



Feasibility of Audio Training for Identification of Auditory Signatures of Small Arms Fire

by Kim Fluitt, Jeremy Gaston, Vandana Karna, and Tomasz Letowski

ARL-TR-5413

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Human Research and Engineering Directorate, ARL

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14. ABSTRACT Soldiers are exposed to weapon fire, and the ability to identify a specific weapon can greatly improve their situation awareness and enhance their combat effectiveness. Soldiers usually learn to identify the acoustic signatures of these weapons when on the battlefield. Live fire demonstrations prior to missions are important for Soldiers' auditory skills development, but such demonstrations are not always available and are usually limited by the number of weapons available for comparison. The purpose of this study was to assess the feasibility of conducting auditory training in the recognition of small arms fire using high quality audio recordings and headphone playback. Eighteen subjects (ages 22–53) participated in the study. Several recorded exemplars of sounds produced by four weapons (AK47, M4, M9, and M14) were presented through headphones. Participants were allowed to train at their own pace, were tested using the recorded material; and were taken to a firing range where they were tested a second time using live fire sounds. Results of the study show that participants' ability to identify the four weapon sounds improved with training and that the results of the training with audio recordings of small arms fire translate well to live fire situations.					
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1. Introduction

When Soldiers are exposed to weapons fire, the ability to identify a specific weapon can greatly improve their situation awareness and enhance their combat effectiveness. By understanding where the fire originates and what type of weapon is used, the Soldier can react more quickly and effectively to threats, take cover when needed, and avoid potential fratricide.

After World War II and during the Korean War, Katzell et al. (1952) interviewed Combat Arms veterans in an effort to identify the components that contributed to situational awareness and target identification. According to surveys collected, the researchers found that the Soldiers most frequently suggested training to recognize relevant enemy sounds, as visual cues were often unavailable. Specifically of interest to the veterans were the sounds of enemy vehicles and weapon firing noises. These Soldiers also indicated that the acoustic signatures of enemy rifles were so distinct that they did not use captured weapons for fear of fratricide. The authors also stated that the Soldiers “frequently recommended” having live demonstrations of enemy equipment, and that these demonstrations should take place in a field setting.

The number of weapons to which current Soldiers are exposed has increased over the years due to a number of factors including conflicts involving more than two nations, the joint operations of multinational forces, and the sheer increase in number of weapon types used in modern warfare. In addition, the operational environment of the modern battlefield has significantly changed from the Korean War, with urban operations tending to dominate current conflicts (Cordesman, 2001). In such operations where the visibility of both enemy and friendly forces is limited, and the complexity of the sonic environment is greatly increased, the use of small arms and improvised explosive devices (IEDs) dominates the battlefield. These environmental elements highlight the need for acoustic training that aids the Warfighter in the recognition and identification of enemy as well as friendly auditory signatures. However, no such formal training module for sound source identification (prior to deployment to a theater of operations) exists. These skills are mostly learned “on the job” after deployment, which is far from a desirable situation.

Live fire demonstrations are critical for Soldiers’ auditory skills development, but such demonstrations are not always available and are usually limited in the number of weapons available for comparison. Therefore, a broad and easily accessible training module in weapon recognition and identification that can supplement live fire demonstrations is needed. One challenge to developing such a training module is the accurate reproduction of weapon sounds. Ideally, high fidelity binaural recordings of weapon firings and related sounds could be played through stereo headphones to replicate live sounds closely enough to allow learning that can be transitioned to a live environment. However, there are no studies available that demonstrate the translational capability of such reproduction in the case of weapon fire. Beyond the simple

question of generalization from recorded to live environments, a more complex question involves the extent to which learning gained from recordings made under specific source conditions can be generalized to live environments where a few or many of the source conditions have changed. In general, we refer in this report to source conditions as a constellation of specific weapon properties (e.g., barrel length, round type), environmental conditions (e.g., temperature, wind speed, reverberant properties of the sound field; proximal and distal distance) and dynamic event related conditions (e.g., cyclic rate of fire, mode of firing: single shot or automatic). Changes in aspects of any of these classes of source condition will affect the nature of the resulting sound reaching the perceiver. Thus, for any auditory based training to be effective, it must be demonstrated that knowledge gained from a set of specific recorded source events can be generalized to inherently variable live situations. In the present study, weapon sound recordings were made with a shooter firing weapons at 0°, 30°, and 60° angles (angles of incidence) and recorded at 180° to the shooter (recording angle). These recordings were used for both training and evaluation.

Traditionally, the study of complex meaningful sounds has focused on either human speech or music, with other natural sound classes largely ignored (Pastore et al., 2008). However, in the past two decades, a growing number of studies have begun to investigate listener perception and classification abilities for complex non-speech, non-musical sounds. While a few studies have investigated the broad classification abilities for sets of complex natural sounds (e.g., Balas, 1993; Balas and Mullins, 1991; Gygi et al., 2007), most have focused on the perception of specific types of impacting objects where variability in the sounds produced was primarily due to some static property of the impacting objects. For example, Lakatos et al. (1997) investigated listener perception of size and shape for impacted bars, Carello et al. (1998) investigated listener perception of length for dropped rods, and Grassi (2005) investigated perception of ball size from balls dropped onto ceramic plates. A limited number of studies have looked at source events where there was considerable variability in the static and dynamic properties producing the impacting sounds. For example the gender classification of humans clapping (Repp, 1987) and humans walking (Li et al., 1991).

More recently, Pastore et al. (2008) investigated the ability of listeners to judge walker posture for recorded sequences of footsteps. Here, there was considerable variability in the sounds produced due to large differences in both the static anthropometric and dynamic biomechanical source characteristics of the recorded walkers. In the study, listeners performed a two-interval forced choice task (w/feedback) in which listeners choose the “upright” from “stooped” walking sequence among within-walker sequence pairings. Prior to the experimental block, listeners completed a practice block consisting of one presentation of each of two walking sequences from seven walkers. The experimental block (experienced performance) consisted of an additional repetition of each walking sequence. Despite large variability in source attributes, as well as the resulting sound properties across the seven walkers, average listener accuracy was better than 80% with some listeners achieving better than 90%. More importantly, when given a new set of

seven walkers, listeners achieved comparable performance in the absence of practice, thus demonstrating generalization of learning. These results are consistent with auditory training studies for unfamiliar segmental speech, where typically learning and generalization is best when there is greater variability in the input distribution (e.g., Logan et al., 1991). These types of auditory training studies using simple feedback-based learning for unfamiliar segmental speech have had moderate (8% increase) to very good success (21% increase) in improving listener performance (Jamieson and Morosan, 1986; Logan et al., 1991; Bradlow et al., 1997; Wang et al., 1999). Thus the present study uses a similar method to facilitate learning for the presented small arms weapon sounds. A brief introduction to education philosophies and auditory training methodologies that assisted with the formulation of the current study is provided in appendix A.

The current study is the first of several studies addressing the development of the Soldiers' skills in recognizing and memorizing acoustic signatures that are critical in conducting military operations. It addresses the technical feasibility of conducting auditory training in the recognition of small arms fire using high quality audio recordings and earphone playback. It is assumed that once the targets and methodology of such training are developed, training materials can be presented in a comprehensive CD-based course that can be completed in several hours and reviewed when needed.

2. Methodology

2.1 Description of Study

The goal of the reported study was to assess whether participants trained to recognize sounds of recorded weapons could translate this knowledge to a live fire situation. The study was comprised of five parts, a Baseline Test (Phase 1), a Familiarization Session (Phase 2), a Practice Session (Phase 3), a Post-Practice Test (Phase 4), and a Live Fire Test (Phase 5). Phases 2 and 3 were training segments and Phases 1, 4, and 5 were evaluations. Participants were evaluated initially on four weapons for the Baseline Test, and trained on the same four weapons sounds for the Familiarization and Practice Sessions. Two additional weapons were added as distracters for the Post-Practice and Live Fire Tests. A description of the participant task is given in the Training and Procedures (2.8). Participants completed Phases 1 through 4 either individually or in pairs. The Live Fire Test was conducted in two groups of five and seven participants each.

