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EFFECTIVENESS OF UNI-SENSORY AND MULTISENSORY TRAINING IN THE IDENTIFICATION OF WEAPON FUNCTION SOUNDS

by

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Abstract

EFFECTIVENESS OF UNI-SENSORY AND MULTISENSORY TRAINING IN THE IDENTIFICATION OF WEAPON FUNCTION SOUNDS

Kristin Hartman

As modern warfare has changed the profile and strategies of enemy forces, military and law enforcement personnel have become increasingly interested in weapon identification. While multisensory learning approaches have proven effective in enhancing identification of environmental sounds, little research exists to delineate the effects of uni-sensory and multisensory learning, specifically on weapon identification. The purpose of this study was to assess the effects of uni-sensory and multisensory training and background noise condition on weapon identification performance. Results of this study showed a significant effect for background condition and weapon type. Participants had significantly different performance in each background noise condition, with the poorest performance in the impulse condition. Participants demonstrated the poorest accuracy when identifying the M4 infantry rifle and the Mossberg shotgun. Although the uni-sensory group had slightly better performance than the multisensory group, there was no significant difference as a result of training modality. This research has direct applications to the training of military personnel and can also be applied to a broader scope of environmental sound identification for any field that requires a rapid response to an auditory cue.

Keywords: multisensory, environmental sound, identification, weapons training, gunfire acoustics

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CHAPTER 1

Introduction

Military strategy has appealed to tacticians since the advent of war. However, due to the heightened sensitivity to terrorism in recent years and the changing profile and strategies of enemy forces, American military and law enforcement personnel have become increasingly interested in weapon identification. While there is an existing body of literature regarding the identification of generalized environmental sounds, there is a dearth of research in the area of weapon identification through the use of acoustic cues. Specifically, there is little research assessing various factors affecting performance in weapon identification.

The foundations of identification are built upon the memory systems utilized to learn new information. Learning involves a variety of sensory-perceptual and neural systems and occurs as a result of the context or environment for which the new information is experienced. Specific factors that affect new learning, and subsequent recall and performance, include the influence of the sensory modality of weapon identification training and the congruency between target weapon sounds and background noise. Through the provision of an identification test of weapon function sounds, this thesis examines the effects of sensory modality and stimulus congruency on performance. The results of this study have direct implications to military training strategies and preparation for combat. Determining the most effective weapon identification technique can provide greater identification skills, which could enhance environmental awareness, safety, decision-making strategies, and overall effectiveness in the field.

CHAPTER 2

Review of Literature

Memory and Learning Processes

Learning is a complex process that involves sensing information from the environment, saving these sensations in temporary storage, and comparing sensory experiences with previously stored information to determine how the new information fits with previous experiences. Learning happens in context and involves the actions of many sensory-perceptual and neural systems. Memory, the system that stores and accesses stored information, is critical to learning.

Short-term memory. Short-term memory (STM) is described as a "central cognitive function that provides an interface between perception, action, and long-term memory" (Grimault et al., 2014, p. 96). STM was a previously used term that assumed a single system was responsible for STM encoding and long-term memory (LTM) transfer. Atkinson and Shiffrin (1968) proposed a modal model, which suggested a more complex network of systems at play in the encoding process. Following this initial shift in perspective was the prominent Baddeley and Hitch (1974) study, which brought into focus the working memory (WM) model. Much of the recent literature regarding short-term learning processes focuses on the concept of WM specifically. While STM is proposed to be solely for storage , WM can be utilized for both temporary storage and information processing (Baddeley, 1986; Baddeley & Hitch, 1974; Shahabi, Abad, & Colom, 2014; Vergauwe & Camos, 2014). Warrington and Shallice (1969) and Basso et al. (1982) analyzed studies of patients with brain injuries in the regions contributing to STM and found that patients were still able to process and store new information in LTM (as cited in Logie, 2014). Such findings are interpreted to mean that either WM is not the sole predecessor to LTM or that WM has a much more complex network of connections to LTM, with some remaining intact among the patients with brain injuries.

Although its primary purposes are involved with the encoding of new stimuli, WM is not only a holding cell, but also supports higher-order cognitive skills, such as reasoning and comprehension , maintenance of attention to relevant content, and the filtering of irrelevant content (Baddeley, 2003; Harrison et al., 2013; Shipstead, Lindsey, Marshall, & Engle, 2014). Similarly, Alloway and Alloway (2013) described WM as the "cognitive controller" responsible for maintaining focus on goals and information pertaining to the achievement of goals "in the face of concurrent processing and/or distraction" (p. 21). Although WM is often discussed in terms of short-term contributions, Rose, Buchsbaum, and Craik (2014) found that WM sometimes requires the use of LTM retrieval. For the purpose of this study, working memory is conceptualized as part of the STM and all of its related constructs.

Short-term memory capacity. While STM has a large capacity for new learning, it is not capable of processing an endless amount of stimuli simultaneously. The capacity of STM is defined by memory span: the number of items that can concurrently exist within STM. Memory span is established using tasks that involve the recall of words or digits and measures the number of correctly recalled items (Matlin, 2003). Rose et al. (2014) conclude that the capacity of the STM varies but is typically limited to approximately one to four items, and this capacity limit is influenced both by attention and complexity of the items presented. Cowan (2000) identified a similar limit on STM span; STM is limited to a maximum of four chunks, or units of information grouped in terms of related themes. While chunking requires use of STM processing, a strong connection to LTM is clear. In order to form meaningful groupings of information, LTM must access previous experiences with similar information or categories recalled. The natural use of chunking assists in the capitalization of short-term capacity.

Components of short-term memory. Baddeley and Hitch (1974) proposed a model of STM that contains three distinct components: the phonological loop, the visuo-spatial sketchpad, and the central executive system. These constructs comprise the cognitive systems required to process stimuli within the auditory, visual, and executive functioning domains.

The phonological loop is responsible for the temporary storage of auditory information, including the processing of speech stimuli and learning of new words (Baddeley, Papagno, & Vallar, 1988; Logie, 2014; Matlin, 2003). The phonological loop is divided into two stages, which ensures the maintenance of auditory information within STM (Baddeley, 2003). The initial stage includes the storage of stimuli that rapidly decay until the activation of the second stage, which invokes sub-vocal rehearsal, or silent repetition for the purpose of retaining new content (Baddeley, 2003; Service, 1992). The ability of the brain to consciously or subconsciously rehearse information is contingent upon the complexity of the information. For example, utilizing the presentation of verbal stimuli, a long set of easily pronounceable, short words can be recalled more readily and accurately than a list of words with more syllables and complexity (Logie, 2014; Matlin, 2003). Although the phonological loop is an essential system of the STM, it does not work in complete isolation from the other components.

The visuo-spatial sketchpad is responsible for the temporary storage of spatial, visual, and kinesthetic information (Baddeley, 2003; Matlin, 2003). Pickering, Gathercole, Hall, and Lloyd (2001) suggested that the visuo-spatial system functions by maintaining visual stimuli and components assessing spatial stimuli. Logie (1995) proposes two parts of the visuo-spatial sketchpad, the visual cache and the inner scribe. The inner scribe initiates "rehearsal of movement information and paths between objects" while the visual cache processes fixed visuo-spatial characteristics, such as size, shape, or arrangement (Lehnert & Zimmer, 2008, p. 159). By imagining the location of stimuli, regardless of the modality of presentation, stimuli can be encoded within the visuo-spatial sketchpad (Lehnert & Zimmer, 2008). Furthermore, visual stimuli can also be encoded through the phonological loop by performing articulatory rehearsal (Baddeley, 2003).

The third component of the classic Baddeley and Hitch (1974) model is the central executive system. Rather than functioning as a storage unit, like the phonological loop and visuo-spatial sketchpad, the central executive operates as a hub for the integration of information from other components and manages STM processes (Matlin, 2003; Service, 1992). Much like the term for this component implies, the central executive is also involved in higher-order operations, including reasoning and decision-making, based upon the inputs from the visuo-spatial sketchpad and phonological loop (Logie, 2014). In addition to integrating information from STM, the central executive is critically involved in controlling attention and further works to suppress information irrelevant to the primary task (Baddeley, 2003; Engle & Conway, 1998; Repovš & Baddeley, 2006).

