ARMY RESEARCH LABORATORY

Sensory Perception in the Human Research and Engineering Directorate: Thrust Areas and Recent Research 2011–2014

by Bruce E Amrein, Mary Binseel, V Grayson CuQlock-Knopp, Kelly Dickerson, Mark Ericson, Paul Fedele, Kim F Fluitt, Ashley Foots, Lamar Garrett, Jeremy Gaston, Paula P Henry, Joel T Kalb, Kathy L Kehring, Andrea Krausman, Tomasz R Letowski, Maranda McBride, Timothy Mermagen, Kimberly Myles, Kimberly Pollard, Miller Roberts, Angelique Scharine, Christopher Stachowiak, Phuong Tran, Barry Vaughan, Samantha Wallace, Rachel Weatherless, and Timothy L White

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14. ABSTRACT
The US Army Research Laboratory's (ARL's) Human Research and Engineering Directorate conducts a broad-based program of scientific research and technology development directed into 2 focus areas: 1) enhancing the effectiveness of Soldier performance and Soldier-machine interactions in mission contexts and 2) providing the US Army and ARL with human factors integration leadership to ensure that Soldier performance requirements are adequately considered in technology development and system design. This report provides an overview of ARL/HRED's sensory perception research during 2011–2014. The goal of this research is to understand the perceptual requirements of interpreting unaided and aided visual, auditory, and tactile signals in complex, dynamic, militarily relevant environments. Research is conducted in 3 areas: 1) fundamental sensory capabilities of the Soldier; 2) methods, devices, and technologies for aiding perception; and 3) advanced approaches for augmenting perception. Models of human visual, auditory, and tactile perceptual capabilities that drive detection, recognition, and spatial orientation are being developed. Ultimately, this research will provide a foundation for principled guidance to the materiel development community.

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sensory perception, night vision, audition, tactile, bone conduction, target acquisition

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Contents

Preface

This report is an update to the sensory performance portions of the following special report:

Amrein BE, Cassenti DN, Cosenzo KA, Krausman AS, LaFiandra ME, Lance BJ, Lockett JF, McDowell KG, Oie KS, Rice-Berg VJ, Samms CL, Vettel JM. Human research and engineering directorate, major laboratory programs: current thrust areas and recent research. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2010. Report No.: ARL-SR-213. Also available at: http://www.arl.army.mil/arlreports/2010/ARL-SR-213.pdf.

The research listed here includes only recent and current research not previously included in ARL-SR-213.

1. Introduction

The goal of this research area is to understand the perceptual requirements of interpreting unaided and aided visual, auditory, and tactile signals in complex, dynamic, militarily relevant environments. Research is conducted on unimodal and multimodal sensory performance in 3 areas: 1) fundamental sensory capabilities of the Soldier; 2) methods, devices, and technologies for aiding perception; and 3) advanced approaches for augmenting perception. Using the same principles that enable optimal perception for our Soldiers, research will reverse the perspective to develop approaches to deny perceptual information to the observer or adversary. Models of human visual, auditory, and tactile perceptual capabilities that drive detection, recognition, and spatial orientation are being developed. As the work progresses from highly controlled laboratory conditions to a rich field environment, high-fidelity measures of performance will necessarily be developed. Ultimately, this research will provide a foundation for principled guidance to the materiel development community.

2. Background

Warfighter performance is impacted by sensory-related factors such as the presence of loud or constant noise, sudden transients in luminance, glare sources, and operation in periods of zero or reduced illumination (which can include operating at night, in foul weather, in caves, and in darkened interior spaces). The sensory perception research conducted by the US Army Research Laboratory's Human Research and Engineering Directorate (ARL/HRED) is a Soldier-oriented research and development (R&D) program designed to advance and improve human factors design principles and guidance for enhancing Soldier and small team sensory, perceptual (auditory, tactile, and visual) performance, while providing the materiel development community with the information necessary for effectively designing systems that are best suited to the operator, maintainer, and trainer. Recommendations attempt to quantify tradeoffs between the benefits of providing new technology and the cost to the dismounted Soldier of having and using that technology. The overarching goal of this research is to provide the Soldier with optimal situation awareness (SA) while minimizing perceptual signatures through technologies, skill development, and immersive training, resulting in greater mission effectiveness and safety by characterizing equipment and environmental effects on Soldier performance to provide the Army with guidelines and predictive models to influence acquisitions that meet Soldier needs.

Sensory perception research addresses a Soldier's ability to detect, identify, and localize perceptual information about the situation using natural senses and technological enhancements (this area represents efforts that fell under Soldier performance in Amrein et al. [2010]). The SA required to move, shoot, and communicate requires a balance of protection and access to sensory information. ARL/HRED's sensory perception research program, developed in response to input from the Technical Assessment Board's Soldier Systems Panel, encompasses 3 types of research:

- Psychometric research that quantifies the basic sensory-perceptual capabilities of the Soldier and identifies environmental and cognitive factors that affect these abilities.
- Human factors research intended to identify the effects of sensory aids on performance, thus guiding development and acquisition.
- Identifying and developing methodologies for augmenting or altering sensory information, so Soldiers can more effectively process the information.

Current research includes topics targeting basic sensory perception and the effects of sensory aids on perception. The research topics include vision and auditory research, as humans primarily gather information from, and interact with their natural environment via these channels. However, in complex systems, these sensory channels are frequently overloaded. For this reason, tactile research is included as an alternative sensory solution for unburdening the visual and auditory channels. Together, these sensory research areas address:

- How Soldiers communicate with one another.
- How they recognize and identify important events in their environment.
- How they localize those events.

These questions are largely addressed in the context of how environmental conditions, personal protective equipment (PPE), communications systems, and augmenting technology affect performance.

Vision research studies the effects of night vision devices on depth perception and target recognition and is incorporated into models of target detection used to train Soldiers. The perception and night vision sensor design research focuses on assessing electro-optical devices and algorithms that compress the dynamic range of scenes in order for Soldiers to extract maximal information from the scene. Additional vision research attempts to quantify visual flash from weapon-mounted flash suppressors to effectively reduce an enemy's ability to detect, identify, and localize a shooter's location.

Auditory research includes the study of recognition, identification, and spatial perception of military-relevant sounds and speech as a function of noise and PPE use. Research characterizing the features responsible for the identification and localization of weapons-fire sounds and vehicle noise provides insight into the sources of error. These data have strategic value, allowing one to determine the extent of one's perceptual footprint and to manage it. The environment of the Soldier requires PPE headgear including hearing protection and helmets. Research questions are based on how best to implement various forms of communications devices, such as bone conduction (BC) headsets, earmuffs, and earplugs, and the role of nonlinear hearing restoration in various forms of hearing protection. Communications headsets, also known as tactical communications and protection systems (TCAPS) provide hearing protection as well as communications.

The Army's move toward providing TCAPS for a greater proportion of ground Soldiers potentially increases compliance with safety mandates but leads to new research questions related to how best to evaluate and select such systems. ARL/HRED researchers serve as subject matter experts (SMEs) when specifying performance requirements for such systems to ensure adequate auditory spatial perception and communication ability. To answer the question of what constitutes "adequate" perception, research must go beyond optimal auditory SA to incorporate the real challenges experienced by the Soldier who requires ballistic protection while performing a cognitively and physically demanding mission. To achieve this aim, our research is expanding to include auditory perception is an immersive multimodal environment with the goal of answering the question of what capabilities are required to be "fit for duty" and complete one's mission.

Vibro-tactile research efforts include integrating the head-mounted tactile display with a BC communication system. Such a dual-use communication system will be possible via the development of one transducer that is capable of conveying both tactile and BC signals. The tactile research area is promising for extending the use of an information channel that is underutilized. ARL/HRED's goal is to integrate the tactile sensory channel as a conduit for battlefield communication (without diminishing Soldier SA)—an additional, independent input mode to convey information or as a redundant mode to increase the salience of visual and auditory cues. Enhanced display design is a result of current research to determine optimal operational parameters such as tactor placement for the torso and head, and vibration signal frequency and intensity, and has afforded laboratory and field research that quantify the benefits and costs of tactile technology to Soldier performance. Torso-mounted efforts have included quantifying the effect of Soldier movements on the identification and localization of tactile signals and patterns. In addition, ARL/HRED has invested in developing a head-mounted tactile display and determining its efficacy for Soldier use. The use of vibration on the head is a relatively new concept, and recent efforts have quantified the benefit for Soldier performance in replacing a visual aided navigation task with a tactile aided navigation task during periods of high visual workload.

The following sections describe each research thrust and current relevant areas of study. Appendix A provides abstracts of sensory perception research protocols and published works (2011–2014). Appendix B provides additional insight into the depth and breadth of our research portfolio by citing all publications authored by the ARL sensory perception research group. Appendix C provides abstracts of selected topics from the sensory perception research portfolio. Appendix D provides an overview of the entire sensory perception research portfolio.

3. Sensory Performance Topic Characteristics

Funding:	45%, 50%, 0%, 5% (6.1, 6.2, 6.3, customer)
Research Efforts:	85%, 15%, 0% (internal, collaborative, external)
Primary Collaborations:	Adaptive Technologies, Inc. Army Research Institute (ARI) US Army Communications-Electronics Research, Development and Engineering Center (CERDEC) Night Vision and Electronic Sensors Directorate (NVESD) Embry-Riddle Aeronautical University Missouri University of Science and Technology New York University North Carolina Agriculture and Technology State University The Johns Hopkins University (Computational Sensory-Motor Systems Lab) The Merritt Group Towson University US Army Aeromedical Research Laboratory (USAARL)
Significant Designators:	Technical Program Agreements (TPA): NA-HR-2012-01: Head-Mounted Tactile Displays & Soldier Performance CE-HR-2012-01: Human Factors Issues for Night Vision Devices TA-HR-2013-01: Sound-source perception in real and simulated environments NA-HR-2013-01: Modeling the effects of Soldier PPE on auditory performance CE-HR-2014-02: Human Factors Issues for Night Vision Devices AR-HR-2014-01: Perceptibility of Suppressed Small-arms Auditory and Visual Stimuli

3.1 Thrust Area 1: Sensory Performance, Vision

3.1.1 Research Area 1.1: Visual Target Acquisition

- Research: 6.2 = 100%
- Funding: internal = 100%
- Research projects: 1; work concluded in fiscal year 2013 (FY13)
- ARL lead: Barry D. Vaughan, Ph.D.
- Collaborations:

- US Army Natick Soldier Research Development and Engineering Center (NSRDEC): Guidance on Infantry Warrior Simulation (IWARS) behavioral model and shortcomings of current implementation
- US Army Materiel Systems Analysis Activity (AMSAA): Support for defining experimental conditions that best match how IWARS uses the AQUIRE/TTP-M model

- Keywords: vision, peripheral, motion, detection

Aim: NSRDEC and AMSAA have collaborated to develop the IWARS, a high-resolution combat simulation to assess the operational effectiveness of Warfighter equipment, particularly in individual and small-unit dismounted situations. Currently, IWARS models eye movements with a fixed path, independent of visual events or viewer intent. Our hypothesis is that by improving the ecological validity of the IWARS, its performance (predictive accuracy as well as running time) will be improved. To this end we have empirically characterized the probability of visual detection of low-contrast moving stimuli presented in the far visual periphery. Such a characterization will allow IWARS developers to predict situations when shifts of covert attention (i.e., eye movements) to peripheral events may occur in a more realistic manner and thus more accurately model Soldier tasks that require central vision, such as friend-or-foe determination and target identification.

Methods: Developed custom software and used an existing immersive virtual environment (a Cave Automatic Virtual Environment in the HRED Tactical Environment Simulation Facility) to generate stimuli presented in the far periphery of participants' field of view. Detection accuracy across various eccentricities and simulated target ranges was used to determine thresholds for speed of target motion required to reliably summon attention across a variety of conditions. Leveraged adaptive psychophysical methods (QUEST) and pilot testing to define stimuli and procedures to allow for the calculation for 15 thresholds per participant in a single experimental session. Results will be provided to NSRDEC in the form of an ARL technical report. NSRDEC and AMSAA are responsible for evaluation of new versus old IWARS models.

Progress: In FY10, the ARL Institutional Review Board protocol for data collection was approved, and software development was initiated. In FY11 and FY12, software was developed, luminance measures were taken, and pilot testing, experimental data collection, and analysis were completed. In FY12 and FY13, a draft technical report was created.

Current Goals: The goal is to provide information to NSRDEC in the form of an information paper or technical memorandum report, then prepare and submit a manuscript to a refereed journal and publish an ARL technical report.

3.1.1.1 Recent Publications:

Vaughan BD, Fedele PH, Kalb JT, Kehring K. Measured visual motion sensitivity at a fixed contrast in the periphery and far periphery. Aberdeen Proving Ground (MD): Army Research Laboratory (US); forthcoming technical report, 2014.

3.1.2 Research Area 1.2: Aided and Unaided Visual Detection of Threats and Terrain Obstacles

- Research: 6.2 = 100%
- Funding: Internal = 50%, CERDEC-NVESD = 25%, US Special Operations Command (SOCOM) = 25%
- Research projects: 2
- Technical Program Agreements (TPAs):
  - CE-HR-2012-01: Human Factors Issues for Night Vision Devices
  - CE-HR-2014-02: Human Factors Issues for Night Vision Devices
- ARL lead: Grayson CuQlock-Knopp, PhD
- Collaborations:
  - ARL/HRED and CERDEC-NVESD are collaborating on human factors and visual-perception studies related to extending depth of field (DOF) in night-vision goggles (NVGs), the transition from green-phosphor to white-phosphor NVGs, and the incorporation of hue as a parameter in the ARL/HRED model of target saliency.
  - Based on feedback from counter-improvised-explosive-device (IED) training centers, ARL/HRED and ARL's Computational and Information Sciences Directorate are collaborating to update and expand the ARL counter-IED training that has been recently delivered to 50 sites in the United States and in 4 additional countries.
  - ARL/HRED, USSOCOM, and the US Border Patrol are conducting visual-perception and human-performance studies relevant to the transition from green-phosphor to white-phosphor NVGs.
  - ARL's Perceptual Sciences Branch is working with Morgan State University (MSU) to support the computer modeling needed to incorporate hue as a parameter in the ARL/HRED model of target saliency.
- Keywords: dual focus, stereopsis, depth of field, night vision

Aim: During night operations, Warfighters often experience excessive workload associated with continual refocusing of NVGs to set the shallow DOF to a range optimal for a given task. Shallow DOF creates at least 3 types of problems: 1) Soldiers miss or incorrectly assess targets that fall outside the DOF, 2) Soldiers are often forced to view blurry imagery when walking with their weapon at the ready because they have no hands free to readjust the focus of the NVGs, and 3) Soldiers may be forced to shoot prior to adequate identification of friend or foe because they cannot risk having the threats coming too close while they take time to refocus.

Methods: The aim of the R&D work is to mitigate shallow DOF by various NVG design features and by the use of Soldier techniques for focusing the NVGs. An ARL/HRED computational-vision model will be refined to assess the adequacy of these design features and techniques.

Progress: One design solution for shallow DOF is to make it easy for a Soldier to change focus. This solution uses detents (click stops) on the focus ring of the NVG: A Soldier can easily set NVG focus to any distance by turning the ring to 1 of 3 or more detents. A human perception study was completed and published to determine targets that will be visible or camouflaged in night-vision scenes captured at the proposed focus distances for the click stops. A computational vision model was developed by ARL/HRED, based on texture and edge density of scene objects relative to their local backgrounds, to determine when specific targets will be salient or camouflaged by the background at the various focus distances.

A second method to mitigate shallow DOF is what we denote as "dual focus." With this technique, Soldiers focus one objective lens of their binocular NVGs at one distance and the other objective lens at a slightly different distance. Interviews with US Army Rangers indicate that many Soldiers already use this technique, but many experience problems with the disparity between the left-eye and the right-eye images. A study is underway to optimize the dual-focus technique by examining the tradeoff between a possible loss of stereoscopic depth acuity versus the benefit of expanded DOF.

3.1.2.1 Recent Publications:

Wallace SD. Modeling the effects of focus on target saliency: a texture and edge-based method. Aberdeen Proving Ground (MD): Army Research Laboratory (US); in press, 2014.

CuQlock-Knopp VG, Stachowiak C, Wallace S, Merritt J, Starvis K, Faughn J, Fedele P. Visual task performance with binocular night-vision goggles versus monocular night-vision goggles. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6566.

Stachowiak C, Wallace S, Kregel M, Merritt J, Starvis K, CuQlock-Knopp VG. 3D Video IED training lane manual. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014 Jul. Report No.: ARL-TR-6967.

Stachowiak C. Binocular night vision device (BNVD)/AN/PVS-31 human factors issues. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6982.

CuQlock-Knopp VG, Bender E, Wallace S, Merritt J. Techniques for improving the intrascene dynamic range of human vision when using night-vision goggles. Aberdeen Proving Ground (MD): Army Research Laboratory (US); in press, 2014.

Wallace SD, CuQlock-Knopp VG. The 3D HD IED video lane. Invited exposition at the Modern Day Marine Demo; 2013 Sep 24–26; Quantico (VA).

Wallace SD. Binocular fusion as a function of luminance disparity. Poster presented at the 4th International Applied Human Factors and Ergonomics Conference; 2012 Jul 22–25; San Francisco (CA).

Harrison A, Mullins L, Etienne-Cummings R. Sensor and display human factors based design constraints for head mounted and tele-operation systems. Sensors. 2011;11:1589–1606.

3.1.3 Research Area 1.3: Perception of Suppressed Small-Arms Auditory and Visual Stimuli

- Research: 6.2 = 100%
- Funding: internal = 100%; collaborative = 0%
- Research projects: 1
- Special designators: First year of 3-year basic research program supporting Army development efforts. Integrating auditory and visual perception research to support combined stimuli perception for Army equipment development.
- ARL lead: Paul D Fedele, PhD
- Collaborations:
    - TPA No. AR-HR-2014-01: Perceptibility of Suppressed Small-Arms Auditory and Visual Stimuli, with US Army Armament Research, Engineering and Development Center (ARDEC), Picatinny Arsenal, NJ, providing basic research information supporting the creation of a field-relevant performance standard for small-arms suppressors that specifies stealth effectiveness and hearing protection levels for suppressors that are intended for all Army small arms.
    - ARDEC: Assisting in suppressor prototypes and designs.
    - Aberdeen Test Center: Conducting suppressor stimuli quantification and measurement, and identifying measurement equipment and processes for inclusion in standard.
    - Small-Arms Branch, Soldier Requirements Division, Army Maneuver Center of Excellence, Fort Benning, GA: Identifying Soldier needs and desires, and providing materiel use doctrines and methods.