2.2 Participants

A group of 18 listeners between the ages of 22 and 53 participated in the study. They were recruited from the civilian population of Aberdeen Proving Ground (APG), MD. The participants had a varied amount of weapon firing and listening exposure, but none were active hunters or had previous military experience. All listeners had pure-tone hearing thresholds better than or equal to 20 dB hearing level (HL) at audiometric frequencies from 250 through 8000 Hz

(ANSI, 2004) and no history of otologic pathology. All thresholds were conducted in an audiometric booth meeting ANSI S3.1-1999 (ANSI, 1999) requirements for open ear testing. The difference between pure-tone thresholds in both ears was no greater than 10 dB at any test frequency. No previous experience in psychophysical studies or with the evaluated weapons was required. Participants were not compensated for their participation in this study.

2.3 Test Facilities

All listening tests, except for the Live Fire Test, were conducted in the Listening Laboratory of the Environmental for Auditory Research, located at the U.S. Army Research Laboratory (ARL), APG, MD. The Listening Laboratory is a multipurpose auditory test room with noise levels below the NC-15 noise curve (Beranek, 1957) and reverberation time of 0.4 seconds or less in the 250–8000-Hz frequency range (Scharine and Mermagen, 2008). Two listening stations separated by about 6 feet and facing opposite directions were set up in the room. Each station was equipped with a pair of AKG K701 headphones, a PreSonus FirePod, and Dell laptop computer.

Both the recordings of testing materials and the Live Fire portion of this study took place at M-Range at the ARL, APG, MD. The range is a grassy area that is rectangular in shape with the dimensions of approximately 200 m × 600 m. The range has targets that form two horizontal berms 1-m high that run the width of the range at 10 m and 25 m. There are also targets at 50, 75, 100, 150, 200, 250, 300, 400, 500, and 550 m, that form 1-m berms. The grass on the range is maintained at 2–3 inches. The range is surrounded on three sides by trees and underbrush with the forth side furthest away from the shooting stations that also has trees but much less in number. Relative positions of the shooter and the listeners during the Life Fire Test are shown in figure 1.



Figure 1. M-Range. Locations of shooter (S1) and microphone (M) during the sound recording session and locations of shooter (S2) and listeners (L) during the Live Fire Test. The arrows indicate the direction of weapon during recording session. During the Live Fire Test the direction of weapon fire was 180° away from Listeners.

2.4 Weapons

Eight personal weapons from the ARL armory were selected for the sound recording session. The weapons were: M4, M9, M14, M16, AK47, STEYR AUG, CZ75, and the H&K P7. These weapons were selected based on availability and wide spread use or familiarity by U.S. Army and security forces. The pictures of the selected weapons are shown in figure 2. Technical data on all eight weapons are included in appendix B.



Figure 2. Weapons.

The reason that eight different weapons were recorded while the design of this study called for only six weapons was that this was our first study of this kind, and we wanted to make sure that the selected weapons had sufficiently different signatures. Upon the completion of the sound recordings, and after careful perceptual analysis of the recorded weapon sounds, the following six weapons were selected: M4, M9, M14, AK47, STEYR AUG, and CZ75. These weapons were the most distinguishable among the eight recorded weapons. The M16 had a very close signature to the AK47 and because the M16 is being phased out of the U.S. Army this weapon was eliminated from consideration. Similarly, the H&KP7 was not chosen because its signature was very close to that of the CZ75, which was selected because of being of more interest to the Army.

2.5 Weapon Sound Recording

All weapon sounds were recorded during a single recording session (October 30, 2008) at the ARL M-Range (shooting range) shown in figure 1. The sounds were recorded using a SONY Linear PCM D-1 Recorder with a built-in pair of electret microphones. The recorder was placed at a distance of 64 m 180° (directly behind) with respect to the shooter position and orientation. The relative positions of the shooter and the stereo microphone are shown in figure 1. These recordings were a part of a larger recording session conducted at M-Range on that day. The recordings used for this study were single shots separated by a three-second delay between shots.

The shooting angles were 0° (midline, in front of shooter), 30°, and 60° (to the right of the shooter) also shown in figure 1. The levels of recorded sounds measured at the recording microphone are given in table 1. The weather conditions during the recording session were: temperature 46 °F, humidity 48%, barometric pressure 30.36 inches, wind speed 6.5 mph, and dominant wind direction of 301° (NW). These conditions produced an average wind chill factor of 42 °F.

Table 1. Average impulse-weighted sound levels for each weapon. Averages are based on a minimum of four independent measurements.

Level [dB(C)]		
	<i>M</i>	<i>SE</i>
<u>AK47</u>	85.7	0.11
<u>M14</u>	90.1	0.59
<u>M9</u>	82.2	0.23
<u>M4</u>	88.8	0.45
<u>CZ-75</u>	82.9	0.14
<u>Steyr</u>	86.8	0.15

2.6 Test Sounds

The stimuli used in this study were edited to begin 50 ms before the onset of the muzzle blast and had a total duration of 1050 ms. All stimuli were then adjusted to the same peak pressure (−6 dB) in order to minimize potential dominant loudness cues (Gaston and Letowski, 2010). After the sound files were edited they were organized according to angles of incidence and used in the following test phases in table 2.

Table 2. Recording positions for weapon sounds used in study.

Phase	Recording Position	Incidence Angles
Baseline (Phase 1)	64 m-180° (or behind shooter)	0°, 30°, & 60°
Familiarization (Phase 2)	64 m-180° (or behind shooter)	30° & 60°
Practice (Phase 3)	64 m-180° (or behind shooter)	0°, 30°, & 60°
Post Practice (Phase 4)	64 m-180° (or behind shooter)	30° & 60°

2.7 Sound Presentation and Data Collection

The testing paradigm consisted of five separate phases. Phases 1, 4, and 5 were Baseline, Post-Practice, and Live Fire Tests respectively. Phases 2 and 3 were Familiarization and Practice sessions that were the elements of the actual listener training. Participants completed Phases 1 through 4 either individually or in pairs. The Live Fire Test was conducted in two groups of five and seven participants each.

Sound presentation and data collection in all phases of training were controlled by custom designed software run on a Dell laptop computer. The listener started each individual session by a mouse click on the Start button shown on the opening computer screen (refer to figure 3a, upper panel). A click on Start initiated each session and revealed one of the two Listener Response Boxes (LRBs) shown in figure 3 (left and right panels). The LRB shown in the left panel of figure 3b appeared in Phases 1, 2, and 3 of the study and the LRB shown on the right panel of figure 3c appeared in Phase 4. The Exit button, shown on both lower panels of figure 3, served as an “emergency button” for the listener to terminate sound presentation and execution of the current session in the event that there was a problem with a sound presentation. In addition, Phase 3 feedback was provided to the listener via a correct response button turning green (if clicked), and an incorrect button turning red (if clicked).