Encoding memory. The learning process does not simply begin and end with encoding into the STM. Often, the goal of learning is to apply information in a novel context at some later time. This process requires storage, and later retrieval from LTM. As was previously discussed, many systems of learning are interwoven, resulting in the overlap of encoding behaviors between STM and LTM. Conversely, there are also fundamental characteristics that distinguish these two memory systems. Atkinson and Shiffrin (1968) described STM as an "antechamber to the more durable LTM" (as cited in Baddeley, 2003, p. 190). While LTM has comparatively slow input and recall capabilities to that of STM, LTM has vast storage capacity in order to safeguard the memories and experiences collected across the lifespan (Baddeley, 1986; Cowan, 2000; Matlin, 2003). Additionally, short-term storage occurs mostly through phonologic encoding while long-term storage occurs largely through more complex semantic encoding (Baddeley, 1986). Although many techniques for learning are applicable to both the STM and LTM, the following review of these constructs is framed in terms of the levels of processing that facilitate storage within LTM.

Craik and Lockhart (1972) introduced the concept of levels of processing (LOP) in response to previous literature that stressed rigid multi-store models of memory and recall. LOP is considered a broad framework to provide a basis for future studies of memory and learning. The LOP framework holds that memory is simply the result of processing stimuli while performance in recall is dependent upon the level of encoding, or depth of processing. This term suggests that the location of the memory store is not as important as the quality of the encoding. Superficial encoding includes an "analysis of such physical or sensory features" while encoding of greater depth involves "matching the input against stored abstractions from past learning; that is, later stages are concerned with pattern recognition and extraction of meaning" (Craik & Lockhart, 1972, p. 675). These two levels, which form the complementary components of LOP, are known as shallow and deep processing.

Shallow processing. This level of processing involves encoding surface features and perceptual characteristics, such as shape, form, brightness, loudness, and pitch (Craik, 2002; Craik & Lockhart, 1972). According to magnetoencephaolography (MEG) and positron emission tomography (PET) studies, shallow processing invokes areas such as the left parietal and hippocampal regions and the left frontal temporoparietal region (Rugg et al., 1998; Walla et al., 2001). A recent transcranial magnetic stimulation (TMS) study by Innocenti et al. (2010) demonstrated involvement of the left prefrontal cortex during deep and shallow categorization of words. As the term implies, shallow processing uses these active brain regions to create connections based on surface or feature-level aspects of a stimulus. During the initial presentation of new information, often in the form of a list in the case of memory studies, participants are likely to use a mix of conscious and subconscious tricks for memorization. A commonly utilized technique for establishing these connections is rehearsal, refreshing stimuli through memory (Matlin, 2003). Craik and Lockhart (1972) proposed a subdivision of rehearsal called maintenance rehearsal, a basic repetition of the stimuli that does not require use of LTM resources (Matlin, 2003; Naveh-Benjamin & Jonides, 1984; Rammsayer & Ulrich, 2011).

Deep processing. According to Craik and Lockhart (1972), the more meaningful the information is to a person, the more deeply that information is processed, resulting in better retention, both in terms of duration and accuracy. Deep processing involves the formulation of associations between LTM and new information. Similar to chunking, information is bound into larger, more meaningful units or chunks. The anatomical contributions of deep processing include many of the same regions involved in shallow processing, such as the prefrontal cortex; yet, more intense activation of these sites are observed during deep processing (Buckner, Logan, Donaldson, & Wheeler, 2000; Cabeza & Nyberg, 2000; Fletcher, Stephenson, Carpenter, Donovan, & Bullmorel, 2003; Rugg et al., 1998; Walla et al., 2001). Additional regions stimulated during deep encoding include the inferior frontal gyrus and left medial temporal lobe (Badre & Wagner, 2007; Fujii et al., 2002; Schnur et al., 2009). These regions are enlisted to make deep connections in a seemingly more intentional way than the techniques often used in shallow processing. The form of rehearsal seen in deep processing is known as elaborative rehearsal, which links new content to pre-existing LTM (Matlin, 2003; Rammsayer & Ulrich, 2011). Two memory heuristics that use previous knowledge and meaning-based processing are distinctiveness and self-reference.

Distinctiveness is a trait within stimuli, allowing content set apart by detail or novelty to be more readily recalled than "competing memories" without such distinguishable characteristics (Matlin, 2003; Oliva, 2010). Through a personalized filtering of familiar stimuli, novel stimuli can be easily encoded and the distinct nature of content even leads to a sort of priming effect in performance when the distinct stimuli is presented again (Tulving, 1995). The self-reference effect occurs when better recall performance is observed when the stimuli are linked to personal connections (Matlin, 2003). Studies have shown that this effect is quite significant among long-term retrieval and is more successfully utilized than any other strategy of long-term encoding (Conway, 2005; Rathbone & Moulin, 2010; Symons & Johnson, 1997). The process of self-reference improves retrieval performance by supporting and strengthening multiple pathways for recall through elaborative rehearsal (Symons & Johnson, 1997). With such intricate systems of encoding, the question of whether shallow or deep processing is more effective surfaces.

Craik and Lockhart (1972) proposed that depth of processing was related directly to performance during recall. Since then, this idea has been supported by various word retention studies, which have found that participants who use deeper levels of encoding perform better than those who used shallower, phonemic processing techniques (Dikbas & Altun, 2014; Eysenck & Eysenck, 1980). In Rose, Myerson, Roediger, and Hale (2010), the influence of LOP was examined in terms of immediate and delayed recall. Participants were provided with a list of target words, where each target word was followed by two processing words presented simultaneously. Participants were instructed to identify which processing word was related to one of three assigned processing schemes, varying in its depth of processing. The relationship between the target word and processing words was defined by either the color of the word, ability to rhyme the words, or context. For example, the target word "bride" presented in red font was followed by the processing words "dried" in blue font (rhymes with "bride") and "groom" in red font (same color and contextually similar to the word "bride"). Results of the study indicates that the LOP does not affect immediate recall; however, performance after a delay is improved among the participants who relate the words by context, or semantics, instead of more shallow forms of processing. In efforts to explain this effect, Gallo, Meadow, Johnson, and Foster (2008) noted that: "deep processing activates more relevant knowledge than shallow processing, and this activated information becomes associated with the word to form a more elaborate memory trace" (p. 1095). While this concept may prove true in recent literature, the original work by Craik and Lockhart (1972) suggested that the LOP invoked was contingent upon the task and the goal of the learning experience. For example, an exercise that involves immediately repeating a word that was just spoken does not require a depth of processing any greater than phonemic processing (Craik & Lockhart, 1972). In other words, there should be an appropriate match between the intention of the task and the LOP. These effects were almost always observed in the context of linguistic information where shallow (phonetic) and deep (semantic) levels were clear. In recent years, literature has shifted from assessing the matching of intention and LOP or questioning which LOP is more effective, to exploring the value of matching the experience and environment during the initial encoding process to that of recall.

Transfer appropriate processing (TAP) and encoding specificity are two similar principles that recognize the influence of the initial encoding context and the demands of retrieval LTM performance. TAP refers to an improvement in performance when the processing strategy or level of encoding matches the demands of the test that required retrieval of the encoded information (Craik, 2002; Schendan & Kutas, 2007). Similarly, encoding specificity holds that "retrieval from memory in a cued recall task is affected by the extent to which information relating the cue and target was stored during study of the target" (Zeelenberg, 2005, p. 109). The work by Tulving and Thomson (1973) noted the following: "specific encoding operations performed on what is perceived determine what is stored, and what is stored determines what retrieval cues are effective in providing access to what is stored"(p. 369). Encoding specificity and TAP both suggest that a match between the training and test is required for accurate recall of previously encoded information. For example, a group of students preparing for a quiz on the anatomy of the ear might prepare by reading through the text book. If the quiz requires students to recall definitions or phrases found in the text book, this is an appropriate match between the training and the test and, therefore, reflects TAP. An anatomy quiz requiring these same students to label structures on a 3-D model of the ear does not appropriately match the training and would not demonstrate TAP. Perhaps, one of the students studied for the quiz in the anatomy classroom while eating popcorn. If this student also ate popcorn while taking the quiz, the information might be more readily retrieved since there is a strong match between the environment of the encoding and the retrieval, which reflects encoding specificity. These two principles access encoding techniques employed for recall beyond the STM and temporary use.