Aim: Firing small arms produces visual and auditory stimuli that can alert enemy combatants of the presence of Soldier operations. Muzzle flash can indicate a shooter's location, providing a point for enemy return fire. Muzzle blast also contributes to an enemy's ability to localize a shooter's position, and it can damage the hearing of the shooter and that of others near the shooter's position. Small-arms suppressors are used to reduce these detrimental influences of small-arms visual and auditory stimuli. The Army is considering applying suppressors to all its small arms. ARDEC is setting suppressor performance standards necessary to sufficiently reduce unwanted effects of small-arms stimuli. The aim of this research is to help provide ARDEC with quantified visual flash and auditory impulse levels that will effectively reduce an enemy's ability to detect, identify, and localize a shooter's location as well as protect the hearing of the shooter and personnel about the shooter's location.

Methods: HRED's Auditory Detection Model accurately determines the potential detection range for auditory impulsive stimuli, but the model fails to agree with experienced user's impressions of the effectiveness of suppressors in preventing enemy combatants from effectively returning fire to a shooter's location. Therefore, HRED research concerning auditory stimuli will measure stimuli identification and localization in complex sound environments, determining thresholds for impulsive sound identification using various impulsive sounds presented over headphones and in HRED's Environment for Auditory Research (EAR). Expected localization ranges also will be measured for sounds at various identification probabilities.

For visual stimuli, research will determine flash detection levels in various background light environments. Combined auditory and visual stimuli will be used to measureable identification thresholds to dual stimuli. Directional misperception will also be measured for temporally and spatially incongruous stimuli. This effort will apply modifications to HRED's EAR, allowing the additional presentation of temporally and angularly varied visual flash stimuli.

Progress: This is a new research effort. Discussions have been held with representatives of the ARDEC standard development process.

Related research areas:

- Auditory spatial perception
- Sound-source perception of complex natural scene

3.1.3.1 Recent Publications: None (new start for FY14)

3.2 Thrust Area 2: Sensory Performance, Audition and Tactile

Research is conducted in 3 interconnected areas: auditory spatial perception, auditory recognition and identification of complex sound sources, and tactical communications. The Soldier's auditory environment is complex, and auditory events are only some of the many events occurring within it. Yet a Soldier needs to maintain awareness of all relevant information within his environment because failure to do so can have lethal consequences. Sound can be perceived by the Soldier regardless of his orientation, and auditory cues can be the first signal of events that are outside of a Soldier's visual range. TCAPs offer a significant benefit to Soldiers by providing protection while allowing face-to-face and radio communications. However, there are still questions about how these systems should be evaluated and how to specify the requirements for such systems.

Soldier sound-source identification depends largely on the sounds present in the environment and the distinguishing features required to make mission-relevant decisions. Information about the perceptual characteristics that dominate this task for specific military environments has tactical and design applications. For example, understanding how small-arms weapons fire is recognized and localized within a context can be useful in the design and use of flash suppressors and silencers. Neither visual nor auditory signals can be entirely masked; however, using principles of perceptual capture and informational masking could allow Soldiers to increase the ambiguity of their perceptual “footprint,” allowing them to operate more safely.

Many powerful military vehicles are perceptible long before they arrive at their area of operation. Research characterizing how these sounds are perceived within the context of their environment and which features allow them to be identified can be used to develop engineering and tactical methods to reduce the range in which they are detectable.

Although ARL/HRED research has typically focused on ways to optimize perceptual SA, perceptual research can also be used to gain an understanding of how multimodal information in a complex environment is interpreted when the complexity of the perceptual scene and the demands of the mission preclude a full survey of the environment. Change blindness refers to the failure of the human visual system to detect, at times, large changes in the environment. This phenomena is not unique to vision and occurs in audition as well. ARL/HRED research into change deafness is focused on identifying characteristics in the environment that increase the probability that auditory changes are missed, such as the addition of a sound source or a change in location of that source. Research variables such as scene complexity, source location, source similarity, source encoding, and memory are all elements that play a role. Understanding how these factors affect the detection of information that is clearly “above threshold” has applications both in understanding and improving our own Soldier’s SA and reducing the SA of others.

ARL has developed a number of research facilities for use in the simulation of various types of acoustic environments. Most recently, this includes the development of the EAR, a large 4-chamber facility designed for creating spatial auditory environments. In support of the main thrusts of research described here, there are ongoing projects that aim to improve and validate our auditory displays methods.

3.2.1 Research Area 2.1: Auditory Spatial Perception

- Research: 6.1 = 75%; 6.2 = 25%
- Funding: internal = 98%; customer = 2%
- Research projects: 7

- Special designators: TPA No. NA-HR-2013-01: Modeling the effects of Soldier PPE on auditory performance
- ARL lead: Angélique A Scharine, PhD
- Collaborations:
  - NSRDEC: Measure auditory performance (detection and spatial perception) for persons wearing protective equipment such as helmets and hearing protection under development for the Army. Data from this collaboration are being used to develop models of spatial behavior as a function of changes to the head-related transfer function, as well as to pursue questions about the loss or transformation of spatial cues.
- Head Protection Technology and Capability Team (Head PROTECT): Follow-on to an Integrated Product Team (IPT) tasked with the creation of a modular helmet system with mandible and eye protection outfitted with tactical communications and hearing protection capabilities.
- Hearing Protection IPT: Project designed to develop requirements for Soldier hearing protection, identify potential hearing protection solutions, and identify unmet hearing protection needs and research.
  - Program Manager-Special Operations Forces Survival, Support and Equipment Systems: Conduct evaluations of tactical communications and protection systems being considered for use by US Army Special Forces. Performance data being used in models of spatial performance.
  - Combat Equipment and Support Systems, Marine Corps Systems Command: Customer-funded evaluation of nonlinear hearing protection devices resulting in additional questions about factors resulting in "sense of presence" and interplay of attenuation and spatial sensitivity.
  - Public Health Command and Program Manager-Soldier Protection: Ongoing evaluations and development of requirements for TCAPs. Evaluation process highlights basic research needed for TCAPs requirements.
  - US Department of Defense (DoD) Hearing Center of Excellence Auditory Research Working Group: Coalition of DoD auditory researchers that meets at least annually to foster collaboration and identify basic research needs. Using jointly identified hearing critical tasks working to develop immersive test scenarios containing decision points that require auditory and speech cues for the use in the evaluation of mission performance as a function of spatial perception.
- Keywords: sound localization, auditory distance estimation

Aim: Develop a predictive model of spatial auditory perception that accounts for operational factors such as headgear, hearing protection, and battlefield acoustics. Participation by the Auditory Research Team at ARL as SMEs on teams working to develop the next generation of protective headgear, has led to measurement of both the changes to the spectral profile and to auditory performance that results from their use.

Methods: Traditional psychophysical and perceptual measurement paradigms are being used to measure localization and distance estimation performance. The EAR facility, which was designed to simulate the Soldier's real-world acoustical conditions, such as reverberation, distance, and movement, is the primary research space for the studies. Localization performance (accuracy and response time) are measured as a function of various headgear (helmets, masks, hoods, hearing protection, etc.) and acoustic conditions (reverberation, indirect sound pathways, and source azimuth, elevation, distance, and movement). Objective measures of the spectral changes created by headgear are used in a binaural model of localization performance currently under development to predict their effects. Distance estimation performance is measured as a function of the compression and gain used to provide ambient hearing while using a communications headset. Ongoing research data are transitioned to the scientific literature, used to refine models of auditory performance and to provide tools and guidance for product development and acquisition.

Progress: Work is being conducted under a number of protocols and agreements. Recent publications include 4 technical reports, 4 conference proceedings, 6 journal publications, computer software, and a book chapter.

Current Goals: Research is being conducted to develop models, (e.g., IWARS model data) and populate the research literature with auditory performance data in complex acoustic environments.

3.2.1.1 Recent Publications:

Scharine AA, Binseel MS, Mermagen T, Letowski, TR. Sound localization ability of soldiers wearing infantry ACH and PASGT. Ergonomics. 2014;57(8);1–22.

Fluitt K, Mermagen T, Letowski T. Auditory distance estimation in an open space. In: Glotin, editor. Soundscape semiotics: localisation and categorisation. Rijeka (Croatia): InTech; 2014. Available at: http://www.intechopen.com/books/soundscapte-semiotics-localisation-and-categorisation/auditory-distance-estimation-in-an-open-space.

Scharine AA, Weatherless RA. US Marine Corps level dependent hearing protector assessment: objective measures of hearing protection devices. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6780. Also available at: http://www.arl.army.mil/arlreports/2014/ARL-TR-6780.pdf.

Scharine AA, Weatherless RA. Helmet electronics and display system-upgradeable protection (HEaDS-UP) phase III assessment: headgear effects on auditory perception. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6723. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6723.pdf.

Scharine AA, Weatherless RA. Evaluation of variants of 3M Peltor ComTAC tactical communication and protection system (TCAPS) headsets: measures of hearing protection and auditory performance. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6667. Also available at: http://www.arl.army.mil .arl.army.mil/arlreports/2013/ARL-TR-6667.pdf.

Scharine AA, Letowski TR. The measurement of the effects of helmet form on sound source detection and localization using a portable four-loudspeaker test array. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6444.

Henry PP. Evaluation of auditory characteristics of communications and hearing protection systems (C&HPS) part III – auditory localization. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6560. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6560.pdf.

Foots, AN. Effects of amplitude compression on relative auditory distance perception. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-RP-464. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-RP-464.pdf.

Melzer J, Scharine A, Amrein B. Soldier auditory situation awareness: the effects of hearing protection, communications headsets, and headgear. In: Savage-Knepshield P, Martin J, Lockett J, Allender L. editors. Designing soldier systems: issues in human factors. Surry (UK): Ashgate; 2012.

3.2.2 Research Area 2.2: Sound-Source Perception of Complex Natural Scenes

- Research: 6.1 = 100%
- Funding: internal = 100%
- Research projects: 4
- Special designators: TPA No. TA-HR-2013-01: Sound-source perception in real and simulated environments
- ARL lead: Jeremy R Gaston, PhD
- Collaboration:
    - US Army Tank Automotive Research Development and Engineering Center: Work with CASSI-Analytics on aspects of TPA No. TA-HR-2013-01.

- Binghamton University: Project investigating the effects of listening strategy on perceived similarity of environmental sound sources.
- Columbia University: Project investigating neural discrimination and classification of the sounds of small-arms fire.
- University of Osnabreuck (Germany): Project investigating cross-modal bias in simultaneous auditory and tactile localization.
- James Madison University: Project investigating methods for the modeling, synthesis, and perception of stimulus analogs to the sounds of small-arms fire.
- Towson University: Mentoring of several audiology doctorate student thesis projects including the effects of hearing protectors on the identification of the sounds of small-arms fire, localization of virtual sounds of small-arms fire, and localization of impulsive and steady-state noise in a reverberant urban-relevant environment.

- Keywords: sound-source perception, natural sound perception

Aim: Develop an understanding of how Soldiers recognize and interpret important operational and battlefield sounds that are embedded in complex natural auditory scenes. An underlying aspect of this work is to quantify fundamental Soldier ability to interpret environmental sounds. Moreover, based on this fundamental understanding, work in this area aims to identify those salient sound attributes that are perceptually diagnostic of sound-source identity and to leverage those differences to improve Soldier sound-source recognition and identification and thus auditory SA. Near-term goals of this work are to develop a research framework for understanding Soldier auditory sound-source perception abilities, and how ability is affected by environmental factors. Mid- and long-term goals include identification of related capability gaps and development of tools (i.e., training materials and predictive models) to aid the Soldier.

Methods: Psychophysical and perceptual measurement paradigms are used to study discrimination, recognition, and identification performance across simple and complex listening environments. The perceptual mapping between listener performance and sound-source properties provides the input to predictive models of listener sound-source perception. The EAR facility, which was designed to simulate the Soldier's real-world acoustical conditions such as reverberation, distance, and movement, is one of the primary research spaces for these studies.

Progress: Work being conducted looking at listener identification and localization of small-arms fire and vehicle sounds, as well as auditory change deafness for changes in complex, spatially distributed natural scenes. Recent publications include a peer-reviewed article in *Frontiers in Human Neuroscience* that evaluated the effectiveness of a neural discrimination algorithm to differentiate gunshot sounds for contrasted shooter/observer relationships and a peer-reviewed article in *Noise Control Engineering Journal* that examined listener perceived similarity and discrimination of the sounds of small-arms fire.

Current and Future Goals: Our past and current work has helped to develop a understanding of the mechanisms and listener strategies important in the sound-source perception of complex natural events. Our future goals are to further develop an understanding and model perceptual factors related to stimulus similarity, and uncertainty.

3.2.2.1 Recent Publications:

Ericson MA, Matthews J, Blackmore S. Modeling the perception of simulated moving vehicle sounds. Journal of the Audio Engineering Society. In preparation; 2014.

Ericson MA. Findings review on auditory perception. Briefing presented to customer; 2014 Jan 17.

Ericson MA. Auditory perception briefing to customer; 2013 Oct 3.

Sherwin J, Gaston J. Soldiers and marksmen under fire: neural correlates of small-arms fire localization. Frontiers in Human Neuroscience. 2013;7(67):1–14.

Gaston J, Letowski T. Listener perception of single-shot small-arms fire. Noise Control Engineering Journal. 2013;60(3):236–245.

Pastore R, Gaston J. A cognitive concept with relevance to speech perception? In: Zonneveld W, Quené H, Heeren W, editors. Sound and sounds: studies presented to MEH Schouten on the occasion of his 65th birthday. Utrecht (Netherlands): Utrecht Institute of Linguistics; 2012.

Boren B, Ericson MA. Motion simulation in the environment for auditory research. Proceedings on Meetings in Acoustics 2013;14. Available at: http://scitation.aip.org /content/asa/journal/poma/14/1/10.1121/1.4704670.

Gaston JR, Fluitt KF. Listener perception of single and multiple-shot small-arms fire. Paper presented at the 10th Annual Auditory, Perception, Cognition and Action Meeting; 2011; Seattle (WA).

3.2.3 Research Area 2.3: Unconventional Communications: Bone Conduction

- Research: 6.1 = 20%; 6.2 = 80%
- Funding: internal = 90%; collaborative = 10%
- Research projects: 2
- Special designators: none
- ARL leads: Phuong K Tran and Kimberly A Pollard, PhD
- Collaborations:

- Cooperative Research and Development Agreement (CRADA) No. 08-06: Advancement of Mobile Communication Solutions Incorporating BC Devices, Sensory Devices Inc. (SDI): Working with a bone vibrator/microphone manufacturer to develop BC devices with improved communication-oriented performance and design.
- US Military Academy: Assisting with student projects on speech intelligibility over BC.
- Defense Safety Oversight Council (DSOC): Received DSOC funding to conduct a study of BC communications devices for use with full-face respirators and encapsulation safety gear.
- Edgewood Chemical Biological Center Field Element: Working with field element to develop and test BC communication devices for use with full-face respirators and other chemical-biological personal protective equipment.
- Kipple Acquisition Science Technology Logistics Engineering (KASTLE): Harnessing contractor expertise in chemical-biological equipment and current communications devices to assist in our studies of speech intelligibility over BC in encapsulation gear.
- North Carolina A&T University (NCA&T): Working with visiting researcher to assess the ability of BC to present three-dimensional (3-D) audio to listeners.
- Towson University (TU): Serving on doctoral committee for 3 audiology students and assisting them with a study of BC equal loudness curves.

- Keywords: unconventional communications, bone conduction, tactile, speech communication, situation awareness.

Aim: Explore alternative communication means (BC) for the needs of modern combat. The primary objectives are to increase the effectiveness of communication, enhance SA, and reduce information overload on the visual and auditory channels by utilizing multimodal communications. BC transducers leave ear canals open for sound detection, localization, and face-to-face communication—all vital for military operations—and for using operationally specific hearing protection (which might be none at all). BC transducers can be hidden in a cap or under hair with no visible cues. They are relatively insensitive to external vibration or noise. Stealthy BC duplex communication is possible by using whispers or teeth clicks for transmitting coded messages.

Methods: Specific research areas include detection thresholds and loudness perception for bone vibration, speech intelligibility, transducer optimization and interfacing, 3-D audio over BC, and system performance evaluations under a variety of military operational conditions. Research is performed through in-house studies, collaborations, and a CRADA.

Progress: Completed a series of studies on optimal BC transducer placement for both incoming (BC vibrator) and outgoing (BC microphone) signals and the determination of BC signal detection and speech intelligibility limits in quiet and noise for effective speech communication (ARL, NCA&T). Completed study on free-field methods to calibrate BC devices (ARL). Completed study of how individual differences (demography and morphology) affect speech intelligibility over BC. Completed study of BC systems for use with full-face respirators (i.e., mission-oriented protective posture gear for chemical, biological, radiological, nuclear, high-yield explosive [CBRNE] Warfighters) (ARL, DSOC, KASTLE). Completed participant data collection for a study of equal loudness curves for BC (ARL, TU). Completed participant data collection for a study of 3-D audio perception over BC (ARL, NCA&T). Collaboration with SDI resulted in a novel design for BC microphones that provides a 25-dB improvement in sensitivity over the prior microphones. Two in-house experiments are ongoing: 1) protocol ARL-20098-11037; Effects of bone vibrator locations on auditory spatial perception and speech recognition, and 2) project ARL 13-066; Enabling speech intelligibility in a chemical, biological, radiological, nuclear operational environment. Off-site experiments on BC equal loudness curves are ongoing at TU. Data analyses and report preparation for projects are ongoing.

Current Goals: Explore the effects of using multiple BC microphones on speech communication and the effects of bone vibrator locations on auditory spatial perception. Examine the differential transmission of different speech sounds in BC-to-BC communication. Examine sound pathways, perceived loudness, and phase effects of BC at various skull locations. Explore new and modified BC systems for use with full-face respirators. Continue the CRADA with SDI to improve and ruggedize the BC transducers. Future plans involve determining the limitations of concurrent BC and tactile communication and developing comfortable, flexible, dual-use BC/head-mounted tactile communication systems.

3.2.3.1 Recent Publications:

Pollard KA, Garrett L, Tran P. Bone conduction systems for full-face respirators: speech intelligibility analysis. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6883. Also available at: http://www.arl.army.mil/arlreports/2014/ARL-TR-6883.pdf.