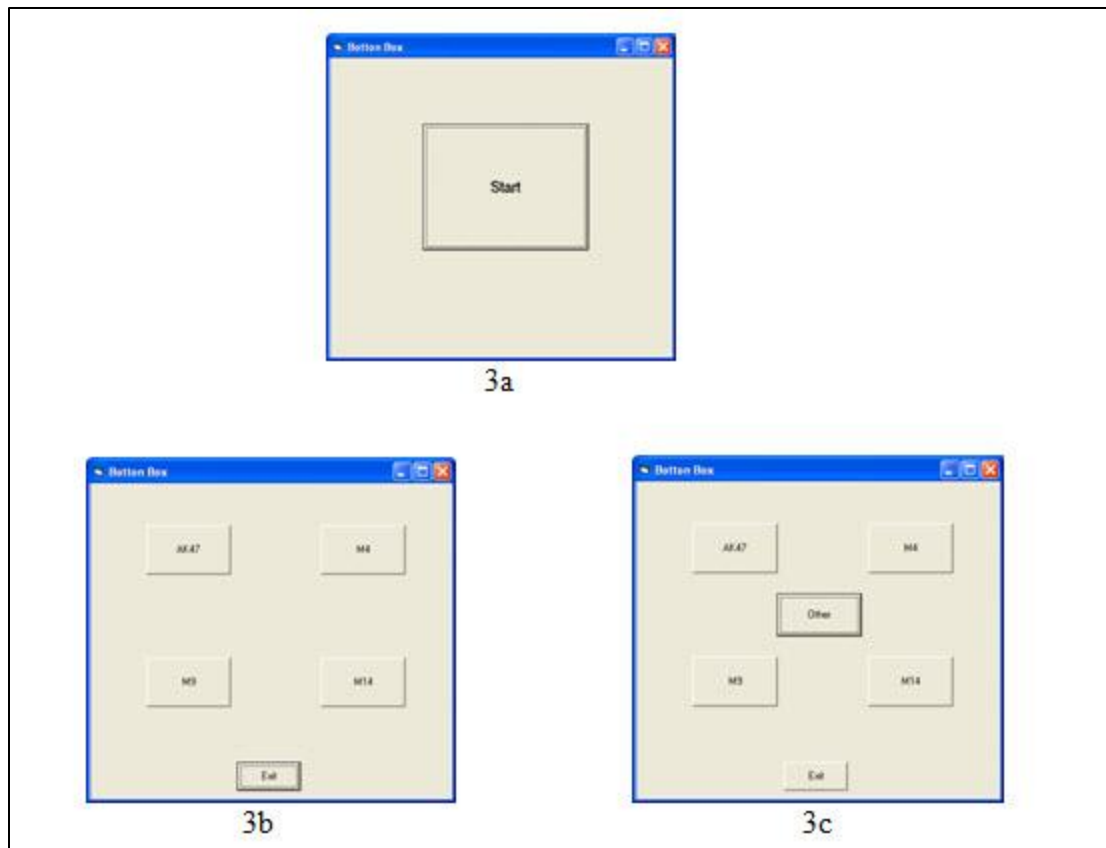


Figure 3. The three control boxes appearing on the computer screen during the study. The “Start” box in figure 3a was used to start individual trials in Phases 1–4 of the study. The box in figure 3b was used in Phases 1, 2, and 3 and the box in figure 3c was used in Phase 4.

2.8 Training and Procedures

2.8.1 Baseline Test (Phase 1)

The purpose of the Baseline Test was to determine participants’ prior familiarity with the sounds of the four weapons used in the study. At the beginning of the test the participants were given the names of the four weapons used in the study (M4, M9, M14, and AK47). They were also told that the Baseline Test would consist of 24 stimuli (six different digital recordings of each weapon type used in the study) presented in random order. The sounds were presented over AKG K701 headphones. A mouse click on the “Start” button triggered a sound and the screen changed into a response box shown in the left panel of figure 3b. The listener’s task was to identify which of the four weapons was the source of a given sound and click the corresponding button on the response box. A click on a response button was recorded as the listener’s answer and after a two-second delay another sound was presented. This was repeated until all 24 sounds were completed.

2.8.2 Familiarization Session (Phase 2)

The Familiarization Session followed the Baseline Test and involved the sounds of the same four weapons (M4, M9, M14, and AK47) as the objects of training. The start of the session was initiated by a mouse click on the “Start” button and the same response box as before with four buttons labeled M4, M9, M14, and AK47, respectively, appeared on the screen (refer to figure 3b, left panel). Clicking a button caused a presentation of one of the six recorded examples of the specific weapon. The sounds were presented through AKG K701 headphones. The participant was allowed to click the buttons in any order, and initiate as many presentations as needed to become familiar with the sounds of all four weapons. The duration of the Familiarization Session was left up to the discretion of the participant and varied from 3 to 22 min across all 18 participants.

2.8.3 Practice Session (Phase 3)

Once the participant felt sufficiently familiar with the sounds of all four weapons listened to in the Familiarization Session, the Practice Session was started. After clicking the “Start” button one of the same 24 sounds used in the Familiarization Session was presented and the participant was asked to determine which of the weapons was “fired” and to click the appropriate button on the response box shown on the screen (refer to figure 3b, left panel). After the participant clicked a button to make a response the button changed its color temporarily providing feedback to the participant to indicate the response was correct or incorrect. If the response was correct the selected button turned green. If the response was incorrect the selected button turned red, then the correct response button turned green. At the end of each trial, the response was recorded as the listener’s answer, and after a two-second delay another sound was presented. This was repeated until all 24 sounds were completed. The Practice Session consisted of a block of 24 presentations. The number of times this session was repeated was left to the discretion of the participants and varied from five to twenty repetitions across participants. If not satisfied with the progress of the Practice Session, the participant could again invoke the Familiarization Session and again listen to the sounds of specific weapons before switching back to the Practice Session. For consistency, we asked our participants to try to achieve at least three closely related scores.

2.8.4 Post-Practice Test (Phase 4)

After the participant was satisfied with the results of the Practice Session the weapon training ended and the participant was given the Post-Practice Test. In this test, in addition to the four original sounds, the sounds of the two additional weapons were used as the distracters (STEYR AUG and CZ-75). The test started with a mouse click on the “Start” button, but this time the response box shown on the right panel of figure 3c was shown on the computer screen after the sound was presented. In addition to the original four buttons that were used as the response buttons in the Practice Session, the “Other” button was added to the response box to be used as a response button when one of the two distracters (unknown sounds) was presented. The sequence

of 24 sounds (6 weapons $\times$ 4 exemplars) was generated in a random order by randomization software and the individual sounds were presented in the same manner as in the Practice Session. A short presentation of various sounds generated by the four original weapons preceded the test as a refresher because the Post-Practice Test was scheduled on a separate day, sometimes two or three days after the end of the training. The listeners were informed about the presence of the two additional “Other” weapon sounds in this phase, these sounds were not demonstrated and their names were not given to the participants.

2.8.5 Live Fire Test (Phase 5)

The Live Fire Test was conducted at the live fire facility (M-Range) at ARL. The participants were tested in two groups, one with five and the other with seven; each group was tested on separate days to allow for scheduling conflicts. At the range, the participants were provided an answer sheet, clipboard, and pen to record their responses. Participants were seated in chairs, in a parking lot behind the shooting range. A shooter was located down the firing line approximately 64 m away from participants (figure 1). No hearing protection was needed since participants were not physically located on the firing range and the pre-measured sound levels did not exceed OSHA and Army exposure standards. Participants were visually occluded from the shooter by earthen berms. Before the Live Fire Phase began, listeners were given two examples of each of the primary weapons being fired. Following this brief familiarization, the shooter fired single shots of the four target and two distracter weapons, four shots per weapon, for a total of 24 shots. The order of shots was randomized. Participants were asked to identify the sounds of the four basic weapons by circling a weapon on their response sheet for each shot presentation. If they did not recognize a weapon sound they were instructed to circle “Other.” The structure of the Live Fire Answer Sheet is shown in figure 4.

1)	M16	M9	AK47	CZ75	Other
2)	M16	M9	AK47	CZ75	Other
3)	M16	M9	AK47	CZ75	Other
4)	M16	M9	AK47	CZ75	Other
5)	M16	M9	AK47	CZ75	Other
⋮					
⋮					
24)	M16	M9	AK47	CZ75	Other

Figure 4. Excerpt of the Live Fire Answer sheet.

The weather conditions for the Live Fire Shooting Sessions were as follows: (1) Session I: temperature of 79 °F, humidity 75%, barometric pressure 29.84 inches, wind speed 3.8 mph, and

wind direction of 304° (coming from the NW) and (2) Session II: temperature of 75 °F, humidity 94%, barometric pressure 29.87 inches, wind speed 1.5 mph, and wind direction of 287° (coming from the WNW). These conditions produced an average WBGT of 80 °F and 76 °F for Session I and Session II, respectively.