Memory recall. To make use of new memories, the brain must be able to go beyond initial encoding processes. Utilizing STM and LTM requires functioning of specialized anatomical structures and cognitive processes to discriminate and identify the characteristics of complex environments.

Anatomical contributions to memory recall. The hippocampus is the most well described structure for human memory (Kumaran, 2008). The hippocampus is an essential structure for activation of the episodic buffer, which serves as the bridge between short-term and long-term recall and supports successful recall during LTM tasks (Baddeley, Allen, & Hitch, 2011; Lech & Suchan, 2013; Lech & Suchan 2014; Tetzlaff, Kolodziejski, Markelic, & Wörgötter, 2012). Lech and Suchan (2014) conducted an fMRI study to assess active regions of the brain during a visual discrimination task and found hippocampal regions contributed significantly to the recognition of complex images. Lee, Scahill, and Graham (2008) specifically noted the anterior hippocampus was active in object processing and the posterior hippocampus was active during spatial processing tasks, within the visuo-spatial realm. In addition, the medial temporal gyrus is integral to the recall of pre-existing memories stored within the hippocampus and this recall is not modality specific (Graham, Barense, & Lee, 2010; Lech & Suchan, 2013; Lewis et al., 2004). Results from an fMRI study performed by Lewis et al. (2004), concluded that retrieval of recognized, and therefore familiar, environmental sounds was supported by the bilateral posterior medial temporal gryus and the superior temporal sulci.

Memory tasks. There are a variety of tasks researchers use to assess memory recall ability. Differentiation of stimuli requires advanced decision-making skills, regardless of the stimuli or sensory modality (Noppeney, Josephs, Hocking, Price, & Friston, 2008). In terms of auditory stimuli, identification is contingent upon various factors, including "the ease with which a mental picture is formed of the sound, context independence, the familiarity of the sound, the similarity of the sound to a mental stereotype, the ease in using words to describe the sound, and the clarity of the sound" (Ballas,1993, p. 262). In research, this conscious sorting of information is often designated as either a discrimination or identification. Taniguchi and Tayama (2010) described discrimination as a comparison of general shapes and identification as a process that distinguishes the details and complexity of individual objects. The defining characteristics of discrimination and identification vary from study to study, with many following a shared perspective of the terms while others appear to blend or mix the definitions (Straube & Fahle, 2011). Much of the current literature on these constructs characterizes discrimination as a differentiation between two stimuli according to pre-determined criteria (Acton & Schroeder, 2001; Troche, Wagner, Voelke, Roebers, & Rammsayer, 2014). Identification requires the generation of a specific response to match each distinct stimulus (Burns & Rajan, 2008; Nosofsky, 1986). Typical discrimination and identification tasks are used for uni-sensory stimuli. The current study seeks to expand on uni-sensory testing paradigms by examining memory-related effects on multisensory identification.

Multisensory Integration

The acquisition of knowledge involves any number of encoding techniques, depending upon the content and how it is presented. When environmental sounds are initially encoded, it occurs within a presentation context, thus additional sensory cues are available to support identification and later retrieval of a new sound (Lewis et al., 2004). This allows for integration of multisensory information at the level of the cortex, and supports a more comprehensive and natural understanding of content. Multisensory cues also provide a greater number of pathways for the retrieval of content. The use of uni-sensory or multisensory information can be evaluated in terms of efficacy of learning during training. Uni-sensory implies the operation of a single sensory system for learning. Multisensory refers to a joining of different sensory systems to "influence perception, decisions, and overt behavior" (Stein, Stanford, & Rowland, 2009, p. 4). While multisensory can refer to any combination of sensory input- visual, auditory, taste, touch, or smell- in the context of this review, multisensory denotes the use of audiovisual stimuli. The following section will explore the anatomical contributions to multisensory integration as well as the efficacy of uni-sensory and multisensory training.

Anatomical contributions to the multisensory integration. There exists a vast array of interlinked neural pathways that have formed within the brain throughout a lifetime of experiences with the environment. Given such complexities, the anatomical structures involved with learning are similarly complex. Studies that have isolated uni-sensory processes have found that auditory stimulation activates the mid to anterior temporal cortex and visual stimulation excites the occipital lobe (Beauchamp, Lee, Argall, & Martin, 2004). Multisensory integration shares these same structures found in auditory and visual uni-sensory regions; yet, multisensory structures also extend beyond the limits of uni-sensory pathways. Known contributions to multisensory integration include the temporal sulcus, medial temporal gyrus, medial frontal gyrus, and superior colliculus (Alvarado, Rowland, Stanford, & Stein, 2008; Beauchamp, 2005; Beauchamp et al., 2004; Ghazanfar & Schroeder, 2006; Lewis et al., 2004; Magosso, Cuppini, Serino, Di Pellegrino, & Ursino, 2008; Senkowski, Saint-Amour, Kelly, & Foxe, 2007). Ghazanfar and Schroeder (2006) also noted that neurons responsible solely for visual input could be stimulated by auditory information and related this finding to the complexity of auditory spatial tuning. The exact structures involved in multisensory processing are not always predictable and vary depending upon the nature of the task initiating activation of a multisensory system (Beauchamp et al., 2004). There is still much to be discovered in terms of the designated roles and collaborative efforts of human neuroanatomy. Despite the absence of a complete knowledge of multisensory contributions, there is currently a burgeoning field to support the efficacy of multisensory training.

Efficacy of multisensory training. From a broad perspective of learning strategies, multisensory training has been identified as an accepted, yet still relatively new approach. In an academic setting, Tindall-Ford, Chandler, and Sweller (1997) assessed a group of first year students in an electrical engineering program to determine the benefits of multisensory learning. Participants were divided into three groups: group one received visual instruction in the form of diagrams and images, group two received an integration of the visual instruction and written text to describe each phase of the instruction, and group three was provided audio-visual instruction in the form of an audio recording of the content in addition to the visual instruction. Results indicated that students from group two and group three, who received some level of multimodal training, perform better than those trained with uni-modal information (Tindall-Ford et al., 1997). Edworthy and Hards (1999) determined that the identification of auditory alarms was more accurate when participants could self-generate their own verbal or graphic cues (i.e., labels), as this provided naturalistic multimodal encoding. Some researchers have suggested that auditory cues alone can support object identification, primarily through semantic influences (Kirmse, Jacobsen, & Schröger, 2009). Still, others identify the auditory system as limited in terms of object recognition without the aid of additional sensory input (Lotto & Holt, 2010). For the identification of environmental sounds, visual stimuli have been deemed a perfect complement, as the combination of sound localization and visuo-spatial cues assist in proper identification of auditory stimuli (Aldrich, Hellier, & Edworthy, 2009; Marcell, Borella, Greene, Kerr, &

Rogers, 2000; Özcan & Van Egmond, 2009). Multisensory training of environmental sounds results in greater accuracy in recall performance and faster reaction times than uni-sensory strategies (Calvert & Thesen, 2004; Marks, 2004; Molholm et al., 2002; Özcan & Van Egmond, 2009; Seitz, Kim, & Shams, 2006; Stein et al., 2009). While much of the literature supports this sentiment, Beauchamp et al. (2004) reported similar accuracy but significantly slower reaction rates to uni-sensory (auditory) identification and even slower reaction times when the task was auditory-visual.

Multimodal training is not without its limitations. The complexity of the physical and semantic characteristics of auditory stimuli directly affects the ease of identifying the appropriate sound to match a visual representation (Özcan & Van Egmond, 2009). For example, sounds that are brief in duration, such as impulses, are more difficult to match alongside comparatively long visual stimulus presentation (Özcan & Van Egmond, 2009). Another concept that calls into question the overall effectiveness of multisensory training is multisensory enhancement. This principle proposes that the greatest benefit from multimodal integration results from individually weak auditory and visual stimuli (Meredith & Stein, 1986; Perrault, Vaughan, Stein, & Wallace, 2005; Stanford & Stein, 2007). In other words, the combination of multiple stimuli improves processing abilities. This notion should be considered with regards to the potential relationship between congruency of stimuli and the benefits of multisensory enhancement.