Pollard KA, Tran PK, Letowski T. Vocal and demographic traits influence speech intelligibility over BC. Journal of the Acoustical Society of America. In review; 2014.

Tran PK, Letowski TR, McBride ME. The effect of BC microphone placement on intensity and spectrum of transmitted speech items. Journal of the Acoustical Society of America. 2013;133:3900–3908.

Pollard KA, Tran PK, Letowski TR. A free-field method to calibrate BC transducers. Journal of the Acoustical Society of America 2013;133:858–865.

Tran PK, Binseel MS, Letowski TR. User evaluation of a BC communication headset during the Patriot 2007 Joint Field Training Exercise. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2012. Report No.: ARL-TR-5973. Also available at: http://www.arl.army.mil/arlreports/2012/ARL-TR-5973.pdf.

McBride M, Tran P, Letowski T, Patrick R. The effects of BC microphone locations on speech intelligibility and sound quality. Applied Ergonomics Journal. 2011;42:495–502.

Toll LE, Emanuel DC, Letowski T. Effect of static force on BC hearing thresholds and comfort. International Journal of Audiology. 2011;50:632–635.

3.2.4 Research Area 2.4: Unconventional Communications: Head-Mounted Tactile

- Research: 6.1 = 30%; 6.2 = 70%
- Funding: internal = 100%
- Research projects: 1
- Special designators: TPA No. NA-HR-2012-01, Head-Mounted Tactile Displays and Soldier Performance
- ARL lead: Kimberly Myles, Ph.D.
- Collaborations:
    - NSRDEC: Working with NSRDEC researchers via a TPA (NA-HR-2012-01) to develop head-mounted tactile displays that convey Soldier-relevant directional and nondirectional information and to assess the advantages for Soldier performance.
    - MSU: Working with faculty and students in the Department of Industrial Engineering. Students execute senior design research projects incorporating human factors principles to improve head-mounted tactile displays for the Soldier.
- Keywords: tactile sensitivity, vibrotactile threshold, head tactile display, multimodal communication, visual overload, situation awareness

Aim: Explore alternative communication means (tactile) for the needs of modern combat. The primary objectives are to increase the effectiveness of communication, enhance SA, and reduce information overload on the visual and auditory channels by using multimodal communications. Similar to BC transducers, tactile transducers leave ear canals open for sound detection and localization and face-to-face communication, and can be hidden in a cap or under hair with no visible cues.

Methods: Conduct laboratory and field studies to determine the efficacy of a head-mounted tactile display in enhancing Soldier performance.

Progress: Research progress includes proof-of-concept results that suggest the use of a head-mounted tactile display versus a map to navigate an unfamiliar urban environment with a complex layout, while concurrently detecting hostile threats, can unburden Soldiers by significantly reducing their overall workload by 37%. Further, in response to the widely held belief that all vibrotactile signals that are applied to the head are likely to be driven by the auditory cues from the tactile signals, we isolated the frequency vibration of tactile signals from their associated auditory cues and concluded that tactile perception is dominant for tactile signals below 64 Hz, and tactile-auditory perception is dominant for tactile signals greater than or equal to 64 Hz. Because the presence of auditory cues can be problematic in a laboratory setting, as ideal tactile signals should produce sensations of vibration without auditory cues, the latter finding establishes a laboratory-appropriate database of tactile signals (below 64 Hz) that may reduce the auditory cues that can accompany tactile signals applied to the head.

Current Goals: 1) Compare a head-mounted and torso-mounted tactile display to determine the capability of each to convey Soldier-relevant information in simulated military operational environments, to specifically identify Soldier-relevant tasks that may interfere with the interpretation of tactile information, such as the detection and localization of tactile signals, and the detection of tactile patterns; and (2) miniaturize and adapt our current head-mounted tactile display for use in squad communications. Future plans include the development of a database of tactile signals to convey nondirectional information to aid in exploring the effects of tactile communication on squad performance and a dual-use BC and head-mounted tactile communication system.

3.2.4.1 Recent Publications:

Myles K, Kalb JT. Head tactile communication: promising technology with the design of a head-mounted tactile display. Ergonomics in Design. 2013;21(4):4–8.

Myles K, Kalb JT, Fluitt KF, Kehring K. Comparison of a visual and head tactile display for soldier navigation. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.; ARL-TR-6742. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6742.pdf.

3.2.5 Research Area 2.5: Unconventional Communications: Torso-Mounted Tactile

- Research: 6.1 = 0%; 6.2 = 100%
- Funding: internal = 100%
- Special designators: none
- ARL leads: Timothy L White and Andrea S Krausman

- Collaboration:
    - NSRDEC: Research was in partial support of the 2009–2011 TPA, Exploring the use of tactile displays in military environments.
    - ARL/HRED Weapons Branch, Fort Benning (GA) field element: Working with field element to assess the effects of real-world Soldier tasks on the identification of tactile signals. Research participants (infantry Soldiers) and the Individual Movement Techniques Course are located at Fort Benning.
    - University of Central Florida: The Dismounted Warrior Branch has an employee in long-term training for a doctoral degree in Applied Experimental and Human Factors Psychology. This employee's doctoral dissertation is still in development but will be on identifying the effects of cross-modal sensory cueing on target detection.
- Keywords: tactile sensitivity, vibrotactile threshold, situation awareness

Aim: Tactile displays may be a viable alternative communication channel to help mitigate the overload and performance degradation that can result from this abundance of information being provided to Soldiers while not interfering with the more commonly used visual and auditory channels. For tactile displays to benefit the Soldier, they must be designed and implemented properly. Therefore, our aim is to determine how the tactile modality can be used most effectively as a communication medium and to identify the types of information that can be relayed while considering the operational environment of dismounted Soldiers. The overarching aim is to establish guidelines for design of tactile displays and develop a tactile language to enhance Soldier communication and performance on the battlefield.

Methods: Methods to accomplish these goals include laboratory and field studies.

Progress: Research progress includes 2 technical reports that document findings from studies examining the effects of stimulus intensity and inter-stimulus duration on perceived urgency and the ability to detect and identify tactile patterns while in a laboratory and performing dismounted Soldier maneuvers. A journal publication and 2 conference presentations provide findings from studies investigating the role of reliability on task performance in a multitask environment where auditory, tactile, and combined auditory-tactile cues were provided. This work was extended to examine the relationship between trust and task performance at varying reliability levels. Drafts of findings are in progress for submission to a journal.

Current Goals: Further explore the applications for using tactile communication in military environments. Results will be used to support the development of tactile displays and inform guidelines for tactile language development.

3.2.5.1 Recent Publications:

Mercado, JE, White TL, Sanders T, Wright J, Hancock PA. Performance effects of imperfect cross-modal sensory cueing in a target detection simulation. The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology. 2014;11(3):211–218.

White TL, Krausman AS. Effects of inter-stimulus interval and intensity on the perceived urgency of tactile patterns. Applied Ergonomics. submitted 2013.

Mercado JE, White TL, Sanders T, Hancock PA, Sanders, T, Wright, J. Improving performance in an imperfect target detection simulation through experience. Proceedings of the Conference on Defense and Military Modeling & Simulation. 2012;44(15):9–16. Best Paper Award.

Mercado JE, White TL, Sanders T, Wright J. Effects of cross-modal sensory cueing automation failure in a simulated target detection task. Proceedings of the 2012 Conference on Defense and Military Modeling & Simulation. 2012;44(15):57–63.

White TL, Krausman AS. The perceived urgency of tactile patterns while performing dismounted soldier maneuvers. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2012. Report No.: ARL-TR-6013.

White TL, Krausman AS, Haas EC. Tactile displays in army operational environments. In: Savage-Knepshield P, Lockett J, Martin J, editors. Designing soldier systems: issues in human factors. Hampshire (UK): Ashgate; 2012.

White TL. The perceived urgency of tactile patterns. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2011. Report No.: ARL-TR-5557. Also available at: http://www.arl.army.mil/arlreports/2011/ARL-TR-5557.pdf.

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Appendix A. Abstracts of Sensory Perception Research Protocols and Published Works (2011–2014)

Thrust Area 1: Sensory Performance – Vision

Research Area 1.1: Visual target acquisition

Protocols:

Vaughan BD, Kalb JT, Fedele PD. Characterizing detection of dismounted human targets in the far visual periphery (ARL-20098-10049)

The US Army acquisition community uses models of human and systems performance to evaluate materiel. One such model, used to assess equipment for the dismounted Soldier, is the Individual Warrior Simulation (IWARS). IWARS simulates human visual search by applying the ACQUIRE target acquisition model to some portion of the visual scene to determine the probability of detecting a target. If no target is detected, it applies ACQUIRE to an adjacent portion of the scene following a fixed path from one corner of the scene to the other until either a target is found or the scene has been searched completely. Though target detection in human vision depends on central vision, the locations of visual fixations are not fixed; rather, they depend greatly on the intent and experience of the observer and on the salience of visual elements and events in the scene itself. Because of how IWARS uses ACQUIRE, the model runs very slowly and produces results that are unrealistic. Our hypothesis is that by improving the ecological validity of how IWARS "searches" a scene, its performance (running time and predictive accuracy) will be improved. Therefore, experiments to empirically characterize the probability of visual detection of low-contrast, moving, or flickering stimuli presented in the far visual periphery will be performed. Stimuli characteristics are based on militarily relevant targets for a dismounted Soldier—individual dismounted enemy forces running for short distances at a range of approximately 50–100 m. We will present stimuli in the far visual periphery (up to 80°), an eccentricity that is important yet poorly studied, and determine the contrast required to reliably detect such targets. Data will be fed back to the IWARS developers at Natick Soldier Center and the Army Materiel and Systems Analysis Activity (AMSAA) for incorporation into subsequent IWARS models.

Publications:

Vaughan BD, Fedele PD, Kalb JT. Detection of simulated dismounted combatants in the far visual periphery. Aberdeen Proving Ground (MD): Army Research Laboratory (US). Technical report in preparation; 2014.

Movement in peripheral vision plays a major part in a predator's visual detection of prey[1,2] and in a Soldier's visual detection of enemy combatants (e.g., Yantis and Hilstrom[3]). Vision models used to simulate Soldier performance do not consider visual detection caused by enemy combatant movements. To support modeling visual movement detection, we have measured visual motion detection sensitivity in the visual periphery. We simulated moving enemy combatants using targets consisting of bivariate Gaussian contrast distributions similar in shape and size to upright human bodies at ranges of 50, 100, and 200 m, with a Michelson contrast of –0.2 relative to a uniform grey background. At 50 m, motion detection thresholds varied from 0.72°•s-1 at 40° eccentricity to greater than 18°•s-1 at 80° eccentricity; at 200 m, thresholds varied from 9.4°•s-1 at 40° eccentricity to, again, greater than 18°•s-1 at 80° eccentricity. When targets become invisible at increasing eccentricities, thresholds naturally become nonexistent: They increase without bound. Visible movement thresholds show individual variability standard error of approximately ±5.6°•s-1, about the average threshold. These measurements indicate the likelihood that a Soldier will see human movement at specific ranges at contrasts produced by specific lighting conditions. Further research is needed to measure visual movement detection thresholds under various contrast lighting conditions.

Research Area 1.2: Aided and unaided visual detection of threats and terrain obstacles

Protocols:

CuQlock-Knopp VG, Stachowiak C, Wallace S, Merritt J, Starvis K, Faughn J, Fedele P. Visual task performance with binocular night-vision goggles versus monocular night-vision goggles (ARL-13-062: 2013)

The objective of this research is to examine the relative performance advantages of viewing a night-time scene with binocular night-vision goggles (NVGs) versus monocular NVGs for various Soldier tasks. Twenty-five male explosive ordnance disposal (EOD) Soldiers will be recruited from the US Army's 75th Ranger Regiment to take part in this research. These Soldiers will perform visual-acuity and common-skill EOD tasks wearing a binocular night-vision device (BNVD) in its monocular or binocular configuration. They will also make subjective judgments of three-dimensional (3-D) night-vision imagery wearing 3-D glasses and respond to interview prompts about their experiences with monocular and binocular NVGs. The tasks will be performed in the Aberdeen Test Center (ATC) Tunnel Complex at Aberdeen Proving Ground (APG) and the US Army Research Laboratory (ARL) Light-Level Laboratory in Building 520 at APG. The equipment used for the experiments are BNVDs, the AN/PSS-14 Mine-Detector Set, and the standard hook-and-line kit. The main independent variables are the ocular configuration

[1] Fouts WR, Nelson DR. Prey capture by the Pacific angel shark, Squatina californica: visually mediated strikes and ambush-site characteristics. Copeia. 1999;2:304–312.

[2] Ioannou CC, Krause J. Interactions between background matching and motion during visual detection can explain why cryptic animals keep still. Biology Letters. 2009;5(2):191–193.

[3] Yantis S, Hillstrom AP. Visual motion and attentional capture. Perception & Psychophysics. 1994;55:399–411.

of the BNVD and ambient-light levels. The dependent variables are errors, time, visual-acuity scores, and subjective ratings. The study will occur on 2 consecutive days, requiring about 3.5 h the first day and 3.0 h the second day.

Wallace SD, CuQlock-Knopp VG, Henderson CP. Binocular fusion as a function of luminance difference between aided and unaided eyes (ARL-20098-10080)

The purpose of this experiment is to examine the effects of interocular luminance difference on human ability to obtain a binocular percept by fusing left- and right-eye retinal images. This study simulates the left- and right-eye luminance differences for a Warfighter who wears a monocular night vision device over 1 eye with the other eye unaided. Thirty male or female participants between the ages of 18 and 30 will be recruited through flyers. The study will take place in the APG Spatial Vision Perception Laboratory in Building 520. To complete the experimental task, participants will use a depth acuity device. The participant's task is to view the depth-acuity targets through 2 different neutral density (ND) filters placed over the left and right eyes. The participant uses 1 hand on a control wheel to adjust the apparent visual distance of the image on one liquid crystal display (LCD) monitor to match the apparent visual distance of the image on another LCD monitor. The experimenter converts these settings to depth acuity scores. The independent variables are luminance ratio between the left and the right eye, ocular configuration (monocular or binocular used in a baseline condition), and ocular-configuration order, for the order of exposure to the monocular and binocular conditions. The dependent variable will be the depth acuity score measured in arc seconds. The participant will need approximately 1.5 h to complete the experiment.

CuQlock-Knopp VG, Stachowiak C, Wallace S, Merritt J, Starvis K, Faughn J, Fedele P. Visual task performance with binocular night-vision goggles versus monocular night-vision goggles (ARL-13-062)

The abstract is not approved for public release.

Publications:

Wallace SD. Modeling the effects of focus on target saliency: a texture and edge-based method [dissertation]. [Baltimore (MD)]: Morgan State University; 2013.

In this research, we concentrate on the creation of a saliency model based on texture and edge density. This model evaluates the saliency of targets in a scene with respect to the focus range used to capture the image. The dataset included static images with different focal conditions. The 4 focus conditions used for the experiment were at 7 ft, 20 ft, 20 ft with a reduced aperture, and infinity focus. To validate the model, a human factors study was completed to evaluate target detection and reaction times with the 4 focal conditions. Both research efforts concluded that the focal condition with a reduced aperture presented the best depth of focus within the scene. The output of the model showed a higher target saliency with the reduced aperture condition than with the other 3 focal conditions. The human performance data validated that information with participants detecting and reacting faster to targets with the reduced focus condition.

CuQlock-Knopp VG, Stachowiak C, Wallace S, Merritt J, Starvis K, Faughn J, Fedele P. Visual task performance with binocular night-vision goggles versus monocular night-vision goggles. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6566.

The abstract is not approved for public release.

Stachowiak C, Wallace S, Kregel M, Merritt J, Starvis K, CuQlock-Knopp VG. 3D Video IED training lane manual. Aberdeen Proving Ground (MD): Army Research Laboratory (US); Report no: ARL-TR-6967.

The abstract is not approved for public release.

Stachowiak C. Binocular night vision device (BNVD)/AN/PVS-31 human factors issues Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6982.

The abstract is not approved for public release.

CuQlock-Knopp VG, Bender E, Wallace S, Merritt J. Techniques for improving the intra-scene dynamic range of human vision when using night-vision goggles. Aberdeen Proving Ground (MD): Army Research Laboratory (US). In press; 2014.

The abstract is not approved for public release.

Wallace SD, CuQlock-Knopp VG. The 3D HD IED video lane. Invited exposition at the Modern Day Marine Demo, Quantico (VA), 2013 Sep 24–26.

The abstract is not approved for public release.

Wallace SD, CuQlock-Knopp VG, Henderson CP. Binocular fusion as a function of luminance difference between aided and unaided eyes (ARL-20098-10080)

The purpose of this experiment is to examine the effects of interocular luminance difference on human ability to obtain a binocular percept by fusing left- and right-eye retinal images. This study simulates the left- and right-eye luminance differences for a Warfighter who wears a monocular night vision device over one eye with the other eye unaided. Thirty male or female participants ages 18–30 will be recruited through flyers. The study will take place in the APG Spatial Vision Perception Laboratory in Building 520. To complete the experimental task, participants will use a depth acuity device. The participant's task is to view the depth-acuity targets through 2 different ND filters placed over the left and right eyes. The participant uses 1 hand on a control wheel to adjust the apparent visual distance of the image on one LCD monitor to match the apparent visual distance of the image on another LCD monitor. The experimenter converts these settings to depth acuity scores. The independent variables are luminance ratio between the left and the right eye, ocular configuration (monocular or binocular used in a baseline condition), and ocular-configuration order for the order of exposure to the monocular and binocular conditions. The dependent variable will be the depth acuity score measured in arc seconds. The participant will need approximately 1.5 h to complete the experiment.

Wallace S. Binocular fusion as a function of luminance disparity. Poster presented at the 4th International Applied Human Factors and Ergonomics Conference, San Francisco (CA), 2012 Jul 22–25.

