		playing	explicit
8. What was on the map?		new road	unprimed
9. What is on the shelf?		matches	explicit
10. What was by the front door?		yes	unprimed

Condition #2		Correct response	Paradigm
Track 4			
1. What are they doing tonight?	(g _ _ ng o_t)	going out	implicit
2. What did the cat jump over?		a fence	explicit
3. Who left home?	(li _ _ l _ b _ y)	the little boy	implicit
4. Who opened the drawer?		mother	explict
5. What color shirt did he wear?		yellow	explicit
6. Where did the lady sit?		in her chair	unprimed
7. What did the cat drink from?		saucer	explicit
8. What did the lady pack?		her bag	unprimed
9. What does he need?	(_ aca _ __n)	vacation	implicit
10. What is she washing?		her new silk dress	explicit
Track 5			
1. What were the young people doing?		dancing	unprimed
2. What did the tall man tie?	(sh _ _ s)	his shoes	implicit
3. What was in the pitcher?		milk	unprimed
4. What fell on the floor?	(_ et _ _ r)	letter	implicit
5. What did they watch?		a scary movie	unprimed
6. Where is the shirt?	(cl _ _ e _)	closet	implicit
7. What did the boy do?		handstand	explicit
8. How long did they wait?		an hour	explicit
9. Where did the truck drive?		up the road	unprimed
10. Where did they take the food?	(ou_ s _ _ e)	outside	implicit
Track 6			
1. What did the dog do to the neighbors?		growled at them	unprimed
2. What does the grocer sell?	(b _ t _ _ r)	butter	implicit
3. What did the baby break?		his cup	explicit
4. What did the husband bring his wife?		flowers	unprimed
5. What fell on the house?		tree	explicit
6. Who was hiding?		silly boy	unprimed
7. What did the children wash?		plates	explicit
8. Where did they go?	(_ _ cat _ _ n)	vacation	implicit
9. Who shut the gate?		mailman	unprimed
10. What did the mother tie too tight?	(s _ _ _ ng)	string	implicit

Condition #3		Correct response	Paradigm
Track 7			
1. What was soaking wet?		dishcloth	unprimed
2. Where are cows?	(_ ast _ _ e)	in the pasture	implicit
3. What flavor pudding did they have?		chocolate	explicit
4. Whom did she speak to?		the eldest son	unprimed
5. What was open?		the oven door	unprimed
6. Who stirred her tea?		mother	explicit
7. What did the lady wear?		coat	explicit
8. What did he break again?		his leg	unprimed
9. What is she paying for?	(br _ _ d)	bread	implicit
10. What are the cups on?		table	explicit
Track 8			
1. What type of game was over?	(_ oo _ b _ ll)	football	implicit
2. Who helped their teacher?		children	explicit
3. Who was crossing the road?		someone	unprimed
4. Where did the cat lay?		the bed	explicit
5. What is she using to eat?	(_ po _ n)	spoon	implicit
6. What kind of bags did they carry?		shopping	unprimed
7. What did she stand by?		the window	unprimed
8. Which clock was wrong?	(_ _ tch _ _)	kitchen	implicit
9. What type of cake did mother cook?	(_ _ rt _ d _ y)	birthday	implicit
10. What bounced very high?		the ball	unprimed
Track 9			
1. What is very sweet?		sugar	explicit
2. What does the baby want?	(b_ tt _ _)	bottle	implicit
3. What got out early today?		school	explicit
4. What hit the goalpost?	(_ o o _ b _ l _)	football	implicit
5. What is the fire truck doing?		coming	unprimed
6. Who got a sauce pan?		mother	explicit
7. What are the two children doing?	(_ aug _ _ in_)	laughing	implicit
8. What broke the window?		ball	explicit
9. What type of wreck was there?	(_ ra _ n)	train	implicit
10. Where did the boy run away from?		from school	unprimed