Influence of stimulus congruency. Congruent stimuli refer to a shared context between auditory and visual stimuli that assists in accessing the appropriate "target" information (Gygi & Shafiro, 2011). Congruency of multimodal information "facilitates detection, identification, and categorization of objects or novel events in our environment" (Noppeney et al., 2008, p. 598). Studies have shown that the benefits of multisensory training are contingent upon stimulus congruency and disappear when the visual and auditory stimuli do not appear to match (Ghazanfar & Schroeder, 2006; Hecht, Reiner, & Karni, 2009). Researchers suggest that this difficulty in accurate identification following the presentation of incongruent stimuli originates at the cortical level due to influences of neural processing and suppression (Komura, Tamura, Uwano, Nishijo, & Ono, 2005; Noppeney et al., 2008). Noppeney et al. (2008) noted that when an auditory stimulus was primed in the context of an incongruent visual stimulus, a greater demand was placed on the processing system required to accurately identify the auditory stimuli. Results of the study reflected increased time and decreased accuracy in the identification of content primed with incongruent stimuli. Challenges to the congruency debate include a lack of significant congruency and incongruency effects and the finding that identification of auditory stimuli is even greater in the presence of an incongruent context (Gygi & Shafiro, 2011; Leech, Gygi, Aydelott, & Dick, 2009). Congruency effects have been demonstrated to occur under a variety of conditions and in opposing directions. It is of note that while multisensory integration can be beneficial, not all combinations of auditory and visual stimuli are beneficial. The current study, in part, evaluated the presence of multisensory training effects where congruent audio-visual stimuli were presented in order to determine if performance enhancements or decrements were observed.

Environmental Sounds

Environmental sounds are a category of non-verbal stimuli described as naturally occurring, or "everyday sounds" (Houix, Lemaitre, Misdariis, Susini, & Urdapilleta, 2011). These sounds are given purpose and meaning through the process of identification and discrimination.

Identification and discrimination. Identification of environmental sounds, or the selection of a label for a sound, is often related to the particular context (Özcan & Van Egmond, 2009). Hearing a series of bells or tones while standing near the front door leads to the generation of the label "doorbell"; however, this sound may be identified differently if the listener were standing in the middle of the zoo. Thus context and expectation influence sound source identification. With the exception of speech and music, many auditory stimuli may be deemed environmental in nature (Houix et al., 2011). These sounds may be categorized in any number of ways to suit the purpose of research, including human actions, living and non-living sound sources, and physical properties of sound (Engel, Frum, Puce, Walker, & Lewis, 2009; Galati et al., 2008; Giordano, McDonnell, & McAdams, 2010; Gygi & Shafiro, 2011; Houix et al., 2011; Özcan & Van Egmond, 2009; Pizzamiglio et al., 2005). For the purpose of the current study only a small class of sounds were examined, specifically, impulsive and continuous background sounds and weapon function sounds.

Weapon sounds. Weapon function sounds are the sounds generated by the various operations of a firearm. These sounds are usually associated with actions in preparation to discharge the weapon, such as the safety release and the ammunition magazine insertion. When firing the weapon, an acoustic impulse, known as a muzzle blast, is generated (Beck, 2011; Lo & Ferguson, 2012) from the explosion of gases leaving the end of the gun barrel. Once the ammunition exits the barrel, it propels at the speed of sound and produces a sonic boom (Rasmussen, Flamme, Stewart, Meinke, &

Lankford, 2009). The signature of the gunshot varies depending upon the type of ammunition, internal ballistics, class of firearm, distance from the target, and physical condition of the firearm (Beck, 2011; Djeddou & Touhami, 2013). While parameters of firearm blasts are regularly reviewed in the literature, research is essentially void of data regarding the acoustic characteristics of the other sounds related to the functioning of firearms. Sounds such as, inserting or removing the ammunition magazine, or charging a firearm in preparation for firing are acoustically distinct and should be highly salient in military-relevant environments. While some research exists on the identification of different weapons based on the acoustics of the firing event there are currently no studies examining weapon function sound identification (Djeddou & Touhami, 2013). Further, the ease with which these sounds are identified is an open question.

Summary

Learning involves a variety of STM and LTM systems. STM assists in sorting, maintaining, and storing new information while LTM makes use of various LOP and initial encoding contexts to enhance performance during recall. The multisensory approach to identification of environmental sounds is well supported within the current hearing, psychology, cognitive science, and neurology literature. While studies have validated the use of multimodal learning, the identification of weapon function sounds following auditory and auditory-visual training has not been assessed. Based upon the findings within previous literature, the focus of the current study is to demonstrate the advantage of multisensory training within the context of weapon function sound identification. Studies have suggested that complex auditory environments can be simplified through combining conceptual and perceptual training and gaining exposure to the auditory stimuli prior to entering a "more complex auditory scene" (Lotto & Holt, 2010; Melcher & Schooler, 2004). This research has direct applications to the training of military personnel and preparation for military combat. Preliminary training of weapon function sounds utilizing this multisensory technique could provide greater identification skills, which could enhance their environmental awareness, safety, decision-making strategies, and overall effectiveness in the field.

Purpose of Study

The purpose of the current study was two-fold: to assess the efficacy of uni-sensory and multisensory training of weapon function sounds and to determine the effects of background noise.

CHAPTER 3

Methodology

Participants

Thirty-one individuals were recruited for this study, one of which was excluded as he did not meet the hearing screening criteria. Thirty participants (10 males, 20 females) between 20-43 years of age (M = 26.07, SD = 4.87) completed testing for this study. Seventy percent of the participants were current students of Towson University, and 66.7% of those students were enrolled in the Audiology doctorate program. Participants were provided a free hearing screening as compensation for their time.

Participants were recruited through an email listserv to the general population of faculty, staff, and students of Towson University and word of mouth. To determine eligibility for the study, a hearing screening was performed using common clinical audiology methods and included an otoscopic examination, tympanometry, and pure tone screening to establish normal hearing sensitivity and health of the middle ear. Tympanometry was performed using a Tympstar and pure tone testing was completed using a GSI-61 audiometer and EAR Tone 3A insert earphones. The Tympstar was utilized to assess the mobility of the tympanic membrane with a 226Hz probe tone by varying air pressure in the ear canal. All tympanometry results reflected Jerger Type A tracings (Jerger, 1970). Air conduction pure tones were screened at 25dB HL for frequencies between 250-8000Hz. Participants were instructed to respond to each tone during the pure tone testing by pressing the provided button.

Prior to the hearing screening, the participants completed a brief questionnaire, which included demographic information, such as age, gender, and a self-report of visual acuity within a normal or corrected-to-normal range. It is of note that participants were asked to bring corrective eyewear as needed for testing. The questionnaire also inquired about previous training in music and firearms. Responses to the questionnaire indicated a wide variety of musical training and weapons training. Forty percent of participants identified previous musical training in voice or instruments for the purpose of academic credit or leisure. Previous weapons training was reported by 26.67% of participants, ranging from limited exposure as a leisure pursuit to frequent exposure through military service. The questionnaire also provided a space for participants to denote interest in completing additional optional testing approximately one week from the initial test date.

Stimuli and Apparatus

The sounds presented throughout the study were weapon function sounds, namely charging sounds recorded from each of the following firearms: M4 infantry rifle, AK47 infantry rifle, M9 handgun, M107 sniper rifle, and Mossberg shotgun. Sounds were recorded using reference quality microphones in a hemi-anechoic chamber, and images and video were acquired using high-quality HD cameras. Audio and visual stimuli were approximately 2 seconds in duration and the peak intensity of each stimulus was always lower than 120 dB peak(P), and thus at least 20 dB lower than the limit of 140 dB(P) referenced by the Occupational Safety and Health Administration (OSHA) standard for unlimited exposure (OSHA, 2008). The charging sounds were presented in isolation or in the presence of either continuous or impulse sounds. Participants completed the training and identification test using a research laptop equipped with E-prime®, a product of Psychology Software Tools, Inc.

Procedure

This study was approved by Towson University's Institutional Review Board and consent forms were provided and completed by all participants prior to testing. Using a randomization generator via random.org, participants were assigned to one of two groups, either the uni-sensory group or the multisensory group. In each group, participants first completed (1) an identification training block, followed by (2) an identification test block.