3. Results and Data Analysis

The present analysis is based on the results of 12 (8 men and 4 women, ages 22–53) of the original 18 recruited participants. The remaining six participants' data were not included in the analysis because they were unable to complete the final part of the experiment. Because our primary goal is to monitor learning and transfer of that learning from laboratory to live fire conditions, we first based our analysis only on responses when the four primary weapon alternatives were presented. Thus, in conditions where distracter weapon sounds were added (Post-Practice and Live Fire) responses to the distracter weapons are for the time being ignored, but will be discussed later since they provide insight into the decision strategies adopted by listeners in the evaluative experimental conditions. Figure 5 shows the average performance for the four primary weapon alternatives across listeners for each condition. Although these data are based only on responses to the primary weapon alternatives, the number of response categories given to listeners differs across conditions. Thus, figure 5 is separated into two panels. In panel A the two conditions where only four response alternatives appropriate to the primary weapons of interest are depicted along with a dashed line showing the chance performance level of 25%. Similarly, in panel B the two conditions where a fifth “Other” response alternative is possible are depicted along with a dashed line representing the chance performance level of 20%. Because listeners were given the opportunity to run as many practice blocks as they wished, practice performance is based on the average of the last two practice blocks performed by each listener. The average number of practice blocks performed by listeners was 13 ($SE = 1.24$).

We begin with an analysis of the average performance across condition, followed by analyses of performance as a function of weapon alternative, and finally the pattern of listener responses to each weapon alternative. Where applicable, all statistical tests are performed using two-tailed criteria for evaluation unless otherwise stated. In all conditions except Baseline, one sample t-tests show that performance was always significantly better than chance, $t(11) > 4.8$, $p < 0.001$. If listeners are assumed to be naïve with respect to judging weapon identity, then Baseline performance should not be, and was not, significantly different from chance, $t(11) = 2.1$, $p > 0.05$. That performance was numerically lower than expected; chance may simply be indicative of some listeners basing responses on *incorrect* expectations. For example, listener 10 had 54% “M14” responses and only 8% “AK47” responses.

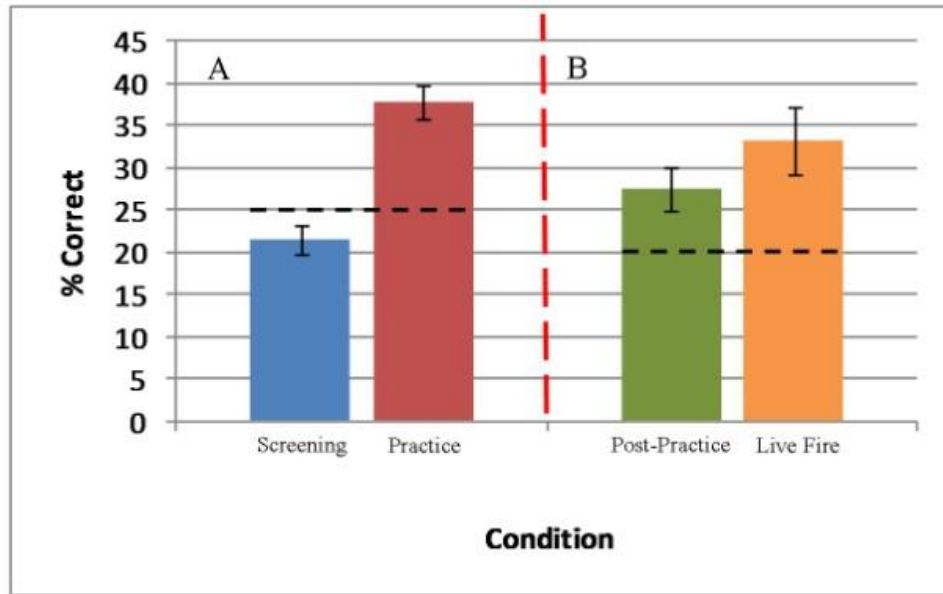


Figure 5. Panel A: uncorrected accuracy for Screening and Practice with dashed line representing chance performance. Panel B: uncorrected accuracy for Post-Practice and Live Fire with dashed line representing chance performance.

Because of the difference in available response alternatives across conditions, the accuracy data were transformed to be on the same scale by accounting for the expected differences in chance performance. This was accomplished by subtracting expected chance from the actual accuracy value and then dividing that value by the range above chance (either 75% or 80%). These transformed values are depicted for each condition in figure 6.

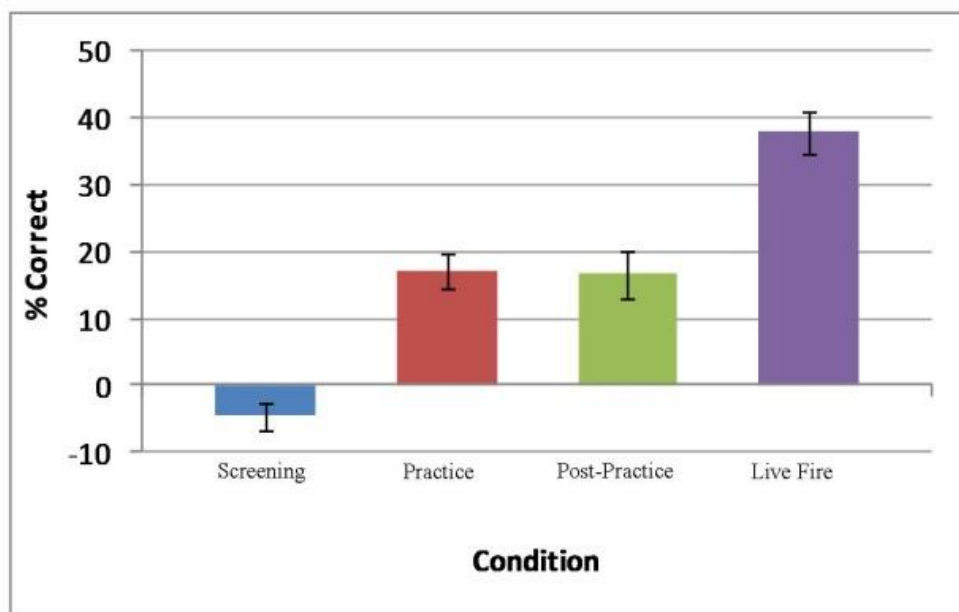


Figure 6. Corrected accuracy relative to chance across conditions.

A repeated measures analysis of variance (ANOVA) showed that there was a significant increase in average performance across conditions, $F(3, 33) = 51.7, p < 0.001$. Follow-up Tukey's HSD post hoc tests were performed to evaluate differences between conditions. Relative to Baseline, all other conditions showed a significant increase in performance, $M_{\text{diff}} > 21.3\%, p < 0.05$, thus indicating significant listener learning. Generalization of feedback-based listening training to the no-feedback laboratory evaluation was good, as evidenced by similar levels of performance across Practice and Post-Practice, $M_{\text{diff}} = 0.5\%, p > 0.05$. Similarly, listening training appears to have successfully generalized to Live Fire conditions, with Live Fire performance being even better than either Practice, $M_{\text{diff}} = 21.0\%, p < 0.05$, or Post-Practice Performance, $M_{\text{diff}} = 21.48\%, p < 0.05$. This increase in performance under Live Fire conditions will be discussed.

4. Discussion

The analysis of average performance indicates that listeners can generalize laboratory audio training to natural listening conditions. To better understand these listener judgments, we now turn to an analysis based on listener performance as a function of individual presented weapon alternative. Figure 7 shows the performance for each of the weapon alternatives separately for each condition.

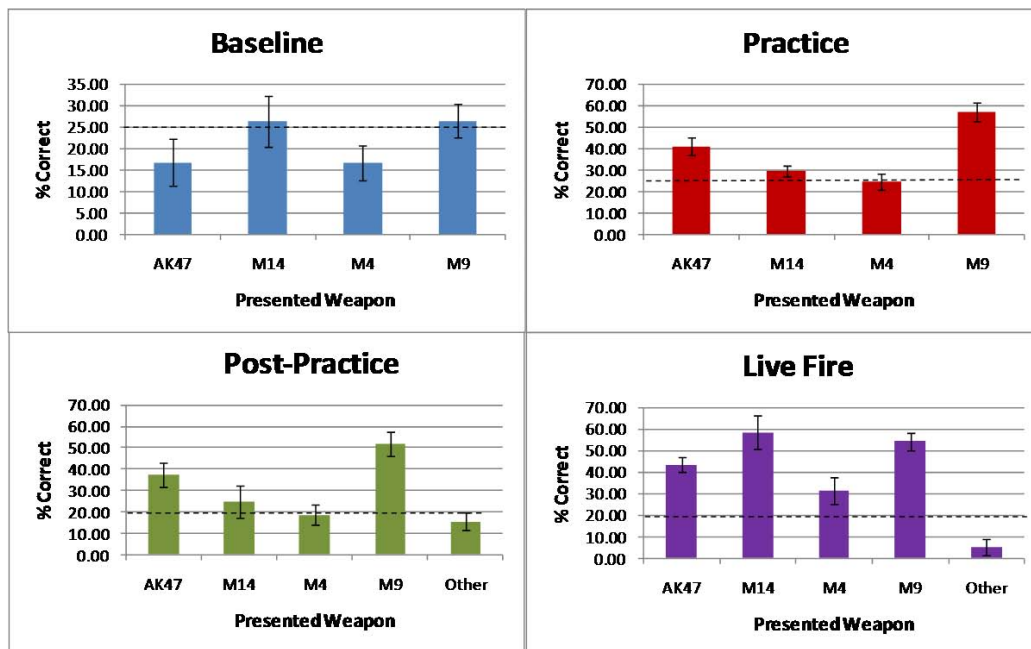


Figure 7. Accuracy for each presented weapon across condition.