An extensive literature discusses why binocular vision is generally better than monocular vision; see Howard and Rogers[4] for a review. Despite the advantages of binocular vision, some Warfighters prefer monocular NVGs over binocular NVGs because monocular NVGs permit users to maintain dark adaptation in the unaided eye, and the unaided eye is not restricted to a 40% field of view. Now that adjustable-gain monocular NVGs are in use, it is possible to dim the display luminance of the NVG to more closely match the luminance level seen by the unaided eye and thus achieve binocular depth perception. This study quantified the effects of interocular luminance differences between the aided eye and the unaided eye on binocular depth acuity, a measure of binocular fusion, by simulating the left- and right-eye luminance differences that would be experienced by Warfighters who wear a monocular NVG over one eye, with the other eye unaided, under approximately quarter- and full-moon conditions. The participants' task was to view depth-acuity targets through various ND filters placed over their left and right eyes. The participants adjusted the apparent distance of one target to match the apparent distance of a second optically superimposed target. Twenty-seven males and females ages 18–30 participated in the experiment. The 15 participants who obtained a depth acuity score of 40 arcsec or better in the binocular baseline condition were used in the analysis. There was a statistically significant difference when the lowest ratio of luminance was compared with the higher ratios of luminance. As expected, participants performed statistically better when the luminance ratio between the 2 eyes was lowest; 46% of the subset participants achieved binocular fusion.

Harrison A, Mullins L, Etienne-Cummings R. Sensor and display human factors based design constraints for head mounted and teleoperation systems. Sensors. 2011;11:1589–1606.

For mobile imaging systems in head-mounted displays and teleoperation systems, it is important to maximize the amount of visual information transmitted to the human visual system without exceeding its input capacity. This paper aims to describe the design constraints on the imager and display systems of head-mounted devices and teleoperated systems based upon the capabilities of the human visual system. We also present the experimental results of methods to improve the amount of visual information conveyed to a user when trying to display a high dynamic range image on a low dynamic range display.

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[4] Howard IP, Rogers BJ. Seeing in depth. Vol. 1 Basic Mechanics and Vol. 2 Depth perception. Toronto: Thornhill; 2002.

Thrust Area 2: Sensory Performance – Audition and Tactile

Research Area 2.1: Auditory spatial perception

Protocols:

Scharine AA, Weatherless R. HEaDS-UP phase IV – auditory localization (ARL 13-067)

Measurements of auditory localization ability will be made for 12 test conditions: bare head, US Army advanced combat helmet (ACH), and 10 Helmet Electronic and Display System-Upgradeable Protection (HEaDS-UP) phase IV helmet/tactical communications and protection system (TCAPS) combinations. The bare head and ACH will serve as reference points. Data will be used with head-related transfer function (HRTF) measurements to develop a model of the relationship of direction-dependent spatial-temporal changes to auditory localization performance.

Scharine AA, Weatherless R. Headgear-induced changes to head-related transfer functions (HRTFs) (ARL 13-079)

Protective gear such as helmets and hearing protection can alter the monaural cues responsible for auditory localization, in particular by increasing the prevalence of localization errors in which the front and rear are confused and reducing the ability to localize in elevation.[5] Since Soldiers must wear this personal protective equipment (PPE), it is the task of system designers to design and select PPE that minimally affects hearing capability—the ability to both detect ambient sounds and localize them.

The directionally dependent cues known as the HRTF[6] that results from the reflection, diffraction, and absorption of sound waves due to head and torso geometry can be captured by recording the sound binaurally through microphones placed in the participant's ears. Thus, the physical effects of wearing a helmet can be recorded and analyzed to determine how they correlate to changes in auditory localization performance. To model the relationship of HRTF changes to changes in auditory localization performance, HRTFs are being measured for participants wearing no helmet, the currently fielded ACH, and 2 prototype systems being developed as a part of the HEaDS-UP Army Technology Objective. These data are being analyzed in conjunction with auditory localization performance data with the same helmets to better understand the relationship of headgear use to spatial auditory perception.

Gaston J, Dickerson K, Mermagen T, Scharine A. Localization of sound-source changes in complex auditory scenes; 2014 (ARL 14-017)

This study will be the first of its type to examine change recognition errors in conjunction with localization errors. Based on previous work from this lab (protocol ARL 13-082), we expect to

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[5] Scharine AA, Binseel MS, Mermagen T, Letowski, TR. Sound localisation ability of soldiers wearing infantry ACH and PASGT helmets. Ergonomics. 2014;57(8):1–22.

[6] Shaw EA. Transformation of sound pressure level from the free field to the eardrum in the horizontal plane. Journal of the Acoustical Society of America. 1974;56:1848–1861.

find high rates of detection errors across all conditions. Based on findings from the visual literature, we expect that localization errors will also occur at a rate of greater than 30%, suggesting that change deafness extends to both recognition and localization of changes.

In audition, like vision, it is generally accepted that there are distinct identification ("what") and a separate localization ("where") information processing pathways. The extent to which identification and localization errors are independent would inform the development of theories on efficiency in auditory information processing. Further, these results will inform future studies on the nature of auditory attention and aid in the development of techniques for improving Soldier situational awareness.

Publications:

Fluitt K, Mermagen T, Letowski T. Auditory distance estimation in an open space. In: Glotin H, editor. Soundscape semiotics – localisation and categorisation. Rijeka (Croatia): InTech; 2014. Available at: http://www.intechopen.com/books/soundscape-semiotics-localisation-and-categorisation/auditory-distance-estimation-in-an-open-space.

The purpose of the study was to expand our knowledge about auditory distance estimation at larger distances in an open field environment in which auditory sensations are affected by meteorological factors such as wind, temperature, and humidity. Of particular concern are the conditions where visual distance estimation is compromised and auditory distance estimation has important military implications and contributes to Soldier safety and mission effectiveness. Our goal was accomplished by collecting acoustic (target sound and noise levels) and meteorological (wind direction and strength, temperature, atmospheric pressure, and humidity) data for each experimental trial. Twenty-four subjects (men and women, ages 18–25) participated in this study. Seven types of sounds together with blank (no sound) trials were presented to the listeners. The sounds were delivered from 6 loudspeakers located 25, 50, 100, 200, 400, and 800 m from the listener. The actual loudspeakers were spread across the field together with 12 additional dummy loudspeaker boxes providing visual uncertainty regarding the sound source location. The results of the study indicate that auditory distance judgments in the open field at a 25-m distance and beyond underestimate the actual distances to sound sources regardless of the distance.

Scharine AA, Weatherless RA. US Marine Corps level dependent hearing protector assessment: objective measures of hearing protection devices. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6780. Also available at: http://www.arl.army.mil/arlreports/2014/ARL-TR-6780.pdf.

To characterize the effects of 4 level-dependent earplug-style hearing protection devices (HPDs), measurements were made of the passive attenuation of steady-state and impulsive noise, as well as the localization ability of listeners while they wore each HPD. Three HPDs were mechanical (Moldex BattlePlugs, 3M Combat Arms Earplugs, and the SureFire EP4 Sonic Defenders Plus).

These triple-flange earplug-style HPDs provide level-dependent protection by incorporating a filter that allows the user to hear ambient sounds with minimal attenuation but protects against impulsive noises above about 105-dB peak. We tested the fourth HPD (Etymōtic Electronic BlastPLG EB15) in the inactive condition only, but it can provide ambient environmental hearing via external microphones and uses electronic circuitry to limit or shut off the transmission of unsafe levels of noise. The 3 mechanical earplugs provided similar (8- to 14-dB) passive attenuation of steady-state pink noise presented at 105 decibels A-weighted (dB A). One-third octave band analyses of this attenuation showed differences in the spectral profile at higher frequencies. The inactive EB15, tested with foam ACCU·Fit ER38-14F ear-tips, provided 28 dB of passive attenuation. The devices all provided in excess of 30-dB attenuation of an impulsive noise presented at approximately 157-dB peak; in particular, the inactive EB15 provided more than 34 dB of passive attenuation. All 4 devices caused an increase in average localization error—near 0° and 180°, most likely due to reversals. The average unsigned azimuth error did not differ significantly across the 4 earplugs, ranging from about 38 to 42. All 4 earplugs, as tested, provide sufficient protection against noise. The significance of the mechanical earplugs' differential effects on the spectral content of lower-level steady-state noise on spatial orientation and, ultimately, user acceptance are discussed. Similarly, we note the limitations of inferences made from tests of the EB15 in only a passive mode.

Scharine AA, Weatherless RA. Helmet electronics and display system-upgradeable protection (HEaDS-UP) phase III assessment: headgear effects on auditory perception. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6723. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6723.pdf.

Two prototype modular helmet systems were evaluated for their effects on auditory perception. The systems consist of a helmet, eye and mandible protection, and a TCAPS that incorporates earmuffs (EMs), earplugs (EPs), or both. Minor differences in passive directional attenuation were measured for the 2 systems. The output levels of the situation awareness (SA) microphones of the TCAPS were measured as a function of noise level and amplification setting. It was shown that they limited noise transmission when ambient levels exceeded 85 dB A; however, it was possible to amplify levels at 85 dB A by 20 dB. The attenuation of 145- and 160-dB peak impulses was measured for the EP and EM with the SA microphones off and when turned on. When the SA microphones were on, the TCAPS provided impulse noise protection equivalent to that of passive protection. When the helmets were worn without mandibles, auditory localization ability was similar to that observed for the ACH. Wearing the mandible caused significant decreases in localization ability. Listeners wearing the TCAPS showed no impairment of recognition for speech presented in quiet as compared to unaided listening.

Scharine AA, Weatherless RA. Evaluation of variants of 3M Peltor ComTAC tactical communication and protection system (TCAPS) headsets: measures of hearing protection and auditory performance. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6667. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6667.pdf.

The auditory effects of the 3M Peltor ComTAC III accessory rail connector and the 3M Peltor ComTAC IV Hybrid headsets were compared with the 3M Peltor ComTAC III. Passive and active attenuation were measured in 2 steady-state noise levels (85 and 105 dB A) and 3 microphone settings (off, low, and high). When the noise level was 85 dB A and the microphones were set to high, the systems provided approximately 20 dB of amplification. However, at 105 dB A and the microphones off, attenuation was equivalent to that of passive attenuation. The devices provided attenuation of impulsive noise (154-dB peak) exceeding 25 dB for all measured settings. Of the 3 types of eartips available for the ComTAC IV, the "skull screw" style eartips provided the most impulsive noise attenuation. Auditory localization performance was measured for 12 listeners while wearing the ComTAC systems in combination with 2 Ops-Core FAST helmets (ballistic and lightweight carbon). There were fewer front-to-back localization errors when wearing the lightweight carbon helmet than when wearing the ballistic helmet, but there was no significant difference between the ComTAC systems in their effect on localization performance.

Scharine AA, Letowski TR. The measurement of the effects of helmet form on sound source detection and localization using a portable four-loudspeaker test array. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6444.

The objective of this research was to evaluate the effectiveness of a portable, 4-loudspeaker array for assessments of helmet effects on wearer's detection and localization of sound sources. Military and civilian helmets affect the wearer's ability to detect and localize sound sources. Industry needs to evaluate auditory effects in helmet development and modification processes, but ongoing well-controlled laboratory studies are prohibitively time-consuming and costly. A portable 4-loudspeaker test array was used to compare the auditory effects of 2 prototype and 2 fielded helmets to a bare-head condition. Detection thresholds were measured for one-third-octave noise bands (125–8000 Hz). Localization performance was assessed for low-pass (<500 Hz) speech sounds and high-pass (greater than 2 kHz) breaking glass sounds in the presence of 2 background noises. Detectability of sound sources varied with the helmet type and the sound source type/location. Average sound attenuation across all test conditions was less than ±1.5 dB for each helmet but varied with frequency, reaching −7.0 dB for some helmets. Effects of helmet on sound source localization were large, significant, and varied with type of helmet.

Henry PP. Evaluation of auditory characteristics of communications and hearing protection systems (C&HPS) part III – auditory localization. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6560. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6560.pdf.

Devices that provide hearing protection, situation awareness, and radio communications are often referred to as communications and hearing protection systems (C&HPS). Soldiers use these systems to maintain auditory awareness within their environment, communicate with their team members, and protect their hearing. Each of the 3 features of select C&HPS (hearing protection, speech communication, and SA) were independently evaluated by ARL. This report is the third in a series of 3 and focuses on the auditory localization performance obtained from 2 commercially available C&HPS: Nacre QuietPro and Silynx QuietOps. These 2 systems were selected from 3 C&HPS evaluated for attenuation characteristics in the first report and speech intelligibility in the second report; the third system provided insufficient attenuation to be included. Results of the auditory localization testing indicated that both C&HPS negatively affected auditory localization accuracy performed in background noise, but the observed decrement was not significantly different between the 2 systems. Evidence from objective measures of the systems such as directivity, calculation of interaural level differences), and the measurement of input/output functions indicate that changes in binaural intensity difference cues were the primary factor driving the reduction in performance.

Foots AN. Effects of amplitude compression on relative auditory distance perception. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-RP-464. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-RP-464.pdf.

Military C&HPS use amplitude compression to provide protection and prevent distortion that has the potential to affect relative auditory distance perception by reducing the level differences between sounds. The focus of the study was to investigate the effect of amplitude compression on relative auditory distance perception.

Impulse responses were recorded through KEMAR simulations and convolved with pink noise and a dog bark to create stimuli. Two levels of amplitude compression were applied to the recordings through Adobe Audition sound-editing software to simulate military C&HPS.

Data were collected in 12 conditions based on combinations of 3 independent variables: reference distance (6.5 ft, 16.5 ft), stimulus (pink noise, dog bark), and compression (none [linear], low, high). Participants listened to the stimuli through insert earphones in a 2IFC adaptive task and selected the stimulus they perceived to be farther away. As the participant selected the correct stimulus, the computer program reduced the separation in the next trial. The dependent variable was the smallest average separation in distance across 3–5 runs.

A 3-factor analysis of variance showed significant main effects of distance and compression as well as significant interactions between the 3 variables. Follow-up analyses within each stimulus indicated that the effects of compression varied between the 2 stimuli. For both stimuli, listeners needed increased separation as the compression level increased. For the pink noise, the effect of compression was greater for the 6.5-ft distance than the 16.5-ft distance. For the dog bark stimulus, the low level of compression affected perception greater at the 6.5-ft distance than at the 16.5-ft distance.

Melzer J, Scharine A, Amrein B. Soldier auditory situation awareness: the effects of hearing protection, communications headsets, and headgear. In: Savage-Knepshield P, Martin J, Lockett J, Allender L, editors. Designing soldier systems: issues in human factors. Hampshire (UK): Ashgate; 2012.

Hearing is the only human sensor that functions in the full 360° sphere. Often the Soldier's first warning and source of information about the identity and location of an event is through hearing. Thus the Soldier needs to be able to hear even the quietest of events. Unfortunately, the Soldier is commonly exposed to very loud noises from weapons and vehicles that can adversely affect his auditory SA by causing temporary and permanent threshold shifts, thus reducing his sensitivity to sounds. In spite of these threats, Soldiers are often reluctant to wear hearing protection, feeling that it reduces their sensitivity to those quiet auditory cues in their environment and makes communication difficult. Hearing protection must be carefully selected to allow the Soldier to hear his/her environment while still protecting against noise-induced hearing loss. While communications systems are essential for the Soldier, the wrong headset can interfere with auditory SA and compromise the efficacy of hearing protection. The microphone and transducer may not transmit well or may transmit the noise of the environment making speech communications difficult. They may also be uncomfortable and may not be rugged enough to withstand military use. Finally, auditory SA can be impaired by other Soldiers' gear and helmets, which can interfere with spatial localization cues. Thus, careful consideration of Soldier's operating environment is needed when designing or selecting hearing protection, communications headsets, and other headgear to ameliorate or eliminate these issues. This chapter discusses hearing and communication needs and provides design guidelines based on experimental research and practical experience in order to support further development of quality communications and hearing protection equipment for the Soldier.

Binseel MS. Three variants of the dual-mode combat arms earplug – an assessment of attenuation performance in continuous and impulse noise. Poster session presented at the National Hearing Conservation Association's 36th Annual Hearing Conservation Conference; 2011; Mesa (AZ).

The Combat Arms Earplug (CAE) is currently the US Army's earplug of choice. It offers 2 protection modes: linear and nonlinear (level-dependent). The original CAE was a double-sided plug. One side was a standard triple-flange plug; the other side entrained a nonlinear element, or filter, within an acoustic pathway through the plug. The user had to remove, reverse, and reinsert the plug to change modes. The second-generation plug used a rotating cylinder to align the pathway (nonlinear mode) or interrupt the pathway (linear mode). The latest generation uncovers (nonlinear mode) or caps (linear mode) the pathway by means of a rocker switch. A comparison of the performance of these 3 generations of earplugs is presented. Performance measures include continuous noise reduction in 68-dB sound pressure level noise and impulse peak reduction using a 151-dB peak pressure level impulse in both linear and nonlinear modes. No statistically significant differences were found in impulse peak reduction in either mode. In continuous noise, there were some statistically significant differences, mostly in the linear mode, but the magnitudes of the differences were small and occurred at a subset of tested frequencies. The conclusion is that the earplugs perform essentially equivalently.

Research Area 2.2: Sound-source perception of complex natural scenes

Protocols:

Dickerson K, Gaston J. Quantifying change detection failures during the perception of complex auditory scenes (ARL-13-082)

The purpose of this experiment is to determine what factors influence the prevalence of change detection errors during the perception of naturalistic scenes. Change deafness, a failure to detect large changes within an auditory scene, has only recently gained interest in the research community. In a typical change deafness task, participants are briefly exposed to 2 versions of the same auditory scene (A/A') and asked if the scenes are the same or different. The experiments described here will follow the same general procedure as other change deafness studies, but here a novel spatial manipulation is introduced for presentations of complex naturalistic scenes. Sounds will be presented spatially separated rather than through a single channel. Further, the changes themselves will be spatial in nature; sounds can either disappear or appear within an auditory scene. Additionally, a cued-recall test will be administered to ensure that participants are encoding all the content of each scene. All participants will be tested using headphones in a sound chamber with the loudspeaker array in the Sphere room in a standard change deafness listening paradigm. Based on previous research, it is expected that detection errors will occur 30%–50% of the time despite strong performance in the cued-recall control condition.

Sherwin J, Gaston J. Neural correlates of the localization of small-arms fire (ARL-12-029)

The purpose of this project is to investigate the neural correlates of listener shot localization. This project will present listeners with the recorded sounds of small-arms fire at different shooting angles played against common acoustic background scenes. Neural signals will be measured using electroencephalography (EEG) techniques while listeners perform a task in which they must differentiate between different shooting trajectories, weapons, and other possibly identifying characteristics. The neural data collected will be analyzed using machine learning techniques. For each experimental session, 1 participant will listen to recordings of small-arms weapons fired from multiple relative angles. The participant will respond with a button-press signaling his/her identification of the shot's initial direction. Where possible, participants will be either Soldiers or civilians that are highly familiar with the sounds of small-arms fire.