Training block. In the training block, both the uni-sensory and multisensory groups were presented with the charging sounds described above through a two-part module. During each of the two training modules, the charging sound was presented from each firearm seven times for a total of 35 trials per module and a total of 70 trials during the training block. On each trial, listeners answered a multiple choice question, identifying which of the five firearms made the charging sound by selecting a corresponding number key from a keyboard. Participants received immediate feedback, which varied based upon the training modality group. For both groups, text appeared on the computer screen, identifying the response as 'correct' or 'incorrect'. Next, participants heard an audio recording of a male speaker, who stated the name of the correct weapon. The uni-sensory group was then re-presented the training audio of the correct weapon sound. The multisensory group's feedback was similar, except that a video of the charging action was paired with the audio of the correct weapon sound.

Identification block. The identification test followed the same general procedures of the training block, with the same instructions and multiple choice options for participant responses. In the test block, no feedback was given to participants. In addition, there were three types of trials. The first type was the charging sound presented in isolation. The second type consisted of the charging sound played in the context of two different continuous background contexts comprised of three environmental sounds. The first continuous background context was comprised of sounds generated by a helicopter, tank, and motorcycle. The second continuous background recording included a plane, bus breaks squealing, and a truck idling. The third type of trial consisted of a charging sound played in the context of two impulsive background contexts. The first impulsive recording was comprised of a jackhammer, M4 carbine firing, and a bike wheel turning while the second impulsive recording included a dog bark, cell phone ring, and a bell. All of these sounds occurred simultaneously in the background of the track, which had a duration of approximately one to two seconds. Each sound was played ten times for each condition, for a total of 150 trials.

Research Design

This study was a quantitative assessment of uni-sensory and multisensory training of weapon function sounds. The dependent variable was the accuracy in percent correct for identification. The independent variables were the training modality (between subjects), firearm (within subject), and background noise (within subject).

Statistical Analysis

The initial analysis was a 2x3x5 mixed ANOVA, which assessed the two training modalities, three background conditions, and five firearms. Post-hoc testing was conducted to determine specifically how identification performance changed as a function of background and weapon type.

CHAPTER 4

Results

Results of this study were analyzed using a 2x3x5 mixed ANOVA to assess the effects of the between subjects factor, training modality (uni-sensory, multisensory) as well as the within-subject factors of background noise condition (isolation, continuous noise, & impulse noise) and firearm (M4 infantry rifle, AK47 infantry rifle, M9 handgun, M107 sniper rifle, & Mossberg shotgun). Significant findings were subjected to post hoc analyses, using a Bonferroni correction to identify the significance of each level within the variables. Alpha levels were set at $p < .05$ for all analyses. Huynh-Feldt corrections were used for significance values for main effects involving the background noise variable due to violations of the sphericity assumption.

Effect of Modality

Results of the mixed ANOVA indicated no significant main effect of modality on performance of the identification test, F (1, 28) = 1.96, p >.05. Table 1 shows the mean accuracy across weapons and noise conditions as a function of modality. Overall performance was better in the uni-sensory group, however, the difference between the two training groups was not significant (see Figure 1).

Table 1

Mean accuracy of uni-sensory and multisensory groups

Modality	Mean	Std. Error
Uni-sensory	0.74	0.04
Multisensory	0.65	0.04

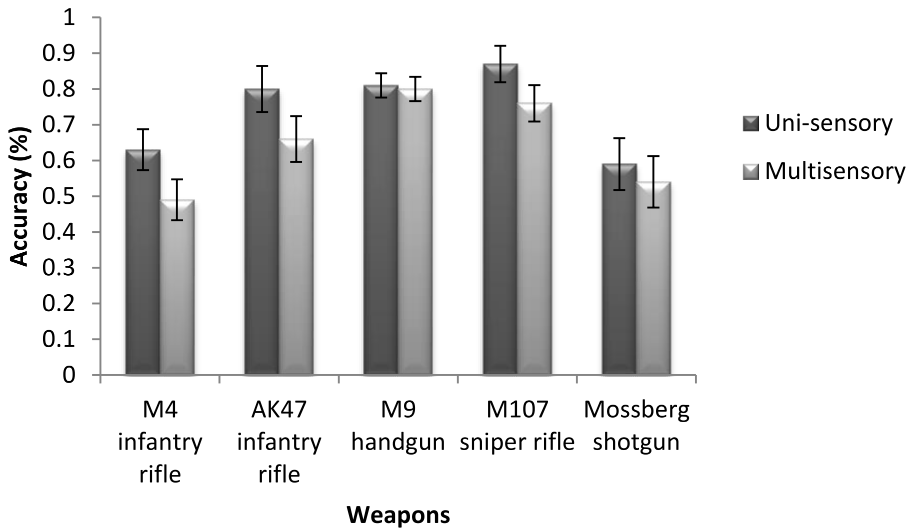

Figure 1. Mean accuracy and measured standard error of weapon identification by modality. Error bars denote 1 standard error.

Effect of Background Condition

The mixed ANOVA revealed a significant main effect of background noise on the performance of the identification test, F (1.76, 45.18) = 26.11, $p < .001$, $\eta^2 = 0.56$. Table 2 and Figure 2 reflect the mean and standard error data for each background condition. Participants performed significantly worse in the impulse noise condition than the continuous and no noise conditions (see also Table 3 and Figure 3). The subsequent post hoc testing verified that all background conditions were significantly different from each other. Figure 3 also illustrates performance changes as a function of weapon type, detailed in the following section. No significant interactions were found between background noise and either of the other variables.

Table 2

Mean percentage of accuracy for background conditions

Background Condition	Mean	Std. Error
Isolation	0.77	.04
Continuous noise	0.69	.03
Impulse noise	0.63	.03

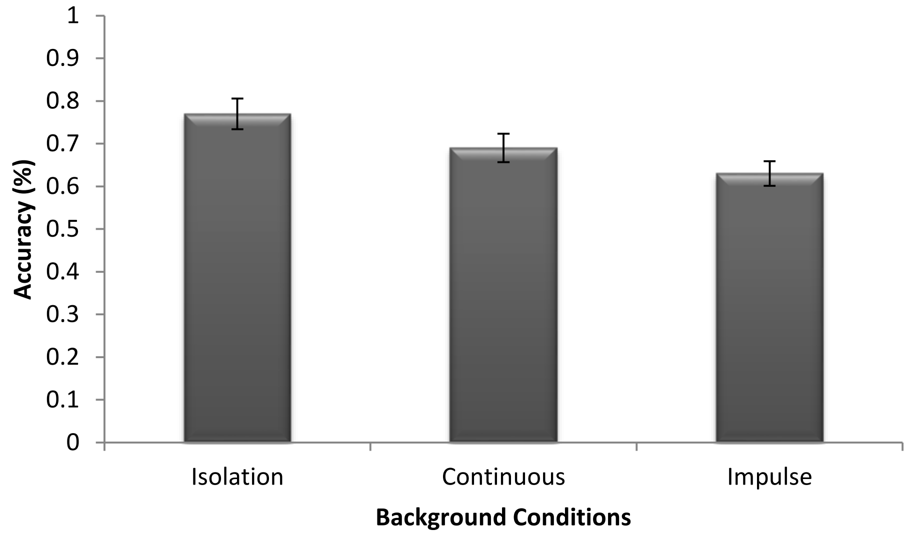

Figure 2. Mean accuracy and measured standard error for background condition. Error bars denote 1 standard error.