As indicated earlier, Baseline performance was slightly below chance, and this result is driven by poorer than expected performance for the AK47 and M4. However, because listeners did not

perform significantly above chance levels for any of the weapon alternatives, we can be confident that our participants began the study as relatively naïve listeners. The effect of feedback training was to significantly increase performance for identifying the AK47, $t(11) = 3.62, p = 0.004$, and M9, $t(11) = 5.90, p < 0.001$ but did not elevate performance for either the M4, $t(11) = 0.17, p = 0.87$ or M14 $t(11) = 1.92, p = 0.082$, above chance levels. The earlier analysis based on average performance (and ignoring “Other” responses) did not show any difference between the average Practice and Post-Practice performance, and here the patterns of performance across weapon type are also very similar.

For Live Fire, there are both similarities and differences in the patterns of performance across weapon type. Performance for the AK47 and M9 in Live Fire was not significantly different from Post-Practice performance, $t(11) < 0.83, p < 0.42$. Performance for the M4 did increase numerically (Post-Practice: $M = 18.8, SE = 4.49$; Live Fire: $M = 31.3, SE = 6.25$), however, that numerical difference in performance was not significant, $t(11) < 1.8, p = 0.082$. That performance for these weapons was statistically similar across laboratory and live evaluations indicates that knowledge gained from controlled laboratory training was successfully generalized to live conditions for these weapons. However, this cannot be said for the M14, where performance was significantly better than that achieved in Post-Practice, $t(11) < 3.37, p = 0.006$. What might be driving this increase in performance? Recall that in laboratory conditions the levels of each recorded stimulus were equated for peak sound level in an effort to avoid having listeners base their decisions on only intensity differences. During Live Fire however, listeners were given two examples of each of the primary weapons prior to the evaluation. The sound levels collected during the Live Fire evaluation (refer to table 2) show that the M14 was the most intense weapon and this intensity difference (not present during laboratory testing) may have provided listeners with a partial cue to the M14’s identity. If this was the case for the M14, then it might also be possible that intensity cues under live conditions may also have been important for the M9, which was the least intense weapon. Based on the analysis up this point, additional learning of differences in absolute peak amplitude seem unlikely to have influenced performance since there is surprising consistency in performance across laboratory and live conditions. Thus, it may be that unexpected high performance in Live Fire for the M14 is a unique case.

To further explore the nature of listener decision making for these small arms sounds, we now offer a discussion of the pattern of responses to the individual weapon alternatives and how these patterns change across listening condition. Figure 8 shows separate panels for each of the four primary weapon alternatives, as well as the two distracter weapons. Looking at the distribution of responses across weapons, we see that in most cases the general pattern of responses is similar across condition, although there are some important differences. First, looking at the distribution of “Other” responses, from the incidence of responses across weapons, it is apparent that “Other” was chosen much more frequently during Post-Practice than Live Fire. Indeed, listeners made an average of 2.25 ($SE = 0.37$) “Other” responses in Post-Practice and only 0.67 ($SE = 0.38$) during Live Fire. Further, all except one listener during Post-Practice used “Other” at least once, but

only three listeners ever used “Other” during Live Fire. This suggests that although listeners during Post-Practice may have based judgments on five response categories, during Live Fire, listeners generally seem to have based judgments on only four response categories; the overall better performance seen during Live Fire may in part be due to this difference in the number of listener used response categories across conditions.

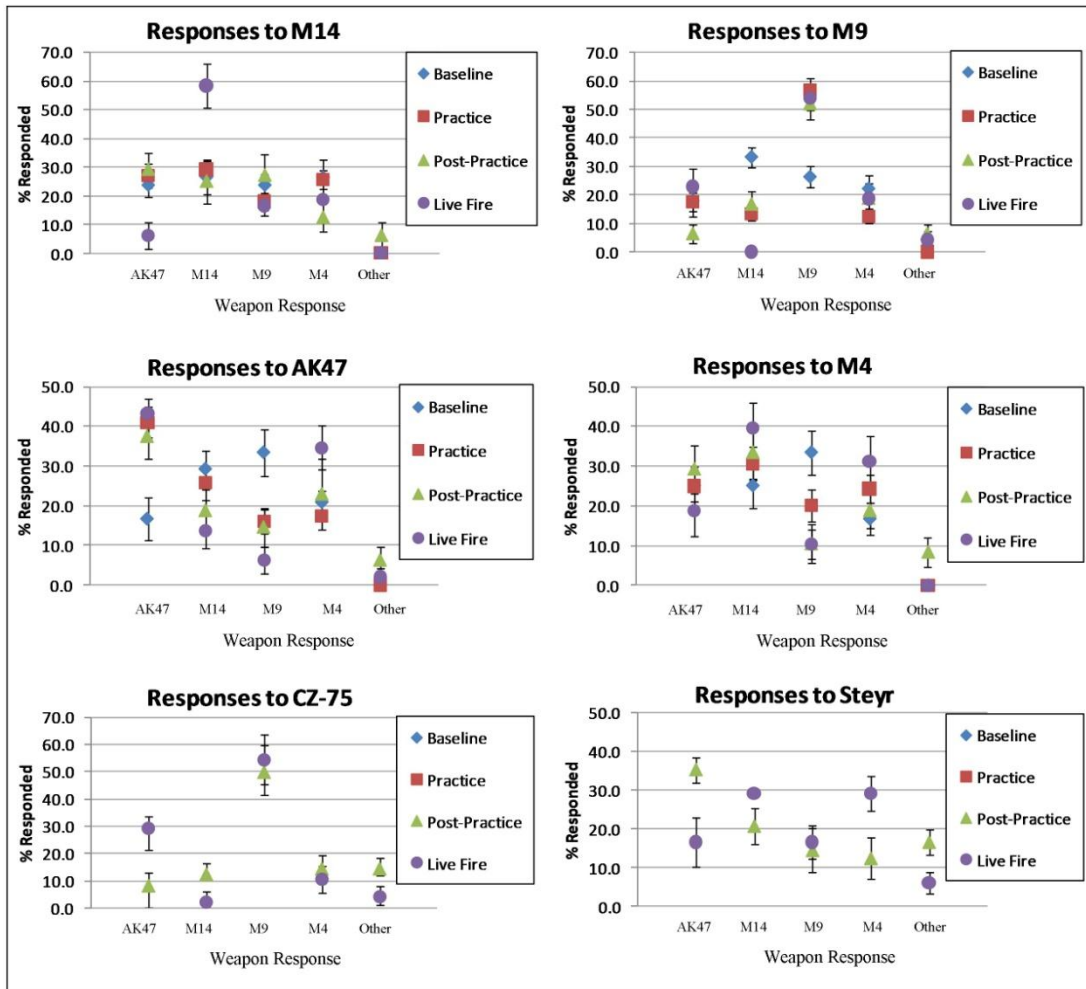


Figure 8. Listener responses across conditions separately for each condition.