Ploechl M, Gaston J. Audio-tactile cue localization and causal inference (ARL-13-028)

Integration of information across 2 different sensory channels may lead to interactions that can change the perception in 1 or both modalities. By investigating the mutual influence between auditory and tactile cues in a localization paradigm, we aim to better understand how information processing across these modalities can be optimized. Participants will be seated in the center of a circular loudspeaker array and will wear a belt with 30 evenly spaced vibromotors in it. Auditory and tactile cues will be presented simultaneously with varying amounts of spatial disparity (i.e., either from the same direction or with an offset between 12° and 48°). We will also modulate the amplitude of both stimuli in an either coherent or an incoherent manner in order to facilitate or hamper the perception that both stimuli are interrelated. After each trial, the participants' task will be to report the perceived location of both the auditory and the tactile stimuli. They will also be asked to indicate whether they perceived the 2 stimuli as being causally related or as occurring independent of each other (i.e., whether or not they had the impression that the belt signal was triggered by the sound). Based on the participants' responses, we will analyze if and how the perceived locations of auditory and tactile cues are influenced by their relative position with respect to the observer (i.e., front, back, left or right), their spatial disparity, and their perceived causal relation. Complementary to collecting the participants' behavioral responses, we will record their neural activity via EEG. The obtained en vivo data will be used to study the neural mechanisms underlying the expected multimodal interactions.

Gaston JR, Letowski TR, Fluitt KF. Listener perception of single and multiple event small-arms fire (ARL-20098-10032)

Our previous work investigated listener ability to differentiate small-arms fire for single impulse events recorded from a fixed position behind the shooter. This work found that listeners could reliably distinguish handgun fire from rifle fire but had difficulty distinguishing between individual rifles. Further, it was found that source properties of the weapons and the resulting sounds produced were moderately good in predicting listener recognition ability. The present study represents a logical progression of this initial work. In the initial study, listener perception of only single impulse event sounds was investigated for "listener" positions behind the shooter, and this is not representative of small-arms fire typically encountered in operational environments. Thus, the present study is designed to look at listener perception for "listener" positions in front of the shooter for not only multiple-shot contexts, but also how perception changes as the context changes (i.e., 1- to 3- to 6-shot contexts). It is expected that as the context changes, the qualitative changes in the availability of potentially diagnostic acoustic cues will improve listener ability to differentiate small-arms rifle fire. For example, in a 3-shot context, differences in cyclic rate of fire may offer diagnostic information to distinguish the AK-47

(600 rounds/min) from variants of the M4 carbine (700–950 rounds/min). Under 6-shot contexts, a qualitative difference between firing modes of the AK-47 (fully automatic) and M4 carbine variants (3-round bursts) should provide very salient cue for differentiating the rifles.

Publications:

Ericson MA, Matthews J, Blackmore S. Modeling the perception of simulated moving vehicle sounds. Journal of the Audio Engineering Society. In preparation; 2014.

Military ground vehicles often produce sounds that are specific and identifiable by listeners in an environment due to the sounds produced by their diesel engines, exhaust tuning characteristics, and heavy-duty tires or tracked wheels. These power train components produce sounds that are typical of most military vehicles. This paper discusses the analyses used to characterize the acoustic features of a gasoline and diesel engines. Analyses were performed on gasoline and diesel engine vehicles for stationary and moving vehicle conditions with Mel frequency cepstral coefficients (MFCC) of the spectrum, amplitude modulation components of the envelope, and the residual noise spectrum. These acoustic attributes were characterized at recording locations at the front and back of stationary vehicles with the engine running around 1,000 rpm. The vehicles were also measured as they moved past an Aachen Head-HMM 2 acoustic manikin that faced toward the approaching vehicle at 4 different speeds of 5, 10, 15, and 20 mph. A separate recording was made of the friction sound of the wheels and the pavement using a Beyerdynamic MCE 86 shotgun microphone. The stationary tire, front, and rear recordings were classified spectrally using MFCC, temporally using the amplitude modulation envelope and energetically using the residual noise spectrum. With the features of the stationary vehicles compared with features of the moving vehicles, the change over time was analyzed to provide better insight into the perception of a moving complex sound source.

Sherwin J, Gaston J. Soldiers and marksmen under fire: neural correlates of small-arms fire localization. Frontiers in Human Neuroscience. 2013;7(67):1–14.

Important decisions in the heat of battle occur rapidly, and a key aptitude of a good combat soldier is the ability to determine whether he/she is under fire. This rapid decision requires the Soldier to make a judgment in a fraction of a second, based on a barrage of multisensory cues coming from multiple modalities. The study uses an oddball paradigm to examine listener ability to differentiate shooter locations from audio recordings of small-arms fire. More importantly, we address the neural correlates involved in this rapid decision process by employing single-trial analysis of EEG. In particular, we examine small-arms expert listeners as they differentiate the sounds of small-arms firing events recorded at different observer positions relative to a shooter. Using signal detection theory, we find clear neural signatures related to shooter firing angle by identifying the times of neural discrimination on a trial-to-trial basis. Similar to previous results in oddball experiments, we find common windows relative to the response and the stimulus when neural activity discriminates between target stimuli (forward fire = observer 0° to firing angle) versus standards (off-axis fire = observer 90° to firing angle). We also find, using windows of maximum discrimination, that auditory target versus standard discrimination yields neural sources in Brodmann Area 19, i.e., in the visual cortex. In summary, we show that single-trial analysis of EEG yields informative scalp distributions and source current localization of discriminating activity when the small-arms experts discriminate between forward and off-axis fire observer positions. Furthermore, this perceptual decision implicates brain regions involved in visual processing, even though the task is purely auditory. Finally, we use these techniques to quantify the level of expertise in these subjects for the chosen task, having implications for human performance monitoring in combat.

Gaston J, Mermagen T, Dickerson K. Acoustic measurement and model predictions for the aural nondetectability of two night-vision goggles. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6738. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6738.pdf.

This study evaluates 2 different NVGs to determine if the devices meet level II aural nondetectability standards of MIL-STD-1474D[7] for a detection distance of 10 m. These systems (PVS-14 and PVS-7D) were tested while mounted on a ACH placed on the Knowles Electronic Manikin for Acoustic Research Auditory Test Fixture in the Environment for Auditory Research (EAR) Dome Room, a semi-anechoic research space at ARL's Human Research and Engineering Directorate. All tests were conducted in both the linear and automatic gain control (AGC) modes of operation for each system, and measurements were made at 8 locations around the devices. The results of the testing revealed that in the linear mode both devices emitted a faint tone centered at 2 kHz, but in no case did the NVGs fail the nondetectability criteria of 10 m. In AGC mode, both systems emitted a tone but the PVS-14 did not fail the nondetectability criteria. However, the PVS-7D failed the 10-m detection criteria at several of the measurement positions.

Pastore RE, Gaston JR. A cognitive concept with relevance to speech perception? In: Zonneveld W, Quené H, Heeren W, editors. Sound and sounds: studies presented to MEH Schouten on the occasion of his 65th birthday. Utrecht (Netherlands): Utrecht Institute of Linguistics OTS; 2012.

An understanding of the processes responsible for perceptual categories of speech may depend upon accumulating knowledge about general principles of cognition and how those principles apply to changes in the nature and complexity of the focal stimulus elements and the stimulus context in which the focal stimulus is presented. The current research follows this strategy for tone glides whose context changes to roughly approximate 1- and 2-formant CV and VC syllables.

Boren B, Ericson MA. Motion simulation in the environment for auditory research. Proceedings on Meetings in Acoustics; 2013. Available at: http://scitation.aip.org/content/asa/journal/poma/14/1/10.1121/1.4704670.

[7] MIL-STD-1474D. US Department of Defense Design Criteria Standard, Noise Limits; 1997 Feb 12.

Virtual sound source motion has been implemented in ARL's EAR, which contains a 57-channel spherical loudspeaker array located in a semi-anechoic chamber. Using the low-latency PortAudio application programming interface from the Psychophysics Toolbox Version 3, 57 channels of streaming audio are dynamically updated in real-time using MATLAB for signal processing. Both distance-based amplitude panning (DBAP) and vector base amplitude panning (VBAP) have been implemented in MATLAB for controlling source motion. Sources are defined on a given path, such as a circle, ellipse, or the "dogbone" pattern often used in aviation. Although DBAP works convincingly for virtual sources located on the sphere defined by the loudspeaker array, VBAP is needed to position sources outside the array. Source motion paths are defined parametrically with respect to time, and the playback buffer updates the panned position every 11.5 ms. Based on the source's instantaneous distance, diffuse-field or free-field amplitude attenuation is added in MATLAB as well as air absorption filtering. This virtual sound source method will be used for a variety of audio simulations and auditory experiments.

Gaston JR, Letowski TR. Listener perception of single-shot small-arms fire. Noise Control Engineering Journal. 2012;60(3):236–245.

The ability to identify and interpret impulse sounds from small-arms weapons fire is a very important element of soldier's situation awareness that is critically needed to avoid potential danger. For example, differentiation of hostile from friendly weapons fire can indicate the need for increased vigilance and reveal the approximate location of an enemy element. In addition, estimation of weapon size can be used to infer the resources of an enemy element. Despite the potential operational importance of these sounds, little is known about listener perception of impulse weapons sounds. The present work investigates listener ability to differentiate signatures of various small-arms weapons on the basis of high-quality recordings of single-shot impulse sounds. Experiment 1 measured listener perceived similarity for paired small-arms impulse sounds. A multidimensional scaling solution based on listener ratings showed significant overlap in perceptual space for most rifle sounds, but the mappings of handgun sounds were largely segregated from all rifle sounds. These mappings correlated well with measured source and sound properties of the small-arms weapons. Experiment 2 measured discrimination performance for selected sets of contrasted weapon pairings. In general, discrimination performance correlated well with the listener perceptual space measured in Experiment 1, with best performance for handgun-rifle pairings and worst performance for rifle-rifle pairings.

In ARL-SR-213, tactile research was covered in Thrust Area 3: Sensory Performance – Tactile. In this update, unconventional (nonvisual and nonauditory) communications includes bone conduction communications and all aspects of tactile communications (head- and torso-mounted).

Research Area 2.3: Unconventional Communication: Bone Conduction (BC)

Protocols:

McBride M, Tran P, Pollard K. Effects of bone vibrator locations on auditory spatial perception tasks (ARL-13-040)

This study seeks to assess the effects of varying bone conduction (BC) transducers' locations on sound localization performance for use in virtual 3-D BC audio systems. Twelve male and female subjects solicited from the local community will listen and respond to audio signals transmitted by a BC headset. Their HRTFs will be measured and used for signal processing. A special headband will be used to couple a pair of BC vibrators to symmetrical points on the head. Once the bone vibrators are in the proper position, the participant will listen to a string of static noise sounds lasting approximately 3 s, which will be preprocessed through his/her individual HRTF. The sound sources will be based on 16 different horizontal locations around the participant's head and 4 elevations directly in front of the participant. After listening to each string of static noise sounds, participants will indicate the location from which they perceive the sounds came from by clicking on a particular spot on the computer interface that maps the location in the environment. This process will be carried out 5 times (once for the signal coming from actual loudspeaker arrays to assess the general localization ability of the participant, once from a pair of earphones to assess the ability to localize based on the head related transfer function, and once for each of the bone vibrator locations tested with the virtual spatial sound source). Each time, all 16 azimuth locations and 4 elevations will be tested. Each participant will be involved in the study for approximately 3 h.

Pollard KP, Tran PK, Letowski TR. A free-field method to calibrate BC devices (ARL-20098-11025)

The aim of this study is to develop a method of calibrating BC transducers, analogous to the free-field calibration of air conduction (AC) earphones. One goal of this study is to develop a method that can be applied to various BC transducer devices worn on various skull locations. This methodology will provide a means of reliable and repeatable calibration for different devices and skull locations, allowing research data to be compared meaningfully across studies, researchers, and labs. The ultimate goal is to use the developed methodology to compare and evaluate the performance of different bone transducers and skull locations. This information will help with the design and proper use of BC communication devices for military applications. Participants will listen to 1/3-octave noise bands played alternately from a bone transducer and a free-standing loudspeaker. The participant will use an amplifier to adjust the output of the bone transducer to perceptually match the loudness of the signal from the loudspeaker. The resulting audio signal going to the bone transducer will be measured with an audio voltmeter. Participants will be exposed to 22 frequencies, 2 transducer device types, and 2 skull locations. All sounds will be at safe levels. To examine and control for possible individual differences, the researchers will also take demographic data, head measurements, and HRTFs of the subjects. The study will involve no more than 12 subjects, and these will be recruited via word of mouth, email, and advertisements. Total participation time, including several breaks, should not exceed 2.5 h. To examine intra-subject reliability, at least 2 volunteers will repeat blocks, and their total participation time, including several breaks, should not exceed 4.5 h. All tests will be performed in a controlled lab environment in APG Building 520.

McBride M, Weatherless R, Tran P, Pollard K, Letowski T. Effects of bone vibrator locations on auditory spatial perception and speech recognition tasks (ARL-20098-11037)

This study seeks to assess the effects of varying BC transducers' locations on sound localization performance for use in virtual 3-D BC audio systems. Twelve male and female subjects solicited from the local community will listen and respond to audio signals transmitted by a BC headset. Their HRTFs will be measured and used for signal processing. A special headset will be used to couple a pair of BC vibrators to symmetrical points on the head. Once the bone vibrators are in the proper position, a string of 8 static noise sounds lasting approximately 3 s preprocessed through individual HRTF function of a given listener will be transmitted through the headset. The sounds can be located at 16 different locations around the participant's head. After listening to each string of static, participants will indicate the location from which they perceive the sounds came by clicking on a particular spot on the computer interface designed specifically for this type of study. This process will be carried out 4 times (once for each of the bone vibrators locations tested), and all 16 sound locations will be tested for each bone vibrator location. In addition to the sound source localization task, each listener will participate in a speech-on-speech masking task to assess the effects of vibrator location on speech perception in 2-channel communication. The task will involve listening to 2 sentences presented in parallel, each though one of the vibrators, and reporting the 4 key words used in the target sentence. Twenty pairs of sentences will be presented and the listener will be asked to respond by selecting the appropriate words from word lists presented on the computer screen. Each participant will be involved in the study for approximately 3 h.

Pollard KP, Tran PK, Letowski TR. Factors affecting speech intelligibility in bone conduction communication (ARL-20098-10020)

Successful radio communication is important for military personnel to safely and effectively complete their missions. BC communication uses vibrations transmitted through the skull and soft tissues of the head, and its use in radio devices offers many advantages over traditional air-conduction audio communication. Advantages include reduction in background noise, little sound leakage, and the ability to be used along with hearing protection devices or with uncovered ears to improve situational awareness. However, BC systems are not yet in widespread use, partly due to poor speech intelligibility over these systems. Solving intelligibility issues in BC communication is a critical step for improving acceptability and useful employment of this technology. Our study thus seeks to examine the effects of device placement, background noise, and users' individual differences (vocal attributes, facial dimensions, and demographic characteristics) on speech intelligibility over BC. Talker participants will speak words from the Modified Rhyme Test (MRT) list under different background noise conditions and will be recorded using BC microphones placed on different locations on the head. These recordings will be played to listener participants in different background noise conditions and wearing BC vibrators on different locations on the head. Speech intelligibility will be measured using listeners' scores on the MRT. These data will be analyzed to uncover the effects of noise, device placement, talker individual characteristics, and listener individual characteristics on intelligibility. Results will indicate whether speech intelligibility over BC can be improved by modifying device use, implementing signal filters, or customizing these strategies to meet the needs of users with different vocal attributes, facial dimensions, or demographic characteristics.

Tran PK, Weatherless R, Letowski T. Bone conduction microphone study: the effect of incoming voice from two BC microphones on speech intelligibility (ARL-20098-11003).

The purpose of this study is to investigate speech intelligibility (SI) of signals received via 2 BC microphones at various locations on the talker's head and compare them with the best location of traditional 1 BC microphone input. These data will be used to assess the effectiveness of a combined signal on the improvement of speech intelligibility for radio communication in tactical environments. The ultimate goal of this study is to develop human factors guidelines for BC microphone interfaces to be used for military applications. The voice signals for the Callsign Acquisition Test speech intelligibility test will be recorded simultaneously at 4 different locations on the talker's head. The talker will talk in 3 conditions: whisper, speak at normal conversation level in a quiet background, and speak with a raised voice in background noise. The resulting 2-microphone combinations and single microphone recordings of each speech signal will create the database of speech signals to be used in the listening sessions for SI evaluation. The listeners' task is to listen to the presented sounds through a BC headset and select on a computer screen what they hear. All recording and listening tasks will be performed in a controlled laboratory environment in APG Building 520. The number of subjects in this study will be 2 talkers and 18 listeners. The 2 talkers (1 male and 1 female) will be members of the Visual and Auditory Processes Branch Auditory Research Team. The listeners will be recruited through word of mouth, email, and advertisements. Each recording session will last about 30 min and each listening session will last about 3–3.5 h including rest breaks.

Publications:

Pollard KA, Garrett L, Tran P. Bone conduction systems for full-face respirators: speech intelligibility analysis. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6883. Also available at: http://www.arl.army.mil/arlreports/2014/ARL-TR-6883.pdf.

Difficult environments, such as chemical, biological, radiological, nuclear, and high-energy explosives (CBRNE) environments, pose a unique communication challenge: Effective communication is essential to stay safe in these environments, yet safety gear itself impedes communication. Noisy decontamination devices (power sprayers, etc.) and PPE (e.g, full-face respirators) can impede successful speech transmission. BC communication systems are a promising solution. These systems are relatively insensitive to background noise and can capture speech directly from a user's skull vibrations before airborne speech is disrupted by a respirator. To assess the potential of BC systems for use by encapsulated personnel, 3 communication systems were tested for speech intelligibility using the MRT. Sixteen participants wore the M50 Joint Service General Purpose Mask full-face respirator and communicated via radio using 3 different communication systems in 2 levels of background noise. A BC earpiece performed best, followed by a mask-mounted BC system. Both BC systems outperformed the currently fielded AC communication system. The results support the use of BC technology for improved encapsulated communication, which may improve safety and effectiveness for CBRNE personnel. Results are discussed and recommendations are provided.

Pollard KA, Tran PK, Letowski T. Vocal and demographic traits influence speech intelligibility over bone conduction. Journal of the Acoustical Society of America. In review; 2014.