Table 3

Comparison of mean difference data for background conditions

Background Condition		Sig.
Isolation	Continuous	p<.001
	Impulse	p<.001
Continuous	Impulse	p<.001

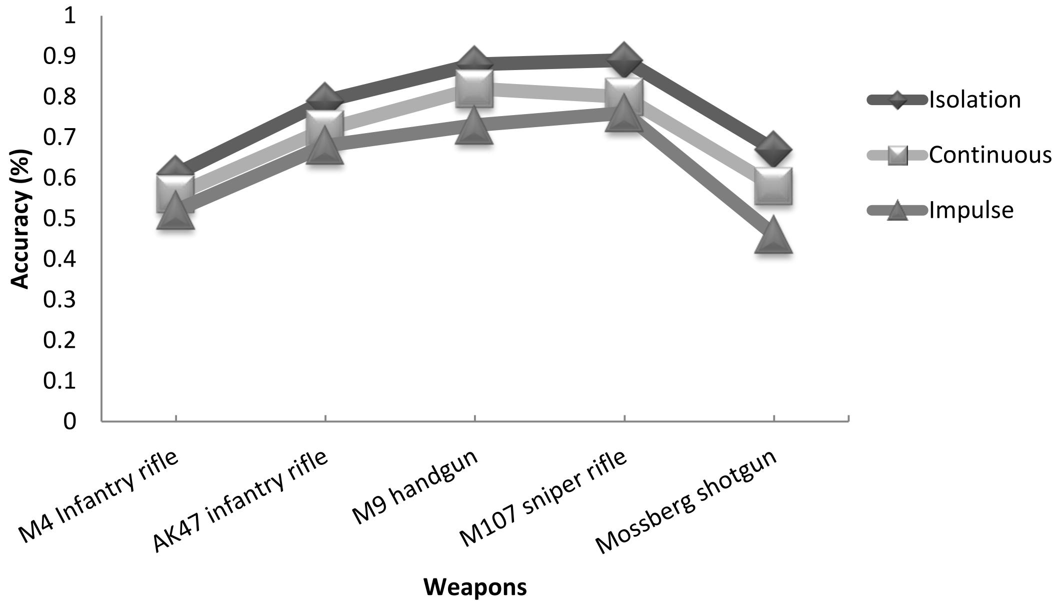

Figure 3. Accuracy of weapons identification by background condition.

Effect of Weapon

Results of the mixed ANOVA identified a significant main effect for weapon in the performance of the identification test, $F(3.84, 107.58) = 18.61$, $p < .001$, $\eta^2 = 0.69$. Table 4 and Figure 4 show the mean and standard error data for each of the weapons. The performance for each weapon was compared in a post hoc analysis. Participants were significantly less accurate when identifying the M4 infantry rifle compared to all other weapons. Participants were also significantly less accurate when identifying the Mossberg shotgun compared to all other weapons. Table 5 shows the p-values of each weapon compared to the M4 and the Mossberg. While participant performance was poorest for the M4 infantry rifle and Mossberg shotgun, the difference in performance between the two weapons was not significant, $p > .05$. No significant interactions were found between weapon and modality.

Table 4

Mean accuracy of weapons

Weapon	Mean	Std. Error
M4 infantry rifle	0.56	.04
AK47 infantry rifle	0.73	.05
M9 handgun	0.81	.02
M107 sniper rifle	0.82	.04
Mossberg shotgun	0.57	.05

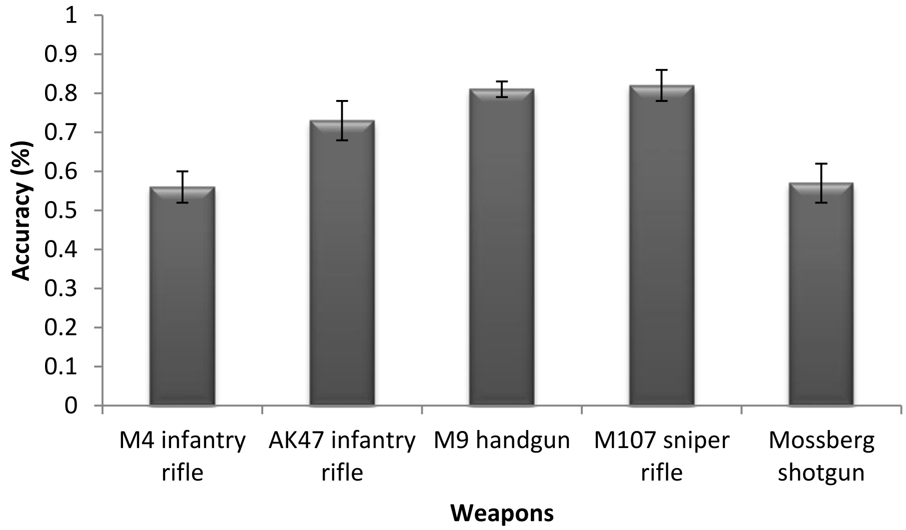

Figure 4. Mean and measured standard error of weapons. Error bars denote 1 standard error.

Table 5

Comparison of performance between weapons

	Weapon	Sig.
	AK47 infantry rifle*	p=.001
	M9 handgun*	p<.001
M4 infantry rifle	M107 sniper rifle*	p<.001
	Mossberg shotgun	p=1.00
	M4 infantry rifle	p=1.00
	AK47 infantry rifle*	p=.005
Mossberg shotgun	M9 handgun*	p=.001
	M107 sniper rifle*	p<.001

Note. All other pairwise comparisons were not significant. The asterisk denotes significant effects.

CHAPTER 5

Discussion

The current study assessed the effects of training modality (uni-sensory or multisensory), background noise condition (isolation, continuous, & impulse), and firearm (M4 infantry rifle, AK47 infantry rifle, M9 handgun, M107 sniper rifle, and Mossberg shotgun) on weapon identification performance. A significant main effect was found for background condition, with significantly different performance in each condition and the poorest performance in the impulse condition. A significant main effect was found for weapon, with the poorest identification noted for the M4 infantry rifle and the Mossberg shotgun. Although the uni-sensory group had slightly better performance than the multisensory group, there was no significant difference as a result of training modality.

Modality

The primary purpose of the study was to determine the efficacy of uni-sensory and multisensory training for identification of weapon function sounds. Based upon recent literature, the expected outcome was a clear advantage of multisensory training for weapon identification (Lotto & Holt, 2010; Melcher & Schooler, 2004; Noppeney et al., 2008) . Results indicated there was no significant difference in performance as a function of training modality. In fact, there was a slight trend towards poorer performance among the participants provided with multisensory training. This effect may have been due to the differences in TAP between the uni-sensory and multisensory groups. The uni-sensory group may have performed slightly better due to the greater similarity between the training and test conditions, which were both auditory only conditions. The multisensory group may have relied too heavily upon the visual cues provided in training, which, perhaps, did not generalize to the testing condition and may have even distracted participants from the task. A processing strategy during training that matches the requirements of a retrieval or test condition results in better outcomes due to the higher level of transfer appropriate processing (Craik, 2002; Schendan & Kutas, 2007; Tulving & Thomson, 1973). Participants who completed uni-sensory or auditory only training were training and coding stimuli under the same condition as the identification test, which may have ultimately resulted in better performance among this group.

Performance may also have been poorer among the multisensory group due to issues with the visual component of the training. Characteristics of the multisensory feedback, such as the angle or size of the video or the depth perception during the demonstrations of the weapons charging, may have distracted the participants from the task or negatively impacted their perception of the charging stimuli (Anderson & Hanson, 2010; Nathan, Anderson, Field, & Collins, 1985).

Another aspect of testing that may have contributed to the lack of significant modality effects was the technique used to manipulate the feedback received by each of the two modality groups. While the uni-sensory group's training was designed to provide only auditory feedback regarding the correct answer after each trial, text regarding the correct answer also appeared on the computer screen. The addition of text is enough to produce a multisensory component of the training and, therefore, reduces the strength of the manipulation of the modality groups in the current study (Lehnert & Zimmer, 2008).

Additionally, participants in the uni-sensory group may have simply imagined or somehow visualized the action of charging a firearm, which would have accessed a visuo-spatial component of learning- leading to a sort of unintentional and uncontrollable multisensory training (Lehnert & Zimmer, 2008). Participants may also have associated training stimuli with previous memories or experiences, which could result in deeper encoding and better performance during recall compared to participants who used shallower processing of the weapon sounds (Dikbas & Altun, 2014). These potential individual differences in strategy cannot be ruled out as a potential factor involved in performance outcomes.