We now turn to the distribution of weapon responses made to the specific presented weapons, and begin with listener responses made to the M14. Across Practice and Post-Practice, the patterns of responses are very similar, being somewhat evenly distributed among the four primary weapon alternatives. In Live Fire, there is a large increase in the number of “M14” responses from Post-Practice (33%), but there also is a sizable decrease in the number of “AK47” responses (23%). We may speculate from this pattern that if listeners used additional intensity-based information gleaned from just prior to Live Fire evaluation, the effect may have simply been to help disambiguate AK47 from M14 fire, thus leading to the observed increase in performance. In contrast to responses made to the M14, there was incredible consistency in

responses made to the M9 across the conditions. One of the only exceptions is that during Live Fire, listeners never responded “M14.” From the pattern of responses to the M9 it is also apparent that listeners did not seem to incorporate any potential intensity cues learned just prior to Live Fire evaluation. Indeed, if this were the case, we would see much lower non-M9 responses during Live Fire relative to Post-Practice. Responses to the AK47 also were generally consistent across conditions, with the only notable differences being a slight reduction in “M14” and “M9” responses and a slight increase in “M4” responses. For the M4, responses were also fairly consistent across conditions. Turning to the responses to the distracter weapons, we see that responses to the CZ-75 were almost identical to those of the M9, and this is not surprising since they are both 9-mm handguns. For the Steyr, responses were not similar across Post-Practice and Live Fire, and this simply indicates that listeners were not able to reliably categorize this *untrained* weapon.

5. Final Comments and Conclusions

The present study summarizes the results of short-term training for weapon sound recognition based on audio recordings of small arms fire and the translation of the acquired knowledge to the Live Fire situation. This research for single weapon impulse events is perhaps not typical for some of the weapons engagements, but these single-shot sounds represent some of the more difficult battlefield sounds to identify. Therefore, such sounds represent a logical starting point for evaluating the feasibility of audio training for battlefield-relevant sounds.

The main challenge for the researcher interested in listener source identification of complex natural sound events is to include in the evaluation process those sources of variability that cannot be controlled for or appear naturally, while seeking to exert control over sources of variability that are of primary interest, in this case impulsive small arms fire. Therefore, in the present study, the full set of audio recordings for a given weapon did not share identical source characteristics and thus there was a resulting inherent degree of variability in sounds produced. Controlled sources of variability included selection of the weapon set, the shooting distance (64 m) and the angle of shooting incidence (0°, 30°, and 60°). In addition, the recordings also differed in type and level of background sound due to ongoing changes in environmental conditions and included, for example, sounds due to wind, wildlife and even passing road and aerial traffic. In respect to the last class of sounds a strong effort was made to limit the presence of the most obvious extraneous weapon-irrelevant sounds; however, some variation in sound recordings due to environmental factors will always be present in recordings made in natural settings and was a desired feature of the collected sounds. Such an approach permits some degree of data generalization since sound identification was not based on single tokens but was based on multiple tokens recorded under various firing conditions.

A goal of source identification research is to understand listener ability to meaningfully categorize sounds generated by a specific sound source as opposed to the ability to memorize and identify one specific token of sound source production. In the categorization process involving several exemplars of the sound source production, only attending to variation along source-relevant properties will reliably cue identity, while attending to source-irrelevant variation should only lead to chance identification. Despite this type of experimental approach, it is still feasible that listeners could over time practice and learn to categorize sounds based on only indexical information. However, this likelihood is significantly reduced by having a sufficiently large set of input sounds that each has unique sets of weapon-irrelevant sounds. Here the set of recorded sounds included six tokens each of four weapons during Practice. Thus, it is most likely that in the present study, the observed increase in identification performance in Post-Practice was due primarily to listeners learning about weapon-relevant sources of variability in the recorded sounds. More convincing, however, is that for listeners to transfer any learning gained from laboratory training to the natural Live Fire event, learning must have been based on weapon-relevant variability since there could be no match based on recording-specific indexical variation. Indeed, the highly similar pattern of responses between the trained and the untrained CZ-75 is indicative of listener learning for weapon relevant information and transfer of that knowledge to a novel, but similar weapon. The fact that handguns were perceived as very similar and highly distinguishable from rifles is consistent with a related study on perceived similarity and discrimination of small arms weapon sounds by Gaston and Letowski (2010). Such a distinction can be important especially considering the effective ranges of these different broad classes of weapons. For example, the CZ-75 represents only a short range threat with a maximum effective range of approximately 50 m, whereas the maximum effective range of the AK47 is approximately 400 m, and thus represents a much longer range threat.

In conclusion, the combination of passive (Familiarization) and active-feedback training (Practice) given to listeners in the present study, resulted in a performance gain of more than 16% from Baseline to Post-Practice, which is consistent with some of the more successful demonstrations of auditory training for human speech (e.g., Bradlow et al., 1997; Jamieson and Morosan, 1986; Logan et al., 1991; Wang et al., 1999). Although there were some important differences in the patterns of responses (i.e., enhanced performance for M14) across laboratory to Live Fire evaluation, these differences are fully explainable and in general the consistency of the observed recognition patterns supports successful transition of laboratory learning to live fire conditions. Such audio training is by no means intended to replace live fire training, but may represent an inexpensive, time saving augmentation to traditional training paradigms. This type of training can be applied to a broad range of sound classes that can inform the Warfighter about their environment.

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Appendix A. Training and Training Methods

Introduction

Training is a learning process that involves acquisition of knowledge and practical skills in order to enhance performance of specific tasks or functions. Training may involve variety of structured or less formal activities including classroom-based courses, on-the-job training, problem solving, simulation activities, and discussions. The effectiveness of training depends on the thorough beforehand analysis of the training goals, timeframe, and metrics. Well designed training should be built around existing knowledge and skills of participants, motivate participants, and fulfill participants' expectations.

There are many types of training that differ in the type of knowledge and addressed audience. Most common types of training are general knowledge training (e.g., high school program), vocational training (e.g., car mechanic or sonar operator training), art training, military training, management training, physical training, business training, and specialized/remedial training geared toward addressing specific deficiencies of the participants. One additional type of training is perceptual training that is intended to improve sensory awareness of the surrounding environment and perception of the changes affecting this environment. Perceptual training may address visual skills, auditory skills, or other single-sense skills of a participant as well as the multi-sensory perception of the environment.

Military Training

Small Arms Signature Identification Training (SASIT) addressed in this Technical Report is a limited-scope perceptual training method intended to improve skills of the participants in recognition of acoustic signatures of small arms fires. This is a specialized form of training addressing a limited set of weapon sounds. However, the methods and techniques used in this training can be easily extended to other types of small arms sounds (e.g., weapon manipulation sounds), other types of weapons, or to other types of acoustic signatures such as helicopters, ground vehicles, footsteps, or human voices.

Since SASIT is primarily intended for military personnel and security forces it should take advantage of methods and techniques used in other military trainings. Military training, in some aspects is very similar to that of civilian instruction. For example, skills used in operating or repairing tactical vehicles are not very different than skills used to operate armored cars and fire trucks. However, there are some skills that are unique to combat and weapons systems such as targeting and munitions handling that are for the most part distinctly military. While formal training exists for some of these distinct responsibilities, on the job training has in the past been a very large part of some other skill sets such as the auditory identification of weapon signatures.

The need to train Soldiers in identifying the auditory signatures of enemy fire arms has been recognized for a long time and become even more critical in the modern warfare setting. The number of types of weapons used by various countries has increased greatly over the last 30 years and many modern weapons have very similar sound signatures, which presents a challenge for the Soldiers to identify whether the sound is coming from the enemy's weapon or from one used by a supporting multinational force. Therefore, the need to clearly identify the auditory signatures of the various types of firearms and other weapons has become critical to Soldiers' situational awareness, especially in modern fast-paced urban warfare.

Soldiers can improve their auditory skill to discern between enemy and other small fire arms via live fire demonstrations and training, which are usually expensive and depend on the number of weapons available. An alternative is to train Soldiers on auditory signature identification using the pre-recorded sound of firearms projected over loudspeakers or earphones. The audio-signals based training using pre-recorded sounds can be efficient and relatively less expensive. However, due to a lack of studies on the use and effectiveness of such an approach in training Soldiers to enhance their auditory skills, there is no established training material, approach, and protocol for pre-recorded auditory signature identification training. There is also a lack of a general teaching approach in sound identification regardless of the live or pre-recorded sounds. Therefore, ARL initiated a program to design sound identification training methodologies, to develop supporting training materials, and to evaluate their effectiveness in training Soldiers in both field and audio (virtual reality) environments to distinguish and identify the source of sound based on its auditory signature. The specific goals of this program are to develop audio library and computer-based training materials that can be used for both group instruction and individual self-paced Soldier training.