BC communication systems can provide multiple benefits over AC systems, but BC systems are not in widespread use, partly due to problems with speech intelligibility. While contributing factors such as device location, static force, and background noise have been previously explored, little attention has been paid to the role of individual user differences. Because BC signals travel through an individual's head, skull, and facial tissues, factors such as the user's age, sex, race, regional origin, and vocal traits may influence sound transmission. Along with microphone placement and background noise, these factors can affect BC speech intelligibility. To assess these factors, 8 diverse talkers were recorded with bone microphones on different skull locations and in different background noise conditions. Twenty-four diverse listeners listened to these samples over BC and completed MRTs for speech intelligibility. Results indicate that age, sex, and vocal traits influence BC speech intelligibility in complex ways, but no main effects were found for race or regional origin. Thoughtful application of this knowledge can help improve the BC communication experience for diverse users.

Tran PK, Letowski TR, McBride ME. The effect of bone conduction microphone placement on intensity and spectrum of transmitted speech items. Journal of the Acoustical Society of America. 2013;133:3900–3908.

Speech signals can be converted into electrical audio signals using either conventional AC microphone or a contact BC microphone. The goal of this study was to investigate the effects of the location of a BC microphone on the intensity and frequency spectrum of the recorded speech. Twelve locations, 11 on the talker's head and 1 on the collar bone, were investigated. The speech sounds were three vowels (/u/, /a/, /i/) and two consonants (/m/, /ʃ/). The sounds were produced by 12 talkers. Each sound was recorded simultaneously with 2 BC microphones and 1 AC microphone. Analyzed spectral data showed that the BC recordings made at the forehead of the talker were the most similar to the AC recordings, whereas the collar bone recordings were most different. Comparison of the spectral data with speech intelligibility data collected in another study revealed a strong negative relationship between BC speech intelligibility and the degree of deviation of the BC speech spectrum from the AC spectrum. In addition, the head locations that resulted in the highest speech intelligibility were associated with the lowest output signals among all tested locations. Implications of these findings for BC communication are discussed.

Pollard K A, Tran P K, Letowski TR. A free-field method to calibrate bone conduction transducers. Journal of the Acoustical Society of America. 2013;133:858–865.

BC communication systems employ a variety of transducers with different physical and electroacoustic properties, and these transducers may be worn at various skull locations. Testing these systems thus requires a reliable means of transducer calibration that can be implemented across different devices, skull locations, and settings. Unfortunately, existing calibration standards do not meet these criteria. Audiometric BC standards focus on only 1 device model and on limited skull locations. Furthermore, while mechanical couplers may be used for calibration, the general human validity of their results is suspect. To address the need for more flexible, human-centered calibration methods, we investigated a procedure for bone transducer calibration, analogous to free-field methods for calibrating AC headphones. Participants listened to third-octave noise bands alternating between a bone transducer and a loudspeaker and adjusted the bone transducer to match the perceived loudness of the loudspeaker at each test frequency. Participants tested 2 transducer models and 2 skull locations. Intra- and inter-subject reliability was high, and the resulting data differed by transducer, by location, and from the mechanical coupler. The described procedure is flexible to transducer model and skull location, requires only basic equipment and directly yields perceptual data.

Tran PK, Binseel MS, Letowski TR. User evaluation of a bone conduction communication headset during the Patriot 2007 Joint Field Training Exercise. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2012. Report No.: ARL-TR-5973. Also available at: http://www.arl.army.mil/arlreports/2012/ARL-TR-5973.pdf.

Despite many advantages using BC technology, it has not yet made inroads in military communications applications. Military systems applications need to be subjectively evaluated by Soldiers to assess their utility and acceptance in military environments. In this study, a commercial BC headset was used and evaluated by the National Guard Special Operations Forces during the 2007 Joint Field Training Exercise. Five participants wore BC headsets for 40 h (continuous) during sustained operations. After completing the mission, the participants rated the BC communication system regarding speech intelligibility, SA, face-to-face communication, comfort, ease of use, and overall satisfaction of the device, and were asked to provide suggestions for improvement. The participants were also asked to rate an AC headset for comparison. The overall rating score for the BC headset was high (5/5) compared with the AC system (2.5/5), indicating the technology was favored over the AC system. The BC headset was chosen over the AC due to its light weight and because it allowed the user to maintain awareness of ambient sound. However, some important issues and suggestions for improvement were raised, including the need to ruggedize the system and to incorporate a quick-disconnect cable.

McBride M, Tran P, Letowski T, Rafael P. The effect of bone conduction microphone locations on speech intelligibility and sound quality. J. Appl. Erg. 2011;42:495–502.

This paper presents the results of 3 studies of intelligibility and quality of speech recorded through a BC microphone (BCM). All speech signals were captured and recorded using a Temco HG-17 BCM. Twelve locations on or close to the skull were selected for the BCM placement. In the first study, listeners evaluated the intelligibility and quality of the bone conducted speech signals presented through traditional earphones. Listeners in the second study evaluated the intelligibility and quality of signals presented through a loudspeaker. In the third study, the signals were reproduced through a BC headset; however, signal evaluation was limited to speech intelligibility only. In all 3 studies, the forehead and temple BCM locations yielded the highest intelligibility and quality rating scores. The collarbone location produced the least intelligible and lowest quality signals across all tested BCM locations.

Toll LE, Emanuel DC, Letowski T. Effect of static force on bone conduction hearing thresholds and comfort. International Journal of Audiology. 2011;50:632–635.

Objective: To assess the effect of the static force of a bone vibrator on the results of BC threshold measurements and comfort. Design: BC thresholds were determined for 40 participants using the standardized P-3333 headband and a leather adjustable headstrap with variable static forces (2.4, 3.4, 4.4, and 5.4 N). Comfort ratings were examined using a 5-point Likert scale. Results: Mean BC thresholds were within ±2 dB across all conditions; differences may be considered small enough to be clinically insignificant. Participants experienced significantly greater discomfort with the P-3333 versus the adjustable headstrap. The mean static force of the P-3333 varied considerably and was higher in situ than the calibration standard of 5.4 N. Conclusions: The results suggest that future revisions of relevant international and national standards should address the use of an adjustable headstrap and a static force less than 5.4 N.

Research Area 2.4: Unconventional Communications: Head-Mounted Tactile

(Was Thrust Area 3; Research Area 3.1: Tactile in ARL-SR-213)

Protocols:

Myles K, Kalb J, Fluitt K. Delineating tactile and auditory perception from head tactile stimuli (ARL-13-052)

The efficacy of using vibrotactile transducers on the head for Soldier navigation and cueing has promise as a practical communications solution. However, much is unknown about tactile sensitivity of the head. For example, a number of researchers have abandoned the head as a viable location for tactile inputs due to the assumption that any tactile signal that is applied to the head will also be heard. The researchers assume that users' responses to tactile signals would be driven by auditory cues from the tactile signals and not the tactile cues themselves. This is problematic in a laboratory setting as ideal tactile stimuli should produce sensations of vibration without the auditory cue (i.e., felt and not heard). Thus, this research effort is an attempt to build a database of tactile signals that deliver vibration sensations without the associated auditory cues and to empirically test the assumption that all tactile signals applied to the head are accompanied by auditory cues. We will attain this by conducting 3 experiments. The purpose of experiment 1 is to create supra-threshold tactile stimuli that will very likely be felt by research participants in experiments 2 and 3. Five subjects will be tested to obtain tactile thresholds. Vibrating stimuli will be presented to various body sites and subjects will respond yes or no to indicate if they do or do not feel the tactile stimuli. Ninety minutes will be required to complete the experiment. The purpose of experiment 2 is to isolate the vibration in tactile signals from associated auditory cues by determining vibration hearing threshold frequencies. Twelve subjects will be tested and a psychophysical, adaptive procedure will be used to obtain vibration hearing threshold frequencies for 5 body locations and 3 acoustic environments. Vibrating stimuli will be presented to various body sites in 3 different environments, and subjects will respond yes or no to indicate if they do or do not hear the tactile stimuli. Ninety min will be required to complete the experiment. The purpose of experiment 3 is to isolate the vibration in tactile signals from associated auditory cues by determining vibration hearing threshold amplitudes. The same 12 subjects that were recruited for experiment 2 will also participate in experiment 3 and on the same day. Vibrating stimuli will be presented to 4 head locations, and subjects will respond yes or no to indicate if they do or do not hear the tactile stimuli. Thirty minutes will be required to complete the experiment. Tactors, similar to cell phone vibrators will be used to deliver all vibration stimuli and all study activity will be conducted at APG Building 520. All subjects will be recruited via an ARL dispatch email advertisement, a recruitment agency, and a list of previous subjects maintained by the Auditory Research Team of the Perceptual Sciences Branch. Subjects recruited via the latter 2 sources will be paid $17/h and $20/h, respectively.

Myles K, Kalb JT, Fluitt K, Kehring K. Comparison of a visual and head tactile display for soldier navigation (ARL-12-064).

This is a proof-of-principle study that will evaluate the concept of head tactile communication in an operational setting. The main purpose is to determine the advantages of using a head-mounted tactile display compared with a visual display for Soldier navigation in an unfamiliar urban environment while concurrently detecting hostile threats. Fourteen Soldiers, aged 18–48 with 20/20 visual acuity or better in each eye and normal stereoscopic and color vision, will be recruited for this study. Soldiers recruited for this study will also have served at least 1 tour in Iraq or Afghanistan. A 2 × 2 within-subject design will be used to determine the advantages of using a head tactile display compared with a visual display for Soldier navigation. Participants will navigate 4 relatively similar routes in 2 simulated urban environments (low-rise buildings; high-rise buildings), using directional information given via a head-mounted tactile display or map. Two routes (1 in each urban environment) will be navigated using a tactile display, and 2 routes (1 in each urban environment) will be navigated using a map. All routes will be 1,013 m in length and equally complex in the number of direction options, the number of correct direction choices, and number and types of threats. In addition to collecting various performance measures, overall workload ratings and questionnaire data will also be collected. The study will be conducted in ARL/HRED's Tactical Environment Simulation Facility, which houses an Immersive Environment Simulator (IES) and Omni-Directional Treadmill (ODT). The IES will support the development of virtual terrain routes in an urban environment, and the ODT will facilitate navigation in any direction within the virtual terrain.

Myles K, Kalb JT. The effect of motor activity on the detection of tactile signals (ARL-20098-10037)

The main purpose of this study is to determine how motor activity affects one's ability to detect vibratory tactile signals on the head. A secondary purpose is to collect comfort ratings for tactile signals of varying frequencies. Thirty subjects with short hair of a length that conforms to military regulations, ages 18–35, will be recruited from the area surrounding Aberdeen (MD) /Aberdeen Proving Ground (APG). Advertisements will be sent via an ARL-APG-ALL email and the APG news. A 3 × 4 × 5 within-subject design will be used to evaluate the effect head location (forehead, left temple, right temple, and back of head), frequency (32, 63, 80, 100, and 150 Hz), and motor activity (sitting, walking, and jogging) have on vibratory signal detection and localization accuracy. Motor activity, head location, and frequency are within-subject variables. Participants will don a 4-tactor array helmet-mounted tactile display. They will initially rate 11 vibratory stimuli (1 stimulus at frequencies 32, 45, 50, 63, 80, 100, 126, 150, 158, 200, and 250 Hz) for comfort and annoyance that will be sent to the forehead tactor only. Participants will rate each stimulus for comfort and annoyance using a 5-point Likert scale. Next, while sitting, walking, and jogging (random order), vibrating stimuli will randomly be presented to the participants' head via 4 tactors. For each stimulus, participants will respond yes or no electronically for detection of the stimulus as well as identify which of the 4 tactors was vibrated. Participants' total time commitment will be 1 h. This study will be conducted both indoors and outdoors. The indoor portion of the study will be conducted in Building 520 and the outdoor portion will be conducted in the OpenEAR facility.

<u>Publications:</u>

Myles K, Kalb JT. Head tactile communication: promising technology with the design of a head-mounted tactile display. Ergonomics In Design. 2013;21:4–8.

Although tactile applications have been explored heavily in the past decade, use on the head is rare. US Army researchers are exploring the possibility of using a head-mounted tactile display to augment visual displays currently used for navigation. Such a tactile display has the potential to decrease the amount of information the user would otherwise process visually by off-loading the navigation task from the visual to the tactile modality while providing Soldiers with a covert method of receiving directional information regarding a navigation or sniper detection task.

Myles K, Kalb JT, Fluitt KF, Kehring K. Comparison of a visual and head tactile display for Soldier navigation. Aberdeen Proving Ground (MD): Army Research Laboratory (US);

2013. Report No.: ARL-TR-6742. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6742.pdf.

The purpose of the study was to determine the advantages of a head-mounted tactile display (HMTD) compared with a map for Soldier navigation in an urban environment while concurrently detecting hostile threats. Many technological solutions that provide the Soldier an advantage over the enemy are visually driven, and collectively are in danger of overloading the Soldier's visual capacity, but the tactile modality has been identified as a promising alternative to the visual modality for increasing Soldier performance. Twelve Warfighters participated in the study. Each served at least 1 tour of duty in Iraq or Afghanistan. Participants completed 4 routes in Middle East (ME) and United States urban virtual environments using a map or an HMTD while also scanning for and detecting threats. Data were collected for various performance measures, overall workload ratings, and a questionnaire. Overall workload significantly decreased by 37.8% when participants used the HMTD as opposed to the map to navigate the ME environment. The HMTD was advantageous for decreasing participants' perceived overall workload associated with a complex environment. Thus, for complex environments, off-loading the navigation task to a nonvisual modality and reserving visual resources for the task of detecting threats can unburden Soldiers by reducing their overall workload.

Myles K, Kalb JT. An evaluation of signal annoyance for a head-mounted tactile display. 2014 HFES Annual Meeting. In review; 2014.

The purpose of this study was to evaluate perceived annoyance for vibrotactile signals applied to the head. A head-mounted tactile display, integrated with a BC system (dual-use, tactile-BC communication system), is considered for Soldier navigation and cueing, but previous studies have reported unfavorable user reviews for tactile signals applied to the head, and that high intensity vibrotactile stimuli may lead to discomfort and pain. Vibrotactile signals 32–250 Hz were sent to the foreheads of 30 participants who rated the perceived annoyance of each signal. Higher frequency signals were rated more annoying than lower frequency signals. Consequently, higher frequency signals will most likely not be preferred on the head by most users and generally may be associated with annoyance and other feelings of unsettledness. The challenge will be to identify a range of optimal signals for all users that can be used in many environments, under a number of conditions.

Myles K, Kalb JT, Lowery J, Kattel BP. The effect of hair density on the coupling between the tactor and the skin of the human head. Appl. Erg. In review; 2014.

The purpose of this study was to determine the effect of hair density on thresholds associated with the perception of vibration stimuli applied to the head. Tactile technology is applied to many fields of study as well as many different parts of the body. A number of studies report the tactile sensitivity for various parts of the body, but there is a deficiency of information regarding sensitivity thresholds for the area of the head/scalp. Thirty-three college students ages 18–35 were recruited as subjects from Morgan State University. A $7 \times 3 \times 3$ mixed design was used to evaluate the effect of hair density (low, medium, and high), head location (CZ, T3, T4, PZ, F3, F8, and O2), and frequency (32, 45, and 63 Hz) on vibration detection thresholds. Head location and frequency were within-subjects variables, and hair density was a between-subjects variable. Sensitivity thresholds were obtained using Zippy Estimation by Sequential Testing and hair density was categorized based on a photographic scale. This study found that hair density affects one's ability to detect vibration stimuli on the head and across hair density the temples (T3, T4) and the back region of the head (O2) were the most sensitive head regions. The results of this study fill the gap of information regarding hair and vibration detection thresholds on the head. This research will aid in extending the use of head tactile technology to women.

Myles K, Kalb JT. Efficacy of a head tactile display: the detection of tactile signals on the move. Human Factors. In preparation; 2014.

Tactile communication (i.e., using the skin as a platform to deliver meaningful information) is identified as a technology that can provide Soldiers with an alternative form of communication that can reduce information overload on the visual and auditory channels or help maintain acceptable levels of SA in battle. However, this reduction in information overload and maintenance of acceptable levels of SA is realized only if the tactile information that is conveyed is intelligible, especially amid harsh battlefield conditions. Tactile displays are typically mounted on the body, and the intense movement and maneuver execution that is characteristic of the battlefield may negatively impact the transmission of tactile information by decreasing the intelligibility of the information conveyed. Thus, the purpose of this study was to determine how movement affects one's ability to detect and localize vibrotactile signals on the head.

Thirty participants with short hair of a length that conforms to military regulations, ages 18–35, were recruited for the study. Participants were tested under each of the 3 variables: movement, head location, and frequency. Within each block of movement (sit, walk, and run), participants were sent random tactile signals at different head locations (forehead, left temple, right temple, and back of head) and at varying signal frequencies (32, 63, 80, 100, and 150 Hz). Dependent measures included percent detection and localization accuracy. As the level of movement increased from sitting to running, detection and localization accuracy rates significantly decreased. The interaction effect for movement and frequency showed significant decreases in detection and localization accuracy rates while running at all levels of frequency. However, the largest differences in movement for detection and localization accuracy rates were observed at the lower frequency levels. Thus, the effect of intense movement is marked by a general decrement in the detection and localization of tactile signals on the head, but the decrement is not as severe when using higher frequency tactile signals. While higher frequency tactile signals are recommended to lessen the large effect of intense movement in masking tactile signals applied to the head, the signals must also be chosen with regard to user comfort. Results from this study will be used to develop tactile signals for the head that are appropriate for task-related maneuvers often performed by Soldiers on the battlefield.

Myles K, Kalb JT, Fluitt KF**,** Davis KL. Delineating tactile and auditory perception from head Tactile Stimuli. Journal of Sound and Vibration. In preparation; 2014.