Background Noise

The secondary purpose of the study was to determine the effects of background noise on weapon identification. The current study found a significant effect for background condition. Charging sounds in isolation resulted in the best performance, charging in the context of continuous noise resulted in poorer performance, and charging in the context of impulse noise produced the poorest performance. The charging sound within itself is an impulse sound, which makes the impulse background noise and the target charging sound more similar than the continuous background noise and the target sound. The similarity between the impulse noise and the weapons could have led to an informational masking effect and may have disrupted participants' abilities to use the timing cues of the weapon for accurate identification. Informational masking is described as the "degradation of auditory detection or discrimination of a signal embedded in a context of other similar sounds" (Leek, Brown, & Dorman, 1991, p. 205). In other words, when the background noise is similar to the target sound of interest, identification skills can be negatively impacted. A difference in the effects of informational masking appears to exist between the continuous and impulse conditions. Participants may also have performed poorer in the continuous and impulse conditions due to the unanticipated nature of the background stimuli. Following completion of the testing, multiple participants commented that they felt surprised or caught off guard by some of the sounds and wanted to know the sources of specific stimuli. This divergence from participant expectations may have distracted them and affected their ability to accurately identify weapons in the presence of such complex listening conditions (Berti & Schröger, 2001; Durlach et al., 2003).

Weapon

While the accuracy in identification as a function of weapon type was not intended to be a major component of this study, significant differences were indicated in the analysis. Participants performed better when identifying the AK47 infantry rifle, M9 handgun, and M107 sniper rifle than the M4 infantry rifle and Mossberg shotgun. The differences in accuracy may be contributed to variations in the acoustic characteristics and amplitude envelopes of the stimuli. When identifying the M4 infantry rifle and Mossberg shotgun, many of the errors were in identifying the Mossberg as the M4 and the M4 as the Mossberg. Both of these weapons have similar amplitude envelopes, with the initial onset of the stimuli at similar high amplitudes associated with pulling back the slide of the weapon, followed by similar decreased amplitudes, associated with pushing forward the slide of the weapon (as shown in Figure 5). Both of these weapons were also often incorrectly identified as the AK47. This was probably due to the similarity in the temporal cues: the timing between the onset of the stimuli and the sliding forward motion of the weapon (as shown in Figure 6). While the M4, Mossberg, and AK47 had similar features that may have caused more uncertainty in identification, the better performance for the M9 handgun and M107 sniper rifle may be attributed to the very distinct amplitude and timing cues of the two weapons that assisted in accurate identification.

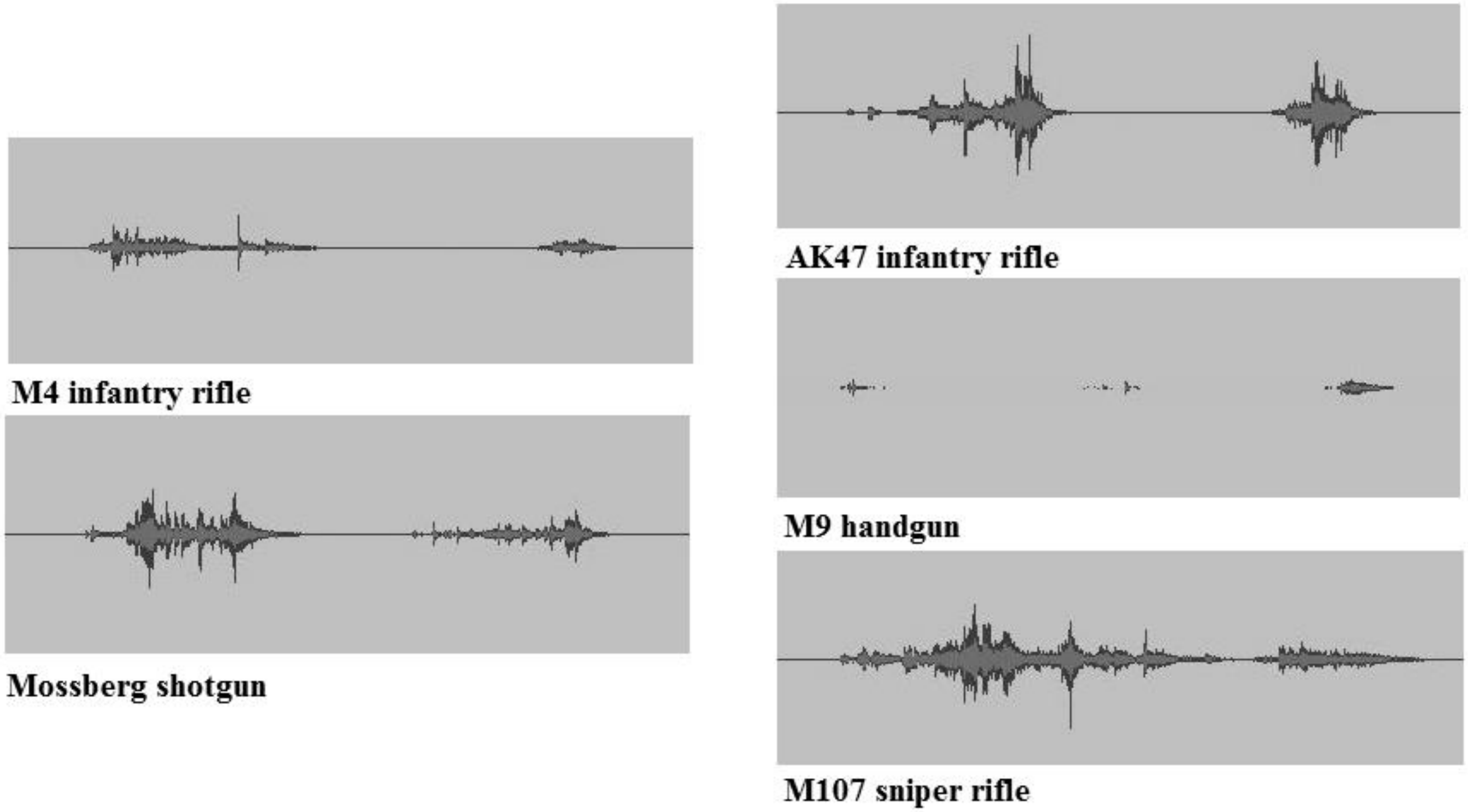

Figure 5. Comparison of amplitude envelopes. A greater similarity between the amplitude envelopes of the M4 infantry rifle and Mossberg shotgun was present in comparison to the AK47 infantry rifle, M9 handgun, and M107 sniper rifle.

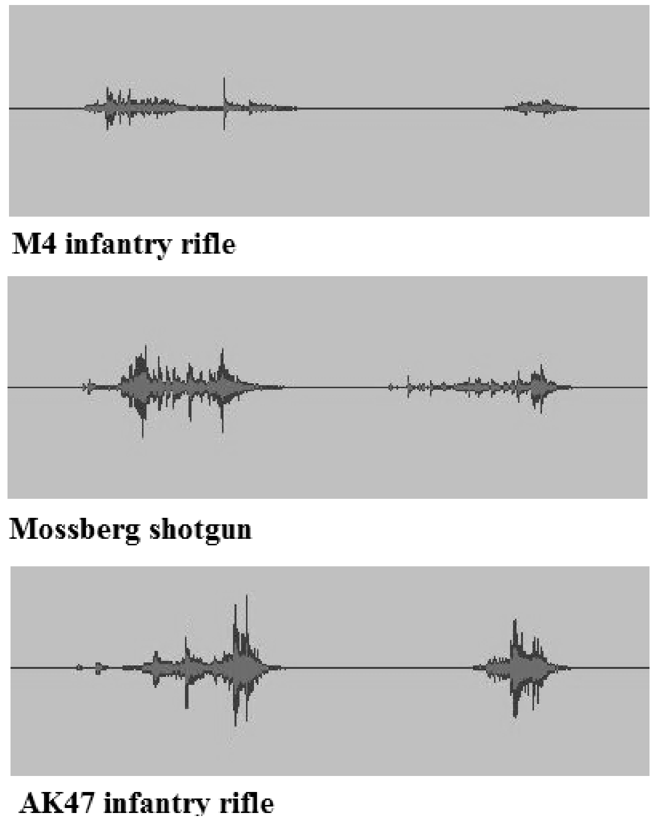

Figure 6. Comparison of temporal cues. Similar timing cues were noted for the M4 infantry rifle, Mossberg shotgun, and AK47 infantry rifle.