Introduction to Instructional Learning

There are several traditional philosophies of human instructional learning that are of potential relevance to military training and, in turn, potential auditory skills training. Two of these traditional learning strategies will be briefly discussed, and then followed by a discussion of current approaches in Army training doctrine.

The theory of adult learning or andragogy (andr– meaning „man“ and agogos–meaning „leading“) is a teaching methodology developed by Knowles (1984) for adult learners. This methodology is based on the assumption that adult learners are highly-motivated and self-directed. The basics of this strategy include the premises of: (1) Self-concept–adults have the need to be involved in the preparation and assessment of their instruction; (2) Experience–a collection of experience including mistakes, provides a foundation for learning activities; (3) Readiness to learn–learning things that have immediate relevance to a job or personal life are of interest to most adults; and (4) Orientation to learning–as people get older their perspectives change and the focus of learning is problem-centered rather than content-oriented.

Criterion Referenced Instructional (CRI) learning assumes that effective learning is facilitated by a clear statement of the objectives and the direct assessment of the performance based on meeting the objectives (Mager, 1975). According to Mager the conditions under which subjects learn should be built into the objective and the criteria for their performance level must be described for the acceptance level. Performance can be measured as a function of speed, accuracy, or quality, and be used when instructor and students are both available (no self-directed studying). Mager provided guidelines for those objectives in terms of (1) Behavior—describing what students need to learn and how a tester will evaluate the progress; (2) Condition—identifying the behavior act that indicates achievement and the criterion of acceptable performance; and (3) Standard—describing separate objective for each learning performance that together constitute acceptable performance.

Current Army doctrine (refer to FM 7-0, 2008 and FM 7-1, 2003) dictates that training be . . . “realistic, safe, standards-based, well-structured, efficient, effective and challenging.” Effective training plans then must utilize combinations of live, virtual, and constructive training scenarios that operate within the parameters of these broad auspices. In the case of the present work, we argue that realistic virtual audio reproduction of important battlefield sounds is a potentially effective way to improve Soldiers’ situational awareness abilities and can become an integral part of training plans. All Army training generally follows the crawl-walk-run approach. The crawl stage focuses on the basic requirements of the task and is paced by the individual needs of the Soldier. At this stage the goal is typically to ensure the individual Soldier develops the skills to perform the basic task. At the walk stage, the task becomes progressively more difficult and more realistic, while ensuring that the task is performed to prescribed standards. In addition there is a push to transfer the knowledge to related skills and to work together in small units. Finally, at the run stage the difficulty increases to match as closely as possible actual combat conditions. Here the focus is to “train as you fight” and the imperative is to build effective team relationships.

The general structure of present Army Training doctrine is closely related to aspects of the previously described instructional learning philosophies. For example, an important part of Army training is the After Action Review (AAR) where trainers lead a discussion with trainees about positive and negative aspects of training outcomes. This collective discussion is then focused on how the lessons learned can be implemented to refine and improve training. This integral part of training is consistent with Knowles’ (1984) notion of the importance of experience, with the knowledge from guided group discussion providing the foundation for future improved training experiences. Further, the general orientation of Mager’s (1975) CRI approach is based on how standards of learning are defined and how those standards are evaluated. The Army similarly focuses on developing clearly defined standards, and ensuring that all training is oriented at meeting the defined standard.

Finally, Army training has begun to embrace the tenets of Outcome Based Education, and has launched a new education program called Outcomes-Based Training & Education (OBT&E)

Previous Army training was largely organized by ensuring Soldiers met the minimum standards for prescribed tasks performed under relatively inflexible task conditions, and thus the focus was on mass output, and not necessarily Soldier quality (Vandergriff, 2010). The current OBT&E method uses an approach in which task, condition, standard (TCS) training provides the foundation for developing a broader understanding of Soldier tasks that allows them to exercise problem-solving skills to apply that understanding in dynamically changing operational situations.

The OBT&E approach has been applied to teaching methods: Combat Applications Training Course (CATC) and Adaptive Leaders Methodology (ALM). CATC is used in initial entry training and its goal is to provide a foundation on which to develop mastery of subject matter by teaching that skill using relevant problem-solving exercises (Vandergriff, 2010). An example of such training given by Vandergriff is the task known as SPORTS (slap, pull, observe, tap, shoot) for performing a weapon function check. Whereas traditionally the task is taught using TCS, the OBT&E approach frames the task in a combat scenario. For example, performing the task while reacting to fire and communicating a status report. ALM is the second application of the OBT&E approach and uses situational exercises in a tactical environment to help develop leadership skills such as professionalism, strength of character, and decision making (Vandergriff, 2010).

Auditory Training

Auditory perception is a result of synergy between physiological and cognitive capabilities of a listener. Physiological capabilities are inherited and in the course of life can be affected by the aging process, illness, medication, surgery, exposure to toxic agents, as well as noise exposure (e.g., Yost, 2007). However, the fact that we hear something depends not only on our physiological capabilities but also on our familiarity with the sound, our attention, expectations, recall, and motivation. All these elements represent our cognitive capabilities that we may engage in the process of active hearing. An act of listening is a conscientious effort to hear something and then compare what we hear with what is in memory. Cognitive listening skills are learned skills, which develop through experience and focus and these skills can be improved by auditory training.

The term *auditory training* is a general term used to describe a teaching process intended to improve cognition-related human auditory capabilities. Depending on the specific goals of the auditory training it may include all aspects of the sound or it may be dedicated to one specific area of auditory perception. Some terms associated with auditory training related to specific areas of sound perception include ear-training (pitch perception training), aural rehabilitation (speech perception training), technical listening training (audio recordings imperfections detection training), timbre training (e.g., *Timbre Solfege* [Letowski, 1985]), product sound quality training (training in assessment whether a specific sound is appropriate for the specific

sound source), etc. However, the above names are used quite liberally and do not always refer to the same specific type of training.

One form of the auditory training focusing on a specific area of auditory perception is sound identification training intended to improve auditory situation awareness of the listener. This training is also referred to as *sound source signature identification* (S³I) training or *auditory identification* training. One example of such training is sonar operator training, where sonar operators learn how to identify reflections of sonar sound from various underwater objects. Auditory weapon identification training, which is the focus of this paper, is another type of sound identification training intended to help Soldiers to identify the specific weapons that were fired by listening to sounds that they produced. The main difference between sonar operator training and weapon identification training is that the former deals with one target sound and its various forms of distortions and the latter deals with many sounds that are actually the by-products of source operation. Similar types of identification training may be focused on aircraft and vehicle sounds, sounds of nature (birds, animals, etc.), acoustic environment (size of space), or material sounds (steel, wood, glass, etc., being struck).

There are several auditory training philosophies and strategies but the practical differences among them are frequently small and superficial. Most of them have their roots in a general notion that people need a period of concentrated instruction and practice in order to improve their auditory performance (Urbantschitsch, 1895). Many of them also use similar techniques and tricks to help the listener to increase effectiveness of listening. Therefore, any extended classifications of auditory training methods may have limited practical value; although, these classifications may have theoretical merit. However, one useful way to classify training techniques is to focus on the way the sound material is used in the training. According to this focus each training technique can be classified as one of the following:

- open-set stimuli technique, which is focused on listening to a large variety of sounds and relying on extensive instructional guidance;
- closed-set stimuli technique, which is focused on discrimination within the small number of preselected sounds; or
- single stimuli technique, which is focused on consecutive mastering of auditory perception of single sounds in various environmental conditions.

In many practical situations all three techniques are used in different phases of auditory training although there are some training programs that rely on a single technique. The use of each of these techniques is associated with one or more of the four basic types of psychological tasks that can be used in the training (Erber and Hirsh, 1978; Erber, 1982):

- detection,
- discrimination,

- recognition, and
- identification (called comprehension in the case of speech perception).