Condition #4		**Correct response**	**Paradigm**
Track 10			
1. What did the angry man do?		shout	explicit
2. When did he loose his hat?	(_ est _ _ d_ y)	yesterday	implicit
3. What did the boy break?	(w _ _ d _ n f _ _ c _)	wooden fence	implicit
4. What is baking?		the cake	unprimed
5. What laid some eggs?		chicken	explicit
6. Who did the man call?		the police	unprimed
7. Who did they meet for dinner?		their friends	unprimed
8. What made it up the hill?		truck	explicit
9. Where did the fish swim?		in the pond	explicit
10. What type of driver got lost?	(n _ _ v _ _ s)	nervous	implicit
Track 11			
1. What did the rain do?		came pouring down	explicit
2. Which boy had black hair?	(nei _ _ _ or)	neighbor	implicit
3. What was very sweet?		the orange	unprimed
4. Who did he take for a walk?		the dog	unprimed
5. Who shut the window?	(m _ _ t _ er)	mother	explicit
6. What is open?		the bakery	explicit
7. When does snow fall?	(_ in _ _r)	winter	implicit
8. Who stayed for lunch?		sister	explicit
9. What was the train doing?		moving fast	unprimed
10. What did the children like?	(st _ _ _ be _ _ ies)	strawberries	implicit
Track 12			
1. What did the woman do to her house?		cleaned it	explicit
2. What is dangerous?		the sharp knife	unprimed
3. What did they have for lunch?	(c _ _ d c _ ts)	cold cuts	implicit
4. Who is she helping move?	(_ ri _ _d)	friend	implict
5. What did they eat?	(le _ _ n p _ e)	lemon pie	implicit
6. What are they doing?		crossing the street	unprimed
7. What did the sun melt?		the snow	unprimed
8. Who went to bed early?		boy	explicit
9. What did the child rip open?		bag	explicit
10. Who is happy?		the little girl	unprimed

APPENDIX H
EXAMPLE OF RESPONSE TIME PRINTOUT FROM THE MATB

Appendix H: Example of response time printout from the MATB test

02-09-2006 12:53:20 MD020912.49M

57.01	6	1.70
63.05	2	4.23
81.01	3	4.12
102.05	5	2.03
152.03	5	1.65
163.01	3	4.95
178.01	5	1.76
204.04	2	1.65

Response Time

Event Code

Elapsed time at beginning of monitoring event

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BIOGRAPHICAL SKETCH

Lynnette Bosse Bardolf was born on 27 May 1964 in Grand Rapids, Michigan. The youngest of seven children, she grew up mostly in Jacksonville, Florida, graduating from Fletcher High School in 1982. She earned her B.S. in Communication Disorders and her M.S. in Audiology from the Florida State University (FSU) in 1989 and 1990, respectively. Also a graduate of the FSU Army Reserve Officer Training Corps (ROTC) as a Distinguished Military Graduate, she received a commission as a 2nd Lieutenant in the Medical Service Corps in 1989. Upon graduating in December 1990 with her M.S. in Audiology, Lynnette entered the active duty Army as a 1st Lieutenant at Ft. Sam Houston, Texas, in January 1991. As an Army audiologist for the past 15 years, and currently ranked a Lieutenant Colonel (LTC), Lynnette's past assignments took her to Colorado, Alabama, Germany, and Hawaii working as a clinical audiologist and hearing conservationist serving active duty members, retirees, and military family members in all branches of the U.S. military. Lynnette's distinguished career has afforded her many wonderful opportunities including a military mission to Nairobi, Kenya, in January 1999 to provide audiology services to victims of the August 1998 Embassy bombings; and selection to the Army's Long-Term Health Education and Training Program, where her current assignment at the University of Florida in the Department of Communication Sciences and Disorders allowed her the opportunity to earn her Ph.D. in Audiology. Upon completion of her Ph.D. program, Lynnette will be assigned to the U.S. Army Aeromedical Research Lab (USAARL) at Ft. Rucker, Alabama. Lynnette has been married to MAJ M. Keith Bardolf (U.S. Army) for 14 years. They have three daughters: Shauna, age 21 (a U.S. Marine); Michaela, age 6, and Rainey, age 3.