The purpose of this study was to evaluate the frequency at which the mechanical vibration, defined by vibrotactile signals, is likely to be heard by perceptually isolating the frequency vibration of the signals from their associated auditory cues. The efficacy of using vibrotactile transducers on the head for Soldier navigation and cueing has promise as a practical and alternative communications solution. However, much is unknown about tactile sensitivity of the head. For example, it is suggested that such signals applied to the head are likely to be perceived via auditory cues from the tactile signals and not the tactile cues themselves. However, no data exist to substantiate the assumption. The presence of auditory cues can be problematic in a laboratory setting, as ideal tactile signals should produce sensations of vibration without auditory cues (i.e., felt and not heard). A psychophysical, adaptive procedure was used to obtain vibration hearing threshold frequency (i.e., the lowest frequency at which an observer is able to detect the sound of vibration) for 5 body locations (4 head locations and the forearm) and 3 ambient noise environments. The main effect of body location was significant, but environment was not. Auditory cues were present at significantly lower signal frequencies on the head than on the forearm, with auditory cues initially perceived at 64 and 69 Hz for the side and top of the head, respectively, and initially at 80 and 93 Hz for the front and back of the head, respectively. In contrast, auditory cues were not initially perceived on the forearm until approximately 226 Hz. It appears that tactile perception is dominant for tactile signals below 64 Hz, and tactile-auditory perception is dominant for tactile signals greater than or equal to 64 Hz. Thus, we conclude that not all tactile signals that are applied to the head are accompanied by significant auditory cues (i.e., can be easily heard). A laboratory-appropriate database that consists of tactile signals below 64 Hz should be the guide for reducing auditory cues that may accompany tactile signals applied to the head.

Research Area 2.5: Unconventional Communications: Torso-Mounted Tactile

(Was Thrust Area 3; Research Area 3.1: Tactile in ARL-SR-213)

Protocols:

White TL, Krausman AS, Pettitt R. Detection and identification of tactile pattern urgency while performing dismounted maneuvers Aberdeen Proving Ground (MD): Army Research Laboratory (US); Report No.: ARL-20098-11028.

Tactile displays may be a viable solution to help mitigate the overload and performance degradation that can result from this abundance of information being provided to Soldiers. If designed and implemented properly, tactile displays may improve Soldiers’ SA and survivability on the battlefield. A number of research efforts have already shown the potential of tactile display systems in military environments. Research efforts to employ tactile displays for orientation, navigation, and communication are ever-increasing.[8] Some researchers are interested in the use of tactile patterns to communicate more complex messages. Previous research suggests that weak tactile patterns may go unnoticed, which is problematic when the information being conveyed by the tactile system is critical to the Soldier. The goal of this investigation is to determine the effects of inter-stimulus interval and stimulus intensity on perceived urgency and on the detection and identification of tactile patterns while performing dismounted maneuvers. During the study, the participants will verbally identify tactile patterns and indicate their perceived urgency level under various levels of stimulus intensity and inter-stimulus duration. Participants will be asked to rate which inter-stimulus interval and stimulus intensity combination they perceive to be most urgent and least urgent. The results of this research will provide further insight on how to effectively employ tactile patterns as a means of communicating information to Soldiers.

Publications:

Mercado JE, White TL, Sanders T, Wright J, Hancock PA. Performance effects of imperfect cross-modal sensory cueing in a target detection simulation. Proceedings of the 2012 Conference on Defense and Military Modeling & Simulation. 2012;44(15); 57–63.

Past research has shown that multimodal sensory cues can reduce the workload of the user while simultaneously increasing performance capacity. This study looks to examine how performance is impacted in a multimodal sensory cueing target detection task in which the cueing automation is imperfect. Twenty-seven undergraduate participants volunteered to take part in the present multimodal sensory automation target detection task. The independent variables were trial (i.e., three 5-min trial blocks) and the cueing method (i.e., tactile or auditory cuing, or a combination) used to assist visual search for target detection across 3 screens. Dependent variables included each participant's response time and rate of accuracy. Results illustrate a significant decrease in response in the final trial when compared with the first trial. Results also illustrated a decrease in response time in each successive trial compared with the previous, each reflective of learning effects. A 1-trial block exposure (5 min) to imperfect automation resulted in a response time decrease of 24%, while a 2-trial block exposure (10 min) resulted in a response time decrease of 38%. Errors of omission results showed significantly lower miss rates in the final trial block when compared with the first trial block. In addition, errors of omission were lower in each successive trial compared with the previous. A 1-trial block exposure (5 min) to imperfect automation resulted in a decrease in misses of 45%, while a 2-trial block exposure (10 min) to imperfect automation resulted in a decrease of 65% in such misses. Our results suggest that interchanging multimodal cues create stronger learning trends in a human-automation system than unimodal cues. Results also showed that in spite of the automation used, automation failure resulted in a significant performance decrement. Auditory automation cueing failure produced a

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[8] Van Erp JBF, Self BP. Tactile displays for orientation, navigation, and communication in air, sea, and land environments. Neuilly-sur-Seine Cedex (France): NATO Research and Technology Organisation; 2008. Report No.: TR-HFM-122.

sevenfold increase in response time, while tactile automation cueing failure and a combination of auditory and tactile automation cueing failure produced a fourfold increase in response time. A speed-accuracy tradeoff is not the cause of these results, because auditory automation cueing failure produces a twofold decrease in accuracy, and a combination of auditory and tactile automation cueing failure produced a threefold decrease in accuracy.

Mercado JE, White TL, Sanders T, Wright J, Hancock PA. Improving performance in an imperfect target detection simulation through experience. Proceedings of the Autumn Simulation Multi-Conference; 2012; San Diego (CA).

Past research has shown an increase in performance over time when humans use imperfect automation. Typically, in these circumstances, imperfect automation was delivered via a single modality. This study examines the effects on performance when imperfect automation is delivered via multiple modalities that alternate during any 1 trial. Twenty-seven participants volunteered to take part in a cross-modal sensory target detection task with 3 trial blocks. The primary dependent variables were the response time and the associated accuracy rates. Results show that response time was significantly faster in the final trial block compared to the first trial block. Results also showed a trend that response time was faster in each subsequent trial than in the previous trial. A 5-min exposure (one trial block) to imperfect automation resulted in a 24% decrease in response time while a 10-min exposure (2 trial blocks) to imperfect automation resulted in a 38% decrease in response time. In regards to errors of omission, results indicated significantly lower miss rates in the final trial block compared with the first trial block, and showed a tendency that errors of omission were lower in each sequential trial block than in the previous trial block. A 5-min exposure (1 trial block) to imperfect automation resulted in a 45% decrease in misses while a 10-min exposure (2 trial blocks) to imperfect automation resulted in a 65% decrease in misses. These results suggest that alternating multimodal cues produce stronger learning trends in human-automation interaction than previous unimodal cue studies.

Mercado JE, White TL, Sanders T, Wright J. Effects of cross-modal sensory cueing automation failure in a simulated target detection task. Proceedings of the Autumn Simulation Multi-Conference; 2012; San Diego (CA).

Cross-modal sensory cueing is a highly useful because it provides redundant information that reduces the workload of the user. However, understanding how performance is affected in a cross-modal sensory cueing target detection task in which automation fails will facilitate mitigation strategies (e.g., implementation of improved automation). As automation use progressively increases, particularly within in visual displays, it becomes vital to maximize its efficiency. If automation is improperly used in a target detection task, targets are missed, false alarms occur, and performance is degraded. Twenty-seven participants volunteered to take part in a cross-modal sensory automation target detection task with 3 automation types (auditory, tactile, or a combination of auditory and tactile). Our results show that regardless of the type of automation used, automation failure led to a significant response time and accuracy decrement.

Automated auditory cueing failure resulted in a sevenfold decrease in response time, tactile cueing automation failure resulted in a fourfold decrease in response time, and combined auditory and tactile cueing automation failure also resulted in a fourfold decrease in response time. These results are not due to a speed-accuracy tradeoff. This is supported by the fact that auditory cueing automation failure resulted in a twofold decrease in accuracy, tactile cueing automation failure resulted in a twofold decrease in accuracy, and combined auditory and tactile cueing automation failure resulted in a threefold decrease in accuracy.

White TL, Krausman AS. The perceived urgency of tactile patterns while performing dismounted Soldier maneuvers. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2012. Report No.: ARL-TR-6013.

This research examines the effects of stimulus intensity and inter-stimulus interval (ISI) on Soldier ratings of signal perceived urgency and Soldier detection and identification of tactile patterns while performing dismounted maneuvers. A tactile system including an adjustable belt developed by Engineering Acoustics, Inc. (EAI), provided the tactile stimuli. This adjustable belt, which consists of 8 EAI C2 tactors positioned at 45° intervals, was worn around each participant's waist. Participants received tactile patterns at an intensity of either 12 or 23.5 dB above mean threshold with an ISI of either 0 (no interval) or 500 ms. Participants were asked to identify each tactile pattern that they received and rate how urgent they perceived the pattern to be on a scale of 1 to 10, where 1 was least urgent and 10 most urgent. Patterns presented at the 23.5-dB intensity with no ISI were rated most urgent, but at the 12-dB intensity, there was no difference in ratings of urgency based on ISI. Patterns presented at the 23.5-dB intensity had significantly greater detection and identification rates than those at the 12-dB intensity. Findings indicate that it is possible to add urgency to tactile patterns in dismounted environments.

White TL, Krausman AS, Haas EC. Tactile displays in Army operational environments. In: Savage-Knepshield P, Martin J, Lockett J, Allender L, editors. Designing soldier systems: issues in human factors. Hampshire (UK): Ashgate; 2012.

As a result of continuous technological advances, Soldiers are being inundated with a wealth of information about combat situations. Because most of this information is being conveyed through the visual and auditory channels, it can result in cognitive overload and degraded task performance. According to the MRT, offloading information to other sensory channels such as the sense of touch may help to mitigate cognitive overload and thereby increase task performance.[9] Research has shown that tactile displays may be a feasible alternative mode of communication to provide information to Soldiers. The skin is largest organ of the body. However, it is seldom used for displaying information in human-computer interfaces.[10] The findings of past research have made the potential of tactile displays as single sensory (unimodal)

[9] Wickens CD. Multiple resources and performance prediction. Theoretical Issues in Ergonomics Science. 2002;3(2):159–77.

[10] Brewster SA, Brown LM. Tactons: structured tactile messages for non-visual information display. Proceedings of the 5th Australasian User Interface Conference; 2004 January 15–23; Dunedin, New Zealand.

and within paired sensory (multimodal) modes of communication evident. This chapter will focus on the use of tactile displays in mounted and dismounted environments as well as in human-robot interface applications (e.g., teleoperation, operation of single or multiple robots, and robotic swarm display applications).

White TL. The perceived urgency of tactile patterns. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2011. Report No.: ARL-TR-5557. Also available at: http://www.arl.army.mil/arlreports/2011/ARL-TR-5557.pdf.

The purpose of this laboratory study was to examine the effects of stimulus intensity and ISI on the perceived urgency and on the detection and identification of tactile patterns. A tactile system that includes an adjustable belt developed by EAI was used to provide tactile stimuli. This adjustable belt, which consists of 8 EAI C2 tactors positioned at 45° intervals, was worn around each participant's waist. Participants received tactile patterns at an intensity of either 12 dB or 23.5 dB with an ISI of either 0 ms (no interval) or 500 ms. Participants were asked to identify each tactile pattern that they received and rate how urgent they perceived the pattern to be on a scale of 1–10. Results show that participants were able to detect and identify tactile patterns with nearly 100% accuracy. Participants rated patterns that were provided at the 23.5-dB intensity with no ISI as the most urgent. Patterns provided at the 12-dB intensity with a 500-ms ISI were rated the least urgent.

Appendix B. Publications Authored by the US Army Research Laboratory Sensory Perception Research Group (2011–2014)

2014

Amrein BE, Letowski TR. Military noise limits: design criteria versus operational effectiveness. Oral presentation at the 167th meeting of the Acoustical Society of America; 2014; Providence, RI.

Dickerson K, Gaston J, Scharine A. Spatial influences on change detection within complex auditory scenes. Poster presentation at the 167th meeting of the Acoustical Society of America; 2014; Providence, RI.

Fluitt K, Mermagen T, Letowski T. Auditory distance estimation in an open space. In: Glotin H, editor. Soundscape semiotics – localisation and categorisation. Rijeka (Croatia): InTech; 2014. Available at: http://www.intechopen.com/books/soundscape-semiotics-localisation-and-categorisation/auditory-distance-estimation-in-an-open-space.

Gaston J, Dickerson K. The effects of spectral fine structure and amplitude envelope on perceived similarity and identification of approaching vehicles. Paper presented at the 167th meeting of the Acoustical Society of America; 2014; Providence, RI.

Hipp D, Dickerson K, Moser A, Gerhardstein P. Age-related changes in visual contour integration: implications for physiology from psychophysics. Developmental Psychobiology. In press; 2014.

Scharine AA, Weatherless RA. U.S. Marine Corps level dependent hearing protector assessment: objective measures of hearing protection devices. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6780. Also available at: http://www.arl.army.mil/arlreports/2014/ARL-TR-6780.pdf.

Taylor G, Hipp D, Moser A, Dickerson K, Gerhardstein P. The development of object perception: a developmental review of the physiology and psychophysics of contour detection. Frontiers in Perception Science. In press; 2014.

2013

Binseel MS, Kalb JT. Localization of head-mounted vibrotactile transducers. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6322. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6322.pdf.

Blue M, McBride M, Weatherless R, Letowski T. Impact of a BC communication channel on multichannel communication system effectiveness. Human Factors. 2013;55(2):346–355. Also available at: DOI: 10.1177/0018720812460247.

CuQlock-Knopp VG, Wallace SD, Stachowiak C. White-phosphor versus green-phosphor findings. Presented to Army Research Laboratory (US), Night Vision and Electronic Sensors Directorate: Aberdeen Proving Ground (MD); 2013 Jun 6.

CuQlock-Knopp VG, Stachowiak C, Wallace SD. Visual performance with binocular night-vision goggles versus monocular night-vision goggles. Presented to Project Manager Soldier Maneuver Sensors: Aberdeen Proving Ground (MD); 2013.

CuQlock-Knopp VG, Stachowiak C, Wallace SD. Potential applications of the 3D HD video lane for requirements of the United States Border Patrol: Special Operations. Presented to Border Patrol (US); Harpers Ferry (WV); 2013.

Fedele PD, Binseel MS, Kalb JT, Price GR. Using the auditory hazard assessment algorithm for humans (AHAAH) with hearing protection software, release MIL-STD-1474E. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6748. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6748.pdf.

Fedele PD, Kalb JT, Vaughan BD, Kehring KL. Measured visual motion sensitivity at fixed contrast in the periphery and far periphery. Aberdeen Proving Ground (MD): Army Research Laboratory (US). In review; 2014.

Fedele PD, Weatherless R, Kehring K, Letowski, T. The effects of simulated hearing loss on simultaneous speech recognition and walking navigation tasks. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6335. Also available at: http://www.arl.army.mil/arlreports/2013/ARl-TR-6335.pdf.

Fluitt KF, Mermagen T, Letowski T. Auditory perception in open field: distance estimation. Aberdeen Proving Ground MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6520. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6520.pdf.

Gaston J, Plöchl M. Auditory-tactile localization and the role of causal inference on localization judgments. Paper presented at the US-German Research Roundtable, Aberdeen Proving Ground (MD); 2013.

Gaston J, Mermagen T, Dickerson K. Acoustic measurement and nondetectability of two night vision devices. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6738. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6738.pdf.

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Kalb JT, Price GR, Fedele PD. Auditory hazard assessment algorithm for humans (AHAAH) with hearing protection software release MIL-STD-1474E. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6748. Also available at: http://www.arl.army.mil/arlreports/2013/ARL-TR-6748.pdf.

McBride M, Fasanya B, Letowski T. Monotic and diotic speech recognition of bone conducted speech. Proceedings of the 2013 Industrial and Systems Engineering Research (ISER) Conference. San Juan (Puerto Rico): Institute of Industrial Engineers (IIE); 2013.

Myles K, Kalb JT. Head tactile communication: Promising technology with the design of a head-mounted tactile display. Ergonomics in Design. 2013;21:4–8.

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Pollard KA. The scent of stealth: the role of olfactory perception in detection, deception, and performance. Army Research Laboratory (US) Director's Strategic Initiative (DSI) proposal; 2013.

Pollard KA, Tran PK, Letowski TR. A free-field method to calibrate BC transducers. Journal of the Acoustical Society of America. 2013;133(2):858–865.

Pollard KA, Tran PK, Letowski TR. Vocal and demographic traits influence speech intelligibility over BC. Journal of the Acoustical Society of America. In review; 2014.

Price GR, Kalb JT. Stability of the auditory hazard assessment algorithm for humans (AHAAH) model. ARL Internet; 2013.

Raglin A, Dai L, Wallace S, Gregory F. The unintentional loss of binocular vision – an obstacle to detecting a stealthy enemy. Army Research Laboratory (US) DSI proposal; 2013.

Scharine AA, Letowski TR. The measurement of the effects of helmet form on sound source detection and localization using a portable four-loudspeaker test array. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6444.

Scharine AA, Weatherless RA. Evaluation of variants of 3M Peltor ComTAC tactical communication and protection system (TCAPS) headsets: measures of hearing protection and auditory performance. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2013. Report No.: ARL-TR-6667. Also available at: http://www.arl.army.mil/arlreports/2013 /ARL-TR-6667.pdf.

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Wallace SD, CuQlock-Knopp VG. Modeling target saliency in imagery: a texture and edge-based method. Presented to Night Vision and Electronic Sensors Directorate, Army Research Laboratory (US), Aberdeen Proving Ground (MD); 2013 Jun 6.

Wallace SD, CuQlock-Knopp VG. Potential applications of the 3D HD video lane for requirements of the United States Marine Corps. Invited briefing to the JIEDDO C-IED Working Group, Camp Pendleton (CA); 2013 Jul 16.

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Wallace SD, CuQlock-Knopp VG. Transfer-of-Training from the 3D HD video lane training to the detection of hidden explosive devices and indicators. Invited briefing at JIEDDO Headquarters, Crystal City (VA); 2013 Sep 13.

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Appendix C. Selected Topics from the Current Sensory Perception Research Portfolio

Effectiveness of enhancement and countermeasure techniques on the perception of military vehicular sounds

Mark A Ericson, Ph.D.

Abstract

Low-frequency sounds from military vehicles, such as armored vehicles and aircraft, can be heard by hostile forces for many miles. Early indication of our friendly vehicle locations often gives hostile forces ample time to prepare for engaging our air and ground vehicles with small-arms fire and rocket-propelled grenades. To quantify how background acoustic conditions affect vehicle sound perception, several experiments were conducted to determine the key components of airborne and ground vehicle acoustic emissions. Acoustic signal processing methods were used to modify aspects of the vehicle sounds that affect the detection, identification, and localization of our vehicle sounds. The Environment for Acoutic Research (EAR) at the US Army Research Laboratory's Human Research and Engineering Directorate was used to create ambient masking sounds. In general, masking sounds that were similar to the vehicle sounds were more effective than dissimilar sounds in reducing aural perception abilities of the listener. Although, the complexity of most vehicle sounds enabled the listeners to perceive the vehicle sounds in many masking conditions. The results of these experiments will be discussed in terms of the aural abilities of human subjects to detect, identify, and localize vehicle sounds in various ambient noise conditions.