Limitations and Future Research

The design of the weapon identification training may not have incorporated a strong enough manipulation of the sensory groups due to the use of visual input in the uni-sensory group, which was intended for auditory feedback alone. Future studies assessing the effect of modality on weapon identification should remove all feedback that provides multisensory learning to better gauge the influence of sensory modalities. Use of audio-visual training with an audio-visual test should also be considered in order to determine if multisensory training results in greater outcomes when there is greater transfer appropriate processing between the training and test conditions. The use of multisensory learning was limited to a video demonstration, which may have negatively impacted identification. Future studies should consider other forms of multisensory integration in training feedback, such as tactile stimuli, or changes to the visual stimuli by evaluating video production issues as a source of training variability.

While the use of various background conditions was implemented, other aspects of the stimuli were not simulated in the current study. Common urban and rural combat environments are comprised of complex surfaces that may distort the perception of acoustic and visual cues drawn upon during weapon identification. The current study utilized stimuli recorded in a hemi-anechoic chamber without the presence of additional surfaces to influence the quality of the stimuli. As a result, the stimuli may not have reflected common urban environments and the complex relationship between environmental conditions and the perception of stimuli. Future studies should aim to explore weapon identification in conjunction with issues of reverberation and distance perception (Brungart, Durlach, & Rabinowitx, 1999). Research is also needed to determine the long-term carryover of these skills, particularly in identifying weapons in complex listening environments.

Conclusions

Findings of the current study conclude that auditory training, rather than multisensory, is likely sufficient for weapon identification training and application. Since more complex background conditions led to greater difficulty in identification, early training of these contexts may prove useful in preparation for the complex environments where these skills will be applied. Weapon identification based upon auditory information alone also has implications for soldier safety. Various weapons, such as the M9 handgun and AK47 infantry rifle, have different effective ranges. The ability to identify which weapon made this sound can assist soldiers in determining if the firearm is a safe distance from their unit or allow them time to adjust their position accordingly. Additionally, military personnel will not always have access to visual information and must be able to base important decisions and countermoves upon auditory information. The findings of the current study can also be applied in a broader scope of environmental sound identification. Beyond military and law enforcement, environmental sound identification continues to prove useful for any field that requires a rapid response to an auditory cue.

Appendices

Appendix A:

Institutional Review Board Approval

TOWSON
UNIVERSITY

APPROVAL NUMBER: 15-A022

OCT 10 2014

To: Kristin Hartman
8000 York Road
Towson MD 21252

From: Institutional Review Board for the Proctection of Human Subjects Patricia Alt, Member

Date: Friday, October 10, 2014

RE: Application for Approval of Research Involving the Use of Human Participants

Office of Sponsored Programs
& Research

Towson University
8000 York Road
Towson, MD 21252-0001

t. 410 704-2236
f. 410 704-4494
www.towson.edu/ospr

Thank you for submitting an Application for Approval of Research Involving the Use of Human Participants to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University. The IRB hereby approves your proposal titled:

Effectiveness of uni-sensory and multisensory training in the identification of weapon function sounds

If you should encounter any new risks, reactions, or injuries while conducting your research, please notify the IRB. Should your research extend beyond one year in duration, or should there be substantive changes in your research protocol, you will need to submit another application for approval at that time.
We wish you every success in your research project. If you have any questions, please call me at (410) 704-2236.

CC: Stephanie Nagle
File

TOWSON
UNIVERSITY

Date: Friday, October 10, 2014

NOTICE OF APPROVAL

TO: Kristin Hartman **DEPT:** ASLD

PROJECT TITLE: *Effectiveness of uni-sensory and multisensory training in the identification of weapon function sounds*

SPONSORING AGENCY: None

APPROVAL NUMBER: 15-A022

The Institutional Review Board for the Protection of Human Participants has approved the project described above. Approval was based on the descriptive material and procedures you submitted for review. Should any changes be made in your procedures, or if you should encounter any new risks, reactions, injuries, or deaths of persons as participants, you must notify the Board.

A consent form: [✓] is [ ] is not required of each participant

Assent: [ ] is [✓] is not required of each participant

This protocol was first approved on: 10-Oct-2014
This research will be reviewed every year from the date of first approval.

Patricia Alt, Member
Towson University Institutional Review Board

Appendix B:

Consent Form for Participation in a Research Project

Consent Form for Participation in a Research Project

Principal Investigator: Kristin Hartman
Title of Study: Effectiveness of uni-sensory and multisensory training in the identification of weapon function sounds

Invitation to Participate

You are invited to participate in a study of hearing and perception by Kristin Hartman of Towson University. Please read this form and feel free to ask any questions you may have prior to agreeing to participate in the study.

Purpose of the Study

The purpose of the study is to determine if multisensory or uni-sensory training results in better identification of weapon function sounds.

Description of Procedure

In this study, you will be asked to listen to recordings of sounds associated with firearms (such as charging and magazine insertion). First, you will be given a hearing screening. The study will include participants with normal hearing or hearing within the range of a normal to mild hearing loss. You will be excluded from the study if your hearing sensitivity is beyond a mild hearing loss or if a condition is found that could interfere with testing, such as an ear infection. You will be given a pre-test, to determine your baseline ability to identify these firearm associated sounds. Next, you will undergo training of the firearm sounds through the presentation of either auditory or auditory and visual stimuli. You will also receive similar training with the addition of various background sounds. The order of these 2 training tests will be randomized. Testing will last approximately 1 $^{1/2}$ to 2 hours and breaks from testing will be provided regularly. All training will be completed using a laptop in a research lab at Towson University. You will be asked to complete a brief questionnaire regarding experience with firearms, military service, and musical training. The questionnaire will also ask if you are willing to return to the research lab in approximately 1 week to complete optional additional testing.

Risks and Inconveniences

We believe there are very minimal risks in participating in this study. Minor discomfort associated with boredom or fatigue from testing may occur. At any time, you are free to withdraw from the study.

Benefits

We hope this study will assist in determining the most effective techniques for training of firearm associated sounds. Additionally, you may benefit directly from the results of your hearing screening and the subsequent recommendations provided.

Confidentiality

All documentation, including the results of your testing and hearing screening, will be remain private. All records will be kept in a locked room and only researchers will have access to these records. No personal identifying information will be included in the event of a presentation or publication of the study.

Voluntary Participation

Participation in this study is completely voluntary. You do not have to participate in the study if you do not wish to do so. If at any time, you change your mind regarding your desire to participate in the study, you may withdraw. There are no penalties or consequences if you decide not to participate. Your decision not to participate will have no bearing on your status as a student, nor will it affect your relationship with or treatment from any party affiliated with Towson University.

Questions?

Take as much time as you like to review this form and make your decision. Please feel free to ask any questions you may have regarding the study. If you have further questions about the study, you may contact the principal investigator, Kristin Hartman, via email at khartm1@students.towson.edu or the faculty advisor, Dr. Stephanie Nagle, at (410) 704-3920. If you have any questions concerning your rights as a research participant, you may contact Dr. Debi Gartland, Chairperson, Towson University Institutional Review Board (IRB), at 410-704-2236.

Authorization

I have read this form and decided that I, ___________________________________, will
(name of subject)
participate in the project described above. Its general purposes, the particulars of involvement and possible hazards and inconveniences have been explained to my satisfaction.

Signature: ________________________________

Date: ____________________________________

_______________________________ _______________________________
Signature of Student Investigator Signature of Faculty Sponsor

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY

Appendix C:

Questionnaire

1. Age: _______

2. Gender: _________

3. Do you have normal or corrected-to-normal (contact lenses or glasses) vision?
   Circle one: YES NO

4. If you wear contact lenses or glasses, do you currently have it with you to wear for testing today?
   Circle one: YES NO I DO NOT WEAR CONTACT LENSES OR GLASSES

5. Have you had experience with either musical training or firearms?
   Circle one: YES NO
   *If you answered "yes", please fill out the details below.

   For which of the following have you gained experience?
   Circle all that apply: MUSICAL TRAINING EXPERIENCE WITH FIREARMS

   Please briefly describe your experience below, including the number of years of experience with these skills and noting if you currently use these skills. For weapons experience, please list specific weapons, if applicable.

   ____

   ____

   ____

6. Are you interested in returning in approximately one week to complete additional testing?
   Circle one: YES NO

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