The open-set stimuli technique mainly utilizes recognition and identification tasks, the closed-set stimuli technique is based on detection and discrimination of sounds, and the single stimuli technique involves detection, recognition, and identification. It is natural that all forms of sound identification training rely ultimately on the sound identification task but depending on the specific approach all other tasks may or may not be used in the training program.

There are two basic modes in which we listen to our acoustic environment referred to in the literature as synthetic listening (holistic listening) and analytic listening (von Helmholtz, 1863; Schneider and Wengenroth, 2009). When we listen synthetically we perceive sound as a whole without paying attention to its components and properties. When we listen analytically we focus our attention on individual elements of the sound, that is, on the organization or construction of the sound with less attention to the overall meaning of the sound. In other words, when we hear a train, thunder, car horn, or specific piece of music we listen synthetically. When we focus on rhythm, loudness, harmonic structure, or distribution of the sound sources, we listen analytically.

The ability of analytical listening is of fundamental importance when we want to identify an unknown sound or to determine how and where it was produced. Two main elements of analytical listening are timbre perception (perception of spectral characteristics of sound) and temporal (intensity pattern) perception. In some cases also a third element, space perception (perception of the size of the acoustic environment and the spatial distribution of the sound sources), plays an important role.

When we initially hear the sound we usually listen synthetically and compare what we hear with the content of our auditory memory in a process of identification. If we cannot recognize the sound or would like to describe it in greater detail we switch to analytical listening and focus on its dominant components and features. Once we complete the analysis we synthesize our findings to form another, but more specific, overall sound image. Thus, in the process of sound identification, listeners can switch several times back and forth between holistic and analytical listening creating more and more specific image of the perceived sound source and its operational conditions.

Finally, any type of sound identification training is focused on two main elements: sound familiarization and listening strategies. Sound familiarization leads to building memory traces that result in the development of a number of memory standards that can be recalled when new sounds are present. Listening strategies are technique to focus attention to continually refine the process of detecting, comparing, and remembering. Furthermore, to enhance the effectiveness of the training, it frequently adopts a *fading* or an *easy-to-hard* (Tremblay and Kraus, 2002) protocol, that is similar in principal to the Army's crawl-walk-run approach to training. This approach has been successfully used in many auditory studies involving, for example, speech

discrimination, non-native phoneme discrimination (McCandliss et al., 2002), and cognitive skills training (Anderson et al., 1995). The easy-to-hard approach is a progressive single stimuli training approach, in which the listener learns to solve progressively more difficult tasks on the same kind of training material. Unlike the *fixed* protocol approach, based primarily on an open-set stimuli technique, in which the listeners are trained on the final difficult tasks, the *easy-to-hard* approach has been shown to take fewer than the fixed number of training sessions to achieve the same level of learning in auditory identification (Liu et al., 2008). There are also more extended forms of training, such as *familiarization, acquisition, monitoring, and estimation* (FAME) *training* (Letowski and Amrein, 2005) but they rely on the similar training techniques and protocols. The differences may involve selection, arrangement, and timing of sound presentations; type and frequency of feedback; role of verbal instruction; use of dynamic or stationary backgrounds; use of multitasking; and criteria of success.

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Appendix B. Weapon Index

Small Arms Weapons Specifications

AK-47 – Is an assault rifle that originated in the Soviet Union in 1949. It weighs 9.5 lb with empty magazine, the length is 34.3 inches or 870 mm, the barrel length is 415 mm or 16.3 inches.

Cartridge: 7.62×39 mm
Action: Gas-operated, rotating bolt
Rate of fire: 600 rounds/min
Muzzle velocity: 715 meters/seconds (2,346 ft/s)
Effective range: 300–400 m



M-16 A2 – Is an assault rifle of caliber 5.56 mm and originated in the United States. The M-16 rifle has been the primary rifle of the United States military since the 1960s. With its variants, it has been in use by 15 NATO countries, and is the most produced firearm in its caliber. It weighs 8.5 lb (3.9 kg), and the length is 39.5 inches (1000 mm) with the barrel length of 20 inches (508 mm).

Cartridge: 5.56×45 mm NATO
Action: Gas-operated, rotating bolt
Rate of fire: 800–900 rounds/min, cyclic depending on model
Muzzle velocity: 930 meters/second (3200 ft/s)
Effective range: 550 m



M14 rifle – M14 is formally the United States’ Battle rifle. It weighs 11.5 lb (5.2 kg), and the length is 46.5 inches (1181 mm).

Cartridge: 7.62×51 mm NATO
Action: Gas-operated, rotating bolt
Rate of fire: 700–750 round/min
Muzzle velocity: 854 meters/second (2,800 ft/s)
Effective range: 460 m



Steyr AUG – Is an Austrian 5.56-mm assault rifle, designed in the early 1970s by Steyr Mannlicher. It weighs 7.9 lb (3.6 kg), and the length is 31.1 inches (790 mm).

Cartridge: 5.56×45 mm NATO
Action: Gas-operated, rotating bolt
Rate of fire: 680–850 round/min
Muzzle velocity: 940 meters/second (3,084 ft/s)
Effective range: Sighted for 300 m



M240 – Is a general purpose machine gun that originated in Belgium and United States. It weighs 27.6 lb and the length is 49 inches (1245 mm). The barrel length is 627 mm or 24.7 inches.

Cartridge: 7.62×51 mm NATO
Action: Gas-operated, open bolt
Rate of fire: 650–950 rounds/min
Muzzle velocity: 905 meters/seconds (2,970 ft/s)
Effective range: Bipod: 600 m, point 800 m



M4 Carbine – M4 has selective fire options that include semi-automatic and three-round burst. The M4 is a NATO ammunition, gas operated, air-cooled, and magazine-fed, selective firearm with a 4-position telescoping stock. The M4 weighs 5.9 lb (2.7 kg) and is 33 inches (838 mm) long.

Cartridge: 5.5×45 mm NATO
Action: Gas-operated, rotating bolt
Rate of fire: 700–940 round/min cyclic
Muzzle velocity: 884 meters/second (2,900 ft/s)
Effective range: 500 m



M9 Pistol – The M9 handgun is formally Pistol, semi-automatic, 9 mm, is a 9×19 mm parabellum pistol of the U.S. military adopted in the 1980s. A short recoil, semi-automatic, single-action/double-action pistol uses a 15-round staggered magazine with a reversible magazine release button that can positioned for either right- or left-handed shooters. It originated in Italy.

Type: Semi-automatic pistol
Cartridge: 9×19 mm parabellum
Action: Short recoil
Feed system: 15-round detachable box magazine
Weight: 2.1 lb (0.97 kg)
Length: 8.54 inches (217 mm)



CZ 75 – The CZ 75 is a semi-automatic pistol made in the Czech Republic, introduced in 1975. It is a short recoil operated, locked breech pistol, and has a capability of being fired single and double action and features a frame mounted manual safety.

Type: Semi-automatic pistol
Cartridge: 9×19 mm parabellum
Action: Short recoil, tilting barrel
Feed system: Detachable box magazine
Weight: 2.47 lb (1.12 kg)
Length: 4.7 inches (120mm)



H&K P-7 – The P-7 is a German 9-mm semi-automatic pistol that came to the public in 1976. In 1979 the pistol was used by the German Federal Police and the German Army's Special Forces.

Type: Semi-automatic pistol
Cartridge: 9×19 mm parabellum
Action: Gas-delayed blowback
Feed system: 8-round box magazine
Weight: 1.75 lb (0.97 kg)
Length: (171 mm)



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List of Symbols, Abbreviations, and Acronyms

ALM	Adaptive Leaders Methodology
ANOVA	analysis of variance
APG	Aberdeen Proving Ground
ARL	U.S. Army Research Laboratory
CATC	Combat Applications Training Course
CRI	Criterion Referenced Instructional
FAME	familiarization, acquisition, monitoring, and estimation
HL	hearing level
IED	improvised explosive device
LRB(s)	Listener Response Box(es)
OBT&E	Outcomes-Based Training & Education
S ³ I	sound source signature identification
SASIT	Small Arms Signature Identification Training
SPORTS	slap, pull, observe, tap, shoot
TCS	task, condition, standard

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