Publications

Boren B, Ericson MA. Motion simulation in the environment for auditory research. Proceedings on Meetings in Acoustics. 2013;14(015006). Available at: http://scitation.aip.org/content/asa/journal/poma/14/1/10.1121/1.4704670.

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Ericson MA. Auditory perception briefing presented to customer; 2013 Oct 3 (SECRET).

Improving CBRNE* Warfighter communication using bone conduction technology

*CBRNE = chemical, biological, radiological, nuclear and high-yield explosive

Kimberly A Pollard, Lamar Garrett, and Phuong Tran

Abstract

Difficult environments, such as chemical, biological, radiological, nuclear, and high-yield explosive (CBRNE) environments, pose a unique communication challenge. Effective communication is essential to stay safe in these environments, yet safety gear itself impedes communication. Personal protective equipment (e.g., full-face respirators) and noisy decontamination devices (power sprayers, etc.) can impede successful speech transmission. Bone conduction (BC) communication systems are a promising solution. These systems are relatively insensitive to background noise and can capture speech directly from a user's skull vibrations, before airborne speech is disrupted by a respirator. To assess the potential of BC systems for use by encapsulated personnel, 3 communication systems were tested for speech intelligibility using the Modified Rhyme Test. Sixteen participants wore the M50 Joint Service General Purpose Mask full-face respirator and communicated via radio using 3 different communication systems in 2 levels of background noise. A BC earpiece device performed best, followed by a mask-mounted BC system. Both BC systems outperformed the currently fielded air conduction (AC) communication system. The results support the use of BC technology for improved encapsulated communication, which may improve safety and effectiveness for CBRNE personnel.

Publications

Pollard KA, Garrett L, Tran P. Bone conduction systems for full-face respirators: speech intelligibility analysis. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2014. Report No.: ARL-TR-6883. Also available at: http://www.arl.army.mil/arlreports/2014/ARL-TR-6883.pdf.

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Tran PK, Letowski TR, McBride ME. The effect of bone conduction microphone placement on intensity and spectrum of transmitted speech items. Journal of the Acoustical Society of America. 2013;133:3900–3908.

Modeling the effects of focus on target saliency: a texture and edge based method

Samantha D Wallace

Abstract

In this research, we concentrate on the creation of a saliency model based on texture and edge density. This model evaluates the saliency of targets in a scene with respect to the focus range used to capture the image. The dataset included static images with different focal conditions. The 4 focus conditions used for the experiment included a near focus ranging 1–10 ft, a midrange focus ranging 10–50 ft, a midrange focus ranging 10–50 ft with a reduced aperture, and a far focus ranging 50 ft to infinity. To validate the model, a human factors study was completed to evaluate target detection and reaction times with the 4 focal conditions. Both research efforts concluded that the focal condition with a reduced aperture presented the best depth of focus within the scene. The output of the model showed a higher target saliency with the reduced aperture condition than with the other 3 focal conditions. The human performance data validated that information with participants detecting and reacting faster to targets with the reduced focus condition. Participants in the reduced aperture condition detected an average of 5.19% more targets than the participants in the other 3 focal conditions. Participants in the reduced aperture condition reacted to targets an average of 10.33% faster than the participants in the other 3 focal conditions.

Publications

Wallace SD. Modeling the effects of focus on target saliency: a texture and edge-based method [dissertation]. [Baltimore (MD)]: Morgan State University 2013.

Visual motion sensitivity at fixed contrast in the far visual periphery

Paul D Fedele, Joel T Kalb, Barry D Vaughan, and Kathy L Kehring

Abstract

Movement in peripheral vision plays a major part in a predator's visual detection of prey and in a Soldier's visual detection of enemy combatants. Vision models used to simulate Soldier performance do not consider visual detection caused by enemy combatant movements. To support modeling visual movement detection, we have measured visual motion detection sensitivity in the visual periphery. We simulated moving enemy combatants using targets consisting of bivariate Gaussian contrast distributions similar in shape and size to upright human bodies, at ranges of 50, 100, and 200 m, with a Michelson contrast of –0.2 relative to a uniform grey background. At 50 m, motion detection thresholds varied from 0.72 °/s at 40° eccentricity to greater than 18°/sc at 80° eccentricity. At 200 m, thresholds varied from 9.4°/s at 40° eccentricity to, again, greater than 18°/s at 80° eccentricity. When targets become invisible at increasing eccentricities, thresholds naturally become nonexistent: They increase without bound. Visible movement thresholds show individual variability standard error of approximately ±5.6°/s about the average threshold. These measurements indicate the likelihood that a Soldier will see human movement at specific ranges at contrasts produced by specific lighting conditions. Further research is needed to measure visual movement detection thresholds under various contrast lighting conditions.

Publications

Monaco WA, Higgins KE, Kalb JT. Central and off-axis spatial contrast sensitivity measured with Gabor patches. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2010. Report No.: ARL-TR-5363. Also available at: http://www.arl.army.mil/arlreports/2010/ARL-TR-5363.pdf.

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Research in perception of combined impulsive auditory and flash visual stimuli

Jeremy Gaston, Kelly Dickerson, Barry D Vaughan, and Paul D Fedele

Abstract

Small-arms weapon suppression involves reducing muzzle flash and blast so that these perceptual stimuli do not interfere with the Soldier's communication, damage Soldier's hearing, or reveal the Soldier's location to the enemy. When Soldiers get a chance to fire suppressed small-arms weapons, they generally want to use suppressed weapons on the battlefield. Standards that ensure the adequacy of suppression are required to acquire suppressors for military small arms. To support suppressor standards development, the US Army Research Laboratory's Human Research and Engineering Directorate (ARL/HRED) is performing research on human perception of combined visual and auditory stimuli to determine how human observers will identify and localize impulsive visual and auditory stimuli at and above the detection limits for such independent and combined stimuli. ARL/HRED has a model that effectively predicts when auditory small-arms stimuli are adequately suppressed to no longer create an auditory hazard. While HRED has an effective auditory detection model, HRED cannot yet predict an observer's ability to identify and accurately localize auditory stimuli. Thus HRED's ongoing research is focusing on localization and identification of impulsive stimuli. This ARL-funded research has been approved by the Program Director for Test and Evaluation in Small Arm Signature Reduction at Picatinny Arsenal (NJ).

Publications

This is a new research effort.

The effect of bone conduction microphone placement on intensity and spectrum of transmitted speech items

Phuong K Tran, Kimberly A Pollard, Tomasz R Letowski,
and Maranda E McBride

Abstract

Speech signals can be converted into electrical audio signals using either a conventional AC microphone or a contact BC microphone. The goal of this study was to investigate the effects of the location of a BC microphone on the intensity and frequency spectrum of the recorded speech. Twelve locations, 11 on the talker's head and 1 on the collar bone, were investigated. The speech sounds were 3 vowels (/u/, /a/, /i/) and 2 consonants (/m/, /ʃ/). The sounds were produced by 12 talkers. Each sound was recorded simultaneously with 2 BC microphones and one AC. Analyzed spectral data showed that the BC recordings made at the forehead of the talker were the most similar to the AC recordings while the collar bone recordings were most different. Comparing spectral data with speech intelligibility data collected in another study revealed a strong negative relationship between BC speech intelligibility and the degree of deviation of the BC speech spectrum from the AC spectrum. In addition, the head locations that resulted in the highest speech intelligibility were associated with the lowest output signals among all tested locations. Implications of these findings for BC communication are discussed.

Publications

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An evaluation of signal annoyance for a head-mounted tactile display

Kimberly Myles and Joel T Kalb

Abstract

The effort to develop current and future warriors that are the most technologically advanced in the world has increased Soldiers' access to vital information. This influx of information is mainly processed via the visual and/or auditory sensory channels, which can place stress on these channels during periods of high workload. The tactile sensory channel is currently a viable option for conveying directional cues to aid navigation, providing alerts to critical events in the environment and may help to alleviate information overload on the other channels. For example, we found that ratings for perceived overall workload significantly decreased for Soldiers who received navigation instructions via tactile cues during periods of high visual workload compared with those who received the same instructions visually. While tactile displays for military applications were designed to be worn on the torso, the prospect of integrating tactile technology with BC technology justified the need to also explore the head as a feasible mounting location. Previously, others did not consider this location practical due to user complaints of "dizziness, disorientation, and a general feeling of unsettledness" when the head was exposed to vibration. Furthermore, there was no additional effort to relate the complaints to attributes of the vibration. Thus, we obtained subjective measures of annoyance as a function of vibration frequency, and established that higher frequency signals (i.e., 250 Hz, at which the sense of touch is optimum and users tolerate very well on the finger and torso) will most likely not be preferred on the head and generally may be associated with annoyance and other feelings of unsettledness.

Publications

Myles K, Kalb JT. An evaluation of signal annoyance for a head-mounted tactile display. Annual Meeting of the Human Factors and Ergonomics Society. In review; 2014.

Myles K, Kalb JT. Head tactile communication: Promising technology with the design of a head-mounted tactile display. Ergonomics in Design. 2013;21:4–8.

Expanding the tactile modality: perceived urgency and tactile patterns

Timothy White and Andrea Krausman

Abstract

This research examines the effects of stimulus intensity and inter-stimulus interval (ISI) on Soldier ratings of signal perceived urgency and Soldier detection and identification of tactile patterns while performing dismounted maneuvers. A tactile system including an adjustable belt developed by Engineering Acoustics, Inc. (EAI), provided the tactile stimuli. This adjustable belt, which consists of 8t EAI C2 tactors positioned at 45° intervals, was worn around each participant's waist. Participants received tactile patterns at an intensity of either 12.0 or 23.5 dB above mean threshold with an ISI of either 0 (no interval) or 500 ms. Participants were asked to identify each tactile pattern that they received and rate how urgent they perceived the pattern to be on a scale of 1 to 10, where 1 was least urgent and 10 was most urgent. Patterns presented at the 23.5-dB intensity with no ISI were rated most urgent, but at the 12.0-dB intensity, there was no difference in ratings of perceived urgency based on ISI. Patterns presented at the stronger 23.5-dB intensity had significantly greater detection and identification rates than those presented at the 12.0-dB intensity. Findings indicate that it is possible to add urgency to tactile patterns in dismounted environments.

<u>Publications</u>

White TL, Krausman AS The perceived urgency of tactile patterns while performing dismounted Soldier manuevers. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2012. Report No.: ARL-TR-6013.

White TL, Krausman AS Effects of inter-stimulus interval and intensity on the perceived urgency of tactile patterns. Applied Ergonomics. In review; 2014.

The effects of Soldier protective headgear on auditory spatial perception

Angelique Scharine, Rachel Weatherless, Timothy Mermagen, and Miller Roberts

Abstract

The unique facilities of ARL's EAR paired with our ongoing relationship with the acquisitions community responsible for the development of helmets, hearing protection, and tactical communications systems allow us to measure the effects of personal protective headgear equipment (PPE) on spatial auditory perception. Current research topics of interest include the development of a predictive model for the effects of PPE on auditory localization ability using head-related transfer function measurements, characterization of the effects of nonlinear compression technologies on distance perception, characterization of the timeline and degree of acclimation that occurs during training with PPE, and what constitutes sufficient spatial perceptual ability as characterized by performance within a multimodal perceptual context.

Publications

Melzer J, Scharine AA, Amrein BE. Soldier auditory situation awareness: the effects of hearing protection, communications headsets, and headgear. In: Savage-Knepshield P, Lockett J, Martin JH, editors. Designing Soldier systems: issues in human factors. Burlington (VT): Ashgate; 2010.

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Scharine A, Binseel M, Mermagen TJ, Letowski TR. Sound localization ability of Soldiers wearing infantry ACH and PASGT helmets. Ergonomics. In press; 2014.

Factors influencing change deafness for complex environmental sounds

Kelly Dickerson and Jeremy Gaston

Abstract

Change deafness is the auditory analogue to change blindness; large changes within complex environments are often missed. The current research has extended knowledge on the causes underlying change deafness by demonstrating a beneficial effect for spatial separation between sources and background heterogeneity. The combination of these effects suggests that change perception errors in complex environments may occur primarily due to information masking. Soldiers on patrol are often operating in complex urban environments where “targets” are often not known in advance but are represented by a change in the environment. Change deafness reflects change perception errors of greater than 30% and represent a serious limitation to Soldier situational awareness. Future work will be focused on acoustic characterization of complex auditory scenes and localization of changes. These studies will enable a better understanding of the complex interplay between physical stimulus factors and cognitive factors such as expectations about sound context and category. This research should contribute significantly to the development of strategies for improving situational awareness in the field.

Publications

Dickerson K, Gaston J. The sound you didn’t hear: change deafness in complex environments. Trends in Cognitive Science. In review; 2014.

Dickerson K, Gaston J. Spatial influences on change detection within complex auditory scenes. Poster presentation at the 167th Meeting of the Acoustical Society of America; 2014; Providence (RI).

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Appendix D. Sensory Perception Research Portfolio

This appendix apprears in its original form, without editorial change.

Auditory Research Portfolio

Effectiveness of enhancement and countermeasure techniques on the perception of military vehicular sounds

A comparison of the single-sided (Gen II) and double-sided (Gen I) Combat Arms Earplugs: Acoustic properties, human performance, and user acceptance

Effects of amplitude compression on relative auditory distance perception

Evaluation of auditory characteristics of communications and hearing protection systems (C&HPS) Part III – Auditory localization

Evaluation of variants of 3M Peltor ComTAC tactical communication and protection system (TCAPS) headsets: Measures of hearing protection and auditory performance

Expanding the tactile modality: coding urgency into tactile patterns

Factors influencing change deafness for complex environmental sounds

Headgear induced changes to head-related transfer functions (HRTFs)

Listener perception of single-shot small arms fire

Localization of sound-source changes in complex auditory scenes.

Neural correlates of small arms fire localization reveal economy of resources and action-based perception in soldiers and marksmen

Perceptibility of suppressed small arms auditory and visual stimuli

Quantifying change detection failures during the perception of complex auditory scenes

Sound localization ability of Soldiers wearing infantry ACH and PASGT helmets

Spatial influences on change detection within complex auditory scenes.

The effects of simulated hearing loss on simultaneous speech recognition and walking navigation tasks

The effects of Soldier protective headgear on auditory spatial perception

The effects of spectral fine structure and amplitude envelope on perceived similarity and identification of approaching vehicles

The effects of speech intensity on the Callsign Acquisition Test and the Modified Rhyme Test presented in noise

The measurement of the effects of helmet form on sound source detection and localization using a portable four-loudspeaker test array

U.S. Marine Corps level dependent hearing protector assessment: Objective measures of hearing protection devices

Vibrotactile Research Portfolio

Improving CBRNE Warfighter communication using bone conduction technology

A free-field method to calibrate bone conduction transducers

An evaluation of signal annoyance for a head-mounted tactile display

Bone conduction equal loudness contours: placement, frequency, and intensity

Bone conduction systems for full-face respirators: speech intelligibility analysis

Comparison of a visual and head tactile display for soldier navigation

Delineating tactile and auditory perception from head tactile stimuli

Effect of static force on bone conduction hearing thresholds and comfort

Effects of bone vibrator locations on auditory spatial perception tasks

Effects of cross-modal sensory cueing automation failure in a simulated target detection task

Effects of inter-stimulus interval and intensity on the perceived urgency of tactile patterns

Efficacy of a head tactile display: The detection of tactile signals on the move

Head tactile communication: promising technology with the design of a head-mounted tactile display

Improving performance in an imperfect target detection simulation through experience.

Morphological differences affect speech intelligibility over bone conduction (soon to be submitted)

Performance effects of imperfect cross-modal sensory cueing in a target detection simulation

Speech intelligibility of air conducted and bone conducted speech over radio transmission

Tactile displays in army operational environments

The effect of bone conduction microphone locations on speech intelligibility and sound quality

The effect of hair density on the coupling between the tactor and the skin of the human head

The effect of vocal and demographic traits on speech intelligibility over bone conduction

The perceived urgency of tactile patterns while performing dismounted Soldier maneuvers

Visual Perception & Target Acquisition Research Portfolio

Modeling the effects of focus on target saliency: A texture and edge based method

Expansion of the regions of interest in the 3D HD Video Lane training beyond the United States Central Command (USCENTCOM) to include the United States Southern Command (USSOUTHCOM) and the United States Africa Command (USAFRICOM)-- Collaboration with the Joint IED Defeat Organization (JIEDDO)

Experimentation to examine the use of dual-focus techniques (objective lenses of NVGs focused at different ranges) to mitigate the shallow depth-of-field problems with NVGs.

Experimentation to help resolve concerns related to a potential transition from green-phosphor night-vision goggles (NVGs) to white-phosphor NVGs.

Integration of the Army's Ground Sign Awareness program with the ARL-HRED 3D HD Video Lane training -- Collaboration with the Joint IED Defeat Organization (JIEDDO)

Motion detection in the far visual periphery

Research in perception of combined impulsive auditory and flash visual stimuli

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List of Symbols, Abbreviations, and Acronyms

AC	air conduction communications
AMSAA	US Army Materiel Systems Analysis Activity
ARDEC	US Army Armament Research, Development and Engineering Center
ARL	US Army Research Laboratory
APG	Aberdeen Proving Ground
ATC	Aberdeen Test Center
BC	bone conduction communications
CBRNE	chemical, biological, radiological, nuclear and high-yield explosives
DWB	ARL/HRED's Dismounted Warrior Branch
EAR	ARL/HRED's Environment for Auditory Research
HRED	Human Research and Engineering Directorate (ARL)
HRTF	head-related transfer function
ISI	inter-stimulus interval
PPE	personal protective equipment
PSB	ARL/HRED's Perceptual Sciences Branch
RDEC	RDECOM's Research Development and Engineering Center
RDECOM	Research, Development, and Engineering Command
SLAD	Survivability/Lethality Analysis Directorate (ARL)
SPD	ARL/HRED's Soldier Performance Division
SPO	ARL/HRED's Special Projects Office
TPA	Technical Program Agreement
USAARL	US Army Aeromedical Research Laboratory
WMRD	Weapons and Materials Research Directorate (ARL)

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